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Morphometry of the Pelvic Ring in Definition of Biomechanical Factors Influencing the Type of Pelvic Fracture

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A B S T R A C T

The aim of the study was to supplement data on pelvic morphology and structural geometry. Using these data, a mathematical and biomechanical model was constructed. The research was divided into two parts. The first part comprised radiogrammetric analysis of pelvic morphology and geometry based on 60 AP x-rays of male and female pelvises. The spatial definition of the pelvis was given by three transverse and one sagittal diameter. Transverse diameters were measured at the level of iliac wings, at the narrowest supraacetabular portion and on the line passing through the center of both femoral heads. The fourth diameter was the height of the pelvis. Geometric properties and structure of pelvic bones and position of muscles in relation to bone elements of the pelvis were analyzed in the second part. Knowing geometric dimensions of the pelvis and the body weight, it is possible to calculate the magnitude of gravitational forces acting upon certain pelvic portions. This biomechanical model serves for simulation of operative methods of fixation and allows search for the optimal solution, which is stable enough to withstand all the forces acting upon fragments of a fractured pelvic ring.

Key words: *pelvic ring morphometry, pelvic fracture, biomechanics*

Introduction

The human pelvis is a highly complex construction of varying geometry[1] and heterogenous structure. Due to the fact that a large number of muscles are attached to pelvic bones, the forces produced by their tonus and contractions are of various directions[2]. In combination with internal forces, an external force of a specific direction and intensity can produce a resultant force of such a direction and intensity, which, depending upon the bone strength and geometry, may cause a pelvic fracture[3]. The position of fracture fragments and the fracture gap cannot be accurately identified using standard x-rays in two projections or in AP and semi-oblique projections. Computed tomography[4] shows more precisely the position of bone fragments in a certain cross-section. After a fracture has occurred, muscle and other internal forces determine the position and stability of bone fragments. During reduction and retention of fracture fragments, it is essential to counterbalance specific internal and muscle forces. In order to achieve this, the forces acting upon bone fragments during reduction as well as during the process of bone healing must be determined. However, this issue remains unknown in the treatment of pelvic fractures.

Knowledge about the structure and position of fracture fragments, fracture gap position, volume and position of muscles acting upon bone fragments in pelvic fractures serves as the basis for approximate calculation of the magnitude and direction of muscle forces acting upon fracture fragments[5]. These data should be incorporated into planning of pelvic fracture treatment. An adequate treatment should comprise devices capable of resisting all muscle and gravitational forces as well as forces of inertia.

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The aim of this study is to supplement the knowledge on the pelvic structure and geometry and improve the application of CT[6] in imaging of the pelvis as well as to obtain additional data from standard x-rays and CT scans without additional imaging or exposure of patients to irradiation. Based on these data, a mathematical and biomechanical model of the pelvis will be constructed in order to analyze and calculate muscle forces acting upon bone fragments in pelvic fractures[7].

Material and Methods

The research study is divided into two parts: A. Morphological and geometric analysis of pelvic x-rays and B. Computed tomography.

A. Morphological and geometric analysis of pelvic x-rays

In the first part, we want to define basic morphological and geometric features of the average human pelvis based on a population sample in the city of Zagreb and determine the final values and specific pelvic types. Using anthropometrical and radiogrammetric methods we want to analyze pelvic AP scans in order to define specific parameters of the female and male pelvis[8]. The aim is to determine the minimum number of measuring parameters that can allow an adequate definition of morphological features of the pelvis and calculation of the most significant geometric and biomechanical properties[9].

Sample

The study was conducted using pelvic AP x-rays in 60 adults ranging in age from 18 to 60 years. There were 30 female and 30 male subjects. AP x-rays were obtained in the orthogonal position. The medial ray was positioned suprapubically in the pelvic center, always at the same point, and the distance of the ray from the table to the line passing through the center of the trochanter served for the calculation of the enhancement factor for structures displayed on the x-ray image at the level of the trochanter and the femoral head center. Indication for x-ray imaging was a suspected pelvic injury and we included only the x-rays showing no fractures or disorders of pelvic geometry. Only the x-rays obtained in the correct AP position (AP projection) were included into the study, which was confirmed by the fact that the line drawn through the center of the pubic symphysis correlated with the midsagittal line passing through the center of the sacrum and the tip of the coccyx. All other images, as well as the images not displaying the entire pelvis, were excluded as incomplete or inadequate. We chose a random sample of x-ray images of adult pelvises of both genders taking into account basic ethical principles during imaging procedure since all x-ray images were performed based on medical indications. On the other hand, all scanned pelvises in this sample may be considered to be normal and with no pathological changes.

