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# Organization of X-ray care for newborns with congenital defects abroad: status, advantages and problems

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**ABSTRACT.** Using the capabilities of diagnostic imaging in newborns, health care workers can achieve early detection, timely intervention and personalized approaches to treatment. Currently, when organizing X-ray care for newborns abroad, it is important to comply with strict safety standards, use modern equipment adapted for working with newborns, a differentiated approach to diagnostics taking into account the age and type of disease, constant introduction of innovative examination methods, ample use of telemedicine and electronic medical records to optimize the diagnostic process and exchange of information between institutions, as well as a multidisciplinary approach to the diagnosis and treatment of newborns. In Europe and America, research is actively carried out to improve visualization methods and develop new approaches to diagnosing diseases in newborns, including the use of alternative methods. At the same time, radiography does not lose its relevance. Despite the wide diagnostic capabilities of X-ray examination in children of the first month of life, it is used with caution due to the possible negative impact of X-rays on the child's body. Doctors prescribe X-rays in exceptional cases when there is no alternative to using other methods and the disadvantages of the examination are negligible compared to making an incorrect diagnosis.

**KEYWORDS:** X-ray care, X-ray examinations, magnetic resonance imaging, computed tomography, newborns, congenital malformations, X-ray radiation

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# Организация рентгенологической помощи новорожденным с врожденными пороками развития за рубежом: состояние, преимущества и проблемы

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**РЕЗЮМЕ**. Используя возможности диагностической визуализации у новорожденных, медицинские работники могут добиться раннего выявления, своевременного вмешательства и персонализированных подходов к лечению. В настоящее время за рубежом при организации рентгенологической помощи новорожденным актуальным является соблюдение строгих стандартов безопасности, использование современного адаптированного для работы с новорожденными оборудования, дифференцированный подход к проведению диагностики с учетом возраста и вида заболевания, постоянное внедрение инновационных методов обследования, использование телемедицины и электронных медицинских записей для оптимизации процесса диагностики и обмена информацией между учреждениями, а также мультидисциплинарный подход к диагностике и лечению. В Европе и Америке активно проводятся исследования по улучшению методов визуализации и разработке новых подходов к диагностике заболеваний у новорожденных, включая применение альтернативных методов. В то же время рентгенография не теряет своей актуальности. При широких диагностических возможностях рентгеновского исследования у детей первого месяца жизни его используют с осторожностью из-за возможного негативного воздействия на детский организм рентгеновских лучей. Врачи назначают рентгенографию в исключительных случаях, когда нет альтернативы применения других методов и минусы обследования ничтожно малы по сравнению с постановкой неправильного диагноза.

**КЛЮЧЕВЫЕ СЛОВА:** рентгенологическая помощь, рентгенологические исследования, магнитно-резонансная томография, компьютерная томография, новорожденные, врожденные пороки развития, рентгенологическое излучение

According to the World Health Organization (WHO), as well as to population surveys, the incidence of congenital malformations (CMs) in newborns ranges from 3 to 6%, which causes mortality (up to 25% of cases) and disability (up to 50% of cases) [1]. Currently, many scientific studies have been conducted to substantiate the methods and means of rapid and qualitative instrumental diagnosis of deviations in neonates' health in the first month of life. Diagnostic imaging is a powerful tool in infant health care, providing early detection of diseases, timely intervention and personalized approaches to treatment. Diagnostic imaging techniques tailored to the unique needs of newborns and healthcare professionals can improve the quality of life for infants and their families [2].

Radiologic imaging studies (RLI) are based on X-rays, which pose a certain hazard to living beings. Currently, classical X-ray and spiral computed tomography (CT) should take into account a radiation dose to reduce its effect on newborns [3–5]. A radiologic community has recommended to use beams of less than 50 mGy (5 rad) for the lowest radiation exposure [6–11].

The RLI method was first used to study bone health more than 100 years ago. Since then, it has saved countless lives and helped to make a number of important discoveries. X-rays are a natural form of electromagnetic radiation found not only in medical facilities, but also in nature. They are produced when charged particles possessing sufficient energy collide with various materials [6, 12–14].

