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Influence of Age on Pelvic Inlet and Outlet Radiographic Views

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Abstract

Background. Unstable fractures of the posterior pelvic ring represent a pressing concern in trauma surgery. Minimally invasive osteosynthesis techniques have gained widespread acceptance in contemporary practice. Accurate radiographic visualization is a critical component for the precise and successful placement of iliosacral and transsacral screws. Obtaining and accurately interpreting X-ray images can pose challenges in specific clinical situations, particularly those involving age-related skeletal changes.

The aim of the study is to assess the influence of the patient's age on the measures of pelvic radiographic inlet and outlet views angles for performing a sacral fracture fixation using cannulated screws.

Methods. A retrospective analysis of CT data was conducted on 106 patients with posterior pelvic ring injuries requiring cannulated screw fixation. Preoperative CT scans were reconstructed into sagittal projections. We performed construction and measurement of the true inlet angle, super-inlet angle, pelvic outlet angle, sacral concavity angle, promontory angle, S1 and S2 outlet view angles. Statistical correlation between sacral tilt angle and the patient's age was assessed.

Results. A two-step cluster analysis divided the patient cohort into two groups with significant differences in pelvic outlet angles and age (N_1 = 64, N_2 = 42). Statistically significant differences were found between the two clusters in all the studied parameters: median values of true pelvic inlet angles were 27.2° [23.2-32.2] and 18.2° [11.4-26.6] respectively ($p<0.001$); super-inlet angles were 42.5° [39.3-47.8] and 36.2° [28.7-42.8] respectively ($p<0.001$); promontory angles were 128.1° [123.3-133.2] and 122.1° [115.6-129.3] respectively ($p=0.003$); pelvic outlet angles were 62.6° [58.4-69.6] and 50.3° [45.9-53.5] respectively ($p<0.001$); S1 outlet angles were 51.8° [48.9-56.5] and 46.8° [43.1-50.2] respectively ($p<0.001$); S2 outlet angles were 40.8° [37.3-44.6] and 35.7° [30.9-38.6] respectively ($p<0.001$); the mean of the sacral concavity angles was 174.8°±10.5 and 152.1°±38.2 respectively ($p<0.001$); and the main age was 41.6±18.7 and 69.2±16.1 years respectively ($p<0.001$). A statistically significant inverse correlation between age and pelvic tilt angle (ρ = 0.534; $p<0.001$) was found. A novel diagnostic method for identifying sacral dysmorphism using angle measurement within the S1 bone corridor is presented. The sacrum was considered dysmorphic if the angle was equal to or less than 5°.

Conclusions. As the patient's age increases by one year, pelvic outlet angle decreases by 26°. If pelvic inlet angles are equal to or less than 14.45°, the difficulties in visualizing S1 and S2 outlet views during surgery are to be expected. The median of angles difference before and after anterior sacral tilt correction using a coccyx pad was 9.4° with interquartile range from 7.8° to 11°. Significant anatomical variations in posterior pelvic ring structure were observed among the study cohort. Preoperative CT sagittal reconstructions allow appropriate planning of intraoperative visualization considering expected intraoperative radiographic inlet and outlet views.

Keywords: true inlet view, standard inlet view, super-inlet view, S1 outlet view, S2 outlet view, bone corridor, pelvic fracture.

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Корреляционная связь между возрастом и рентгенологическими проекциями входа и выхода из таза

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Реферат

Актуальность. Нестабильные переломы заднего полукольца таза являются актуальной проблемой в хирургии повреждений костей скелета. На современном этапе наибольшее распространение получили малоинвазивные методики остеосинтеза. Правильная рентгенологическая визуализация является важной составляющей корректной и успешной установки илиосакральных и транссакральных винтов. Получение и точное интерпретирование рентгеновских снимков может быть сложной задачей в определенных клинических ситуациях, связанных с возрастными изменениями скелета.

Целью исследования являлась оценка влияния возраста пациентов на величину углов рентгенологических проекций входа и выхода из таза для выполнения фиксации переломов крестца канюлированными винтами.

