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KIDNEY TUBULAR ACIDOSIS: CAUSES, SYMPTOMS, DIAGNOSTICS, TREATMENT (LITERATURE DATA AND THE AUTHORS' OWN OBSERVATIONS)*

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Наведені літературні дані по етіології, патогенезу, клініці, діагностики і терапії ниркового тубулярного ацидозу у дітей, а також наведено власне спостереження дитини протягом 9 років з цим захворюванням. Проаналізовано клінічні прояви від початкових симптомів захворювання з 3,5 років у вигляді рецидивуючих ацетонемічних станів, епізодів дегідратації з підвищенням температури, поліурією. Простежено подальша динаміка симптомів у вигляді різкої слабкості в ногах, швидкої стомлюваності, порушення ходи, неможливості бігати, стрибати, X-подібна деформація нижніх кінцівок. Наведено літературні дані помилковості призначення дитині масажу при рахітоподібних захворюваннях без нормалізації фосфорно-кальцієвого обміну і зникнення ознак ацидозу. Проведено ретельний аналіз допущених помилок і продемонстровані позитивна динаміка в клінічному стані і розвитку дитини у відповідь на адекватне лікування після правильно встановленого діагнозу. Диференційний діагноз проведено з синдромом Фанконі, проксимальним ПТА, гиперпаратиреозом, первинною гіпероксалурією. Молекулярно-генетичне дослідження дозволило виключити цистиноз. Подібні діти вимагають постійного спостереження і лікування спеціалістів, перш за все з точки зору профілактики прогресування ниркової недостатності. Знання особливостей перебігу ниркового тубулярного ацидозу істотно допоможе клініцисту у встановленні діагнозу, призначення консультацій вузьких фахівців, а також адекватної тактики лікування.

Ключові слова: нирковий тубулярний ацидоз I типу, нирковий тубулярний ацидоз II типу, діти.

The article presents a literature review on the etiology, pathogenesis, clinical presentation, diagnosis and therapy of renal tubular acidosis in children, as well as our own 9-years-long observation of a child with this disease. Clinical manifestations from the initial symptoms starting at 3.5 years of age in the form of recurrent acetone states, episodes of dehydration with fever, and polyuria were analyzed. Further dynamics of symptoms was traced in the form of severe weakness in the legs, rapid fatigue, gait disturbance, inability to running, jumping, X-shaped deformity of the lower extremities. The literature data on the erroneous prescription of massage to a child with rickets-like diseases without normalization of phosphorus-calcium metabolism and disappearance of acidosis signs are presented. A thorough analysis of these mistakes was carried out and the positive dynamics was demonstrated in the clinical condition and development of the child in response to adequate treatment after a correctly made diagnosis. The differential diagnosis was carried out with Fanconi's syndrome, proximal RTA, hyperparathyroidism, primary hyperoxaluria. Molecular genetic study permitted to exclude cystinosis. Such children require constant monitoring and treatment by specialists, primarily from the point of view of preventing the renal failure progression. Knowledge of the features of renal tubular acidosis course will significantly help the clinicians in making the diagnosis, prescribing consultations of narrow specialists, as well as choosing an adequate treatment tactics.

Key words: renal tubular acidosis type I, renal tubular acidosis type II, children.

Diagnosis of tubulopathy in childhood is a complicated task, whose solution is possible with knowledge of clinical polymorphism of the disease, the features of its onset and course, as well as a thorough diagnostic search. Difficulties in the early diagnosis of tubulopathy are associated both with a rare occurrence of individual forms, and with a significant similarity of clinical symptoms, which causes frequent diagnostic errors.

Renal tubular acidosis (RTA) is a clinical-laboratory symptom complex, resulting from a defect in the reabsorption of bicarbonates in the proximal tubules or impaired acidogenesis in the distal tubules, characterized by metabolic acidosis and a decrease in the ability of the kidneys to acidify urine. One of the main RTA signs is the bone skeleton changes resembling those of rickets [1, 2, 3]. There are 4 types of primary (hereditary) and second-

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dary RTA. RTA type I is considered to be classical [4, 5].

RTA is based on the impairment of one most important kidney function: maintaining the acid-base metabolism (ABM).

In type I RTA, distal tubular acidosis occurs as a result of impaired production or transport of hydrogen ions H^+ [1, 6, 7, 8]. The main pathogenic link is a disorder of the kidneys ability to establish the H^+ ions concentration gradient between the blood and tubular fluid, which causes metabolic hyperchloremic acidosis.