Radiogrammetric measurements

In our opinion, the minimum number of measurements necessary for the definition of the pelvis was measuring in three transverse and one vertical plane. Each of the measured values in the transverse and vertical plane was divided into two or more parts, each of these defining a specific morphological or functional size of the pelvis[10].

1. The upper top transverse level of the iliac crest at which the size of the pelvic diameter is measured connects two most lateral and prominent points of the iliac crest and corresponds, most probably, to the intertubercular line in the topographic anatomy. This dimension is marked as A-dimension and was split into three parts. Part A-1 connects the most lateral point of the iliac crest along this line and the point in which this line crosses the anterior portion of the SI gap, i.e. SI juncture. Part A-2 is the same part but only on the opposite (left) side. The middle segment of this dimension A-3 corresponds to the width of the sacrum at the level of the abovementioned line (Figure 1).

2. The second transverse level passes through centers of both femoral heads and starts at the cross-section with the vertical line drawn from the most lateral point of the greater trochanter on the right side to the same point on the left side. The line B is divided into four segments. B-1 segment starts at the point of cross-section of the lateral tangent of the greater trochanter projection with this

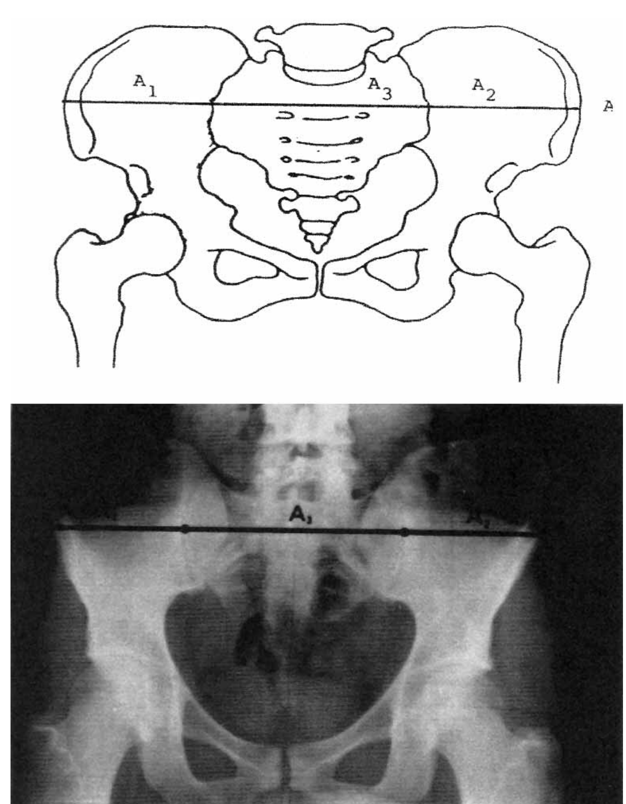

Fig. 1. Diameter A connects the end points of the iliac wing projection.

line up to the center of the femoral head. B-2 segment corresponds to the same distance but on the left side. Segments B-3 and B-4 cover the distance along the same line starting from the center of the femoral head on the left or right side to the median plane of the pelvis (Figure 2).

3. The third transverse level is marked as C and it corresponds to the diameter connecting the most lateral points of the pelvic projection at its narrowest portion, closely above the acetabular roof. This diameter is studied as a whole and is not divided into segments (Figure 3).

4. The height of the pelvic projection connects the lines corresponding to tangents of the highest iliac crest and the lowest part of the ischial projection. This vertical dimension D is also divided into two segments. The border between these two segments is the plane passing through the femoral head center. Segment D-1 connects the highest point of the iliac crest and the femoral head center, while segment D-2 connects the femoral head center with the plane, which like a tangent passes through the lowest point of the pelvic projection. This is most often the lowest portion of the ischiadic bone. These four dimensions and their segments allow calculation of a large number of other parameters that can be used to define geometric and biomechanical properties of the pelvis (Figure 4).

