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Radiographic Assessment of Pelvic Inlet and Outlet View Angles in the Ethiopian Population

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Background: Accurate radiographic assessment is pivotal in evaluating trauma patients with suspected pelvic ring disruptions. The conventional approach of using anteroposterior, 45° inlet, and 45° outlet radiographs for the evaluation of pelvic injury may not consistently align with varying lumbopelvic anatomy. This study aimed to determine the ideal pelvic inlet and outlet radiographic angles when there is limited access to advanced imaging (e.g., computed tomography [CT]) for assessing clinically relevant pelvic osseous landmarks and to investigate variations based on age, sex, and sacral dysmorphism.

Methods: This cross-sectional study investigated patients who were ≥18 years of age who had no traumatic injuries or pelvic ring pathology; we reviewed abdominopelvic CT scans that were obtained between January 1, 2023, and June 30, 2023. Midsagittal reconstruction and 3D rendering of 148 CT scans facilitated the measurement of pelvic inlet and outlet angles. Standard techniques that were based on previous studies were used to determine the ideal angles. Statistical analyses investigated mean pelvic inlet and outlet angles as well as correlations with age, sex, and sacral dysmorphism.

Results: The mean pelvic inlet angle was 23.8° ± 8.4° (95% confidence interval [CI]: 22.4° to 25.2°), and the mean outlet angle was 40.1° ± 5.9° (95% CI: 39.2° to 41.1°). Male patients exhibited greater inlet angles (27° versus 20°), whereas female patients had greater outlet angles (41° versus 39°). Pelves with dysmorphism showed a 3.6° increase in outlet angles when compared with those with normal sacral anatomy. An inverse relationship between age and inlet angle was observed.

Conclusions: This study highlights that the recommended 45° angle for pelvic inlet and outlet views may not optimally align with the anatomy of the Ethiopian population. The findings suggest that the ideal inlet and outlet angles for this population are 25° and 40°, respectively. Understanding these variations is crucial for optimizing pelvic radiographic views in trauma evaluation, potentially leading to more accurate assessments and improved patient care in this demographic.

Level of Evidence: Diagnostic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Pelvic fractures account for 3% to 8% of all fractures. These fractures are the most serious and potentially fatal orthopaedic injuries. Because of the typical instability of the fracture and the related intrapelvic vascular and visceral consequences, these injuries have a high risk of morbidity and death. A pelvic fracture can range in severity from a simple, stable Tile A to a complicated, potentially fatal Tile C[1]. The patient's hemodynamic state affects the clinical manifestations and prognosis of the fracture. It can be difficult to diagnose and treat individuals with pelvic fractures, particularly in settings with minimal resources where there are few medical services and a lack of infrastructure[1-5].

Injury to the pelvic ring requires both clinical and radiographic assessment to determine treatment recommendations. Pelvic fractures should always be considered when a history of high-energy trauma is present. These fractures can be recognized by the presence of pain, tenderness, bruising, swelling, and crepitus in the pelvic region, and can be diagnosed with the appropriate radiographs[1,3,4,6].

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Early management of suspected pelvic fractures starts with an appropriate radiographic evaluation. The standard pelvic images are designed to profile the specific anatomy of the pelvis for diagnostic and treatment purposes. The radiographic assessment aims to define the type of fracture, to recognize the degree of instability of the pelvic ring, and to allow orthopaedic surgeons to choose the most suitable treatment; radiographs can also be used for follow-up. While a single anteroposterior view is generally sufficient for an overview of a pelvic fracture, in the absence of computed tomography (CT), it is important to consider additional imaging such as inlet and outlet views in order to ensure that potential diagnoses that involve posterior pelvic displacement are not overlooked[1,6-8].

CT is the modality of choice for accurately describing complex pelvic fractures. After an initial radiograph, CT is often required for an accurate assessment of the fracture and frequently aids in decision-making regarding surgery. In certain regions where CT scans are available, the use of 3D-rendered reconstruction and ghost images generated from CT has replaced traditional inlet and outlet radiographs. Despite its accuracy in disclosing pelvic fractures, CT is not available in many geographic areas, especially in resource-limited medical facilities such as those found in Ethiopia. Therefore, inlet and outlet radiographic views are still useful parts of the initial assessment of pelvic fractures in resource-constrained institutions[9,10].

