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Variation of Pelvic Diameters Due to Different Scanning Positions – The Experimental Study

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A B S T R A C T

The distortion of human pelvis X ray scans, due to different scanning positions, can cause huge mistakes in estimation of pelvic diameters. The aim of the study was to quantify distortion of pelvic diameters in relation to scanning inclination angles. Twenty anatomically defined spots on the pelvis of a young male cadaver, freed of soft tissues, were marked with 3 mm metal balls. The digitalized X-ray scans were made with seven different but similar inclination angles, and marked spots were recognized by computer software. Obstetrical-gynecological (Ob-Gyn), horizontal and vertical diameters were measured between marked spots, and percentages of distortion were calculated for each new scanning position. Twenty seven distances on human pelvis from seven X-ray scans varied from –35.9% to 28.3%, on average 0.47%. This study has pointed to a high variation of vertical pelvic dimensions (4.94±5.73%), consequently making them unreliable in the estimation of general pelvic shape, and low variation of horizontal dimensions (0.92±0.61%). Generally, the percentage of variation of pelvic dimensions highly increases with inclination angle, in frontal and sagital plane. Alteration of scanning distance by 4 cm has a weak influence on pelvic diameters. The most reliable Ob-Gyn pelvic diameter was conjugata diagonalis, then diameters obliqua prima and secunda, with an average length deviations of 3.4, 4.0, and 6.0% respectively. The conjugata anatomica was the most unreliable with an average variation of 11.5%.

Key words: *pelvis, obstetrics, orthopedics, distances, anthropometry, X-ray*

Introduction

The human pelvis is a ring consisted of the iliac bone, the ischial bone, the pubic bone, and the sacrum, which is a part of the spine, as well. Its function is to carry the body weight connecting the spine and the lower extremities.

There are many factors which could have a negative influence on the pelvic anatomy and its function respectively, like injuries, diseases, overloading or congenital abnormalities. Otherwise, change of the geometrical status of the human pelvis has its clinical impact through the alteration of physiological loads, pressures and forces acting on the human pelvis. Gender differences of the pelvic shape have also their clinical repercussions. Women have a higher hip-joint pressure, which is the result of the smaller radius of femoral head, which could explain, at least partially, a higher incidence of osteoarthritis in female population[1].

No matter which particular geometrical parameter we want to analyze, the X-ray is reliable and the most widely used method in estimation of the mentioned changes. The geometry of the pelvis can be observed on the basis of the antero-posterior (frontal) radiograph of the pelvis, especially the distances between characteristic anatomic points on the pelvis.

X-ray is esential in Ob-Gyn practice in the estimation of birth channel width. Disproportion of pelvic diameters and dimensions of fetal head, ultrasonically measured can contraindicate a trial of labor[2]. Modern radiological techniques, like the new generation of computed tomographies, can present not only the pelvic morphology, but the enlargement of the uterus, intrauterine blood, widening of the symphysis and sacroiliac joints, and gas in the sacroiliac joints as well[3]. Even CT scans show a huge variation of measured diameters, on average 3%[4]. X-ray is still the most commonly used method for the estimation of birth chanel width, in spite of the availability of modern techniques like computer tomograpies.

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However, the main problem in the performing of X-rays is that it is impossible to make absolutely the same X-ray of the human pelvis, even under repeated standard conditions. The distortion of the X-ray scan and alteration of geometric parameters of the human pelvis on the radiogram is a consequence of the different positions of the spine and legs on the X-ray table (pelvis inclination). The problem is even more pronounced on mobile X-ray devices, where beams are not parallel but divergent. Therefore, it is important to be aware of the maximal level of distortion in relation to scanning conditions.

The different scanning positions cause a huge distortion of the human pelvis X ray scans, and the mistakes in the estimation of pelvic diameters. The aim of the study was to quantify the distortion of the pelvic diameters in relation to scanning inclination angles.