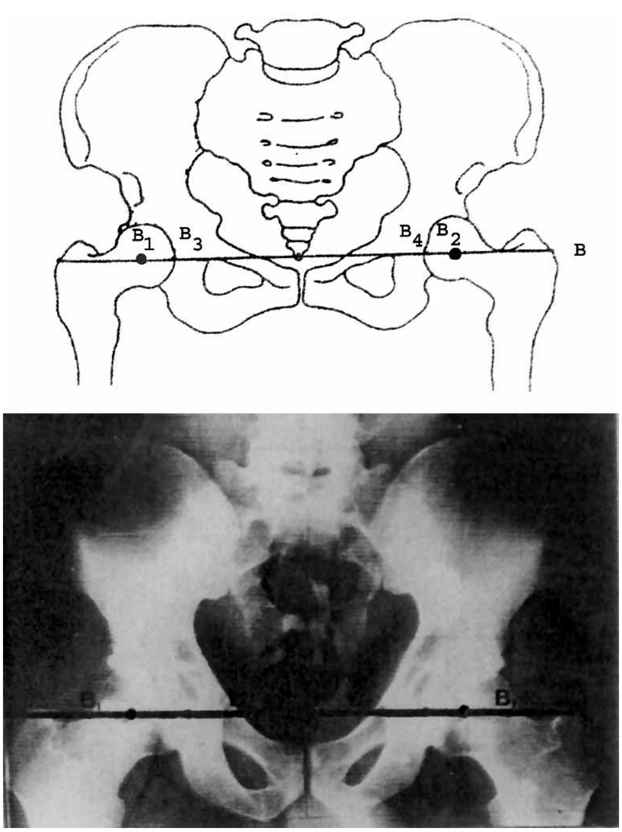

Fig. 2. Diameter B (intertrochanteric diameter) passes through the center of both femoral heads.

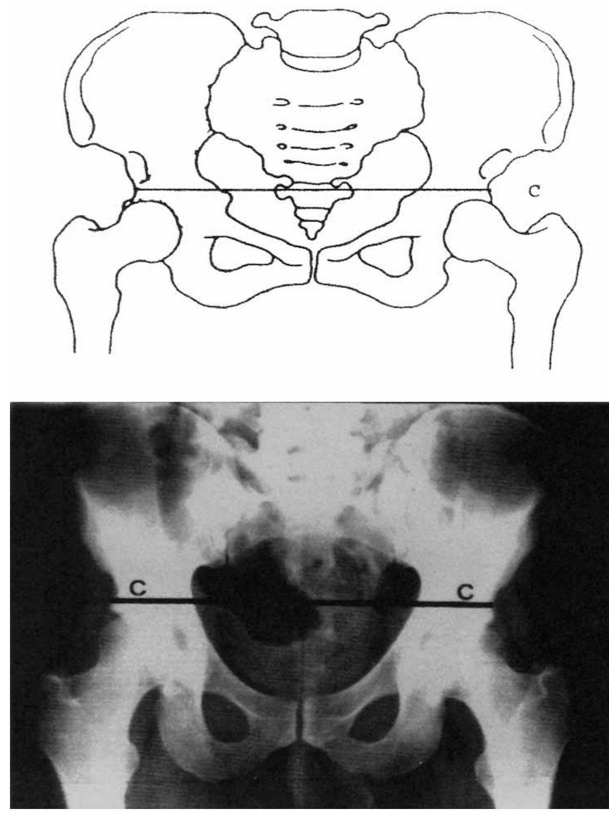

Fig. 3. Diameter C is the supracetabular pelvic diameter.

The quotient of segments A-1 and A-2 is the measure of symmetry of iliac wing projections. The absolute size of the A diameter shows the largest width of the pelvic entrance. The ratio between the A-1 and A-2 segments and the A-3 segment indicates the ratio between the width of the alar projections and the width of the sacrum.

The diameter at the B level indicates the intertrochanteric distance, which is one of the common parameters in the anthropological studies of the pelvis, but we divided this diameter into segments; B-1 and B-2 segments denote the lever arm of pelvic and trochanteric muscles, of the m. gluteus medium, m.gluteus minimus and m. tensor fasciae latae in particular. Segments B-3 and B-4 denote the moment arm of body weight. These measures can be used to calculate the loading of the femoral head and acetabulum during standing on one foot and during gait if the body weight is known.

Diameter C defines the distance from the acetabular roof on one body side to the other and corresponds to the total outer width of the lesser pelvis. Height D corresponds to the height of the pelvic projection and depends upon the degree of anteversion and the position of the pelvis during imaging. This height is also divided into two segments D-1 and D-2, with the plane passing through the center of the femoral head being the marginal point. At the same time rotational axes of the hip pass through this point.

