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Normal and Dysplastic Coxarthrosis (Review) Morphology of Bone Structures of the Hip Joint

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ABSTRACT

Development of bone structures of the hip joint. The ontogenesis of human skeletal bones repeats the stages of bone phylogenesis. At the 5th week of intrauterine development, the skeleton of the human embryo is represented by a chord and a thickening of the embryonic mesenchyme in body segments and limb rudiments. This stage is called blastemic and quickly passes into the cartilaginous stage. Cartilage models of future bones are formed, then nuclei, centers, or ossification points (punctum ossificationis) are laid in the cartilage tissue [1, 2]. There are primary ossification points that are laid in the early stages of intrauterine development; secondary points are laid either before birth or immediately after birth; препубертатномadditional ossification points are laid in the prepubertal period [3]

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This type of bone development is called cartilaginous osteogenesis or endochondral type of development, in contrast to the endesmal type, when ossification points are laid directly in the connective tissue matrix (primary bones). Bones that develop endochondrallyare called secondary bones. Pelvic bone (os coxae) in children and adolescents, it consists of three bones: the ilium (os ilium), the ischium (os ischii), and the pubis (os pubis). Primary ossification points are laid after the 8th week of intrauterine development. The pelvic bone develops from three primary ossification points and several (up to 8) additional points. Primary points form the ilium (appears at the 3rd month of the intrauterine period), the sciatic bone (at the 4th month) and the pubic bone (at the 5th month); additional points complement the elevations, depressions, and edges of individual bones. By the 8th year of life, the branches of the pubic and sciatic bones synostose and form os ischiopubicum. In the acetabular region, all three bones are first connected by cartilage layers (triangular cartilage), in which additional ossification points appear later (by the age of 16-18). Fusion of all ossification points occurs at the age of 20-25 years in the area of the greatest load, namely in the acetabulum,whichis the joint fossa of the hip joint. The ilium occupies approximately 40% of the acetabular area, the sciatic bone — about 40%, and the pubic bone-about 20 % [4, 5]. Synostosis is performed with the participation of additional bone formations that resemble the additional bones of the cranial vault. If these bones are preserved for a long time, they are called ossa acetabuli; on an X-ray, they can be mistaken for bone fragments. The pelvis as a whole undergoes changes, mainly in terms of size and shape. However, the sex differences characteristic of adult women and men begin to differentiate from the age of 8-10 years: the predominance of pelvic height in boys and width in girls. The femurfemurdevelops from 5 ossification points, of which one is primary, diaphyseal, and 4 are secondary. From the primary point (it appears at the beginning of the 2nd month of the intrauterine period), a diaphysis is formed. Secondary points occur at different times: at the end of the intrauterine period — the point of ossification of the distal epiphysis of the femur, at the end of the first or beginning of the second year - the point of ossification in the cartilaginous head of the femur, at 3 years — in the cartilage of the greater trochanter and at the age of 8 years — in the cartilage of the lesser trochanter of the femur. All these bone formations fuse with the femoral diaphysis in 16-20 years. In newborns, only the diaphysis is visible on the X-ray image of the proximal femur; the ossification point in the head appears at the 1st year of life [6-8]. Morphology of the hip joint. The hip joint (articulatio coxae) is formed by the semilunar surface (facies lunata) of the acetabulum and the femoral head (caput femoris). The joint is cup-shaped (art. cotylica), multi-axial in function; flexion, extension (flexio, extension) are possible around the frontal axis;abduction, adduction (abduction, adduction) is possible around the sagittal axis; rotation (rotation), inwardly (pronatio) and outwardly (supinatio) is possible around the vertical axis; when moving from one side to the other. a peripheral or circular rotation (circumductio) is possible, when the proximal end of the limb is fixed, the distal end describes a circle, and the entire limb is a cone shape. The structure of the hip joint in adults is simple (art. simplex), because two bones join together [9, 10]. In the hip joint there are basic elements: 