Material and Methods

The pelvis of a young male cadaver, without any data of pathological or traumatic alterations in the pelvic region in pre and post mortem period, is freed of soft tissues. The anatomically defined spots are marked with 3 mm diameter metal balls by implanting them in the bone[5,6]. The points are marked as stated in Table 1.

TABLE 1
THE ANATOMICALLY DEFINED SPOTS OF HUMAN PELVIS

1	the highest spot of crista iliaca
2	the most lateral spot of crista iliaca
3	tuberculum iliacum
4	spina iliaca posterior superior
5	spina iliaca anterior superior
6	transsection of sacroiliacal joint and terminalis line
7	the most lateral part of terminalis line
8	spina iliaca anterior inferior
9	the highest spot of acetabulum
10	eminentia iliopubica
11	the most medial spot of acetabulum
12	spina ischiadica
13	the highest spot of foramen obturatorium
14	Kohler spot A
15	Kohler spot B
16	the lowest part of foramen obturatorium
17	tuber ischiadicum
A	the lowest spot of simphisis
B	the highest spot of simphisis
C	promontorium

The pelvis with its marked spots is firmly fixed into a special frame, enabling to perform X-rays in antero-posterior (frontal) direction. A total of 7 pelvic radiographs have been made on the basis of standardized conditions for antero-posterior scanning.

The central X-ray is centered between both hip joints, in medial plane, and perpendicular on the middle of the X-ray scan. The distance between the focus of X-rays and scan was 100 cm. The first scanning was made in physiological lying position of human pelvis, with 49° of the inclination angle[7]. The inclination angle during the second scanning was 49°, but the frame was moved 40 mm closer to the source of X-rays. The third scanning was performed with the inclination angle of 54°, the fourth scanning with 59° and the fifth scanning with 65° of the inclination angle. The inclination angle on the sixth scanning was 54° with an additional lateral inclination of 5°, and 10° during seventh scanning. Those conditions were chosen as the most common deviations of human position during X-ray obtaining[8]. However, the natural pelvis inclination of the male pelvis is 55° and 65° of the female pelvis[9].

The distances of human pelvis measured in this study are listed in Table 2. Intra and inter observer variability is avoided by software recognition of centers of metal balls on the computer digitalized scan (Vidar VXR-12 CCD scanner, 600 dpi, 256 gray levels, CorelDRAW 9®, Microsoft, Seattle, USA)[10]. The center was always in the same place, irrespective of the projection or enlargement, because the indication spot was round and clearly visible on all the scans. The measured distances of the human pelvis are presented in Figure 1.

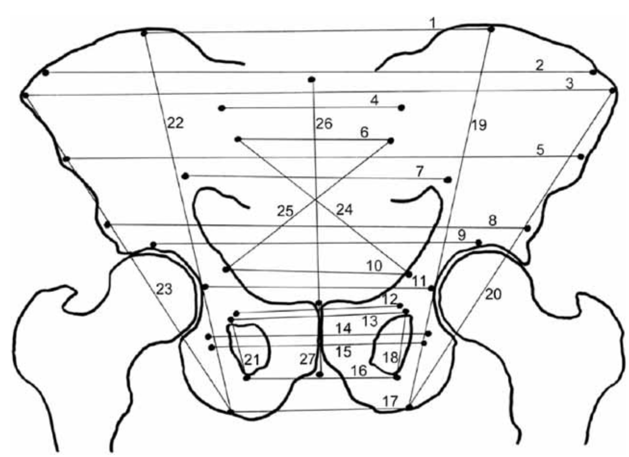

Fig. 1. The anatomically recognizable spots and distances of the human pelvis.

The distances are divided into three groups. The distances from 1 to 17 connect symmetrical points on the left and right sides of the pelvis (horizontal distances), the distances from 18 to 23 are vertical pelvic dimensions, and the distances from 24 to 27 are Ob-Gyn defined distances of the human pelvis[11].