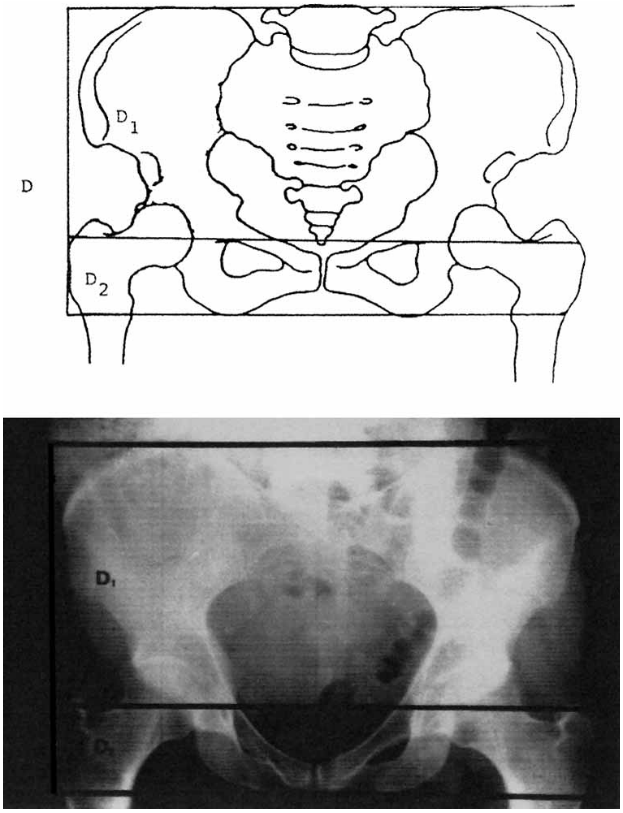

Fig. 4. Total height of the pelvis.

B. Computed tomography

Computed tomography was performed in 50 adult subjects with pelvic fractures of various types and shapes[11] in order to compare the measurements performed on AP x-rays of the pelvis with possibilities of displaying the same measurements in CT slices without detailed statistical analysis. It must be stressed, that in case of a fractured pelvis, certain diameters are disturbed. We chose a model of sampled types of pelvic fractures. Indication for CT was the need for precise definition of the position of fracture fragments in unstable fractures in order to plan the operative procedure[12]. Levels of transverse tomograms were determined on CT scans. Scanning was performed at the angle of 90° to the longitudinal body axis, i.e. at the angle of 90° to the table. The number of slices varied from 4 to 8. The slice through the center of the femoral head allows a more precise calculation of all distances, which makes it possible to calculate moments of muscle forces and determination of static and dynamic loading in the hip joint and the acetabular roof[13]. A slice below this one passes through the lower portion of the pelvis and shows the ramus of the ischium and inferior ramus of pubis of the intertrochanteric portion of the femur as well as all muscles of the femur and lower pelvis (Figure 5).

Using serial CT scans performed in 50 adult patients with pelvic fractures of various shapes and types, geometry and structure of pelvic bones were analyzed. Based on these data, calculation of the forces acting upon certain portions of the pelvis was made. If the body weight and geometric dimensions of the pelvis are known, it is possible to estimate the approximate magnitude of gravitational forces acting upon certain portions of the pelvis, especially in the region of the acetabular roof[14].

Results

Results of radiogrammetric research based on pelvic AP x-rays are presented in five tables (Table 1–5), separately for males and females and including mean value, standard deviation, highest and lowest value, as well as testing of significance of difference between male and female pelvises. Diameter A, the largest diameter between the iliac wings, is slightly larger in females than in males (mean value of 344 mm and 342 mm, respectively) but the range of final values in males was far larger, with much greater standard deviation. In males, this diameter ranged from 278 mm to 390 and in females from 290 mm to 375 mm; however the testing of difference proved insignificant (T=0.338). Female pelvises show insignificant asymmetry of iliac wings as the quotient of right