1) the articular cavity (cavitas articularis); 2) the articular surfaces covered with articular (hyaline) cartilage; 3) the articular capsule (capsula articularis), consisting of the outer fibrous and inner synovial layers; the articular bag is attached along the entire circumference of the acetabulum, on the femur it goes in front along the intertrochanteric line (linea intertrochanterica), runs posteriorly along the neck parallel to the intertrochanteric crest (crista intertrochanterica), somewhat medial; 4) there is a minimal amount of synovial fluid (synovia) in the joint cavity[11]. Minor elements of the joint include: 1) articular lip (labrum acetabulare) — a fibrous-cartilaginous rim attached along the entire edge of the acetabular cavity, which increases the congruence of the articular surfaces; 2) above the notch of the acetabular cavity (incisura acetabuli), the lip crosses in the form of a bridge, forming the intra-articular transverse ligament of the acetabular cavity (lig. transversum acetabuli) [12]; 3) at the bottom of the acetabular cavity there is a fossa of the acetabular cavity (fossa acetabuli), which is occupied by loose adipose tissue — the adipose body (corpus adiposum); 4) in the joint cavity passes the intra-articular ligament of the femoral head (lig. capitis femoris), covered with a synovial membrane, it starts from the edges of the tenderloin and from the transverse ligament, rises and the tip is attached to the fossa of the femoral head (fovea capitis femoris), in which vessels pass to the head of the femur. This ligament plays an important role in the formation of the hip joint, holding the femoral head against the acetabulum [12]. The junction of the femoral neck and the diaphysis is called the cervical-diaphyseal angle, the normal range of values of which is 125±5° [13]. If the values of the cervical-diaphyseal angle exceed 130°, then the hallux valgus position of the head and neck of the femur is formed, and if the values of the cervical-diaphyseal angle are less than 120°, the varus position of the articular end of the hip joint is formed. This point is very important from the point of view of the functional anatomy of the joint. When the femoral head is valgized, the degree of head coverage becomes less, which contributes to excessive freedom of movement in the joint. With the varus position of the head, freedom of movement in the joint is limited. In addition, in cases of violations of the range of values of the cervical-diaphyseal angle, normal movements in the joint are supported by attracting additional strength of the abductor muscles and increasing tension in the bone elements [9, 14]. The formation of a cervical-diaphyseal bend is a dynamic process during which the value of the cervical-diaphyseal angle decreases from 150° at birth to 125° in an adult due to joint remodeling when walking under the influence of stress forces. In addition, there are characteristic features of the position of the femoral head and neck relative to the frontal plane: a slight degree of rotation anteriorly. This medial rotation is called anteversion, which is normally 15-20°. The hip joint is reinforced with extra-articular ligaments, three longitudinal and one circular: 1) the iliofemoral ligament (lig. iliofemorale) is located on the anterior surface of the joint, goes from the spina iliaca anterior inferior to the linea intertrochanterica, prevents excessive extension in the joint — is the most powerful ligament of the human body, can withstand a load of 300 kg, its thickness reaches 1 cm; 2) the pubic-femoral ligament (lig. pubofemorale) runs along the medial surface of the joint from the pubic bone to the small trochanter, interweaves into the joint capsule, restricts abduction and rotation outwards; 3) the sciatic-femoral ligament (lig. ischiofemorale) starts from the edge of the acetabular cavity in the sciatic bone, goes laterally and upwards over the femoral neck and, interweaving in the sac, ends at the anterior edge of the greater trochanter, delays rotation inside and adduction of the femur [15]; 4) zona orbicularis — circular fibrous fibers pass under the described longitudinal ligaments that cover the neck of the femur in the form of a loop. In addition to ligaments, the joint is reinforced with paraarticular muscles [9, 10]. Thus, the abundance of strong ligaments, muscles, curvature and congruence joint surfaces increase the stability of the joint by limiting mobility. According to the literature data [9], the following arteries are involved in the blood supply to the hip joint: the ascending branch of the lateral femoral envelope artery; the deep branch of the medial femoral envelope artery; the round ligament artery; branches of the inferior and superior gluteal arteries; branches