The Development of New High-Tech Technologies and Innovative Equipment for Phototherapy of Hyperbilirubinemia (Jaundice) Newborns

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The phototherapy of hyperbilirubinemia (jaundice) of newborns is one of the clearest examples of the effective use of optical technologies in medicine. According to the data of various authors, the jaundice syndrome is observed in 50–60% of full-term newborns [1] and about 80% of premature infants and is most pronounced by day 3–4 of their life. The indicated noninfectious disease is caused by the excess accumulation in the blood, as well as in subcutaneouous fat cells, of bile pigment (a product of the exchange of hemoglobin) – *Z,Z*-bilirubin IXα – which imparts a characteristic golden yellow color to the skin. For most newborns who manifest the attributes of hyperbilirubinemia, as the operation of the system for excreting bilirubin improves and the biochemical systems of the organism normalize, the jaundice disappears in 1–2 weeks without causing any harm to the child. However, in 6–10% of the infants the jaundice proceeds to a serious form as a consequence of a high bilirubin level and requires intensive therapy. If emergency measures are not taken, the presence of a high concentration of the indicated toxic pigment in the infant's organism can have an effect on his physical and neuropsychic development, as well as being a direct cause of death.

The main methods of treatment aimed at reducing the level of bilirubin in the blood of newborns is phototherapy and exchange transfusion. The standard treatment for neonatal jaundice is phototherapy. And the tactic of therapeutic interventions is usually aimed at achieving a favorable clinical outcome with the help of phototherapy, without resorting to the methods of interventional therapy. Exchange transfusion was the first successful therapy for severe neonatal jaundice. This technique rapidly eliminates bilirubin from the circulation. Circulating antibodies that target the erythrocytes are also removed. Exchange transfusion is especially beneficial in infants who have ongoing hemolysis from any cause. One or two central catheters are placed, and small aliquots of blood are removed from the infant and replaced with similar aliquots of red cells from a donor, mixed with plasma. This procedure is repeated until twice the blood volume has been replaced. During the procedure, serum electrolytes and bilirubin should be measured periodically. The amount of bilirubin removed from the circulation varies according to both the amount of bilirubin stored in tissues that reenters the circulation and the rate of hemolysis. In some cases, the procedure needs to be repeated to lower the serum bilirubin concentration sufficiently.

Typically, invasive methods are only applicable if using phototherapy fails to reduce the concentration of bilirubin in the blood of newborn babies to a safe level. It should be noted that the operations of exchange transfusion of large amounts of blood (to an infant from an adult donor) are heavily beared by the babies, and in some cases exacerbate intoxication of child's body. Mortality of children under this procedure ranges from 0.3% to 5.2% [1]. Thus, one of the main objectives of phototherapy of neonatal hyperbilirubinemia of newborns is the reduction to a safe level of bilirubin in the blood, without resorting to the methods of interventional therapy, potentially causing organism infection and infant mortality.

The principal and most widely used method of treating hyperbilirubinemia of newborns is phototherapy consisting of the total action on the child's body surface of light with a power density of P =0.3–2 mW/cm^2, whose spectral composition corresponds to the long-wavelength absorption band of bilirubin (λ = 400–530 nm). The method began to be widely used in medical practice in the 1970s, and, according to the data of the American Academy of Pediatrics, more than a million infants throughout the world have by now been treated. It is assumed that the determining role in lowering the bilirubin level in the organism of newborns who undergo phototherapy is mainly

played by the processes of photoisomerization of the pigment – the formation of its configurational isomers (*Z*,*E*-bilirubin IXα, *E*,*Z*-bilirubin IXα, and *E*,*E*-bilirubin IXα) and structural isomers (*Z*-lumirubin and *E*-lumirubin). The indicated isomers, and above all lumirubin, being more hydrophilic compounds than native *Z*,*Z*-bilirubin IXα, are characterized by an elevated excretion rate.

Along with a pronounced therapeutic effect, long lasting influence on the infant with fluorescent, halogen and metal halide lamps light may have an adverse side effect on him. Besides the ultraviolet and infrared components, present in the emission spectrum of these lamps, negative impact on the baby can also be made by intense visible light through photosensitized processes involving endogenous pigments (including bilirubin photoproducts) and pharmacological agents.

Currently there is no alternative to the use of LED sources in the devices for phototherapy of neonatal hyperbilirubinemia. Radiation sources of this type of blue-green region of the spectrum correspond to the range of absorption of bilirubin and significantly exceed the widespread lamp sources (mercury, halogen, metal halide) on the set of optical and operational characteristics. The devices for phototherapy of neonatal hyperbilirubinemia (*i*) does not contain the ultraviolet and infrared components (having side effects on the newborn); (*ii*) provides adjustment of the intensity of effecting radiation, depending on the severity of the newborn; (*iii*) allows a uniform distribution of light intensity on the surface of the child's body; (*iiii*) dozen times exceeds lamp on the work resort; (*iiiii*) resistant to mechanical damage and does not represent (in contrast to the mercury vapor lamps) environmental concerns in violation of its integrity and while disposal.

An increase (in comparison to the analogues) in the efficiency of the phototherapy of jaundice is attained due to the

– more high density of the radiation power on the surface of the body of a child;

– possibility to regulate the intensity of the acting radiation depending on the gravity of the disease;

– uniformity of distribution of the radiation-power density over the surface of the body of a child;

– choice of a spectral range, in which the screening action of haemoglobin is lower than in the case where a wide-band radiation of lamps for phototherapy is used;

– increase (due to the definite ratio between the intensities of the blue and green components of the LED radiation) in the content of lumirubin – a photoproduct of bilirubin characterized by a maximum rate of extraction.

Objective:development of equipmentandtechnologies thatimprove efficiency and reduce(eliminate) the adversesideeffectsof phototherapyof hyperbilirubinemia(jaundice) newbornsthrough the use ofLED light sources, optimizing the spectral rangeof radiation and itsintensitybased on the studyof photonicsbilirubin

Urgency of the problem: Traditional methods of phototherapy based on the use of fluorescent and halogen lamps, are ineffective and have a number of adverse side effects (erythema of the skin, bronze baby syndrome, overheating of the body , etc.). For this reason, the duration of phototherapy is 100 hours or more, can not be avoided procedures exchange transfusion of blood. In the course of the project will be developed photophysical approaches and prototypes were made to ensure efficiency of phototherapy and the exclusion of adverse side effects

The main stages of work:

1. Elucidation of the optimal spectral range for effective phototherapy with the optical properties of the baby's skin and the quantum yield of photoisomerization bilirubin wavelength.

2. The study ofphotonicsbilirubin andits effectiveness self-sensitizeddestruction.

3. Optimizing LED illuminator, which provides a uniform intensity of the effect of light on the surface of the baby's body.

4. Creating innovative LED apparatus for implementing the method.

5. The developmentof efficient methods forphototherapyof neonatal hyperbilirubinemia.