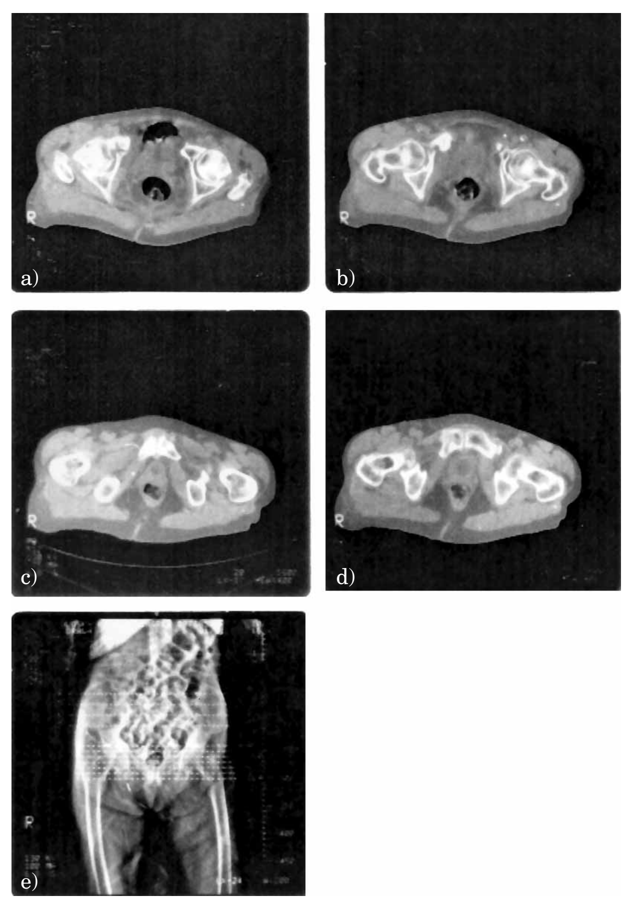

Fig. 5. Fracture of the acetabulum and pubis (joint forces of gluteal and iliopsoas muscles). 5a,b,c, d – axial CT scans of pelvis and both acetabuli, 5e – tomogram of pelvis/ frontal scan.

and left wing projections on x-rays measures 0.9 in females, whereas in males this quotient displays complete symmetry. The ratio between both iliac wings projection and sacrum width is presented in Table 1. In females this ratio is 1.5 and in males 1.3, which means that in males the iliac wing is located closer to the sagittal plane than in females, so that the iliac wing projection on AP x-rays is narrower. Differences between males and females in this quotient of the sum of both iliac projections and the sacrum projection are not statistically significant (T=7.7; AP=0.01).

Data on the B diameter connecting sagittal tangents of both trochanters and passing through the center of femoral heads are shown in Table 2. This diameter is larger in males than females (since male bones are larger) with the mean value being 77 in males as opposed to 72 mm in females. Standard deviation is slightly greater in females. This difference is statistically significant because p is less than 0.01. The ratio between the distance of the trochanter lateral and vertical tangent and the femoral head center (marked as B1 on the right and B2 on the left side) and the distance of the femoral bone center from the medio-sagittal plane is smaller in females than in males (0.69 *vs.* 0.72), which clearly indicates that the pelvic outlet is relatively wider in females than in males. These differences are not particularly great so that the analysis of difference significance yields insignificant result.

The supraacetabular pelvic diameter is larger in males due to relatively greater pelvis with a significantly confirmed difference ($p<0.01$) (Table 3). The total height of pelvic projection D is not only greater but also more perpendicular (250 mm in males *vs.* 235 mm in females, significant difference $p<0.01$). The ratio between the pelvic height segments D 1 and D 2, i.e. the segment stretching from the femoral head center and the pelvic projection apex and the segment extending from the femoral head center to the plane passing through the lowest point of the pelvis, is presented as the quotient of D1 and D2. This ratio is slightly greater in males than females, which means that the distance from the femoral head center to the pelvic apex is relatively slightly greater in males than in females. However, this difference is statistically insignificant (Table 4, 5). The pelvic index, i.e. the quotient between the highest width A and the height of the pelvis is significantly greater in females than in males, so that it measures 1.46 and 1.37 respectively, which is statistically significant ($p<0.01$). On the other hand, the area of the quadrangle formed by the pelvis is larger in males than in females: 850 cm^2 *vs*. 810 cm^2 ($p<0.05$) (Table 1 and 5).

We analyzed geometric properties and structure of pelvic bones[15]. On the tomogram passing through the plane at the level of the interspinal line, we defined first the distance from the iliac crest to the sagittal plane that runs along the anterior margin of the sacroiliac joint and then the distance between the left and right sagittal plane that runs along the anterior margin of the SI joint. These distances are composed by the segments of the pelvic diameters measured also on AP x-rays of the pelvis[16]. New spiral CT allows not only a large number of slices but also lower radiation and a three dimensional reconstruction of a fractured pelvis[17]. For the biomechanical analysis of the pelvis we measured the density of cancellous bone in the hip wings and the thickness of the cortical bone on the inner and outer side. The cortical thickness varies in size same as the bone thickness so that we measured distances in the anterior widest region, in the posterior narrowest region and in the region of the middle portion of the iliac wing opposite to the anterior portion of the SI joint[18]. These data on the thickness of the compact cortical bone and the density of the cancellous bone determine the strength of the connec-

TABLE 1
BASIC STATISTICAL PARAMETERS OF A-DIAMETER

	Gender	$\overline{X}$	SD	N	Min	Max
A	F	311	13	30	290	375
	M	342	27	30	278	390
		t=0.338 df=58 N.S.				
A1/A3	F	0.9				
	M	1				
(A1+A3)/A2	F	1.5	0.1	30	t=7.746	
	M	1.3	0.1	30	df=58 p=0.01	