Материал и методы. Для проведения исследования выполнен анализ данных КТ 106 пациентов с повреждениями заднего отдела таза, требовавшими фиксации канюлированными винтами. Использовали реконструированную сагиттальную проекцию предоперационных КТ. Были проведены построения и измерения углов истинного входа, супервхода, углов раскрытия таза, вогнутости крестца, промонториума, выхода из таза S1, выхода из таза S2. Оценена статистическая корреляция угла наклона крестца с возрастом пациента.

Результаты. Двухэтапный кластерный анализ разделил совокупность пациентов на две группы с существенными различиями по углам раскрытия таза и возрасту (N_1 = 64; N_2 = 42). Между двумя кластерами по всем исследуемым параметрам выявлены статистически значимые различия: медианные значения углов истинного входа в таз — 27,2° [23,2–32,2] и 18,2° [11,4–26,6] соответственно (p<0,001); супервхода в таз — 42,5° [39,3–47,8] и 36,2° [28,7–42,8] соответственно (p<0,001); углов промонториума — 128,1° [123,3–133,2] и 122,1° [115,6–129,3] соответственно (p = 0,003); углов раскрытия таза — 62,6° [58,4–69,6] и 50,3° [45,9–53,5] соответственно (p<0,001); углов выхода S1 — 51,8° [48,9–56,5] и 46,8° [43,1–50,2] соответственно (p<0,001); углов выхода S2 — 40,8° [37,3–44,6] и 35,7° [30,9–38,6] соответственно (p<0,001); среднее углов вогнутости крестца — 174,8±10,5° и 152,1±38,2° соответственно (p<0,001); возраста — 41,6±18,7 и 69,2±16,1 лет соответственно (p<0,001). Выявлена обратная статистически значимая корреляционная связь между возрастом и углом наклона таза (ρ = 0,534; p<0,001). В процессе выполнения исследования был разработан способ определения хирургического дисморфизма крестца с помощью построения угла в пределах костного коридора S1. Угол, при котором мы считаем крестец дисморфичным, равен или меньше 5°.

Заключение. При увеличении возраста пациента на один год угол раскрытия таза уменьшается на 0,26°. При угле истинного входа, равном или меньше 14,45°, следует ожидать сложности визуализации проекции выходов S1 и S2 во время операции. Медиана разницы углов до и после коррекции переднего наклона крестца при помощи подкладывания валика под копчик составила 9,4° с интерквартильным размахом от 7,8° до 11°. Среди включенных в исследование пациентов выявлены значительные анатомические различия в строения заднего полукольца таза. Изображения сагиттальной реконструкции предоперационной КТ позволяют соответствующим образом спланировать предоперационную визуализацию с учетом предполагаемых интраоперационных рентгенологических видов входа и выхода.

Ключевые слова: проекция истинного входа, проекция стандартного входа, проекция супервхода, проекция выхода S1, проекция выхода S2, костный коридор, переломы таза.

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BACKGROUND

Minimally invasive fixation of sacral fractures with iliosacral or transsacral screws is a widespread method of treatment of unstable posterior pelvic ring fractures [1, 2, 3, 4]. Pelvic inlet and outlet views combined with lateral X-ray views are used intraoperatively for screw insertion [5, 6]. A deep knowledge of anatomy helps to distinguish the typical structure of the upper sacrum from different variants of its dysmorphism [7, 8, 9, 10]. Preoperative computed tomography (CT) scans are necessary to understand the structure of the sacrum, to plan the radiographic angles of pelvic inlet and outlet views, and to determine direction of cannulated screws [6, 11]. Neglecting preoperative planning may result in an increased duration of surgery and radiation exposure. Proper patient positioning on the operating table depending on the sacral tilt helps to achieve optimal C-arm angles [4, 12].

Different degrees of sacral kyphosis or lumbar lordosis and the presence of any degree of sacral dysmorphism suggest a wide range of pelvic inlet and outlet angles [5, 13, 14]. Preoperative CT scans not only help to study the features of a fracture but also can be used to preliminarily determine the optimal inlet and outlet angles. This allows surgeons to obtain the necessary image during the surgery in almost all patients. In addition, they may be useful in complex clinical situations including morbid obesity, senile osteoporosis, and intestinal pneumatization.

Aim of the study — to assess the impact of patients' age on the value of angles of radiographic pelvic inlet and outlet views to fix sacral fractures with cannulated screws.