In such patients, the urine pH does not usually fall below 6.0 and is frequently 6.8-7.5. A characteristic feature of this form of acidosis is the fact that bicarbonates are constantly released into the urine, instead of which chlorine ions diffuse into the blood to maintain the osmotic pressure, hyperchloremia and the blood hydrogen carbonates deficiency are developed. For this reason, the renal excretion of acids and ammonia is also reduced. In acidosis, increased sodium excretion causes polyuria. Hyponatremia leads to hyponatremia, and as a result to secondary aldosteronism and hypokalemia. The loss of a large amount of calcium with alkaline urine, hypocalcemia, is the cause of the oxalate and calcium phosphate calculus deposition in the kidneys. By the age of 3-5 years, bilateral nephrocalcinosis occurs [9, 10, 11]. This creates the conditions for the onset of a secondary urinary tract infection. Calcium deficiency leads to osteoporosis and osteomalacia, because hypocalcemia stimulates the production of parathormone. Secondary hyperparathyroidism leads to the bone resorption, calcium enters the bloodstream, which explains normocalcemia.

The main link in the pathogenesis of type II RTA is a defect in the reabsorption of HCO_3^- -bicarbonates in the proximal tubules with acidogenesis maintained [1, 3, 7, 12]. Patients with proximal RTA type have a decrease in the renal threshold bicarbonates concentration, therefore, urinary bicarbonate excretion is sharply increased - more than 10-15% of the filtered amount (with the norm of 0-2%).

The renal threshold for bicarbonate reabsorption falls below 20-22 mmol/L. This form of tubular acidosis is characterized by maintaining the ability to reduce the urine pH and to excrete H^+ . The mechanism of urinary acidification in the distal tubules is not disturbed; urine may have an acid reaction (pH less than 5.5).

It is believed that type I RTA is first detected no earlier than 2-3 years of life, and even in adults, wherefrom the definition of "adult type RTA" came. Sometimes the only symptom of the disease may be a physical developmental delay, and in 2-3 years old children - rickets-like changes in the skeletal system. By 3-4 years of age, a complete clinical and laboratory RTA symptom complex is formed [2,8,13].

Renal tubular acidosis of type II is characterized by the occurrence of periodic vomiting, anorexia, rise in body temperature of unknown origin, hypotrophy developed in the first months of life, children lag behind in physical development, early rickets-like changes in the skeletal system occur, nephrocalcinosis rarely develops. With a delayed diagnosis of the disease, the acidic coma can develop. However, despite the severity of clinical manifestations, spontaneous healing is possible for this type [2, 13].

The treatment is aimed at correcting the disorders inherent in RTA: acidosis and restoration of electrolyte balance, osteoporosis and the prevention of complications [3, 13, 14].

The aim of the research is to familiarize a wide circle of pediatricians with a 9-year observation of a child with renal tubular acidosis (RTA) and therapeutic tactics that have overcome the lag in the child's development and eliminated most of the symptoms.

Below is a case from our own clinical observation.

Girl E., b. 11.2010 (4 years 10 months) was admitted to the children's neurological department of the Mariupol Territorial Medical Association "Child's and Woman's Health" on September 21, 2015 with complaints of weakness in the legs, rapid fatigability, gait impairment, inability to run, to jump.

Life history: early anamnesis without specific findings. The patient started walking from the age of 10 months. The hereditary history is not burdened.

Present history: at the age of 3.5 years (May, 2014), the child was treated at the children's infectious ward of City Hospital No. 4 in Mariupol due to food poisoning. After discharge from the hospital, polyuria, recurrent acetone conditions, and episodes of fever developed. In spring 2015, (at the age of 4.5 years), parents paid attention to a change in gait, weakness in legs, rapid fatigability, the girl stopped running and jumping. These complaints progressed. The significant levels of pain in the lower extremities occurred, their X-shaped deformation was formed. There was a loss in weight (at the age of 4 years the weight was 18 kg, at the age of 5 - 14 kg, the normal weight at the age of 5 being 20.0-20.5 kg), delayed growth (at 3 years of age the body height was 104 cm, at the age of 5 years - 104 cm, the required increase in growth being 5-6 cm per year).