TABLE 2
BASIC STATISTICAL PARAMETERS OF THE INTERTROCHANTERIC DIAMETER OF THE PELVIS AND THE QUOTIENTS OF PARTICULAR SEGMENTS OF THIS DIAMETER

	Gender	$\overline{X}$	SD	N	t=2.685
B	F	72	8.1	30	df=58
	M	77	6.2	30	p=0.01
		$\overline{X}$	SD	N	t=1.546
B1/B3	F	0.69	0.08	30	df=58
	M	0.72	0.07	30	p N.S.
		$\overline{X}$	SD	N	t=1.546
B2/B3	F	0.69	0.08	30	df=58
	M	0.72	0.07	30	p N.S.
					t=1.546
B2/B4	F	0.69	0.08	30	df=58
	M	0.72	0.07	30	p N.S.

B – intertrochanteric diameter of the pelvis (mm)

TABLE 3
BASIC STATISTICAL PARAMETERS OF THE SUPRAACETABULAR DIAMETER OF THE PELVIS AND SIGNIFICANCE OF DIFFERENCE BETWEEN THE MALE AND FEMALE PELVIS

	Gender	$\overline{X}$	SD	N	t=3.110
C	F	253	12.24	30	df=58
	M	263	12.66	30	p=0.01

C – supraacetabular diameter of the pelvis (mm)

TABLE 4
BASIC STATISTICAL PARAMETERS AND SIGNIFICANCE OF DIFFERENCE BETWEEN THE MALE AND FEMALE GROUP WITH REGARD TO THE TOTAL PELVIC HEIGHT (D) IN MM AND THE QUOTIENT OF PELVIC HEIGHTS ABOVE AND BELOW THE HIP JOINT AXIS (NON-DIMENSIONAL)

	Gender	$\overline{X}$	SD	N	t=4.150
D	F	235	10.18	30	df=58
	M	250	16.98	30	p=0.01
		$\overline{X}$	SD	N	t=0.287
D1/D2	F	2.35	0.27	30	df=58
	M	2.37	0.27	30	p N.S.

D – total pelvic height

TABLE 5
BASIC STATISTICAL PARAMETERS AND SIGNIFICANCE OF DIFFERENCE BETWEEN MALE AND FEMALE SUBJECTS WITH REGARD TO PELVIC INDEXES, A-DIAMETER, D-PELVIC HEIGHT (NON-DIMENSIONAL) AND THE SIZE OF PELVIC PROJECTION A-D MM^2

	Gender	$\overline{X}$	SD	N	t=3.148
D	F	1.46	0.08	30	df=58
	M	1.37	0.12	30	p=0.01
		$\overline{X}$	SD	N	t=2.139
D1/D2	F	81.140	6.461	30	df=58
	M	85.934	10.440	30	p=0.05

tion between the fixation screw and the structure of fragments of fractured pelvic bone[19]. In osteoporotic bone, the total area of contact between screws and bone structure will be smaller and contact loading greater.

On the tomogram passing through the inferior anterior iliac spine, we measured the width of the hip bone in the anterior portion and in the posterior narrowing as well as at the anterior margin of the SI joint.

In the region of the acetabular roof, the shape of supracaetabular density of the cancellous bone is displayed and the bone density is determined. In the same section, the largest distance between the most lateral points is measured as well as the distance corresponding to the space C on AP images of the pelvis.

Axial tomogram that passes through the center of the femoral head shows only the femoral head and only the anterior and posterior portion of the acetabulum and the bottom of the acetabular fossa. In this slice, it is only possible to measure the distance between the center of the femoral head and the middle sagittal plane. This slice however does not display the symphysis and trochanter. The lower slice that passes through the trochanters shows the greater trochanter and the lower portion of the femoral neck, the lower arm of the ischium, the lower arm of the pubic bone and the lower part of the symphyis. On this tomogram one can measure the largest distance between both trochanters, which passes through the center of the femoral head and which, along with other parameters obtained from the tomogram, gives data necessary for determination of all segments of the B dimension displayed on x-rays of the pelvis.

