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CONTRAST-INDUCED NEPHROPATHY IN POST COVID-19 PATIENTS



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КОНТРАСТ ВОСИТАЛАРИГА БОҒЛИҚ БЎЛГАН НЕФРОПАТИЯЛАР COVID-19 БИЛАН КАСАЛЛАНГАН БЕМОРЛАРДА

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КОНТРАСТ-ИНДУЦИРОВАННЫЕ НЕФРОПАТИИ У ПАЦИЕНТОВ, ПЕРЕНЕСШИХ COVID-19

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Резюме. *Сўнгги 30 йил ичида урография, ангиография, компютер томографияси ва жарроҳлик муолажалар пайтида рентген контраст воситалардан (РКМ) фойдаланиш сезиларли даражада ошди.Дунёда ҳар йили 60 миллионга яқин РКМ дозаси қўлланилади, аммо янги ва камроқ нефротоксик дориларни қўллашга қарамай, контрастли нефропатия (РКН) хавфи, айниқса, аввалги буйрак етишмовчилиги бўлган беморлар орасида сезиларли бўлиб қолмоқда. Контрастли нефропатия буйракнинг ўткир шикастланишининг жиддий сабаби бўлиб, клиник амалиётда долзарб муаммо ҳисобланади. Бугунги кунда қариндош кўп жиҳатлари ақл зиддиятлар бор. Бироқ, COVID-19 билан оғриган беморларда контраст воситалардан фойдаланиш билан боғлиқ ҳозирги вазият амалиет шифокорлари ва радиологлар учун долзарб масалага айланди.*

Калит сўзлар: *контраст воситаларига боғлиқ бўлган нефропатиялар, рентген контраст воситалари, COVID-19.*

Abstract. *Over the past 30 years, the use of radiopaque agents (RCS) has significantly increased during urography, angiography, computed tomography and surgical procedures.About 60 million doses of RCS are used annually in the world, but despite the use of newer and less nephrotoxic drugs, the risk of contrast-induced nephropathy (CIN) remains significant, especially among patients with previous renal impairment. Contrast-induced nephropathy is a serious cause of acute kidney injury and is an urgent problem in clinical practice. To date, there are contradictions in the understanding of many aspects of KIN.However, the current situation with the use of contrast agents in patients with COVID-19 and causing KIN has become an urgent issue for clinicians and radiologists.*

Keywords: *contrast-induced nephropathy, radiopaque agents, COVID-19.*

Contrast-induced nephropathy is acute renal failure that occurs within 48–72 hours after intravenous administration of a contrast agent. In the absence of other possible causes, CIN manifests itself in an increase in blood creatinine by 44 mmol / l (by 0.5 mg / dl) or more, or an increase in creatinine levels by more than 25% compared with the initial level. AKI is a sudden and sustained decrease in glomerular filtration, or urine volume, or both. In this case, renal dysfunction, existing even for more than 1 month, can be considered as acute. Usually the development of acute renal failure occurs within 1-7 days. The criterion for the sustainability of dysfunction is its registration for 24 hours or more [1].

The aim of our studywas to consider various approaches to the problem of pathogenesis, risk factors and achievements in the prevention of contrast-induced nephropathies in patients who underwent Covid-19.

What is contrast-induced nephropathy? Contrast-induced nephropathy is acute renal failure that occurs within 48–72 hours after intravenous administration of a contrast agent. In the absence of other possible causes, CIN manifests itself in an increase in blood creatinine by 44 mmol / l (by 0.5 mg / dl) or more, or an increase in creatinine levels by more than 25% compared with the initial level. AKI is a sudden and sustained decrease in glomerular filtration, or urine volume, or both. In this case, renal dysfunction, existing even for more than 1 month, can be considered as acute. Usually the development of acute renal failure occurs within 1-7 days. The criterion for the sustainability of dysfunction is its registration for 24 hours or more [1].