of the external iliac and inferior hypogastric arteries. However, the contribution and significance of these vessels in the blood supply to the femoral head are not the same. Until now, there is no consensus on the blood supply to the femoral head via the round ligament artery [12]. The most widespread theory is the gradual decrease in the level of blood supply through this vessel [16, 17], which states that with age, nutrition through the round ligament artery is preserved only in 20-30% of people. The main blood supply to the proximal femur is provided by the branches of the medial artery that surrounds the femur. A much smaller role in the blood supply to the hip joint belongs to the ascending branch of the external femoral envelope artery. Thus, the femoral head is supplied with blood in the upper external, lower internal and posterior parts through a branch of the posterior cervical artery. The anterior part of the femoral head receives nutrition through the branches of the anterior cervical artery originating from the lateral femoral envelope artery; the femoral neck from above, below and behind-through the branches of the posterior cervical artery emerging from the medial femoral envelope artery, in front-the branches of the anterior cervical artery extending from the lateral femoral envelope artery [16, 17]. It should be noted that the lower arteries pass in the free edge Амантиниof the Amantini — Savvin fold, which is 0.5–0.8 cm away from the neck along its entire length. They do not give branches to the neck, but directly enter the lower lateral segment of the head. Inside the head at the level of the central fossa, they reach the level of the epiphyseal line and in 77% of cases form an arched anastomosis, from which numerous branches depart into the substance of the head. Arteries enter the bone substance of the head and neck from synovial folds, some — through the round ligament and, finally, through the vascular openings of osteons, forming a wide network of anastomoses. There is also an intraosseous connection between the blood vessels of the epiphysis, metaphysis and diaphysis. The outflow of blood from the hip joint occurs through the veins that accompany the arterial vessels and then flow into the femoral veins, hypogastric and iliac [9]. The hip joint is well innervated due to the nerves of the periosteum, periarticular neurovascular formations, as well as branches of large nerve trunks: femoral, sciatic, obturator, upper gluteal, lower gluteal and genital nerves [18]. The posterior-lower part of the articular capsule is innervated by branches of the sciatic nerve, as well as the upper gluteal and genital nerves, the anterior part — by the articular branch of the obturator nerve. Anatomical features of the hip joint structure provide a range of motion around several axes, which requires the work of several muscle groups responsible for joint stability. Each joint functions thanks to the well-coordinated work of the muscles, which are topographically grouped into three groups: anterior, posterior, and medial [18, 19]. There are a number of differences in the pelvic biomechanics of men and women [4]. So, in women, due to a wider pelvis in transverse size and less strength of the abductor muscles, an imbalance of forces is created, which leads to joint instability with a predominance of the twisting moment, which critically depends on weight. Features of the hip joint anatomy in women, such as lower values of the acetabular depth, Wiberg angle, and cervical-diaphyseal angle, as well as higher values of the Sharp angle and torsion angle of the femur in comparison with men, may be evidence of a greater prevalence of femoral neck fractures and dysplastic coxarthrosis in women [20, 21]. Features of hip joint morphology in dysplastic coxarthrosis. Dysplastic coxarthrosis is a constantly progressive disease due to congenital connective tissue defects and hip joint underdevelopment, in which severe deformity of the acetabulum and proximal femur leads to discongruence and biomechanical inferiority of the joint [22, 23]. It is the anatomical and biomechanical failure of the articular surfaces that leads to the development of secondary osteoarthritis mainly in persons older than 30 years [24, 25]. Crowe et al. proposed a classification (1979), which is based on an assessment of the level of cranial displacement of the femoral head and includes four types. The authors assumed that on the radiograph of normal hip joints, the lower border of the tear shape and the place of transition of the femoral head to the neck are at the same level, and the height of the head is 20 % of the pelvic height. In Crowe type I, the proximal displacement of the head is up to 50% of the head height or up to 10% of the pelvic