Although radiography is one of the oldest diagnostic methods, it is still the most commonly used. However, as new technologies have been developed in European clinics, the standard X-ray has been replaced by the more sophisticated digital X-ray, which provides a significant reduction in radiation dose during the procedure. As a number of studies have shown, new standards of digital radiology have reduced X-ray doses by 90% [3, 12]. A digital format allows a physician to view an image immediately after the procedure, enlarge the image area of interest, increase its contrast and clarity.

Classical X-ray, spiral CT and magnetic resonance imaging (MRI) are the most frequently used methods of additional investigation to detect CMs, to assess dynamics of treatment, to plan surgical treatment, and to predict the course of neonatal diseases. X-rays are indispensable in diagnosing a number of diseases, including respiratory disorders of newborns (congenital pneumonia, meconium aspiration syndrome, etc.), fractures, oncologic diseases, as well as in abdominal and pelvic examinations.

According to WHO data, additional methods (RLI, CT, MRI) are most commonly required in the practice of neonatologists, intensive care anesthesiologists and surgeons to diagnose the following diseases or pathological conditions:

- diseases of thoracic cavity organs (cystic-adenomatous dysplasia of the lungs, sequestration of lung tissue, etc.);
- diseases of the musculoskeletal system (congenital diaphragmatic hernia (true/false), etc.);
- diseases of the abdominal cavity and retroperitoneal organs (esophageal atresia, duodenal obstruction, intestinal atresia (small/thick), anus atresia, etc.);
- pathology of the anterior abdominal wall (gastroschisis (intrauterine euteration of internal organs through a defect in the anterior abdominal wall), omphalocele (umbilical hernia), etc.);
- diseases of pelvic organs (calycopieloectasia, ureterohydronephrosis, cystic dysplasia, multicystic dysplasia, megaureter, etc.);
- oncologic diseases (teratoma, lymphangioma, hemangioma, etc.) [15–21].

Over the last decade, the growth of therapeutic and diagnostic capabilities of practical healthcare in nursing and treatment of premature and sick newborns has led to a significant increase in the use of X-ray examination in infants in the first month of life. In most developed countries, seven rules and recommendations are followed when organizing radiology care for newborns, which, first of all, are aimed at ensuring the safety and efficiency of medical examination of the child [22–24].

*1. Compliance with clinical protocols.* Health care facilities have developed strict protocols for diagnosing and treating newborns with radiologic technology. They take into account age, weight, and condition of an infant to minimize radiation exposure.

*2. Performing tests at specialized centers.* Neonatal X-ray examinations are often performed in specialized children's hospitals or departments with anesthesiologists and radiologists experienced in working with children.

*3. Minimizing radiation exposure.* Modern radiographic techniques such as low-dose radiography and alternatives to X-rays such as ultrasound (USG) are used. Regular calibration and maintenance of equipment is also carried out to ensure safety.

*4. Special training for medical staff.* Doctors and nurses receive special trainings on newborn handling and radiation safety principles.

*5. Mandatory informing of parents.* Indications for X-RAY, risks and benefits, and ways to reduce stress for a child during the procedure are explained to parents.

*6. Performing the study by a team of specialists.* Neonatologists, radiologists, medical physicists and other specialists work together to ensure quality diagnosis and treatment.

*7. Compliance with standards.* All health care providers must comply with federal and state standards, as well as with recommendations of professional associations such as the American College of Radiology (ACR) and the American Academy of Pediatrics (AAP).

X-ray imaging is used less and less frequently in pediatric practice in the United States because of the potential risks associated with ionizing radiation, even at minimal doses. Modern ultrasound and MRI provide detailed information on the condition of internal organs without harming the health of a newborn [25–27]. However, in some cases, such as bone injuries or suspected bone tumors, X-ray remains the most effective diagnostic method. In such situations, physicians carefully weigh all risks and benefits, choosing the most informative and safe method of examination for each specific patient [3, 28]. Birth traumas are a very common reason for diagnostics, when only X-rays allow to establish the nature and volume of damage. Radiography is also performed after a child has fallen from a height, for example, from a changing table, bed, etc.

