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BASIC MODERN METHODS OF THE PERINATAL DIAGNOSTICS OF THE HIP JOINT DYSPLASIA: WORLD TRENDS

The paper describes in details the modern methods of the comprehensive study of the congenital dysplasia of the hip joint in the antenatal and postnatal periods of infant development. Due to the application of modern technologies there appeared the possibility to visualize the initial changes not only in the osseous tissue but also in the soft tissues, which participate in the formation of the hip joint – cartilaginous tissue, muscles, ligaments, tendons, nervous tissue and vascular structures of the joint. Nowadays the state and density of the osseous tissue of the joint can already be determined in the antenatal period of the fetus development. Modern methods of the investigations enable to study in details and visualize tissues, forming the joint, to the finest details. Main task of the preventive diagnostics of the dysplasia is the decrease of the percentage of children, suffering from hip joint dysplasia (HJD), increase of the level of children health safety. Up to the present there existed two traditional methods of HJ study: clinical and roentgenologic. If clinical diagnostics of the hip dislocation is not very clear, then the detection of the subluxation and HJD in the infants of the first months of life causes certain difficulties. Leading role in the diagnostics of the disorders in the development of HJ is devoted to the roentgenologic method of investigation. However, the radiation dose, absorbed during such treatment does not allow to apply this method of study for the infants of less than three months of age. Besides, the nonostereogenic structures – parts of the femoral head, acetabular roof, which, in the infants of the first year life present greater part of these anatomic formations, are not represented in the X-ray image. As a result, it is impossible to detect the disorders of the enchondral formation, sometimes it is a leading manifestation of the hip joint dysplasia. Application of the method of the artificial contrast study of the joint is rather complicated and dangerous for the child. On the base of studying of various methods of HJD diagnostics, which are scientifically substantiated and widely used in medical practice further development of basically new and improvement of the available diagnostic techniques, aimed at the solution of the problem of the hip joint dysplasia is possible.

Key words: *dysplasia, hip joint, diagnostics, comparison, dysplasia disease, electronic means of diagnostics.*

Introduction

The problem of the consequences of the musculoskeletal system diseases occupies the leading place in modern infant orthopedics and traumatology and with increasing frequency attracts the attention of the specialists of different profiles. Among the deformations of the musculoskeletal system hip joint dysplasia (HJD) is the most common. According to the statistical data hip joint dysplasia in Ukraine is detected in 50 – 100 cases out of 1000 newborn infants. The frequency of this pathology, according to different authors, varies from 3 to 20%.

The disposition to the hip joint dysplasia, according to B. I. Simenach (2005) is inherited mainly of the polygenic type and the formation of the hip dislocation depends on numerous endogenic and exogenic factors. There exists the concept regarding the «relative immaturity of the tissues and disproportion of maturation», which can be the cause of the development of the pathological states of the hip joint (HJ). Etiologic factors, leading to the deviations from the normal development of the hip joint and surrounding muscles are defects of the primary cushioning of the joint during the prenatal development [1 – 3].

There exists the mechanical theory of the prenatal origin of the dysplasia. The dysplasia is caused by the incorrect fetus position in the uterus, the increased tonus of its walls, oligoamnios, that disturbs the internal pressure of limbs. Among the main factors of the postnatal period the following factors are distinguished: tight swaddling, hypofunction of the thyroid gland, weakness of the capsular-connecting apparatus, stipulated by the constitution. The analysis of the recent research and publications shows that the late, postponed process of the hip joint dysplasia treatment induces numerous complications, which become apparent already in the preschool period and further

become the cause of the degenerative-dystrophic changes of the hip joints (HJ) and, as a result, disablement of the patient. One of such publications is the research of the scientist O. D. Dubogaiy who studied that the anatomical-functional and trophic disorders in the hip joint (HJ) without adequate treatment develop during the infant growth, leading to complex structural changes in the joint, causing the impairment of the functions of support and motion, the pelvis position changes, there appears the spinal curvature and many other complications in the teenagers and adults. If the treatment of this pathology starts at the age of up to three months the excellent results are observed in 97% of the infants [2].