height, in type II-50-75 % of the head height or 10-15 % of the pelvic height, in type III-75-100 % or 15-20 %, respectively. Crowe type IV is characterized by a proximal displacement of the head of more than 100 % or more than 20 % of the pelvic height. Thanks to digital parameters, the Crowe classification is clear and unambiguous, but it does not fully take into account changes in the acetabular cavity depending on the degree of dysplasia, which is important for planning the installation of the acetabular component of the prosthesis. Objective interpretation of the degree of dysplastic coxarthrosis is quite complex and requires good knowledge of possible dysplastic diseases. changes in the hip joint, which are caused by some pathogenetic features of the disease. Among the risk factors for the development of dysplastic coxarthrosis, attention is paid to age, physical activity, and genetic characteristics [26], but it is of particular interest to study the impact of impaired anatomy and biomechanics of the articularsurfaces of the hip spines of an isplastic nature [24, 27]. Anatomical and pathogenetic features of the hip joint in dysplastic coxarthrosis of various degrees of severity are described. In type I–II dysplastic coxarthrosis, taking into account the Crowe classification, there was a decrease in the acetabular index by 16% and the Wiberg angle by 28 %; narrowing of the brain cavity and a decrease in the length of the femoral shoulder by 6 %; an increase in the Sharp angle by 12% and the cervical-diaphyseal angle by 6 %. Dysplastic coxarthrosis type III is characterized by the progression of dysplastic manifestations; there is a defect in the roof of the acetabular cavity; the femoral head articulates with the true and false acetabular cavities. Type IV dysplastic coxarthrosis is characterized by maximal dysplastic damage to the bone structures of the hip joint; the acetabular cavity is flattened; but the acetabular roof deficit is insignificant; neoarthrosis is formed, separated from the true cavity [20, 21]. One of the most important studies of the state of the ligamentous apparatus of the dysplastic hip joint is the work Klaueof Klaueetal. [28], in which capsule weakness and "cartilaginous lip syndrome"appear to be the initiating moment. Due to the peculiarities in the structure and functioning of ligamentous collagen in the dysplastic hip joint, generalized weakness of the ligamentous apparatus and overextension of the capsule are noted, which creates conditions for permanent microtrauma during movement [29, 30]. Abnormal redistribution of stress forces in the hip joint in dysplasia leads to overloading of the iliofemoral ligament and excessive pressure in the cartilaginous lip ("acetabular stress"), which causes degenerative changes in the ligamentous apparatus, the appearance of calcification foci in microtrauma [31, 32]. Long-term course of dysplastic coxarthrosis can lead to dystrophic changes in innervating nerve trunks and fibers [33, 34]. Abnormal structure of collagen in dysplastic coxarthrosis causes structural changes in the vascular bed in the hip joint: weakness, tortuosity, and overextension of the arterial and venous walls, and a decrease in the number of anastomosing branches [5]. All these structural changes lead to a decrease in the level of blood supply to the hip joint, to reversible capillary stasis at the microvascular bed level, and to an increase in local tissue hypoxia [6]. In dysplastic coxarthrosis, all hip muscle groups are characterized by weakness, reduced contractility, and degenerative changes in the fibers [37]. In addition, anatomical and biomechanical features of dysplastic coxarthrosis they contribute to the convergence of the attachment points of muscle fibers in the group of abductor muscles, which causes their positional weakness. In dysplastic coxarthrosis, the fundamental point is the violation of biomechanics in the joint and the redistribution of forces that ensure the centralization of the head and stability in the hip joint. For the orthopedic practitioner, the determination of X-ray anatomical features of the dysplastic hip joint and possible biomechanical disorders are necessary for the choice of tactics of surgical treatment of coxarthrosis, because the degree of dysplastic disorders depends on the choice of the acetabular and femoral components of the endoprosthesis, as well as the implementation of total endoprosthesis, which is the "gold standard" of treatment, in combination with the necessary additional techniques, such as acetabular roof plastic surgery to fill its deficit, shortening femoral osteotomy in order to minimize traction damage to paraarticular tissues and restoration of limb length [20].

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