Different radiographic angles to yield proper inlet and outlet projections have been reported in the literature. The classic practice has been 45° caudal and cranial angulation for inlet and outlet views, respectively. However, recent studies have shown there are significant variations and differences in lumbopelvic anatomy based on race and ethnicity. These variations may result in inadequate radiographs, which can lead to missed pathology, misdiagnosis, mismanagement, and an increased risk of the need for repeat imaging. When a repeat radiograph is made, the patient is exposed to an additional dose of radiation, which could have been avoided with proper initial imaging. In addition to patient safety, there is also a substantial financial burden associated with repeat radiographs. To avoid all of these problems, it is necessary to redefine the accurate inlet and outlet views in the Ethiopian population[3,4,8,11-16]. Due to limited access to advanced imaging such as CT, accurate pelvic radiographic views play a crucial role in the initial evaluation of a pelvic fracture and subsequent referral. By addressing specific anatomic variations as well as practical constraints, we can enhance diagnostic precision and improve patient outcomes. Our research provides insights for tailored and effective radiographic evaluations in resource-limited settings, aiming to optimize clinical decision-making and advanced trauma care practices in Ethiopia. In this study we aimed to determine the ideal pelvic inlet and outlet radiographic angles for the accurate assessment of osseous landmarks in the Ethiopian population. We also evaluated differences in pelvic inlet and outlet radiographic angles on the basis of age, biological sex, and sacral dysmorphism.

Materials and Methods

This cross-sectional study was approved by our institutional review board. Over a period of 6 months (January 1 to June 30, 2023), we evaluated routine abdominopelvic CT scans from 148 consecutive patients with an age of ≥18 years (mean age, 45 years) with no traumatic injuries or pelvic ring pathology who had visited the Tikur Anbessa Hospital in 2023. These scans were identified retrospectively from the database of our department of radiology; they had been performed for reasons unrelated to pelvic bone pathology. The CT scans were used to classify each sacrum as either normal or dysmorphic. We used the RadiAnt DICOM (digital imaging and communications in medicine) Viewer to extract and load the images. It was used to