METHODS

A retrospective study enrolled 106 patients admitted to the Sklifosovsky Research Institute for Emergency Medicine with a radiologically confirmed horizontally unstable fracture of the sacrum from anteroposterior and lateral compression (61B1-3 according to the AO/OTA 2018 classification [15]). Patients with vertical pelvic instability (61C according to the AO/OTA 2018 classification), lumbosacral joint ruptures, fracture dislocations of the bases of the iliac bones, as well as U-, H- and Y-shaped fractures of the sacrum (the so-called jumper's fractures) were not included in the study.

The study was carried out from January 2021 to December 2023. All patients underwent preoperative CT examination of the pelvis in the supine position. Data processing and measurements were performed in the image archiving and communication system (ClearCanvas DICOM Viewer) using the RadiAnt DICOM Viewer software.

Plotting and measurement of the necessary angles were performed using the reconstructed CT scans in the sagittal view. The true inlet angle was plotted with the apex on the S2-S3 intervertebral disc along the anterior surface, with the ray coinciding with the vertical line drawn to the horizontal surface of the table on which the patient was lying, and the ray connecting the apex of the angle and the anterior edge of the promontory (Fig. 1 a). The super-inlet angle was plotted with the apex of the angle on the S2-S3 intervertebral disc on the posterior surface, with the ray coinciding with the vertical line drawn to the horizontal surface of the table on which the patient was lying, and the ray lying on the posterior surface of the S1-S2 sacral vertebrae (Fig. 1 b).

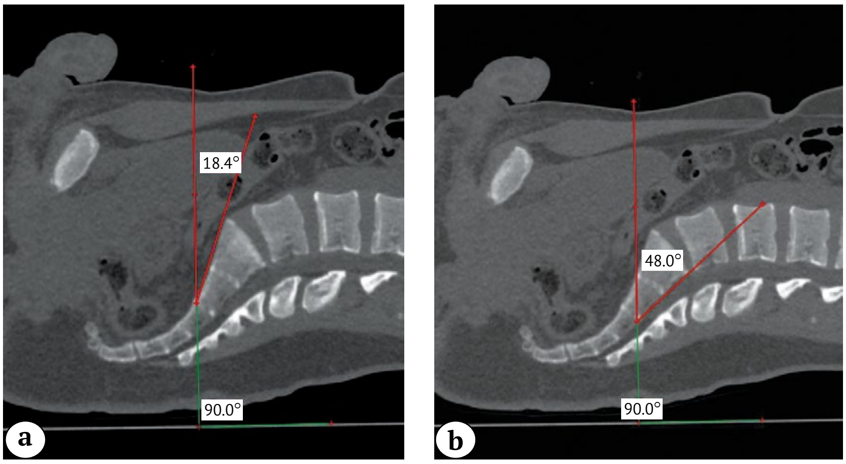

Fig.1. True inlet pelvic angle (a); super-inlet pelvic angle (b)

The S1 outlet angle was plotted with the apex at the midpoint of the superior margin of the S1 sacral foramen, with the ray coinciding with the vertical line drawn to the horizontal surface of the table on which the patient was lying, and the ray connecting the apex of the angle and the superior edge of the pubic bone (Fig. 2 a). The S2 outlet angle was plotted with the apex at the midpoint of the superior margin of the S2 sacral foramen, with the ray coinciding with the vertical line drawn to the horizontal surface of the table on which the patient was lying, and the ray connecting the apex of the angle and the superior edge of the pubic bone (Fig. 2 b).

The sacral concavity angle was plotted with the apex on the S1-S2 intervertebral disc along the anterior surface, with the ray coinciding with the anterior surface of the S1 sacral vertebra, and the ray coinciding with the anterior surface of the S2 sacral vertebra (Fig. 3 a).

The promontory angle was plotted with the apex at the antero-superior edge of the S1 vertebra, with the ray lying on its anterior surface, and the ray lying on the anterior surface of the L5 lumbar vertebra (Fig. 3 b).