The study was performed at the Department for Traumatology, Clinical Center Ljubljana in cooperation with the Institute for Anatomy, Ljubljana Medical School, Slovenia, and approved by the Ethics committee of the Ljubljana Medical School.

TABLE 2
THE HORIZONTAL, VERTICAL AND OB-GYN DEFINED DISTANCES OF THE HUMAN PELVIS

	The horizontal distances
1	the distance between the highest spots of the right and left crista iliaca
2	the distance between the most lateral spots of right and left crista iliaca
3	the distance between the right and left tuberculum iliacum (distantia cristraum)
4	the distance between the right and left spina iliaca posterior superior
5	the distance between the right and left spina iliaca anterior superior (distantia spinarum)
6	the distance between the right and left transecting spot of the sacroiliacal joint and linea terminalis
7	the distance between the most lateral spots of the right and left linea terminalis (diameter transversa)
8	the distance between the right and left spina iliaca anterior inferior
9	the distance between the highest lying spots of the right and left acetabulums
10	the distance between the right and left eminentia iliopubica
11	the distance between the most medial lying spots of the right and left acetabulum
12	the distance between the right and left spina ishiadica
13	the distance between the highest lying spots of the right and left foramen obturatum
14	the distance between the right and left Kohler's spots (measurement A)
15	the distance between the right and left Kohler's spots (measurement B)
16	the distance between the lowest spots of the right and left foramen obturatum
17	the distance between the right and left tuber ishiadicum.
	The vertical distances (three pairs left and right distances)
18	the distance between the uppermost and the lowest spots of the left foramen obturatum
19	the distance between the left tuber ishiadicum and the highest lying spot of the left crista iliaca
20	the distance between the left tuber ishiadicum and the left tuberculum iliacum
21	the distance between the uppermost and the lowest spots of the right foramen obturatorium
22	the distance between the right tuber ishiadicum and the highest lying spot of the right crista iliaca
23	the distance between the right tuber ishiadicum and the right tuberculum iliacum.
	The Ob-Gyn distances
24	the diameter obliqua prima – the distance between the transecting spot of the right sacroiliacal joint and the terminal line and the left iliopubic eminentia
25	the diameter obliqua secunda – the distance between the transecting spot of the left sacroiliacal joint and the terminal line and the right iliopubic eminentia
26	the conjugata anatomica – the distance between the upper edge of symphysis and promontorium (apertura pelvis superior)
27	the conjugata diagonalis – the distance between the lower edge of symphysis and promontorium (apertura pelvis inferior

The methods from descriptive statistic (average, percentage) were used for the analysis of the variation of pelvic distances[12]. The collected data were processed by Microsoft Excel® (Microsoft, Seattle, USA) software.

Results

Twenty seven distances on the human pelvis from seven X-ray scans varied from –35.9% to 28.3%, on average 0.47%. The highest distortions, and the greatest unreliability, were expressed distances number 18, 21 and 25, over 11%.

The measured distances had the highest length variation during the sixth and seventh scanning, on average about one percent. The highest variations of a particular distance measured under a certain condition was noted for distances number 18, 21, 24, and 26, during the fifth scanning: 34.13, 35.86, 14.07, and 28.31% respectively. Other distortions higher than 15% expressed distances numbers 18, 21 and 26 during the forth scanning, and distance number 26 during the sixth scanning.

The distances numbers 14, 15 and 10 had the lowest distortions: 0.11, 0.14, and 0.33% respectively. Distances numbers 7, 8, 9, 11, 12, 13, 16, 17, and 20 had less a one percent of variation as well. The majority of distances measured during the second scanning had 0% of variation, or very close to it. There was no variation for distances numbers 10–13 during the third scanning, the distance number 12 during the forth scanning, and the distance number 11 during the fifth scanning. The most reliable measurements of the pelvic dimensions were achieved during the second, the third and the forth scanning, with the length distortion under 0.33% (Table 3).