The development of the hip joint dysplasia complications (HJD) occurs in 20% of cases, reaching 71% in complicated cases even applying modern methods of diagnosis and treatment of the pathology. Modern instrumental methods of HJD diagnosis are not able to provide precise objective notion regarding the degree of the damage and the state of the metabolic processes of the cartilaginous and osseous structures of HJ in the infants [2, 3, 17].

Nowadays numerous publications are devoted to the study of the role of various biologically active substances (Type I collagen, Type II collagen, Aggrecan, Hyaluronan) in the process of remodeling of the osseous and cartilaginous tissues as well as growth promoting substances and angiogenesis (FGF, VEGF) at various diseases of the joints. Special attention is paid to the participation of the Type I collagen, VEGF, FGF in the initiation and progression of the dysplastic coxarthrosis. However, there are studies of the degree of these biomarkers participation in the mechanisms of HJD progression in children [3 – 8], authors of these studies point out to the changes of Type II collagen as a specific biomarker of the remodeling of the cartilaginous tissue in the adults, the data, regarding its content in children are not available. Other researchers note the participation of the Type I collagen in the remodeling of the osseous tissue, aggrecan and hyaluronon in the remodeling of hyaline cartilaginous tissue, they are not used as the diagnosis biomarkers of the damage at dysplastic changes in HJ in children [4 – 7].

Sickness statistics

HJD occurs almost in all the countries of the world (2 – 3%), but local occurrences have essential ethnic peculiarities. For instance, the frequency of the congenital immaturity of HJ in neonates in Nordic countries reaches 4%, in Germany – 2%, in the USA this disease is higher among the white population than among Afro- Americans and is 1 – 2%, among the American Indians hip dislocation happens in 25 – 50 cases per 1000 infants, whereas congenital hip dislocation almost does not happen in South American Indians, Southern Chinese [8].

The connection of the sickness with unfavorable ecological state is observed. In Ukraine the sickness rate is approximately 2 – 3%, but in ecologically unfavorable regions its rate reaches 12%.

The direct connection of the increased sickness rate with the traditions of swaddling infants is monitored. People who live in tropics do not swaddle the neonates, their motions are not limited, they are carried on the back (the legs of the baby are in a state of flexion and abduction), that is why, the sickness rate is much more lower.

In Japan within the frame of the national project as far back as in 1975 the national tradition of the tight swaddling of the stretched infants legs was changed. As a result the decrease of the congenital hip dislocation from 1.1 – 3.5 to 0.2% was observed.

Probably, there is a connection of the sickness rate with the social economic state of the society. In Ukraine (2002) the congenital dysplasia, subluxation and dislocation of the hip occur from 50 to 200 cases per 1000 of the neonates, i. e., the level of the congenital dysplasia is much more higher than it was on the same territory in the Soviet period.

More frequently this pathology happens with girls (80% of the detected cases), cases of the hereditary disease comprise approximately one third of all the case findings. HJ dysplasia happens 10 times more frequently with those children, whose relatives had the indications of the congenital hip dislocation. Congenital hip dislocation is revealed 10 times more frequently in the neonates at

breech presentation. Left hip joint is affected more frequently (60%), right hip joint (20%) or both (20%) are affected less [9 – 12].

Hip joint dysplasia is a disease, characterized by the immaturity in the process of embriogenesis of all the elements, participating in the formation of the joint: ligaments, cartilages, osseous surfaces, muscles, nervous and vascular structures. Diagnosis of the given disease is rather complicated. That is why, in cases of the delayed detection and treatment of HJD hard irreversible morphologic and functional changes develop in the affected extremities, which further lead to their curtailing, deformation of the joint itself and vertebral column, disorders of the pelvic organs functions. In this connection, many researchers propose to carry out early prenatal and postnatal diagnostics in the prenatal clinics and maternity hospitals, this will help to solve the problem as soon as possible.

The reasons of the dysplasia are the following:

- defects of the embryonal development;
- hormonal disorders of the pregnant woman;
- avitaminosis as a result of the inadequate alimentation;
- severe gestosis of the pregnant;
- infectious diseases, suffered during the pregnancy;
- original disposition;
- medically induced correction of the pregnancy;
- smoking, usage of alcohol;
- breech delivery;
- large or vice versa, premature fetus;
- hereditary factors.