The pelvic outlet angle was plotted with the apex on the S2-S3 intervertebral disc on its anterior surface, with the ray lying on the anterior surface of the S1-S2 sacral vertebrae, and the ray connecting the apex of the angle and the upper edge of the symphysis (Fig. 4 a). The ABC angle for determining the upper sacral dysmorphism was plotted with the apex on the outer wall of the iliac bone base, with the ray that passed as close as possible and parallel to the upper edge of the S1 vertebra without extending beyond it, and the ray connecting the apex of the angle and the upper edge of the contralateral S1 sacral foramen. The measurement of the optimal angle of dysmorphism was performed using the dimensions of the largest pelvis from the entire sample. Taking into account that the largest constrictions in the bone corridors are at the level of the sacral foramen, we measured the length of the AB cathetus of the ABC right triangle (Fig. 4 b).

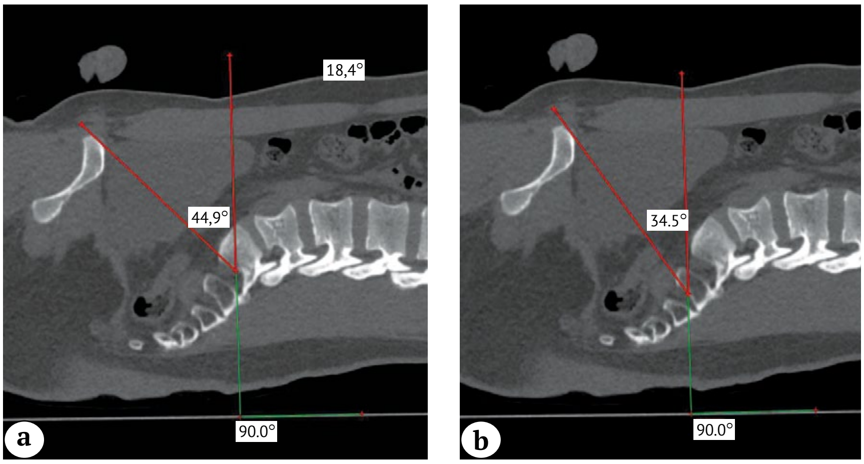

Fig. 2. S1 outlet view angle (a); S2 outlet view angle (b)

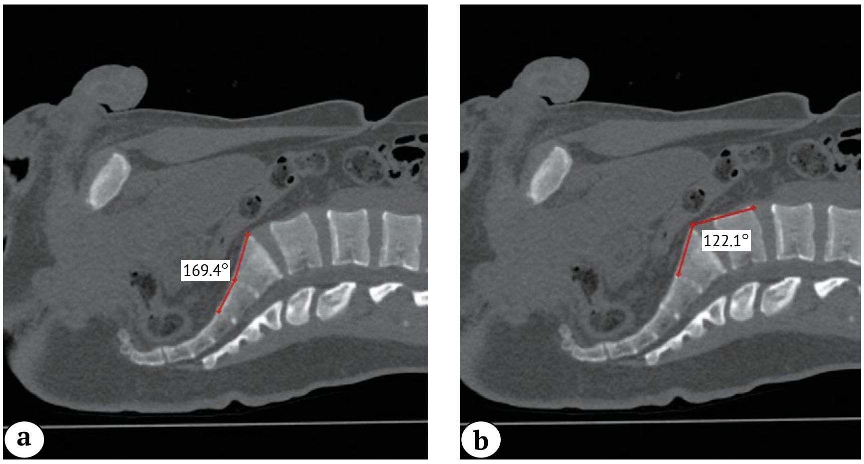

Fig. 3. Sacral concavity angle (a), promontory angle (b)