TABLE 3
THE PERCENTAGES OF VARIATIONS OF THE 27 DISTANCES ON PELVIC X-RAY SCANS, MADE UNDER 7 DIFFERENT SCANNING CONDITIONS

X-ray Distance	1. [mm⁻¹]	2. [%]	3. [%]	4. [%]	5. [%]	6. [%]	7. [%]	Average [%]
Horizontal distances								
1	214	0	1.40	2.33	4.91	1.17	2.69	2.08
2	351.5	0.14	1.28	2.27	4.12	1.28	2.63	1.96
3	376.5	0	1.06	2.06	3.98	1.46	2.52	1.84
4	115.5	0	0.86	1.73	3.46	0.87	1.73	1.44
5	324.5	–0.09	0.92	1.39	2.62	1.23	1.69	1.29
6	114	0	0.44	1.31	2.41	0.66	1.31	1.02
7	162	0.59	0.46	1.23	1.85	0.46	1.23	0.97
8	265	0	0.37	0.75	1.32	1.32	1.04	0.80
9	212.5	0	0.23	0.94	1.18	0.47	0.71	0.59
10	114.5	0	0	0.43	–2.40	0.44	–0.44	0.33
11	147	0	0	0.17	0	1.02	–5.10	0.65
12	112.5	0	0	0	2.66	1.11	0.22	0.67
13	110	0	0	0.23	0.68	1.36	0.68	0.49
14	146.5	0.34	–0.34	–0.34	–0.34	1.02	0.34	0.11
15	143	0	–0.35	0.17	–0.70	1.40	0.35	0.14
16	108.5	1.38	–1.15	–1.38	–1.61	0.69	–0.69	0.46
17	122.5	–0.41	–1.02	–1.43	–1.63	1.02	–0.61	0.68
Vertical distances								
18	52	0	–10.1	–18.8	–34.1	2.40	–12.0	12.1
19	245.5	0	1.22	1.63	1.43	2.24	4.07	1.77
20	245.5	0	–0.81	–1.73	–3.97	1.39	0.20	0.82
21	49.5	0	–10.6	–18.7	–35.9	3.03	–13.1	12.54
22	253	–0.10	1.28	1.78	2.17	0.49	1.88	1.25
23	237.5	0	–1.01	–1.92	–4.65	1.01	–0.20	1.13
Ob-Gyn distances								
24	131.5	0	4.75	8.17	14.07	–3.42	0.38	3.99
25	131.5	0.95	3.04	5.70	9.86	4.75	11.98	6.05
26	113	0	9.73	16.15	28.31	0	15.04	11.54
27	166	–0.30	2.71	4.97	6.93	0.60	5.42	3.39
Average		0.09	0.16	0.33	0.25	1.09	0.89	0.47

A high variation of vertical pelvic dimensions (4.94±5.73%) and Ob-Gyn defined diameters (6.25±3.71%), and low variation of horizontal dimensions (0.92±0.61%) were noted. The most reliable Ob-Gyn pelvic diameter was conjugata diagonalis, then diameters obliqua prima and secunda, with average length deviations of 3.4, 4.0, and 6.0%, respectively. The conjugata anatomica was most unreliable with average variation of 11.5% (Figure 2.).

Generally, the percentage of variation of pelvic dimensions highly increases with the inclination angle in frontal and sagital plane. Alteration of scanning distance by 4 cm has a weak influence on pelvic diameters.

Discussion

The reason for this experimental study was a problem encountered in practice that a radiologist can never make identical X-ray of the pelvis by repeated scanning. The distortion of human pelvis X ray scans due to the different scanning positions can cause huge mistakes in the estimation of pelvic diameters.

The pelvic X-ray scans were performed under seven different inclinations close to common scanning position, to reveal the influence of the scanning position on pelvic dimensions[1,9]. The aim of the study was to find out which pelvic dimensions have increased the alteration of length, and to mark them as insecure for practice and further studies employing anatomical dimensions of the human pelvis.

Relatively huge distortion of anatomical dimensions was noted, the average length distortion in the whole study was 0.47%. Some distances had no or minimal alteration, 43% of measured distances in 6 different scanning positions had the alteration less than 1%.

