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SEXUAL DIMORPHISM OF THE BONY PELVIS: MORPHOMETRIC DIFFERENCES AND THEIR OBSTETRIC SIGNIFICANCE

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Annotation. The article is a literature review of sexual dimorphism of the human bony pelvis. Qualitative and metric sex differences of the hip bone, sacrum, pelvic inlet, cavity and outlet are summarized, together with the Caldwell–Moloy classification of pelvic types, the age at which dimorphism develops, the role of sex hormones, and the evolutionary concept of the "obstetric dilemma". The obstetric significance of pelvic dimensions (true, diagonal and obstetric conjugates, interspinous and intertuberous diameters) and the contribution of external pelvimetry, ultrasound, CT and MRI to the assessment of the birth canal are discussed. The limitations of pelvimetry for prediction of the course of labour and the population variability of pelvic morphology are emphasized. The review is based on published sources; no original patient data or statistics are presented.

Keywords: bony pelvis, sexual dimorphism, pelvic morphometry, pelvic inlet, obstetric conjugate, pelvimetry, obstetric dilemma, cephalopelvic disproportion.

ПОЛОВОЙ ДИМОРФИЗМ КОСТНОГО ТАЗА: МОРФОМЕТРИЧЕСКИЕ РАЗЛИЧИЯ И ИХ АКУШЕРСКАЯ ЗНАЧИМОСТЬ

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Аннотация. Статья представляет собой обзор литературы по половому диморфизму костного таза человека. Обобщены качественные и метрические половые различия тазовой кости, крестца, входа, полости и выхода таза, классификация форм таза по Колдуэллу–Молою, возраст формирования диморфизма, роль половых гормонов и эволюционная концепция «акушерской дилеммы». Рассмотрена акушерская значимость размеров таза (истинная,

диагональная и акушерская конъюгаты, межостистый и межседалищный размеры), а также вклад наружной пельвиметрии, УЗИ, КТ и МРТ в оценку родового канала. Подчёркнуты ограничения пельвиметрии для прогноза течения родов и популяционная изменчивость тазовой морфологии. Обзор основан на опубликованных источниках, собственные данные о пациентках и статистика не приводятся.

Ключевые слова: костный таз, половой диморфизм, морфометрия таза, вход в таз, акушерская конъюгата, пельвиметрия, акушерская дилемма, клинически узкий таз.

Introduction

The bony pelvis is formed by two hip bones, the sacrum and the coccyx, which are joined by the pubic symphysis, the sacroiliac joints and the sacrococcygeal joint. It transmits the weight of the trunk to the lower limbs, provides attachment to powerful muscles of the trunk and hip, supports and protects the pelvic organs, and, in women, constitutes the bony part of the birth canal. The combination of these tasks makes the pelvis the most sexually dimorphic part of the human skeleton.

The distinction between the female and male pelvis is classical in anatomy, forensic medicine and anthropology. At the same time, in obstetrics the pelvis is considered not as a static anatomical object but as a space through which the fetal head and shoulders must pass, and the dimensions of this space are the basis for the concepts of normal and contracted pelvis.

Relevance

Contracted pelvis and cephalopelvic disproportion remain among the recognized causes of obstructed labour and of caesarean section, and the correct evaluation of pelvic shape is a part of the antenatal and intrapartum care. Imaging methods, such as ultrasound, CT and MRI, have extended the opportunities for pelvimetry, but there is no consensus about their routine use, and their predictive value is a subject of debate.

In forensic and bioarchaeological practice, the pelvis is the leading element in sex determination of skeletal remains, and the accuracy of the methods depends on population-specific standards. Furthermore, recent evolutionary studies challenge the simple notion that the female pelvis is a compromise between bipedal locomotion and the large fetal head. All this makes a synthetic review of the morphometric differences and their obstetric meaning relevant.

Aim

The aim of the review is to summarize the published data on sexual dimorphism of the bony pelvis, its morphometric characteristics and development, and to evaluate its obstetric significance.

Main part

General morphological differences between the female and male pelvis

The female pelvis is relatively wide and low, and the male pelvis is narrow, high and more massive. The pelvic inlet of the woman is rounded or transversely oval, whereas in the man it is heart-shaped because of the protruding promontory. The pelvic cavity in the female is closer to a cylinder, and in the male is funnel-shaped, narrowing toward the outlet. The female sacrum is wider and shorter and has a less pronounced curvature; the male sacrum is longer, narrower and more concave. The coccyx in women is more mobile and less incurved into the pelvic outlet.