Neurological status: muscular tone is sharply reduced in the limbs, more in the legs. The child lags behind in height and weight. There is a pronounced X-shaped deformation of the lower extremities, flat valgus feet. The lumbar lordosis is smoothed. The gait is paretic, waddling, the child cannot jump, run, walk up the stairs. An electromyogram (EMG) was taken at the department: diffuse neuronal level of disturbances. A study of the spinal muscular atrophy genes (SMN1, NAIP) was carried out at the regional medical and genetic center; no mutations were detected. Magnetic resonance imaging (MRI) of the brain and the spinal cord was performed: no damage to the brain and the spinal cord was detected.

The child was consulted by a professor at the Department of Pediatric Neurology of the Kharkov Medical Academy of Postgraduate Education, Dr. habil. in Medicine Evtushenko S.K. Diagnosis: Mitochondrial encephalopathy with lower paraparesis, with impaired walking function. Recommendations: EMG in dynamics, blood lactate study, for treatment - cerebrum compositum, coenzyme compositum.

The child's condition has significantly improved against the background of ongoing metabolic therapy. However, after massage courses in the regional children's bone-tuberculosis sanatorium in Mariupol and at home, a significant health deterioration was noted. After the massage courses, the girl had difficulty in walking. Since March 2016 (5 years 3 months), the girl almost stopped walking unassisted. On 19.03.16 EMG showed that the myopathic pattern of disturbances prevailed. On 12.11.15 blood lactate increased to 8.10 mmol/L, by February 2016 it was normalized (on 24.02.16 it was 2.09 mmol/L, the normal value being 0.5-2.20 mmol/L).

The girl was consulted at Kharkov Specialized Medical Genetic Center (HSMHC), where she was examined in May 2016: changes in ketosis metabolites and a de-

crease in Krebs cycle metabolites were revealed; increase in daily urine volume - 2100 ml (N - 700-1200 ml); an increase of creatinine in daily urine was 1.1 g/day (N being 0.27-0.415 g/day) and urea - 401 mmol/day (N - 133-200 mmol/day); increased oxypoline - 63 mg/day (N - 21.1-51.3 mg/day). In the biochemical analysis of blood as of 24.05.2016, the increase in homocysteine was 8.13 $\mu\text{mol/L}$ (N - up to 5 $\mu\text{mol/L}$) and the decrease in phosphorus levels was 0.77 mmol/L (N - 1.45-1.78 mmol/L), creatinine - 22.13 $\mu\text{mol/L}$ (N - 27-62 $\mu\text{mol/L}$) and uric acid - 0.7 U/L (N - 1.68-3.84 U/L). Measuring amino acids in the blood by high performance liquid chromatography (HPLC) revealed a decrease in serine, histidine, glycine, alanine, tyrosine, cystine, methionine, phenylalanine, leucine, and an increase of arginine, cystine, lysine in the urine. In tandem mass spectrometry (TMS) of amino acids in the blood, thin-layer chromatography (TLC) of carbohydrates in urine and in urinalysis, no deviations were detected.

The child was consulted by the Director General of KSMGC, NAMSU associate member, Dr. habil. in Medicine, professor Grechanina Ye.Ya. The diagnosis was: combined defect of oxidative phosphorylation, of respiratory chain assemblies insufficiency with predominant damage of the renal tubules (renal tubular dysfunction). Secondary dysfunction of the parathyroid glands. Hyperhomocysteinemia. Evidence of such a damage is polyuria, high levels of creatinine and urea in the urine; low levels of creatinine, urea, phosphorus in the blood.

The following was prescribed: the diet (a sufficient amount of vegetable proteins and fluid, limiting acidogenic - sulfur-containing amino acids, enrichment with phosphates and alkalizing products - potato and potato-cabbage diet); to normalize the processes of homocysteine remethylation into methionine - stomach support, pyridoxal-5-phosphate (P_5P), folacin; energy-stimulating therapy - coenzyme compositum, ubiquinone compositum, corylip. Taking into account changes in the skeletal, muscular, and urinary systems with secondary dysfunction of the parathyroid glands, examination at the National Children's Specialized Hospital "OKHMATDET" in Kyiv was recommended.

From 13.06.2016 to 29.06.2016, the girl was examined at the nephrology department of Kyiv City Clinical Hospital No. 1.