Three main existing forms of the dysplasia are distinguished:

- dysplasia of the hip cavity – congenital hip dysplasia;
- dysplasia of the proximal section of the femur, the essence of which is the change of the angle between the hip cavity and the head of the femur;
- rotational dysplasia, the essence of which is the change of the head of the femur position relatively the hip cavity as a result of the violation of the geometry in the horizontal plane (the infant's leg while walking is turned inside, so called club-footed child) [12 – 15].

Developmental hip dysplasia

Developmental hip dysplasia (Fig. 1) is the defects of the hip cavity, they can be divided into:

- predislocation (a) – the state of the joint, when the cover of the hip cavity is angled and the proximal section of the femur is displaced from the cavity at a small distance. Such disorder of the joint development without hip displacement is easily defined clinically and roentgenologically and is frequently observed in the neonates;
- subluxation (b) – femur comes off the cavity more than in case of predislocation;
- dislocation (c) – the state of the joint, when the femur is outside the limits of the hip cavity.

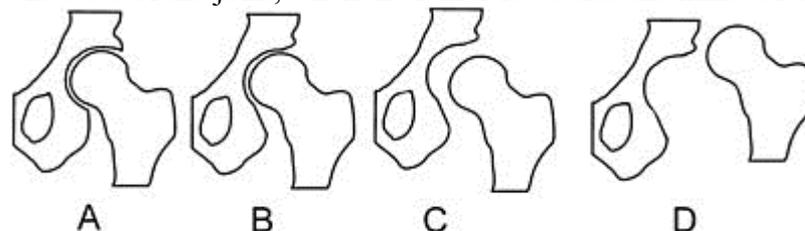


Fig. 1. External view of the developmental hip dysplasia

The majority of the orthopedists consider the hip joint dysplasia as the congenital deficiency, stipulated by the under development of all the structures and tissues, which form the hip joint, that can lead to the subluxation or dislocation of the head of the femoral head. Besides the direct

dysplasia (disorder of the hip joint development) the slowdown of the joint development, immaturity of the structures forming the joint can be diagnosed in children. The slowdown of the joint development is a borderline state but these children are also in the zone of risk of the dislocation development.

In case of the joint dislocation the femoral head completely loses contact with the hip cavity, in case of subluxation – only partially and is characterized by the disorder of the hip joint development without the displacement of the elements, forming it.

Developmental hip dysplasia in newborns may be unilateral or bilateral. The classification is based on clinicoradiologic indices [8 – 20].

For many researchers it is a point of interest: how to determine the hip joints dysplasia already at the stage of the prenatal development of the fetus and in newborns with 100% reliability?

Ultrasonic study of the hip joint

Up to the present two conventional methods of the hip joint dysplasia existed: clinical and roentgenologic. If clinical diagnosis of the hip dislocation is not very clear, determination of the subluxation and hip joints dysplasia in children of the first months of life has certain problems. Leading role in the diagnosis of hip joint (HJ) development disorder was assigned to the roentgenologic method of investigation. However, radiation dose, connected with this method, does not allow to apply this method of investigation for the children of up to three-month age. Besides, the nonstereogenic structures – parts of the femoral head, acetabular roof, which, in the infants of the first year life are greater part of these anatomic formations, are not represented in the X-ray image. As a result, it is impossible to detect the disorders of the enchondral formation, sometimes it is a main manifestation of the hip joint dysplasia. Application of the method of the artificial contrasting of the joint is rather complex and dangerous for the child.