Classical X-ray is not the only method of radial diagnosis of various conditions in children of the first month of life [29–31]. Such methods as spiral CT as well as MRI are often used abroad for more detailed assessment of newborns [12]. The first commercial magnetic resonance tomography (MR) scanners appeared in 1983. At the same time, a letter by Frank W. Smith and his colleagues was published in The Lancet magazine, it described the first MR tomograms they obtained in a pregnant woman [32]. Their initial research contributed to exponential growth of interest in developing and improving MRI techniques in the clinical practice of physicians [33, 34]. Technical progress over the last decade has brought MRI into the first line of noninvasive methods of neuro- and cardiac imaging. This technique of instrumental research has a number of advantages over other tomographic methods, primarily due to the absence of ionizing radiation, which is especially significant in neonatal examinations [35–37]. Another important circumstance is that there is no need to use contrast agents due to the high sensitivity of MRI technique to the blood current velocity [1]. MRI allows repeated studies with preservation of the same scanning parameters set during the initial MR study. They are performed in infants using anesthesia. At the same time, this method has a number of disadvantages for newborns. They are related both to evaluation of certain structures of the visualized area and to the long scanning time, which increases the time of intubation and anesthesia [1, 24, 37–39]. At the same time, a number of studies indicate that CT angiography is the most preferable method of additional investigation for some CMs of heart and main vessels. CT angiography is more informative than MR angiography in many respects [32, 36, 40–42].

Another problem discussed is obtaining high-quality diagnostic information while minimizing the radiation exposure on an infant in order to obtain a maximally informative image at the first attempt [1, 40, 43, 44]. In contrast to adults, it is difficult to fix a newborn in a proper pose, so special devices are used in radiography to obtain a high-quality image without repeated procedures. Proper positioning and immobilization techniques are important to minimize motion artifacts. Radiologists use immobilization devices such as sandbags, band-aids, or specially designed pediatric immobilizers to ensure that a child remains in a proper position throughout the X-ray exposure. Modern American clinics offer the latest solutions for the youngest patients. Special mobile radiographic racks with cradles allow newborns and toddlers up to two years of age to be examined in a comfortable and safe environment. A cradle can move in three planes, providing a secure fixation of a child, which allows to get clear and informative images. Thanks to this technology, practitioners can quickly and accurately diagnose, prescribe the necessary treatment, and ensure the health of small patients [38, 45, 46].

Currently, America and Europe have clearly established principles for organizing and developing radiological care for newborns, among which there are 8 main aspects.

*1. Safety standards.* In both regions there is a strict standard for exposing children, especially newborns, to radiation. Low-dose X-ray technology is used, which minimizes the risk of radiation exposure. Special protective shields and aprons are used.

*2. Specificity of equipment.* It is important to use specialized equipment adapted for working with newborns. This may include portable radiographic machines that allow to conduct studies directly in an ICU.

*3. Approach to diagnosis.* Both regions place a strong emphasis on early detection of disease. For example, radiography can be used to diagnose various lung pathologies as well as to assess bone health.

*4. Multidisciplinary approach.* It is important for radiologists to work closely with other medical specialists such as neurologists, surgeons, and pediatricians to ensure a comprehensive approach to the diagnosis and treatment of newborns.

*5. Staff education and training.* There are training and additional training programs for radiologists who work with newborns. This ensures that specialists are highly skilled and prepared to handle special cases.

*6. Ethics and family.* Ethics and consent to procedures are also important issues. In some cases, methods may be provided to reduce stress and anxiety in newborns and their families during radiologic examinations.

*7. Integration of technology.* The use of telemedicine and electronic health records to optimize diagnosis and information sharing between institutions is also becoming increasingly common.

*8. Research and innovation.* Research is actively being conducted in Europe and the Americas to improve imaging techniques and new approaches to diagnosing disease in newborns, including the use of alternative methods such as ultrasound or MRI when possible.