The study revealed hypocalcemia - 1.28 mmol/L (N - 2.25-2.75 mmol/L), hypophosphatemia - 0.75 mmol/L, (N - 1.45-1.78 mmol/L), increased alkaline phosphatase (ALP) - 897 U/L (N - up to 297 U/L). Subcompensated acidosis was detected - pH - 7.29 (N - 7.36-7.42), a decrease in the bicarbonate blood anion up to 13.8 mmol/L (N - 21-26 mmol/L) and a deficiency of buffer bases - "11.2 mmol/L" (N - " ± 2 mmol/L ") were revealed. In daily urine, hypercalciuria was observed - 4.7 mmol/day (N - 0.5-3.8 mmol/day), alkaline reaction of urine - urine pH was 8.1 (N - 5.5-7.0). Consultations of specialty physicians were held. Neurologist: Myopathic syndrome against the background of the underlying disease. Orthopedist: Osteoporosis, epimetaphyseal dysplasia due to tubulopathy, tibia valgus deformity. Geneticist: To exclude a congenital metabolic disease, blood and urine tests for the amino acid spectrum are recommended. Ul-

trasound study of the kidneys: the kidneys are enlarged: right - 9.6x4.0 cm, left - 10.6x4.3 cm. The renal parenchyma is indurated, the pyramids contours are indurated, thickened. Multiple calcifications up to 5 mm are visualized in the projection of the pyramids. Ultrasound images of other abdominal organs are without abnormalities. Ultrasound images of the thyroid and parathyroid glands are without structural changes. Plain abdominal radiography: Phenomena of nephrocalcinosis. Molecular genetic research (Institute of Molecular Biology and Genetics, Kyiv) dated 20.10.2015: No mutations in the genes of spinal muscular atrophy (SMN1, NAIP).

The following diagnosis was made: tubulopathy. Renal tubular acidosis type I. Chronic renal failure (tubular). Nephrocalcinosis. Subnanism is somatogenic. Osteoporosis. Epimetaphyseal dysplasia due to tubulopathy. Tibial valgus deformity.

The conducted therapy included diet, soda-buffer, alpha-D₃-Teva, calcium-D₃ nycomed, magnerot, dimephosphon, osteogenon, physiotherapy exercises (exercise therapy), braces (removable joint-immobilizers).

In October 2016, the girl sustained a fracture of her right femur during a game.

During the follow-up examinations at the nephrology department of Kyiv City Clinical Hospital No. 1 09.04. - 15.04.2017 and 13.12. - 18.12./2017, in the blood biochemical analysis indices of potassium, calcium, phosphorus, alkaline phosphatase, creatinine were normalized. The glomerular filtration rate was slightly decreased - 103 ml/min (N - 133 ± 27 ml/min /m² of body surface), blood acidosis was detected - pH - 7.26; decrease in the bicarbonate blood anion to a lesser extent than before - to 19.0 mmol/L (N - 21-26 mmol/L) and deficiency of buffer bases to "7.9 mol/L" (N - " ± 2 mmol/L "). The daily fluctuations in the specific gravity (SG) in the urine analysis according to Zimnitsky are insufficient - 1011-1014; Ca in the daily urine was within normal limits - 2.8 mmol/day.

Ultrasound study of the kidney retains signs of nephrocalcinosis. The genetic study of 13.12.2017 at the "EUROLAB" laboratory by direct automatic sequencing of the nephropathic CTNS cystinosis gene coding sequence revealed no pathogenic and probably pathogenic variants. Recommendations are given: diet, long-term soda-buffer, alpha-D₃-Teva, calcium-D₃-nycomed. Courses of magnerot, agvantar (L-carnitine), dimephosphon, osteogenon (then aleander), blemaren, smart omega for children were prescribed. Growth hormone (somatin) was prescribed: s/c 4 IU once a day, 5 days a week.

From 08.06 to 23.06.2017 the girl was treated in the traumatological department of Kyiv City Clinical Hospital No. 1.

Shortening of the left lower limb is detected. Misaligned pelvis on the right. Coxa valga on the left. Valgus deformity in both legs of a severe degree. Valgus deformity of the feet.

In June 2017, surgical correction of the valgus deformity in both legs was performed - medial epiphysiodesis of the femoral lower third, upper third of the tibia from 2 sides using titanium plates. In February 2018, screws were removed from the lower third of both femurs and the upper third of the tibia.

Fig. 1. Photo No. 1-2 - March 2017, a radiograph of the lower extremities before the operation (6 years 4 months). Photo No. 3 - after surgical correction of the valgus deformity in both legs - epiphysiodesis (6 years 10 months).