The subpubic (pubic) angle in women is wide (approximately a right angle or more, forming a rounded arch), while in men it is acute, V-shaped. The greater sciatic notch is wide in women and narrow in men, the ischial spines are less prominent, the obturator foramen is triangular in women and oval in men, the acetabulum is relatively small, and the iliac wings are more flared. The preauricular sulcus and the ventral arc of the pubic bone are among the features that are considered to be characteristic of the female skeleton and, in the forensic literature, are used in sex assessment. The pubic bone is longer in the female, which increases the anteroposterior and transverse diameters of the inlet.

Morphometric parameters

In obstetric practice the dimensions of the pelvis are subdivided into those of the inlet, the cavity (wide and narrow parts) and the outlet. The conventional measurements include the anatomical (true) conjugate between the promontory and the upper margin of the pubic symphysis, the obstetric conjugate (the shortest distance between the promontory and the posterior surface of the symphysis), which is the clinically decisive anteroposterior dimension of the inlet, the transverse diameter of the inlet and the oblique diameters. The diagonal conjugate, from the lower edge of the symphysis to the promontory, is the only one of them which can be determined by vaginal examination, and the obstetric conjugate is calculated by subtracting an appropriate value from it. The dimensions of the outlet are described by the interspinous diameter (the narrowest transverse dimension of the pelvis), the intertuberous diameter and the

anteroposterior dimensions.

The external pelvic measurements widely used in Russian-language obstetrics (distantia spinarum, distantia cristarum, distantia trochanterica and external conjugate, or Baudelocque diameter) give only an indirect idea of the internal dimensions. Their textbook values are approximately 25–26, 28–29, 30–31 and 20–21 cm, respectively, and the Michaelis rhomboid and the Solovyov index (wrist circumference as a gauge of bone thickness) are added to improve interpretation. Nevertheless, a number of authors consider these measurements to be of limited value and note that the correlation between the external and internal dimensions is not strong.

In forensic anthropology the pelvic indices (for example, the ischiopubic index and the sciatic notch measurements) and discriminant functions are employed. The reported accuracy of sex estimation from the hip bone is generally higher than that from other skeletal regions, but it varies between populations and between methods, and the formulae developed for one population are not always applicable to another. This is one more argument for local reference samples.

Caldwell–Moloy classification and pelvic types

The classification of Caldwell and Moloy, based on the shape of the inlet, distinguishes the gynecoid (rounded; considered the typical female form), android (wedge- or heart-shaped; masculine), anthropoid (long oval in the anteroposterior direction) and platypelloid (flattened, transversely oval) types. Real pelves frequently show mixed features, and the front and back segments of the inlet may belong to different types. The classification has historical importance and is retained in teaching, but modern studies indicate that the distribution of types varies between populations and that its prognostic value for the course of labour is modest. The anthropoid type is considered more favourable for occipito-posterior positions, and the platypelloid type is linked to transverse arrest, but these statements are based on clinical observations of varying quality.

In addition to the normal types, the classical obstetric classification includes the contracted pelvis (generally contracted, simple flat, flat rachitic, obliquely distorted, and pelves deformed by trauma, tumours or developmental anomalies, e.g. the Naegele and Robert pelves), which are now rare in countries with good nutrition and medical care but remain relevant in other areas. The rickets, osteomalacia and chronic malnutrition influence the formation of the pelvis during growth, which demonstrates the dependence of pelvic shape on environmental conditions as well as on heredity.

Development of dimorphism: ontogenesis and hormonal regulation

Sex differences of the pelvis are minimal in early childhood. The studies of subadult skeletons indicate that some differences (the sciatic notch, the subpubic angle) can be seen even in prenatal and infant periods, but they are small, and the main divergence takes place during puberty, when the female pelvis widens under the influence of oestrogens and the growth of the male pelvis, in contrast, is more directed toward height and the development of muscle attachment sites under androgens. The growth plates of the hip bone (the triradiate cartilage and the iliac crest, ischial and pubic apophyses) fuse in late adolescence, and the pelvis completes its growth in young adulthood.

Later changes include pregnancy-related loosening of the symphysis and sacroiliac joints under the action of relaxin and progesterone, which transiently increases pelvic outlet dimensions, and postmenopausal bone loss. Some researchers have proposed that the shape of the pelvis continues to change in adult life, but this hypothesis is not unanimously accepted.