European photonics scientists have developed a new image processing algorithm, autocorrection, that reduces X-ray scattering, meaning that children can receive safer, high-contrast, low-dose X-rays. Thanks to innovative "scatter correction software", doctors have been able to obtain low-radiation digital X-ray images without the use of anti-scatter gratings [2, 47]. When an X-ray or CT scan is performed, the beam enters the body and is reflected or "scattered" inside. This scattering process creates "noise" and results in a loss of image quality, making the resulting x-rays appear blurred because the scattered signal can interfere with the underlying contrast of the patient's body features, such as bones or organs [48]. However, image contrast can be improved by counteracting scattering with an "anti-scattering grid" (a metal plate made of lead strips that creates -parallel rays of light). At the same time, this grid usually requires a higher X-ray dose and can be dangerous for newborns [49–51].

Despite the development of radiologic devices, the most urgent problem in this area is still the safety of children, especially newborns [3, 52, 53]. The reason for this is that all organs and systems of a newborn are in the most active period of growth and development during the first months, and direct exposure to X-rays can cause various degrees of damage and cause serious consequences. Knowledge about protecting newborns from X-ray exposure during imaging should be widely disseminated among physicians. When prescribing X-ray examination, physicians should comprehensively analyze the condition of a child and be sure to weigh the pros and cons. Each X-ray of a newborn should have a clearly justified reason. In addition, it is necessary to rationalize the methods of their performance. Photographic examinations with low radiation doses, more diagnostic information and high reliability should be chosen for children with clinical indications, avoiding fluoroscopic examinations [54].

Since children have smaller body size and lower tissue density, the reasonable optimization of technical conditions can reduce low-energy X-ray radiation that interferes with the formation of useful images, thereby reducing the radiation dose to the skin and glands in children. And therefore, photography with high kilovolts (kV), low milliamperes (mA) and short time (s) should be maximized, and its relatively long distance (m) should be provided. Careful selection of a central position should be made during each exposure to control a radiation field to the minimum required range and to keep the edge of the radiation field as far away from sensitive tissues as possible.

According to the recommendations of the American Children's Radiological Center (New York), special attention should be paid to the availability of effective shielding materials when selecting a radiological apparatus for the examination of newborns to protect them from radiation exposure. Methods such as contact, shadow, or molded shielding are appropriate. For example, the sex glands, thyroid gland, girl's breast, eye lens and bone marrow should be shielded as much as possible with a 0.5 mm thick aluminum equivalent lead apron to minimize the area of exposure [36, 44, 46, 55].

Thus, in order to minimize radiation hazards and effectively improve the level of neonatal protection during X-ray procedures, physicians are required to adhere to the basic principles of radiation protection, among which are:

- a full understanding of x-ray examination in children;
- widespread promotion of knowledge about protecting a child from X-rays and the use of X-ray technology in a rational manner;
- optimizing the technical conditions of exposure;
- rational selection of a child's body position during the examination and strict control of an exposure field;
- increased attention to shielding and protection to ensure low damage to non-testable parts;
- improvement of technical level of radiation personnel and elimination of technical operation errors [2, 28, 38, 55].

In addition, when organizing X-ray inspection, the staff should conscientiously perform their duties, continuously improve their professional level and awareness of patient radiation protection, and pay due attention to protect staff by applying new radiation technologies.

Accordingly, at present, the organization of radiological care for newborns abroad is focused on compliance with strict safety standards, use of modern equipment adapted to work with newborns, a differentiated approach to diagnostics taking into account age and a type of disease, constant introduction of innovative methods of examination, use of telemedicine and electronic medical records to optimize the diagnostic process and information exchange between institutions, as well as the use of telemedicine and electronic medical records. Research is being actively conducted in Europe and America to improve imaging techniques and develop new approaches to diagnose diseases in newborns. At the same time, radiography has not lost its relevance. However, despite wide diagnostic possibilities of X-ray examination in infants of the first month of life, it is used with caution because of the possible negative impact of X-rays posed on children. In this regard, assessment of the harm-benefit ratio, as well as strict justification and dosage of radiation exposure is especially important.

## ADDITIONAL INFORMATION

**Author contribution.** Thereby, all authors made a substantial contribution to the conception of the study, acquisition, analysis, interpretation of data for the work, drafting and revising the article, final approval of the version to be published and agree to be accountable for all aspects of the study.

**Competing interests.** The authors declare that they have no competing interests.

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