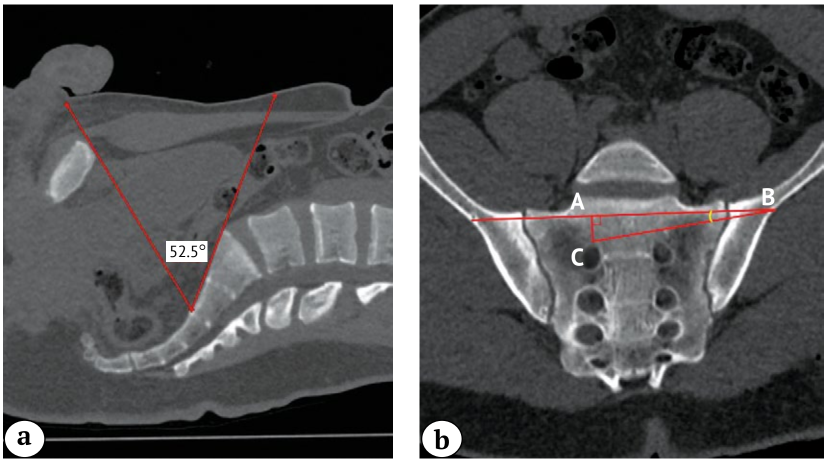

Fig. 4. Pelvic outlet angle (a); construction of the triangle for identifying the angle of dysmorphia of the upper sacrum in S1 (b)

Since we assumed that the optimal diameter of the bone corridor was 10 mm, it would determine the length of the AC cathetus. We applied the obtained data to the formula for calculating the angles in the right triangle:

$$\text{tg (ABC angle)}\ \frac{AC}{AB} = \frac{10\ \text{mm}}{114\ \text{mm}} = 5.013°.$$

The angle of less than 5° was considered a CT sign of surgical dysmorphism.

Osteosynthesis of sacral fractures was performed minimally invasively in the supine position. The surgical field was showered with antiseptics, and the patient was covered with sterile drapes according to the internal protocol. Regional or combined anesthesia with mechanical ventilation and myorelaxants was used. Osteosynthesis of the sacrum was performed with full-threaded 6.5 mm cannulated screws (NPO “Implant-N”, Russia) and 2.5 mm guiding wires with threaded tip (AO “Osteomed”, Russia) using the free-hand technique. A C-arm (Siemens Arcadis Varic, Healthineers AG, Germany) was used for X-ray control during the osteosynthesis. We applied iliosacral and transsacral methods of screw insertion through the sacrum depending on its morphological type. In case of a normal one, the transsacral screws were placed at the level of the S1 bone corridor. In case of a sacral dysmorphism, the transsacral screws were inserted at the level of S2, and the iliosacral screws were placed at the level of S1 with an individual angle in the coronal and axial planes. To tilt the sacrum anteriorly, a lumbar roller was used to form excessive lordosis. To tilt the sacrum posteriorly, a roller was placed under the coccyx to flatten the lordosis in the lumbar region of the spine. The resulting extension of the trunk by raising the pelvis above the table allows to increase the inclination of the C-arm orbit to visualize the pelvic outlet view. To measure the angles before and after the sacral tilt correction, we digitally saved the C-arm images and then calculated the corresponding angles on the computer.

Statistical analysis

The measurement values obtained were statistically processed using parametric and nonparametric tests in IBM SPSS Statistics 27 software. Quantitative variables were evaluated for conformity to normal distribution. The Shapiro-Wilk test was used for this purpose (with the number of observations less than 50) or the Kolmogorov-Smirnov test (with the number of observations more than 50). Quantitative variables with distribution different from normal were described using the median (Me) and lower and upper quartiles [Q1-Q3]. The Mann-Whitney U-test was used to compare independent samples if they did not follow the normal distribution of data. The Kruskall-Wallis test was used to compare multiple samples of non-normally distributed quantitative variables. We used the nonparametric Spearman's rank correlation coefficient to study the correlation between the events described by quantitative variables with non-normal distribution. The strength of correlation was assessed using the Chaddock scale (ρ). Paired or multiple linear regression was used to elaborate a predictive model describing the dependence of a quantitative variable on factors also represented by quantitative variables. The ROC-curve analysis was used to assess the diagnostic significance of quantitative variables in predicting a certain outcome, including the probability of the outcome, calculated using the regression model. A two-step cluster analysis was used to put patients into groups based on the similarity of their measured parameters.

RESULTS

The study group included 59 women (55.7%) and 47 men (44.3%). The mean age was 52.6±22.3 years (95% CI: 48.3-56.9 years).

The mechanism of injury and characteristics of pelvic ring injuries are shown in Table 1.

The mean time to surgery was 4.9 days (min – 1, max – 28). Osteosynthesis of the pubic bones with locking nails was performed in 37 (35%) patients. Open reduction and internal fixation of the symphysis rupture with a plate were performed in 12 (11.3%) patients.