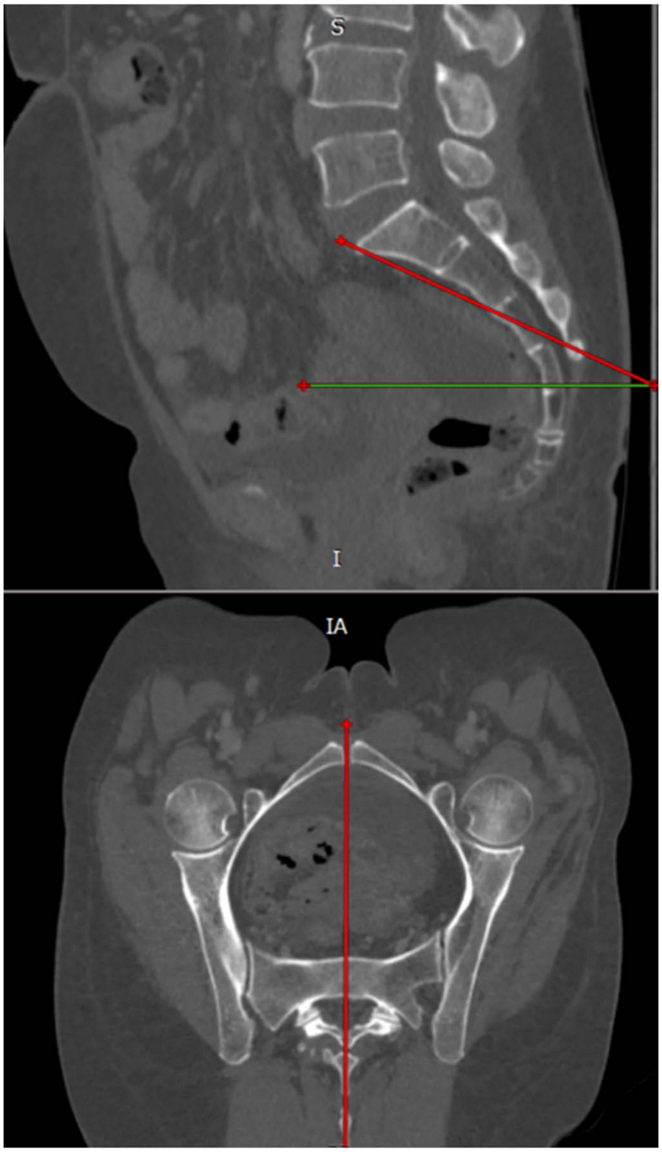

Fig. 1
The pelvic inlet angle was measured on the midsagittal reconstruction (top) as shown by the red and green lines. The gray line (far right) is parallel to the CT table, and the green forms a 90° angle with the gray line. The red line on the axial section (bottom) shows the level where the angle was measured. S = superior, I = inferior, and IA = inferior anterior.

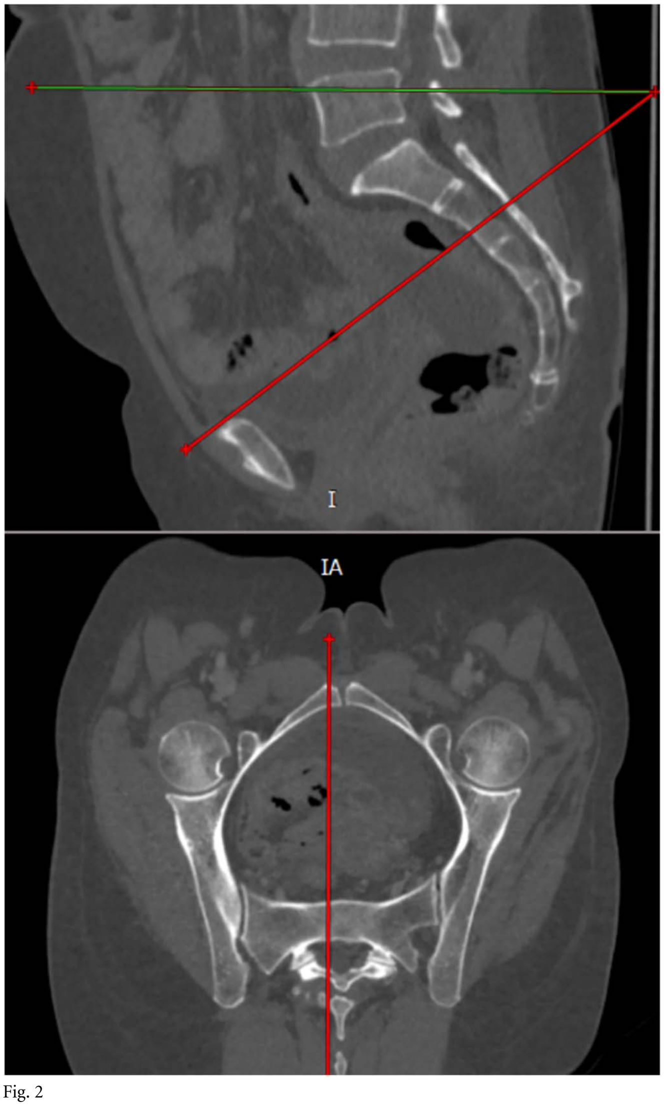

Fig. 2
The pelvic outlet angle was measured on the paramedian sagittal section (top) between the red and green lines. The gray line (far right) is parallel to the CT table, and the green line forms a 90° angle with the gray line. The red line on the axial section (bottom) indicates the paramedian level. I = inferior and IA = inferior anterior.

manipulate the routine axial CT slices to produce a 3D multiplanar reconstruction (3D MPR) and 3D rendering. The 3D MPR allowed us to navigate the images on all planes (i.e., axial, coronal, and sagittal). The 3D reconstruction is a volume rendering of the pelvis where the bones appear solid. Midline and paramedian sagittal views as well as 3D rendering were used for measurements with standard techniques that were derived from Aydın et al. and Pekmezci et al., respectively[11,12]. A reference line for midline and paramedian sagittal reconstruction was provided in all of the CT images as a line that was parallel to the surface of the CT table. Another line was drawn vertical to this reference line. First, the anterior edge of the S1 superior end plate and the anterior edge of the S2 inferior end plate were used for drawing a line to simulate the pelvic inlet radiographic view. The angle between this line and the vertical line was the pelvic inlet radiographic angle (Fig. 1). Second, a line was formed by connecting the upper border of the pubic bone with the center of the S2 body. The angle between the vertical line and this line was the pelvic outlet radiographic angle (Fig. 2). The ideal inlet and outlet angles that are necessary to profile clinically relevant pelvic anatomy were also