All parameters measured on AP x-rays of the pelvis can be determined also by CT[20]. However, the method of CT allows direct measuring of specific distances without factors of enhancements and also in another projection, i.e. in the axial cross-section. Since all subjects were not examined by CT (only those with pelvic fractures and indication for CT were included), we were able to compare only their AP x-rays and the data obtained by CT. Differences between the parameter measured by CT were a bit smaller that those measured on AP x-rays of the pelvis, even after correction with the enhancement factor of x-ray, but the difference in measurements of the same parameters did not exceed 4-5%. The height of the pelvis was determined on a tomogram displayed in the AP projection, with the position of the pelvis being similar to the position during x-ray scanning. However, due to the fact that scattering of x-rays was avoided and consequently also errors caused by deformation of x-ray projection, the differences in the height after correction with the factor of enhancement were less than 3%.

Discussion

The subject of pelvic fractures is well-covered in the literature. The majority of works present etiological, epidemiological and statistical analysis of certain fracture types and classifications[21]. The position of fracture gap in relation to the areas of increased and decreased density, two fracture types may be differentiated. In the first type, the fracture gap direction does not correspond to the direction of weakened pelvic portions[22]. This fracture type seems to be caused by high kinetic energy and occurs mostly in young patients[23]. In the second type, the fracture gap correlates with weakened pelvic portions. This type is more often seen in older and osteoporotic patients and is a consequence of low kinetic energy, mostly falls.

Anthropometric and radiogrammetric measurements of the pelvis for the purpose of defining specific basic morphological and geometric properties of the average human pelvis[24,25] were conducted in 30 adult male and 30 adult female subjects. Due to high variability, such a sample is not sufficient for a completely reliable statistical workup but our aim was not to obtain final statistical parameters but to define the value of certain measurements that can be performed in a rather simple way using AP scans of the pelvis. Measured parameters or certain segments of these measurements are also significant for the biomechanical definition of the static construction of the pelvis[26], calculation of loading in the acetabular region during standing on both feet, calculation of symmetrical and asymmetrical loading of the pelvis during standing on one foot and specific stances during walking. We chose only three transverse pelvic diameters; the upper diameter (diameter A) defines the entrance of the great pelvis and the iliac crest with the attachments of the lateral abdominal muscles and the *m.*

quadratus luborum. Segments A-1 and A-3, that correspond to the projection of the iliac wing on the AP image of the pelvis, indicate in fact the moment arm of muscle forces acting in the area of the SI joint. This may be important for the analysis of forces in oblique fractures of the iliac wings that run from the great ischiadic incisure upwards or in case of open SI joint.

B-diameter connects lateral tangents of both trochanters and passes through the center of the femoral head. This diameter corresponds to the intertrochanteric distance, the parameter that is often determined in obstetrics. In our study, this diameter was set through the center of both femoral heads because the analysis of this diameter by its segments allows the insight into the relation between the moment arm and the resulting loading forces that act upon the femoral head and the actebular roof.

B-1 segment corresponds approximately to the moment arm of muscles attached to the greater trochanter and the gluteal rough surface, which counterbalances the entire body weight during standing on one foot and during gait when the contralateral foot is in the air. The force of gravitation acts upon the rest of the body, i.e. on the body weight diminished by the weight of the foot on which a person stands. If the center of gravity is approximately in the mediosagittal region, this distance from the center of the femoral head to the middle sagittal plane (marked as B-3 on the right and as B-4 on the left side) corresponds to the arm of the gravitational force acting upon the body. By analyzing this diameter, it is also possible to check whether the x-ray was preformed correctly. If there are no fractures in the neighboring area, the coccygeal axis must coincide with the symphiseal area in the symmetrical pelvis.

C-diameter of the pelvis connects the narrowest parts of the pelvic projection immediately above the acetabular roof and includes the massiveness of the supraacetabular portion of the hip bone, a portion of the entrance to the small pelvis and the spatial orientation of the hip bone. This diameter is bigger in males than in females, which can be explained by the fact that the male pelvis is more massive due to stronger skeleton.

The pelvic height, expressed as D diameter, shows a clear gender-based difference, which is statistically significant despite all skeletal varieties. The ratio of pelvic heights, from the lowest point of pelvic projection to the plane passing through the femoral head center up to the highest point of the pelvic projection on the AP image, displayed as the non-dimensional ratio D-1/D-2, is on average similar for males and females.