The child was examined at the Orphan Diseases Center of the Children's National Specialized Hospital "OKHMATDET" on 03.12.2018. (7 years 3 months):

1. Urinary screening: test for protein is negative; Feling test - negative; Sulkowitch test - (+); test for hyperaminoaciduria is negative; Benedict test is negative; test with dinitrophenylhydrazine (DNPH) - negative; Obermeyer test - negative; Legal test - negative; test for cystine - negative;

2. TLC of carbohydrates in the urine is within the norm; glucosaminoglycans (GAG) in the urine of CPC (cetylpyridinium chloride) - 45/213 from CPC/g of creatinine.

3. Tandem mass spectrometry (TMS) of amino acids and acylcarnitines in the blood: the level of the studied metabolites is within normal limits.

4. On 19.07.2017 HPLC of amino acids in the urine was performed: increased concentration of arginine, cystine, lysine was detected. HPLC of amino acids in the blood: generalized aminoacidemia.

On 18.12.2017, HPLC of amino acids in the urine showed the following: decrease in the concentration of glycine, threonine, alanine, tyrosine, phenylalanine. HPLC of amino acids in the blood revealed no amino acids concentration disorders in the blood.

Geneticist's consultation: Tubulopathy, progressing with skeleton disorders. This condition requires differential diagnosis with cystinosis, renal tubular metabolic acidosis, De Toni-Debre-Fanconi disease. There are no data testifying to the hereditary diseases of amino acid, acylcarnitines metabolism.

The last hospitalization in the nephrology department of Kiev City Clinical Hospital No. 1 from 04.11. to 08.11. 2019. Examination data: potassium, sodium, calcium, ionized calcium, phosphorus, chlorine, PTH, alkaline phosphatase, glucose, creatinine, 25-OH vit. D₃ is normal. Blood acidosis persists - pH 7.26 (N - 7.36-7.42) with a slight decrease in the bicarbonate blood anion to 19.9 mmol/L (N - 21-26 mmol/L); and the buffer bases deficiency - " - 7.6 mmol/L" (N - "± 2 mmol/L"), a decrease in glomerular filtration to 100 ml/min. (N - 133 ± 27 ml/min/m² of body surface), insufficient fluctuation in the urine SG according to Zimnitsky - 1008 - 1010.

Diagnosis on discharge: First degree chronic kidney disease. Renal tubular acidosis type I. Fanconi's syndrome. Chronic renal failure (tubular). Nephrocalcinosis. Osteoporosis. The state after the operation of correction of the both legs tibial valgus deformity, medial epiphysiodesis of the hip lower third, upper third of the lower leg from 2 sides using titanium plates.

Against the background of the therapy, a significant positive dynamics is noted. Normalized levels of calcium, phosphorus in the blood and urine are observed. The level of creatinine, blood urea is within normal limits. Changes in blood acid-base balance (ABB), a low level of glomerular filtration rate (GFR), insufficient fluctuation of the urine specific gravity in the sample according to Zimnitsky test are preserved. Signs of nephrocalcinosis according to renal ultrasound study do not increase. During the first 6 months of therapy, growth hormone (somatin) has increased by 12 cm, the girl gained 5 kg in weight. Today, the child is 9 years old, the height is 130 cm, the weight is 26 kg, the normal weight according to the centile tables is 25.5-32.0 kg, the normal height according to the centile tables is 128.5-136.5 cm.

The girl runs, jumps, dances, and is active. There is no weakness in the legs, fatigue, pain in the lower extremities. There are no complaints. The patient attends school. She continues to receive soda-buffer, growth hormone, alpha-D₃-Teva (detrimax); receives courses of magnerot, agvantar (L-carnitine), dimephosphon, osteogenon (aleander), blemarin, smart omega for children. Calcium preparations are withdrawn, the dose of alpha-D₃-Teva is reduced.

The above case report demonstrates a rare hereditary disease of type I renal-tubular acidosis. In our patient, the disease manifested itself at the age of 3.5 years, which was manifested by recurring acetonemic conditions, episodes of dehydration with fever, and polyuria. However, only 1.5 years after the disease manifestation, the complaints of sharp weakness in the legs, rapid fatigability, impaired gait, inability to run, jump, the X-shaped deformation of the lower extremities were the reason for a more thorough examination.

Fig. 2. Photo No. 4-6 – August, 2019 (8 years 9 months).

The prescription of massage was erroneous, and it led to deterioration in the child's condition. According to the published data, the prescription of massage for rickets-like diseases is only indicated with normalization of phosphorus-calcium metabolism and disappearance of acidosis signs [2, 7]. Insufficient weight gain, growth retardation, pronounced later (after 3.5 years of life), rickety manifestations in the form of the bent lower extremities were ignored.