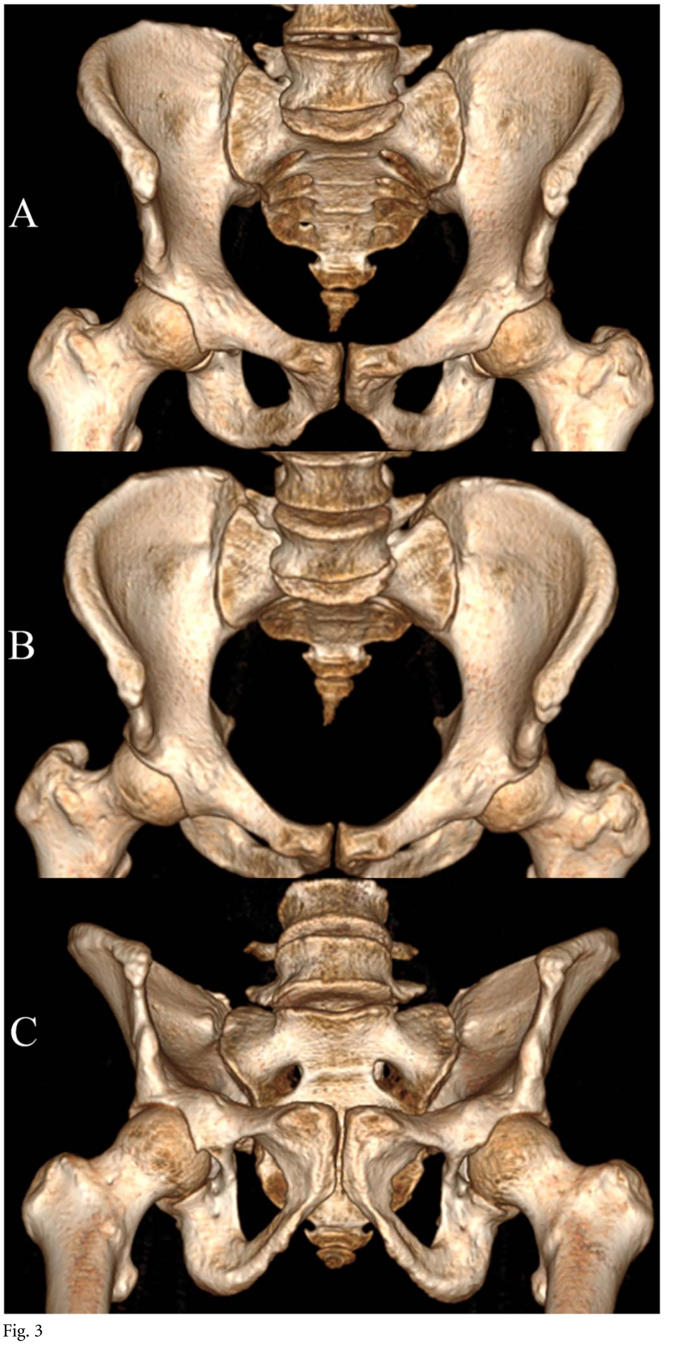

Fig. 3
Figs. 3-A, 3-B, and 3-C Three-dimensional rendering showing the anteroposterior (**Fig. 3-A**), inlet (**Fig. 3-B**), and outlet (**Fig. 3-C**) views.

TABLE I Inlet and Outlet Angles

	Average Angle *(deg)*	95% Confidence Interval *(deg)*	Minimum Angle *(deg)*	Maximum Angle *(deg)*	Standard Deviation *(deg)*
Ideal inlet angle	23.8	22.4-25.2	0.2	55.4	8.4
Inlet angle on 3D reconstruction	23.5	22.2-24.9	1.0	55.0	8.3
Ideal outlet angle	40.1	39.2-41.1	24.3	52.7	5.9
Outlet angle on 3D reconstruction	40.1	39.1-41.0	24.0	52.0	5.9

determined for each patient with the use of 3D-rendering CT data (Figs. 3-A, 3-B, and 3-C). The 3D rendering can be easily manipulated to create standardized views. Each 3D rendering was rotated in the sagittal plane 1° at a time. Zero degrees of rotation corresponded to the initial anteroposterior view of the pelvis with the patient lying supine on the table.