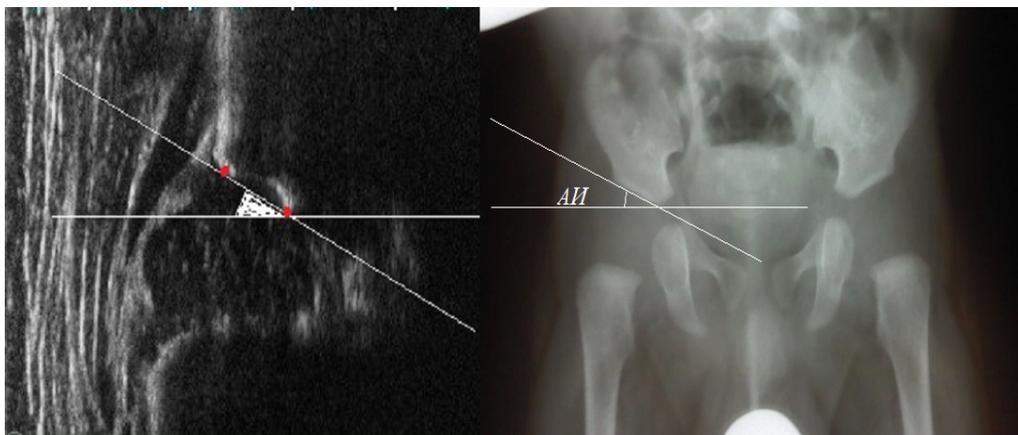


Fig. 2. Picture of the example of the hip joint dysplasia study on the roentgenologic and ultrasound images

In recent 15 years the orthopedists of the whole world conduct a search for the new methods of early diagnosis of the hip joint dysplasia of various severity levels in the infants of the first year of life. In 1977 R. Graph successfully used for this purpose ultrasound, by means of which it became possible to obtain the representation of both osseous and cartilaginous structures of the joint. However, the author presented the study of the hip joint, aimed at detecting of the disorders of the anatomic relations, without the indication on the technique and the assessment criteria of the degree of correspondence to the norm of the structure of the cartilaginous components of the joint. Besides, R. Graph uses for the diagnosis of the congenital dislocation of the hip the sonographic picture, obtained only in one projection. Meanwhile, according to the modern notions, anatomic symptom complex of the congenital dislocation of the hip goes beyond the disorders of the spatial relations in

the joint, it comprises one more component – disturbance of the enchondral formation. Neglecting the latter is the reason of the emerging of the so-called «late» dislocations.

Ultrasonic diagnosis is based on the principle of the echography i. e., radiation of the probing pulse of the ultrasound and receiving the signals, reflected from the surface of separation of the tissue environment, that have various acoustic properties. Signals, reflected from the acoustically non-uniform structures, are transformed on the screen of TV display, forming spatial 2D image. In orthopedics the ultrasonic radiation is used, which equals the threshold intensity, i. e., such intensity which does not cause permeability of the cell membranes and the regulatory-reparative processes are not started in the cells, aimed at liquidation of the consequences, caused by these changes. According to the data of numerous research, this threshold coincides with the cavitation threshold i. e., with such parameters of ultrasound which do not exceed the temperatures of the biological medium to the catastrophic for the biological objects values [15 – 19].

To carry out the research of the HJ ultrasonic devices of the company «Aloka» «Toshiba» and linear sensors with the frequency of 3.5 – 5 MHz, that combine perfect separation capacity with the penetration depth were used. The adjustment of the ultrasonic device was carried out so that the intensity of radiation, its duration enabled to obtain the reflection of the hyaline cartilage of the femur head on the monitor in the form of «acoustic hole», i. e., such image that does not reflect at all or weekly reflects the sound signal. The size of the image must allow to perform necessary measurements of the sonogram, the recommended enlargement ratio is 1:2. Reflection on the sonogram is considered to be correct, if the «acoustic shadow» of the ilium is located in parallel to the screen edge of the monitor.

Ultrasonic scanning occupies the leading positions among various methods of visualization both of HJD and other orthopedic diseases. In certain cases it can even be the alternative to magnetic resonance imaging.

The advantages of the given method is the simplicity of carrying out the procedure, accessibility, high information content, that enables to study not only the osseous structures but also soft tissue elements of the hip joint, possibility of multiple usage to control the treatment, lack of the radiation exposure as compared with the x-ray imaging, also ultrasonic diagnostics is a non-invasive method, safe for a child. By means of the ultrasound study it is possible to detect congenital dislocation of the hip at the early stages. Ultrasound study is performed by such evidences:

- availability of the clinical implications of HJD;
- severe development of pregnancy and delivery;
- muscle tone reduction in the lower limbs.