Evolutionary aspects: the "obstetric dilemma" and its critique

The obstetric dilemma hypothesis, which was formulated by Washburn in the middle of the twentieth century, claims that selection for bipedal locomotion narrowed the pelvis, whereas selection for the larger brain increased the size of the neonatal head, with the result that childbirth is difficult and dangerous in humans in comparison with other primates. The human fetus passes through the birth canal in a series of rotations (engagement, descent, flexion, internal rotation, extension, restitution and external rotation), because the inlet, midpelvis and outlet have different orientation of the largest diameters.

Subsequent research has qualified this view. Comparative and biomechanical studies suggest that the width of the pelvis is not a simple limit of efficient walking, that the pelvic floor and soft tissues constrain the birth canal as well, and that the energetic capacity of the mother (energetics of gestation and growth) may limit fetal size no less than the pelvic dimensions. The hypothesis of sex difference development has also been refined: the differences between male and female pelves seem to have arisen earlier than the modern human lineage and are linked to the life history, the growth rate and the body size. It is also known that pelvic shape covaries with stature and with the shape and size of the head, and that the possible mismatch is partly compensated by this covariation. The current view is therefore that the female pelvis is a product of multiple selective pressures, and that the birth difficulty depends on the combination

of fetal, maternal and environmental factors.

Obstetric significance

The clinical value of pelvimetry lies in the recognition of cephalopelvic disproportion before or during labour. Clinical (digital) assessment during antenatal examination and at the beginning of labour remains the basis of practice; it includes the estimation of the diagonal conjugate, the shape of the sacrum and the pubic arch, the prominence of the ischial spines and the inclination of the lateral walls. The external pelvimetry and the Müller–Hillis manoeuvre are used in some countries as supplementary tools.

Radiological and imaging pelvimetry (conventional X-ray, CT and MRI) provides objective dimensions of the inlet, midpelvis and outlet. MRI is attractive because it does not involve ionizing radiation. However, systematic reviews and clinical guidelines have not found that routine imaging pelvimetry improves obstetric outcomes and have noted that the thresholds for contraction are not universally defined; therefore, it is recommended mainly in selected situations, such as breech presentation or previous complications. The reason for the limited predictive value is that the outcome of labour depends on many variables apart from the bony dimensions: the size, position and moulding of the fetal head, the strength of uterine contractions, the mobility of the pelvic joints, the maternal posture and the soft tissues.

The population and individual variability of pelvic dimensions is also significant. Maternal height and body proportions, nutrition in childhood, the ethnic background and the habitual physical activity affect the pelvis, and it is therefore difficult to use a single threshold for all women. Increased attention is paid to the pelvic outlet and the subpubic angle in relation to mode of delivery and perineal injury, but the evidence is still heterogeneous.

Forensic and anthropological use

The same morphometric features are used in sex determination of skeletal remains. The combination of metric and morphoscopic traits of the hip bone (the greater sciatic notch, the ventral arc, the subpubic concavity, the medial aspect of the ischiopubic ramus) increases accuracy. Modern approaches utilize geometric morphometrics, CT-based three-dimensional models and machine learning classification; however, they depend on the representativeness of the reference sample, and in populations with scarce data, results should be interpreted cautiously.

Discussion

The analysis of the literature shows that sexual dimorphism of the pelvis is the best-

documented dimorphism of the human skeleton, and its main features (width, subpubic angle, sciatic notch, sacral proportions) are described consistently by different authors. At the same time, the degree of expression of these features overlaps between the sexes, differs between populations and is affected by age, nutrition and body size, so that no single trait can be used as an absolute criterion.

From the obstetric point of view, the key problem is the transition from the descriptive anatomy to the individual prognosis. Pelvic dimensions are necessary, but not sufficient, for predicting the mode of delivery, and the traditional classifications (Caldwell–Moloy, degrees of contraction) have limited predictive power. Future research may combine three-dimensional pelvic shape analysis with fetal biometry and biomechanical modelling. The limitation of this review is that it is based mainly on published summaries and that the heterogeneity of methods does not permit a quantitative synthesis; no meta-analysis was performed.

Conclusion

The bony pelvis exhibits pronounced sexual dimorphism that develops mainly in puberty and reflects the combination of locomotor and obstetric functions. The morphometric differences of the inlet, cavity and outlet have established clinical significance for the recognition of the contracted pelvis, but the prediction of the course of labour requires the consideration of fetal, maternal and functional factors, and not only of bony dimensions. Population-specific reference data and a critical approach to the use of imaging pelvimetry remain necessary.

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