Table 1

Mechanism of injury and characteristics of pelvic ring injuries

Parameter	n (%)
Mechanism of injury	
Traffic accident (driver)	22 (21)
Traffic accident (pedestrian)	31 (29)
Falling on the side from a ground standing position	48 (45)
Other mechanism	5 (5)
AO/OTA classification (2018)	
61 B1	38 (36)
61 B2	51 (48)
61 B3	17 (16)

As a result of the two-step cluster analysis, two clusters were determined in the structure of the studied sample. The share of the first cluster in the total structure amounted to 60.4%, of the second cluster – 39.6%. The silhouette value of cohesion and separation amounted to 0.3, which corresponds to an average quality of clusters. The results of comparison of the obtained clusters by the studied parameters are presented in Table 2.

In patients of the first diagnostic related group (first cluster N_1), the mean age was significantly lower than in patients of the second diagnostic related group (second cluster N_2): the values were 41.6±18.7 and 69.2±16.1 years, respectively. Statistically significant differences ($p<0.001$) were found upon comparison of the variables using Student's t-test.

The values of sacral concavity angles, true inlet angles, super-inlet angles, S1 and S2 outlet angles, promontory angles, and pelvic outlet angles were compared using the Mann-Whitney U-test. Statistically significant differences were found for promontory angles with $p=0.003$ and for all other angles with $p<0.001$.

The correlation between the age and the pelvic outlet angle, assessed using Spearman's rank correlation coefficient, is statistically significant ($p<0.001$). A statistically significant negative correlation between the pelvic outlet angle and the age of the patients was found ($\rho = 0.559$; $p<0.001$): as the age of the patient increased, the pelvic outlet angle decreased. The correlation was of moderate strength according to the Chaddock scale.

Table 2

Data for comparison between clusters

Parameter	Cluster 1 N_1 = 64	Cluster 2 N_2 = 42	p
Age, years old, M±SD	41.6±18.7	69.2±16.1	<0.001*
Sacral concavity angle, deg., M±SD	174.8±10.5	152.1±38.2	<0.001*
True inlet angle, deg., Me [IQR]	27.2 [23.2-32.2]	18.2 [11.4-26.6]	<0.001*
Super-inlet angle, deg., Me [IQR]	42.5 [39.3-47.8]	36.2 [28.7-42.8]	<0.001*
S1 outlet angle, deg., Me [IQR]	51.8 [48.9-56.5]	46.8 [43.1-50.2]	<0.001*
S2 outlet angle, deg., Me [IQR]	40.8 [37.3-44.6]	35.7 [30.9-38.6]	<0.001*
Promontory angle, deg., Me [IQR]	128.1 [123.3-133.2]	122.1 [115.6-129.3]	0.003*
Pelvic outlet angle, deg., Me [IQR]	62.6 [58.4-69.6]	50.3 [45.9-53.5]	<0.001*

* — differences are statistically significant (*p*<0.05).

Paired linear regression was used to determine the relationship between the pelvic outlet angle and the age. The relationship observed is described by the equation:

$$Y = 72.1 - 0.26 \times X,$$

where Y – pelvic outlet angle (deg.); X – age (years old).

A 1-year increase in age should be expected to decrease the pelvic outlet angle by 0.26° (every 10 years should be expected to decrease the pelvic outlet angle from the initial one by 2.6°). The correlation between the age and the pelvic tilt angle was negative, moderate (Chaddock scale), and statistically significant (ρ = 0.534; p<0.001). The factors included in the model determined 28.5% of the variance of age (Fig. 5).

ROC analysis was used to determine the relationship between the prediction of potential difficulties with visualization of the S1 and S2 outlet view during surgery and the angle of true inlet by CT. The area under the ROC curve was 0.992±0.060 (95% CI: 0.98-1.00). The threshold value of the angle of the true inlet by CT at the cut-off point was 14.45°. A true inlet angle equal to or less than this value predicted a high risk of difficulty in visualizing the S1 and S2 outlet view during surgery. The sensitivity and specificity of the method were 94% and 98%, respectively (Fig. 6).

For a more detailed statistical analysis of the estimated quality of the model, we calculated the magnitude of type I and type II errors (Table 3).