The measured ideal angles and the 3D angles were compared. The mean, standard deviation, range, and 95% confidence interval (CI) were established for all of the ideal angles that were measured for the pelvic inlet and outlet angles. The difference between the inlet and outlet angles was calculated. Each of these angles was also compared with the 45° angle described in the literature, and a significant difference was considered present if the calculated 95% CI of the ideal angle found in our study did not include the suggested 45° angle.

The relationships between the calculated ideal angles and biological sex, age, and pelvic anatomy (normal versus dysmorphic) were assessed. All data analysis and visualization were conducted using RStudio (Posit). Significance for all tests was defined as $p < 0.05$.

Results

Our study included 148 patients, with an even distribution of 74 men and 74 women. The median age of the patients was 45 years (interquartile range [IQR], 35 to 57 years). Eighty patients (54.1%) had a dysmorphic pelvis, while 68 (45.9%) were determined to have normal pelvic anatomy.

The ideal inlet angle for the entire patient cohort was determined to be 23.8° ± 8.4° (95% CI: 22.4° to 25.2°). This value was not significantly different from the ideal inlet angle calculated on 3D reconstruction, which was 23.5° ± 8.3° (95% CI: 22.2° to 24.9°). The ideal outlet angle for all patients was 40.1° ± 24.3° (95% CI: 39.2° to 41.1°). There was no significant difference from the ideal outlet angle on 3D reconstruction, which was calculated to be 40.1° ± 5.9° (95% CI: 39.1° to 41.0°). There was a difference between the inlet and outlet angle measurements (23.8° ± 8.4° versus 40.1° ± 5.9°, respectively; $p < 0.001$) among the patients (Table I).

The calculated ideal inlet and outlet angles were significantly lower than the recommended 45°, as that angle was not included within the 95% CI of each type of ideal angle. While 144 (97.3%) of the inlet measurements were less than this previously recommended 45°angle, there were 4 patients (2.7%) with inlet angle measurements of >45° (range: 46.4° to 55.4°). There were 115 patients (77.7%) with outlet angles that were less than the recommended 45°; 33 patients (22.3%) had values that were >45° (range: 45.1° to 52.7°).

The men had greater inlet angles (27.1° ± 7.8° versus 20.1° ± 7.8° for women; $p < 0.001$), while the women had greater outlet angles (41.3° ± 5.4° versus 39.0° ± 6.3°; $p = 0.016$). There was no significant difference in inlet angle measurements between patients with normal and dysmorphic pelvic anatomy (22.5° ± 7.1° versus 24.9° ± 9.3°; $p = 0.083$). However, a significant difference in outlet angle was observed on the basis of pelvic anatomy:

TABLE II Inlet and Outlet Angles by Sex, Anatomy, and Age*

	Number	Ideal Inlet Angle *(deg)*	P Value	Inlet Angle on 3D Reconstruction *(deg)*	P Value	Ideal Outlet Angle *(deg)*	P Value	Outlet Angle on 3D Reconstruction *(deg)*	P Value
All patients	148	23.8 (8.4)		23.5 (8.3)		40.1 (5.9)		40.1 (5.9)	
Sex			<0.001		<0.001		0.016		0.023
Male	74 (50.0%)	27.1 (7.8)		26.6 (7.9)		39.0 (6.3)		39.0 (6.3)	
Female	74 (50.0%)	20.1 (7.8)		20.4 (7.5)		41.3 (5.4)		41.2 (5.2)	
Anatomy			0.083		0.059		<0.001		<0.001
Normal	68 (45.9%)	22.5 (7.1)		22.1 (6.9)		38.2 (5.7)		38.0 (5.7)	
Dysmorphic	80 (54.1%)	24.9 (9.3)		24.7 (9.2)		41.8 (5.7)		41.8 (5.5)	
Age, change per year†		−0.277	<0.001	−0.281	<0.001	−0.002	0.981	−0.014	0.870

*Angular values are given as the mean, with the standard deviation in parentheses. †The mean age was 45 years (interquartile range, 35 to 57 years).

on average, patients with a dysmorphic pelvis had an outlet angle that was greater by 3.6° ($p < 0.001$).