The most insecure anatomical parameters (the highest distortion) were the distances number 18, 21 and 25,

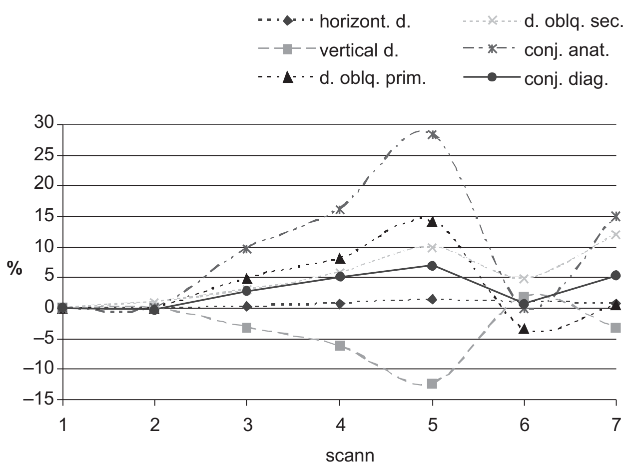

Fig. 2. The variations of horizontal and vertical pelvic distances, conjugate anatomica and diagonalis, and diameters obliqua prima and secunda through the 7 scanning conditions.

with the length alteration over 11%. The conditions described for the sixth and seventh scanning were the riskiest with the average variation for all 27 distances about one percent. This study has pointed to a high variation of vertical pelvic dimensions (4.94±5.73%), consequently making them unreliable in the estimation of general pelvic shape, and low variation of horizontal dimensions (0.92±0.61%).

The most reliable scanning conditions were during the second, the third, and the forth scanning, with the length distortion less than 0.33%. Obviously, there is a tendency that the insecurity of dimension measurement at scans of the human pelvis increases with the inclination angle in the frontal and sagital planes.

On average, Ob-Gyn diameters varied 6.25±3.71%. The most reliable Ob-Gyn pelvic diameter was conjugata diagonalis, then diameters obliqua prima and secunda, with average length deviations of 3.4, 4.0, and 6.0% respectively. The conjugata anatomica was the most unreliable with average variation of 11.5%. Increase in the inclination angle makes Ob-Gyn distances longer, virtually making the delivering channel wider as it really is.

The results from this study could be helpful in the real estimation of the pelvic channel in obstetrics[7,13]. Such studies are rare, the most similar study based on CT scans reports a distortion transverse diameter up to 6 mm, while our study reports of 1.85%, or 3 mm distorsion of transverse diameter[6].

Another clinical application of our data could be the interpretation of pelvic X-ray scans in the diagnostic of developmental displasia of the hip (DDH). Increased or decreased lordosis virtually affects the position of the distance number 11, important line for the estimation of femoral head position in DDH. Forced position of legs lying on X-ray table, with consequential hyperextension of hips, causes the anterior pelvic inclination and the narrowing of foramina obturatoria (distances numbers 18 and 21) and the alteration of Shenton line[14]. The lateral pelvic inclination manifests as asymmetrical width of foramina obturatoria, and causes a decrease in acetabular angle[15,16]. This study has shown that the increase in the inclination angle reduces the distance between the highest and the lowest points of foramen obturatum (distances numbers 18 and 21) for 35.86 %, making those distances the most unreliable in the whole study.

Special attention should be paid to the estimation of diameter on pelvises which were previously osteotomied due to DDH. The average transverse diameters of the inlet and outlet at the osteotomied pelvises were significantly smaler in comparison to normal pelvises[17]. Some osteotomies, like Chiari, Salter and Sutherland lead to a more or less narrowing of the intertuber-ischial diameter of the pelvic outlet, while triple osteotomies according to Steel, Carlioz and Tonnis lead to a narrowing of the middle part of the bony pelvic cavity. It is necessary to inform the patients who are operated after the end of growth that a future pregnancy may have to be terminated by a caesarean section[18].