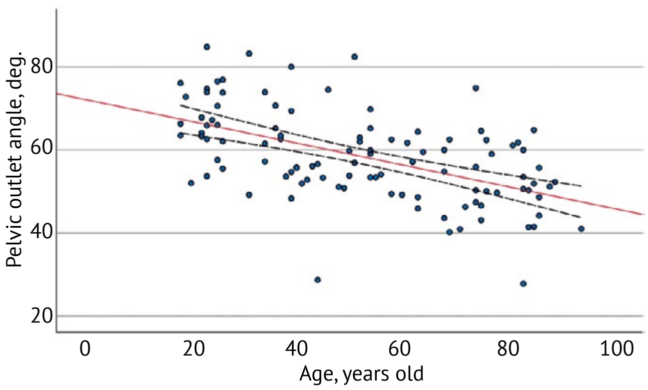

Fig. 5. Scatter diagram characterizing the correlation between pelvic outlet angle and age with approximating curve and lines [95% CI]

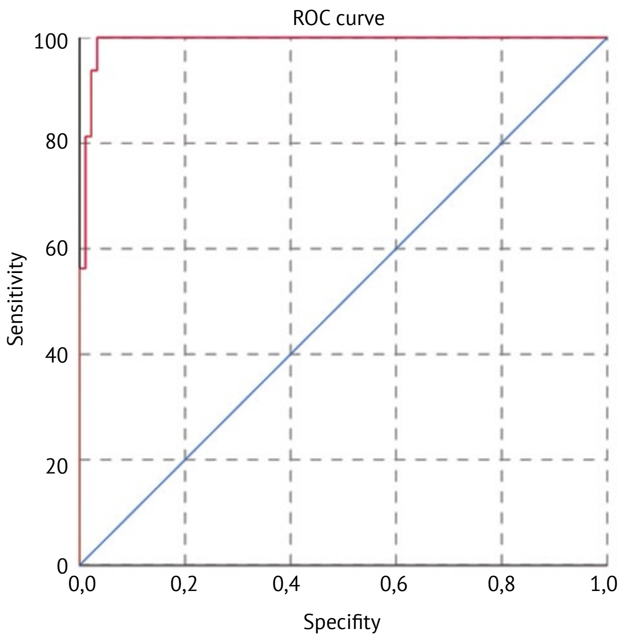

Fig. 6. ROC curve analysis of the assessment of diagnostic value of the outcome

Table 3

Assessment of model quality using fourfold table

Actual outcome	Predicted outcome	
	Yes (1; true inlet angle > 14.45°	No (0; true inlet angle <14.45°
Yes (1)	TP 15	FN 1
No (0)	FP 2	TN 88

When analyzing the fourfold table, we obtained the values of the following parameters:

$$Se = \frac{TP}{(TP+FN)} = \frac{15}{(15+1)} = 0{,}94 \qquad Sp = \frac{TN}{(TN+FP)} = \frac{88}{(88+2)} = 0.98$$

$$PPV = \frac{TP}{(TP+FP)} = \frac{15}{(15+2)} = 0{,}88 \qquad NPV = \frac{TN}{(TN+FN)} = \frac{88}{(88+1)} = 0.99$$

$$\text{Diagnostic efficiency} = \frac{(TP+TN)}{N} = \frac{(15+88)}{106} = 0.97,$$

where Se — the sensitivity of the method; Sp — the specifity of the method; TP — true-positive result; TN — true-negative result; FN — false-negative result; FP — false-positive result; PPV — positive predictive value; NPV — negative predictive value; N — the number of measurements.

After correction of the pelvic position on the operating table, a posterior sacral tilt different from the initial one was noted in all cases (n = 16). The median difference between the angles before and after correction of the anterior sacral tilt by placing a roller under the coccyx was 9.4° [7.8-11°].

DISCUSSION

Standard inlet, outlet and lateral views are usually used to examine the posterior pelvis [16, 17, 18]. Obtaining high-quality intraoperative images, along with the ability to correctly interpret pelvic radiographic landmarks and their correlation with anatomical structures, are extremely important [19, 20, 21].