CT allows a precise and far more accurate osteometric measuring of the pelvis and densitometric analysis of the cancellous and compaact bones of the pelvis[27]. Pelvimetric analysis is performed by direct measuring of all desired distances on the CT image with satisfactory accuracy for this purpose. Measuring of certain dimensions, as seen in our results, is not significantly different from measuring of certain distances on x-ray images, of course after correction with the factor of enhancement. However, the factor of enhancement varies in individual patients. It is smaller in smaller pelvises and thin persons, and larger in corpulent and adipose persons. In case of CT images, such problems are not encountered. Measuring of bone density using absolute values read from x-rays is incorrect. Direct measuring of density of cancellous or compact bone using the method of CT does not give sufficiently reliable data unless the etalon is recorded and correction of the result is made by comparison with the etalon of density. We worked out the etalon for bone density analysis using the method of CT in another study[28] and used it in this study. This etalon consisted of plastic cylinders filled with various concentrations of calcium chloride solution. These cylinders were scanned in the transverse plane in the same slice as examined bones and their density was compared with the bone density. Using a special program, measured density values were converted into values that correspond to the etalon, i.e. all data were reduced to the common denominator because even the slightest change in the voltage may lead to differences in the air stiffness and deviations in bone density measurements. By measuring bone density of fractured pelvis in various time intervals, we found out that bone density was reduced to a certain degree, which was then confirmed after all corrections.

Conclusion

Morphological and geometric properties of the pelvis can be defined using radiogrammetric AP scans of the pelvis[29,30].

Four measuring parameters (dimensions) are sufficient for the basic analysis. Each of these dimensions consists of several parts.

The largest diameter between the most lateral points of iliac wings was on average slightly larger in females than in males, but the range of final values was much larger.

The ratio between the projection of the sacral width and projection of the iliac wing was larger in females than in males, which indicates that the iliac wing in males is located closer to the sagittal plane than in females.

The line that connects sagittal tangents of both trochanters and that passes through the center of the femoral head is larger in males than in females. Segments of this line from the trochanter tangent to the femoral head center and from the femoral head center to the meadio-sagittal plane are smaller in females than in males.

The outlet portion of the pelvis is relatively larger in females than in males.

The total height of the pelvic projection is significantly larger in males, in whom the pelvis in not only larger but also more vertical than in females.

The distance from the line passing through the femoral head center to the pelvic tip is also larger in males than in females, but this difference is not statistically significant.

The pelvic index, the quotient between the greatest width and height of the pelvis, is significantly larger in females than in males.

After deducting the factor of enlargement, these radiogrammetric parameters can serve for individual calculation of static forces, as well as forces of gravitation and inertia in certain portions of the pelvis[31].

The method of CT proved to be highly suitable for three-dimensional definition of fracture fragments; however this method also gives additional data[32,33].

Fixation and stabilization of fractures must be performed in order to use favorable stabilization forces, but stabilization must be stable enough to resist muscle forces acting on fragments[34].

Practical usage of research results is improvement in the treatment of pelvic fractures, first of all for individual setting up of indications and planning of therapy.

Serial CT yielded three-dimensional geometric and structural definition of fractured pelvis and approximate but highly reliable insight into the size, direction and line of resulting forces acting upon fracture fragments. Knowing basic features of allenthesis, it is possible to plan fixation of these fractures[35] that will be stable enough to withstand presumed static and dynamic forces during time of healing and to avoid fixation failure or breaking of fixation implants due to fatigue of material.

R E F E R E N C E S

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MORFOMETRIJA ZDJELIČNOG PRSTENA U DEFINICIJI BIOMEHANIČKIH ČIMBENIKA KOJI UTJEČU NA TIP PRIJELOMA ZDJELICE

S A Ž E T A K

Cilj je rada dopuniti saznanja o strukturi i geometriji zdjelice. Dobiveni podatci su poslužili za izradu matematičko-biomehaničkog modela zdjelice. Istraživanja su podijeljena na dva dijela. Prvi dio je morfološka i geometrijska analiza zdjelice na temelju radiogrametrijske obrade 60 AP-rendgenskih snimaka zdjelice odraslih osoba obaju spolova. Geometrija zdjelice je definirana sa tri transverzalna i jednim vertikalnim promjerom. Transverzalni promjeri učinjeni su području krila zdjelične kosti, najužeg supraacetabularnog dijela zdjelične kosti, te kroz središte zakrivljenosti glave bedrene kosti. Četvrti vertikalni promjer označava visinu zdjelice. Drugi dio istraživanja je analiziranje geometrijskih značajki koštanog dijela zdjelice i strukture kosti, te položaja mišića u odnosu na koštane elemente zdjelice putem kompjutorizirane tomografije. Iz geometrijskih dimenzija zdjelice, uz poznavanje tjelesne težine ozljeđenika, moguće je izračunati gravitacijske sile što djeluju na pojedine dijelove zdjelice, a napose u području krova acetabuluma. Na takovom biomehaničkom modelu zdjelice mogu se simulirati stabilizacijske operativne metode i tražiti optimalno rješenje koje treba odoljeti svim silama što djeluju na fragmente prelomljene zdjelice.