We observed no relationship between age and outlet angle measurements ($p = 0.981$). A significant negative Pearson correlation coefficient (−0.277, $p < 0.001$) was observed between age and inlet angle—i.e., a decrease in inlet angle with increasing age (Table II).

Discussion

Pelvic fractures are assessed and treated based on anteroposterior, inlet, and outlet radiographic images. Different angular values have been suggested in the literature for inlet and outlet views. Inlet and outlet radiographs have classically been made by diverting the beam 45° caudally and 45° cranially from the direct anteroposterior view. Based on CT scans of patients with normal anatomy, Ricci et al. advocated using 25° for the inlet views and 60° for the outlet views[14]. These recommendations have varied over time, and various investigations have revealed that the angles required to achieve inlet and outlet views also differ significantly among individuals[7,16,17]. The initial anteroposterior pelvic radiograph provides a useful overview of pelvic injuries, but additional tests are required to assess the extent of injury and to help in treatment planning. In an emergency situation, especially in underdeveloped countries, proper pelvic inlet and outlet views are critical. Because CT is scarce in resource-constrained settings, accurately made inlet and outlet radiographic images are critical for comprehensive evaluation of known or suspected pelvic ring injuries.

Angles between 40° and 60° have been recommended for inlet radiographs, with 45° being the most typical recommendation. The recommended outlet angle has ranged from 30° to 45°, with 45° being the most typical, providing an orthogonal view to the 45° inlet view. However, these recommendations have typically been based on Level-V evidence. Pennal et al. created an instructional video in 1961 that has been cited as the origin of inlet and outlet views in radiography[1,4]. Furthermore, these angles have typically been reported with the assumption that orthogonal radiographs of the pelvis would provide the most accurate portrayal of the anatomy. The data from our study provide objective evidence to recommend in favor of 25° for inlet and 40° for outlet radiographs to provide ideal screening of the pelvic ring in the Ethiopian population. In the absence of additional information that would allow tailoring of the views to the individual with an injury, these angles are best for imaging the posterior portion of the pelvis. Individualized views are advised when CT data are available because pelvic anatomy varies widely. In 2010, Ricci et al. recommended an inlet angle of 25° and an outlet angle of 60°, which demonstrated a higher outlet angle and a similar measurement for the inlet angle when compared with our investigation, emphasizing the necessity of considering anatomic variations and population-specific factors when determining ideal radiographic angles for pelvic imaging[14]. Pekmezci et al., who used 3D reconstruction to reevaluate data from Ricci et al., concluded that the ideal inlet angle should be 25° and the ideal outlet angle should be 45°[12]. While our findings closely align with these results, it is essential to note that our study addresses a distinct geographic area and population, reinforcing the notion that variations in ideal pelvic angles are influenced by ethnicity and race. Another study that was performed in India showed that the mean angle of caudal tilt for the