Anatomical variability of the pelvis has been well described in the literature [11, 13, 22]. Traditionally, inlet and outlet views were obtained by directing the ray at the 45° angle caudally and 45° cranially from the vertical line [14, 23, 24]. This position has evolved over time, and several studies have since shown that the angles required to obtain inlet and outlet views differ significantly [14, 22]. M.L. Graves and M.L. Routt in their study identified ideal angles for radiographic inlet and outlet views: 25° (21-33°) and 42° (30-50°), respectively [22]. In our study, we got similar values: the true inlet view averaged 25° (18-31°) and the S1 outlet view averaged 50° (46-54°).

Obtaining clear intraoperative X-rays is challenging in patients with obesity and osteoporosis. A.N. Miller and M.L. Routt have found that excessive fat density associated with morbid obesity and senile osteoporosis make the visualization of pelvic bone landmarks much more complicated [25]. Preoperative CT allows to assess the individual position of each patient's sacrum and helps the surgeon to correctly position the C-arm in the operating room, which will ultimately contribute to a safe hardware implantation.

In addition, we have noted some technical difficulties in obtaining the outlet view in patients with a pronounced anterior tilt of the sacrum. When the C-arm orbit is tilted caudally, its X-ray detector (especially if it is flat and with a large diagonal) rests on the patient's lower extremities, thus making it impossible to achieve a correct outlet view due to insufficient angle of the orbit boom. This can be corrected by placing a roller under the sacrum. A roller placed under the lumbar spine increases lordosis and tilts the sacrum anteriorly. By placing the roller under the coccyx area, the sacrum can be tilted posteriorly by flattening the lordosis. Moreover, extending the lower limbs by lifting the pelvis above the table increases the inclination of the C-arm orbit. By applying rollers of different heights, it is possible to change the sacral angle to 20° [26]. In our study, we obtained lower values: the median value of the sacral angle from the initial state was 9.4° [7.8-11.0°]. Nevertheless, this manipulation helped to achieve correct pelvic outlet views in all cases (n = 16).

One more problem concerning correct placement of cannulated screws is the presence of the upper sacral dysmorphism. It is determined by the absence of a bone corridor of sufficient width for insertion of a transverse transsacral screw [4, 11, 27]. D.G. Bliznets et al.

suggest using five morphotypes of the sacrum depending on how many transsacral screws can be placed in one sacral vertebra: four-corridor, three-corridor, two-corridor, one-corridor, and no-corridor [11]. From our point of view, of all the variety of transitional forms, only two are of practical interest to us: those where one transsacral screw can or cannot be inserted through the S1 vertebra. If the screw cannot be inserted, this is a criterion for the so-called surgical dysmorphism. If otherwise, we consider the upper sacrum as a variant of normal.

Various ways of detecting the surgical dysmorphism by orthogonal views have been proposed in the literature [11]. Instead of these cumbersome calculations, we propose to determine just one angle from a single reconstructed oblique-horizontal view. In our opinion, a bone corridor is an imaginary cylinder with a diameter of at least 10 mm that passes through the sacrum through both bases of the iliac bones while not affecting the sacral foramen and the sacral canal. Empirically, we have found that such corridor is optimally sized for insertion of standard 6.5 and 7.3 mm cannulated screws. A bone corridor of less than 1 cm in diameter was associated with a high risk of sacral foramen or sacral canal damage. Thus, in our study, we diagnosed surgical dysmorphism of the upper sacrum in 16 (15%) patients. This anatomical feature had no correlation with the sex of the patients. If necessary, transsacral screws were inserted in such patients at the level of the S2 bone corridor.

CONCLUSIONS

We have revealed a statistically significant increase in the anterior sacral angle with the age increase. The average age of 69.2 years and older is a risk factor for a difficult verification of the outlet view in the supine position. A decrease in pelvic outlet angle of 0.26° should be expected with an increase in age by 1 year.

Radiographic pelvic inlet and outlet angles are in a wide range, so we recommend performing a preoperative pelvic CT scan to determine them in each patient individually. This information will help to achieve correct views using the C-arm in the operating room, especially in patients with obesity, excessive intestinal pneumatization, and senile osteoporosis.

If the true inlet angle is equal to or less than 14.45° in CT scans, there is a high risk of difficulties in visualizing the S1 and S2 outlet views during surgery, which requires placing a roller under the coccyx to tilt the sacrum posteriorly.

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