The neurological pathology was initially excluded at the children's neurological department of the Mariupol Territorial Medical Association "Child's and Woman's Health" due to the presence of severe muscular weakness and impaired walking. Spinal muscular atrophy, organic damage to the brain and the spinal cord were excluded. Considering changes in the bones (late rickets deformity of the lower extremities), muscles (severe muscular weakness), urinary system (polyuria, constant alkaline reaction of the urine, the presence of nephrocalcinosis), the child was suspected of tubulopathy, and therefore the child was referred to the children's nephrology department of Kyiv, where metabolic acidosis, metabolic disorders of phosphorus and calcium were detected. To identify distal RTA, the differential diagnosis was carried out with Fanconi syndrome (there was no glucosuria and aminoaciduria), with proximal RTA (there was no acidification of urine - pH <5.5 in the presence of nephrocalcinosis).

After molecular genetic studies, cystinosis was excluded. In our case, we also excluded hyperparathyroidism, primary hyperoxaluria, the child did not receive nephrotoxic drugs. Adequate RTA therapy gave positive results in the form of a complete leveling of the child's lagging in the weight, growth and development, and significantly improved the patient's quality of life. Such children require constant monitoring and treatment by specialists, especially in terms of preventing the renal failure progression. Each observation of a child with renal tubular disorders permits to expand the clinical concept of these diseases.

References

1. Ignatova MS. Detskaya nefrologiya. M.: Meditsinskoye informatsionnoye agentstvo; 2011. 696 s. [in Russian]
2. Novikov PV. Rakhit i nasledstvennye rakhitopodobnye zabolevaniya u detey: diagnostika, lechenie, profilaktika. M.: Triada H, 2006. 336 s. [in Russian]
3. Jerman MV. Nefrologiya detskogo vozrasta. SPb: Specialnaya Literatura; 2010. 620 s. [in Russian]
4. Loymana Ye, Cygin AN, Sarkisyan AA. Detskaya nefrologiya. Prakticheskoe rukovodstvo. M.: Litterra; 2010. 400 s [in Russian]
5. Laing CM, Unwin RJ. Renal tubular acidosis. J. Nephrol. 2006; 19 (9): 546–552.
6. Batlle D, Haque SK. Genetic causes and mechanisms of distal renal tubular acidosis. Nephrol. Dial. Transplant. 2012; 27(10):3691-3704
7. Baranov AA. Pediatriya: Natsionalnoye rukovodstvo. T.1. M.: GJeOTAR-Media, 2009. 1017 s. [in Russian]
8. Kartamysheva NN, Vashurina TV, Mazo AM, Sugak AB, Cygina EN, Bakanov MI, Cygin AN. Kanaltsevye disfunktsii s rakhitopodobnym sindromom. Pediatr. farmakol. 2011; 8(4):140-145[in Russian]
9. Kurtz I. Renal Tubular Acidosis: H+base and ammonia transport abnormalities and clinical syndromes. Adv. Chronic Kidney Dis. 2018 July; 25(4):334–350.
10. Osmanov IM, Zakharova IN, Kolbe OB, Mumladze YeB, Bekmurzaeva GB, Tambieva EV. Pervichnye tubulopatii. Ros. Vestn. Perinatol. i Pediatr. 2018; 63(1):81–89. doi: 10.21508/1027-4065-2018-63-1-81-89 [in Russian].
11. Volyanyuk EV, Lutfullin IJa. Klinicheskiy sluchay renalnogo tubulyarnogo atsidoza 1-go tipa u rebenka v vozraste odnogo mesyatsa. Kazanskiy meditsin-skiy zhurnal. 2017.98(1):129-131[in Russian]
12. Haque SK, Ariceta G, Batlle D. Proximal renal tubular acidosis: a not so rare disorder of multiple etiologies. Nephrology Dialysis Transplantation. 2012; 27(12):4273-4287.
13. Papayan AV, Savenkova ND. Klinicheskaya nefrologiya detskogo vozrasta: Rukovodstvo dlya vrachey. SPb: Levsha; 2008. 600 s. [in Russian]
14. Proshlyakova TYu, Korotkaya TS, Kuznetsova SYu. Sravnitel'naya kharakteristika rakhitopodobnykh zabolevaniy. Ros. Vestn. Perinatol. i Pediatr. 2018; 63(3):19–25.

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