Besides the above mentioned advantages, ultrasonic study enables to perform the functional tests in real time mode, that allows to assess the presence and degree of the femoral head displacement relatively cotyloid cavity, location and state of the limb and the joint capsule as well as carry out the dynamic monitoring in the process of treatment.

The most optimal term for carrying out screening investigation – 1 – 1.5 month. At the given age all the elements of the joint develop very rapidly and the pathologic changes, revealed in the joint in this period, respond to orthopedic correction [12 – 17].

Sonography, according to the method of R. Graph (1984) is an accurate method of diagnosis only on the condition of the strict following the technique of the investigation and assessment of the results. Widespread errors on the stage of the diagnosis were incorrect installation and position of the sensor, hence – incorrect visualization of the anatomical landmarks, as a result it became impossible to measure correctly the angular indices of the HJ (errors of α and β angles measurement).

Roentgenologic studies

The traditional method of diagnostics is roentgenologic method, that records changes only in osseous structures, number of which in the infants of the first months of life is comparatively small.

In the opinion of various authors roentgenologic study of HJ becomes informative at the age of 3 – 5 months of life.

In the process of roentgenologic study of the disorders of HJ ratios Hilgenreiners scheme, 1925 is widely used. Also the modified Tonnis scheme (2015) is used, it enables to determine the roentgenologic type of HJ if the ossification site of the femoral head epiphase is missing.

Main errors in the process of roentgenologic study realization is the distortion of the pelvis and external rotation of legs. That is why, prior to making X-ray picture it is necessary to follow such conditions: symmetric placing of the newborn, minimum time of the execution of the procedure, usage of the protective liners. During the realization of the roentgenogram the participation of the assistants or parents, who can fix the baby in the needed pose, is required.

Dysplasia of the hip joint has specific roentgenologic features:

- slope of the roof of the hip cavity;
- transposition of the femoral head from the central axis;
- mismatch of the dimensions of the hip cavity and dimensions of the head;
- displacement of the femur outwards the vertical line.

Variations of the roentgenologic study

Arthrography – roentgenologic study of the joint after the introduction of the contrast substance and/or air into its cavity. Simultaneous introduction of the contrast substance and air (double contrast) enables to visualize the contours of the soft tissue structures and articular surface. Several X-ray pictures of the joint are taken, depending on the volume of motions in it. Arthrography enables to study roentgenonegative elements: the state of ligaments, joint capsule. By means of this method even the hip joint dysplasia of the first degree can be detected. On the arthrogram the position of the head and its form, fibrosis of the capsule, fusion of the hip cavity. The procedure is carried out under the general anesthesia [15, 16]. By means of the thin needle the skin cover, subcutaneous fat, capsule are pierced, penetrated in the hip joint cavity. Iodinated contrast media or noble gas is administered. Then X-ray pictures are taken .

Arthrography (Fig. 3) is recommended for the treatment of constant pain or disorders of the joint function of the vague etiology. Complications of the method comprise stable crepitation in the joint and development of the allergic reaction on the administration of the contrast substance. The alternative of the arthrography is MRT of the joint.



Fig. 3. Arthrography

There exists two methods of the administration of roentgenocontrast substance:

- in the joint cavity the contrast substance is administrated, the substance contains either iodine (positive contrast), or air (negative contrast).
- in this case the mixture of air and roentgenologic substance (of positive and negative

contrast) is used.

If joint capsule and ligaments are damaged the method of positive contrast is used. Meanwhile, in case of meniscus rupture, cartilages defects examination of children, the preference is given to the second method. Puncture of the joint and administration of the contrast is performed in sterile conditions. If there is a fluid in the joint cavity then prior to the administration of the contrast it is tapped. Amount and composition of the roentgeno-contrast substance depends on the dimensions of the joint. The contrast substance is rapidly absorbed, that is why, the X-ray pictures are taken immediately after its administration, otherwise the X-ray pictures will be blurred [17].

Arthroscopy

The conductor with a camera is introduced in the cavity of the joint, the images of all the elements – osseous surfaces ligaments, cartilages are shown on the screen.

Arthroscopy (Fig. 4) – is miniinvasive surgical manipulation, carried out with diagnostic and treatment goals in case of joints disease.