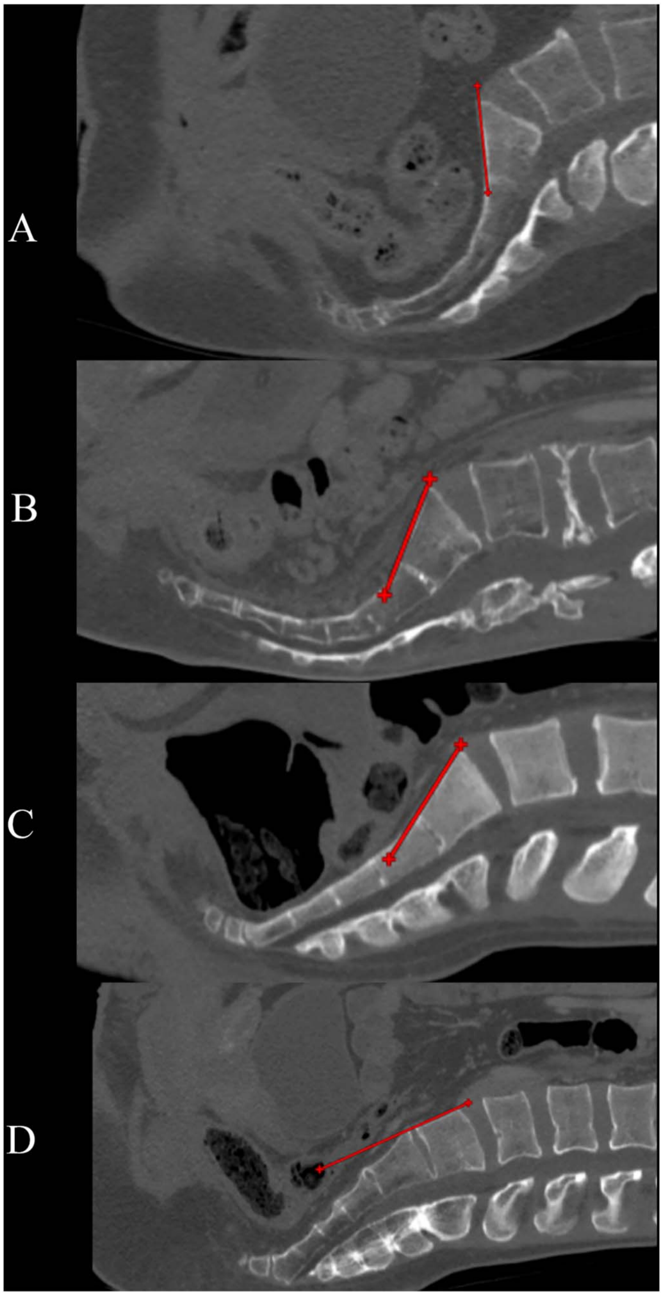

Fig. 4

Figs. 4-A through 4-D CT midsagittal reconstructions. To replicate the patient lying supine on the table, each image has been turned 90° from vertical. The red line runs parallel to the front cortex of the S1 body, to which the x-ray beam would need to be parallel to obtain the inlet view. The posterior pelvic anatomic variability is shown in 4 different patients. The S1 body in **Fig. 4-A** is oriented nearly vertically. The lordotic alignment has increased in **Fig. 4-C**, and the S1 body is almost horizontal in **Fig. 4-D**.

ideal screening using the inlet view was 33°, and the mean angle of cephalic tilt for the ideal screening using the outlet view was 56°[15]. The data from the study by Karkhur et al. differ from the data in our study; however, their study does reinforce the fact that a substantial deviation from the conventional approach of using 45° for the inlet and outlet radiographic views should be used in different races and ethnicities[15].

Numerous studies have documented the anatomic variability of the pelvis[16,17]. In order to produce an ideal inlet view that parallels the anterior cortex of the S1 body, the x-ray beam needs to be slanted differently in each patient, as shown in Figures 4-A through 4-D.

In contrast to the findings of Ricci et al.[14], Karkhur et al.[15], and Park et al.[3], we observed an inverse correlation between age and inlet angle: as age increased, the inlet degree decreased. This difference also supports variation in pelvic anatomy based on ethnicity. We observed no relationship between age and outlet angle measurements. Sex has been described as another potential source of interindividual variation. Our data revealed that men had greater inlet angles than women (mean, 27° versus 20°), and women had greater outlet angles than men (41° versus 39°); both differences were significant and demonstrate variation in pelvic anatomy among individuals. Despite observing a higher prevalence of dysmorphic sacra, we found no significant difference in inlet angle between the normal and dysmorphic pelves. However, our investigation revealed an increase of 3.6° in the outlet angle in dysmorphic pelves, which highlights the complex relationship between sacral morphology and pelvic view angles in different populations[3,12-14].

There are a few obvious limitations to this study. Although the sample size was relatively high, the alterations in the anatomy brought on by the fractures could not be considered since the calculations in the study were performed on imaging of uninjured pelves. However, the focus of our study was to determine the optimal pelvic inlet and outlet radiographic angles in patients without pelvic ring injury. These findings should be confirmed by a follow-up study that tests these values in a prospective cohort of trauma patients.