Additionally, in urology, pelvis X-ray measurements should be performed in all neonates with bladder exstrophy before reconstructive surgery for a better understanding of the malformation[19].

The main limitation of this study could be that only one pelvis of young adult male cadaver was analyzed. But, descriptions in human anatomy are based on a young healthy male cadaver. The child pelvises are not suitable for this study due to huge amount of cartilage, the geriatric pelvises are not appropriate as well, because it might contain osteophytes or other patomorphologic deviations.

The majority of analyzed distances were common anatomical, orthopedic and obstetrics defined pelvic distances[5]. Other distances were geometric parameters which could be used as referential values for further anthropometrical, biomechanical and other studies after adjusting to body height and the inclination angle for each participant.

Anatomy, shape and structure are a base for all biomechanical researches. In equilibrium, the shape is a result of the function and it can help as a model in deductive-analytical analyzing of function and clinical consequences[20,21]. Methods and results from this study could certainly be a useful complement to some previous anthropometrical studies, and clinical studies of pelvic deformities, urology, and experimental human and animal studies[13–16]. To the best of current knowledge, this is the first analysis of its kind, which analyses the impact of pelvis position during scanning, which is the most common cause of X ray scan distortion. Less common and less powerful factors influencing pelvic dimensions are well explored, such as the technique of scanning (CT vs. ultrasound vs. X-ray), gender and anthropological evolution of human pelvis, even influence of vaginal delivery[2–4,22–25].

Generally, the inclination angle in frontal and sagital plane highly increases the percentage of distortion of pelvic dimension, and the alteration of scanning distance by 4 cm has a weak influence on pelvic diameters. Further anthropometric, radiological and virtual calculations of the pelvic geometry should be complemented to this study. The current study at least alerts clinicians to be careful in estimating pelvis geometry on X-ray scans.

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PROMJENE ZDJELIČNIH DIJAMETARA UZROKOVANE RAZLIČITIM POLOŽAJIMA PRI SLIKANJU – EKSPERIMENTALNA STUDIJA

SAŽETAK

Distorzija RTG slike zdjelice čovjeka uzrokovana različitim položajem tijekom snimanja može stvoriti velike pogreške u procjeni dužine dijametara zdjelice. Cilj ove studije je bio kvantificirati stupanj distorzije zdjeličnih dijametara u odnosu na kutove inklinacije pri slikanju. Dvadeset anatomski definiranih točaka zdjelice mladog muškog kadavera, bez mekotkivnih dijelova, markirani su metalnim kuglicama presjeka 3 mm. Digitalizirani RTG snimci iz sedam različitih kutova inklinacije sadržavali su markirane točke koje su prepoznate računalnim softwareom. Između tih točaka izmjereni su horizontalni i vertikalni dijametri koji se koriste u porodništvu, te je izračunat postotak distorzije za svaku novu poziciju. Dvadeset sedam distanci zdjelice čovjeka, slikano iz različitih ali sličnih pozicija, variralo je između –35,9% i 28,3%, u prosjeku 0,47%. Ova studija je ukazala visoku varijaciju vertikalnih zdjeličnih dijametara (4,94±5,73%), posljedično ih čineći nepouzdanim u procjeni oblika zdjelice, te malu varijaciju horizontalnih dimenzija zdjelice (0,92±0,61%). Općenito, postotak varijacije dimenzija zdjelice raste sa kutom inklinacije slikanja, i u frontalnoj i u sagitalnoj ravni. Promjena udaljenosti slikanja za 4 cm ima malen utjecaj na zdjelične dijametre. Najpouzdaniji porodničko-ginekološki dijametar bila je conjugata diagonalis, potom diametar obliqua prima i secunda, sa prosječnim devijacijama dužine od 3,4, 4,0 i 6,0%. Conjugata anatomica bila je najnepouzdanija sa prosječnom varijacijom od 11,5%.