Fig. 4. Arthroscopy

The given manipulation is carried out by means of the arthroscope. With the help of the arthroscopy minivasive operation interventions on the joints are carried out. The given method is applied in case of such pathology:

- meniscus injury;
- meniscus suture;
- injury of the knee-joint ligaments;
- inflammatory disease of the sinovium;
- conventional dislocation and patella dysplasia;
- rheumatoid arthritis;
- injury and disease of the articular cartilage;
- aseptic necrosis of the femur outgrowths;
- injury and disease of the fat body – chronic hyperplasia of the fat body (Hoffa disease);
- deforming arthrosis of the knee-joint;
- obscure clinic while injury or disease of the joint, which can not be specified by means of the clinic or roentgenologic methods of study;
- obscure complains after previously performed operative interventions [17].

Methods of joints examination

Modern medicine uses such high technological methods of joints examination:

- computer tomography on the base of roentgenologic study;
- multispiral computer roentgenologic tomography;
- densitometry roentgenologic or ultrasonic, based on the measurement of the mineral density of the osseous tissue;

– magnetoresonant tomography (computer tomography on the base of magnetic-resonance study).

Computer tomography (CT) is a modern method of diagnostics and it belongs to the technologies of the structural or anatomic visualization. The basis of the diagnostics is the registration of the weakened X-ray radiation after passing across the zone of the diagnostic interest. By means of computer tomography (CT) the sections of any part of human organism can be obtained, it enables to form the conclusions, regarding the topography of the organs, localization and the character of the pathologic process duration and the interaction with the surrounding tissue.

Spiral computer tomography (SCT) opened new possibilities in the sphere of diagnostics. In spiral computer tomography (SCT) the technology of «slip ring» is used, the continuous motion of the X-ray tube along the spiral at parallel longitudinal motion of the table with patient is performed, this greatly decreases the duration of the investigation and radiation dose. SCT provides the possibility of greater diagnostic information as compared with the conventional CT due to the possibility of the considerable reduction of the section thickness.

The most accurate diagnostic method is **magnetic-resonance tomography** (MRT), which is separate diagnostic method, based on the ability of certain atoms to behave as the magnetic dipoles. Modern MR-tomographs are «adjusted» for the nuclei of hydrogen (in the tissue liquid or adipose tissue), which, being in the magnetic field, under the impact of the external electromagnetic field are able to absorb the energy and then release it in the form of radiosignal, MRT enables to obtain the image of the thin sections of the human body in any cross-sections and, unlike CT, represent well the soft tissues: muscles, fatty arrays, cartilages, vessels.

When the procedure is performed, the X-ray radiation does not influence the patient, that is why MRT can be used even for the examination of the newborns. MRT produces 3D images. You can see not only the state of the hip joint bone but also vessels. The given method of the investigation is safe for the pregnant women.

The weak point of MRT is that it takes much time to prepare the patient and carry out the study as compared with the roentgenologic methods.

MRT cannot determine the specific density of the osseous tissues, as the densitometry does. More accurate data can produce roentgenologic and not ultrasonic densitometry [17 – 21].

Conclusions

The standard complex of clinic-instrumental studies enables to determine only the expressed changes of the structural components of the hip joints in children in the dynamics of the pathologic process.

For early diagnostics and objective assessment of the dysplasia changes it is expedient to include in the complex examination of the children with HJD along with traditional laboratory and instrumental methods monitoring of the basic markers of the cartilaginous tissue (aggrecan, hyaluronan) remodeling and angiogenesis factor in the blood serum.

For diagnostics, forecast of HJD course and assessment of the result of the treatment method, it is expedient to use mathematical regression model of the probability of dysplasia process formation.

Practical implementation of the developed diagnostic algorithm will allow to determine the group of risk for the children regarding the development of a vascular necrosis and early coxarthrosis as the complications of HJD.

On the base of analysis of various methods of HJD diagnostics, which are scientifically substantiated and widely used in medical practice, further development of basically new methods and improvement of the already existing diagnostic techniques for the solution of the problem of the hip joint dysplasia is possible.

The application of the developed technologies in the system of complex examination of the orthopedic patients in the perinatal period will improve the treatment and prevention of HJD.

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