In conclusion, this study redefines the best inlet and outlet angles to use in Ethiopians; we found that the typical angles required to produce the best pelvic inlet and outlet views are a caudal tilt of 25° and a cephalad tilt of 40°, respectively. Three-dimensional rendering is a fast, easy, and accurate way to measure inlet and outlet angles when CT is available. Biologically, men have greater inlet angles and smaller outlet angles than women. Patients with a dysmorphic sacrum require an outlet view made with a greater angle than those with normal sacral anatomy. As age increases, the required inlet angle decreases. ■

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References

1. Pennal GF, Tile M, Waddell JP, Garside H. Pelvic disruption: assessment and classification. Clin Orthop Relat Res. 1980 Sep;(151):12-21.

2. Mendel T, Radetzki F, Wohlrab D, Stock K, Hofmann GO, Noser H. CT-based 3-D visualisation of secure bone corridors and optimal trajectories for sacroiliac screws. Injury. 2013 Jul;44(7):957-63.

3. Park DY, Kim JH, Nair SG, Won YY. Optimal Pelvic Inlet and Outlet Radiograph Angles in Korean Patients. J Korean Orthop Assoc. 2012 Feb;47(1):9-14.

4. Helfet DL, Kellam J, Vrahas M, Tile M. Fractures of the Pelvis and Acetabulum: Principles and Methods of Management. Fourth Edition. AOTrauma; 2015.

5. Miller AN, Routt MLC Jr. Variations in sacral morphology and implications for iliosacral screw fixation. J Am Acad Orthop Surg. 2012 Jan;20(1):8-16.

6. Young JW, Burgess AR, Brumback RJ, Poka A. Pelvic fractures: value of plain radiography in early assessment and management. Radiology. 1986 Aug;160(2):445-51.

7. Mostafavi HR, Tornetta P 3rd. Radiologic evaluation of the pelvis. Clin Orthop Relat Res. 1996 Aug;(329):6-14.

8. Parker S, Nagra NS, Kulkarni K, Pegrum J, Barry S, Hughes R, Ghani Y. Inadequate pelvic radiographs: implications of not getting it right the first time. Ann R Coll Surg Engl. 2017 Sep;99(7):534-9.

9. Housseini A, Yousef K, Al-Kady L, Elsherif M. Role of Multidetector Computed Tomography (MDCT) in the Evaluation of Patients with Pelvic Trauma. Suez Canal Univ Med J. 2022;25(4):12-8.

10. Draffan D, Clements D, Farrell M, Heller J, Bennett D, Carmichael S. The role of computed tomography in the classification and management of pelvic fractures. Vet Comp Orthop Traumatol. 2009;22(3):190-7.

11. Aydın D, Sarı E, Erler K. Computerised Tomography Analysis of Pelvic Inlet and Outlet Fluoroscopic View Angles. Indian J Orthop. 2020 Jun 27;54(5):687-94.

12. Pekmezci M, Rotter P, Toogood P, Morshed S, Kandemir U. Reexamination of pelvic inlet and outlet images using 3-dimensional computed tomography reconstructions. J Orthop Trauma. 2014 Jun;28(6):324-9.

13. Ricardo J, Chua B, Unsay JDC. The Pelvic Inlet and Outlet Radiographic View in Filipinos: A Retrospective Study of CT Scan Measurements and 3-Dimensional Computed Tomography Reconstructions. International Journal of Medical Imaging. 2022;10(2):16-21.

14. Ricci WM, Mamczak C, Tynan M, Streubel P, Gardner M. Pelvic inlet and outlet radiographs redefined. J Bone Joint Surg Am. 2010 Aug 18;92(10):1947-53.

15. Karkhur Y, Tiwari A, Maini L, Bansal V, Kakralia A. Radiological evaluation of pelvic inlet and outlet radiographic view in Indian population. J Clin Orthop Trauma. 2018 Oct-Dec;9(4):334-7.

16. Handa VL, Lockhart ME, Fielding JR, Bradley CS, Brubaker L, Cundiff GW, Ye W, Richter HE; Pelvic Floor Disorders Network. Racial differences in pelvic anatomy by magnetic resonance imaging. Obstet Gynecol. 2008 Apr;111(4):914-20.

17. Ziran BH, Wasan AD, Marks DM, Olson SA, Chapman MW. Fluoroscopic imaging guides of the posterior pelvis pertaining to iliosacral screw placement. J Trauma. 2007 Feb;62(2):347-56.