Epidemiology. The prevalence of CIN in the population is 2–8%. The likelihood of this phenomenon may increase up to 50% among patients with underlying renal pathology or exposed to several risk factors. The likelihood of developing CIN depends not only on the somatic status of the patient, but also on the type of examination, the type and volume of the injected contrast agent. It was found that in patients with normal renal function CIN developed rarely - in the range from 0 to 5% of cases. When analyzing the results of a study of more than 16,000 patients (CT of the head and internal organs, cardiac and peripheral angiography), CIN was detected in 1% of patients (*n*= 174). In another large epidemiological study, CIN was diagnosed on average in 14.5% of patients, but its frequency varied significantly from 0 to 90% depending on the presence of risk factors, especially previous renal impairment, diabetes mellitus, class and volume of CSW [6]. So, if in patients with diabetes mellitus (DM) with a slight decrease in kidney function, the frequency of nephropathy was 9–40%, then with a significant violation, it increases to 50–90%. In-hospital mortality in acute renal failure among patients undergoing coronary angiography is 35.7%, and two-year survival these patients - 18.8%. An increased risk of death, however, was due to both pre-existing non-renal disease and association with conditions such as sepsis, bleeding, coma, or respiratory failure.

Pathogenesis. The mechanisms underlying the development of AKI associated with the use of RCS are not fully understood, but most likely they include several pathogenetic links. There are five most important pathogenetic mechanisms that provoke the development of nephropathy [9]. 1. Direct toxic effect of the contrast agent on the epithelium of tubular cells. Since the contrast agent is freely filtered and not reabsorbed, it increases the osmolarity in the tubules, as CIN occurs in patients who have had COVID-19 in 18% of cases. 2. Contrast-induced change in renal microvascular hemodynamics. Studies investigating changes in blood flow in renal arteries exposed to a contrast medium have shown an initial increase in blood flow (increased activity of renal vasoconstrictors - vasopressin, angiotensin II, endothelin, adenosine) followed by a steady decline. The toxic effects of reactive oxygen species released during reperfusion also contribute to kidney damage. 4. Toxicity due to inflammation. As in other tissues, renal parenchymal lesions can be exacerbated by contrast-mediated activation of the compliment cascade and release of inflammatory cytokines. 5. Activation of the tubuloglomerular feedback mechanism: due to an increase in hydrostatic pressure in the renal tubules, a spasm of the vessels of the glomerular substance of the kidneys occurs, which leads to a decrease in renal filtration and an increase in vascular resistance [10]. It is assumed that CIN arises as a result of a synergistic combination of the direct toxic effect of RCS on tubular epithelial cells. Intrarenal mechanisms for the occurrence of CIN include: 1) an increase in pressure inside the tubules due to osmotic diuresis; 2) increased viscosity of urine; 3) direct toxic effect on tubular epithelial cells; 4) tubular obstruction; 5) increased activity of renal vasoconstrictors (vasopressin, AT II, dopamine-1, endothelin, adenosine); 6) reduction of vasodilation mediated by local prostaglandins and nitric oxide; 7) increased oxygen consumption; 8) ischemia of the renal medulla. Clinical studies have shown that the osmolarity of RCC plays an important role in the development of nephropathy. Contrast agents are freely filtered in the renal glomeruli and are not reabsorbed by the tubules, and therefore their concentration in the urine is 50-100 times higher than the concentration in the blood plasma. Experimental studies have shown that hyperosmolar RCS cause changes in renal hemodynamics and have direct toxic effects on renal epithelial cells. Similarly, non-contrasting hyperosmolar solutions (eg, mannitol) can cause vasoconstriction, resulting in a decrease in renal blood flow and glomerular filtration rate (GFR), although to a lesser extent than with RCS [6]. The main hemodynamic effect caused by RCS is vasoconstriction with decreased renal blood flow and GFR. These shifts are accompanied by a number of other non-specific mechanisms - activation of the tubular-glomerular feedback mechanism due to osmotic diuresis, stimulation of the renin-angiotensin system (RAS), increased hydrostatic pressure in the tubules, causing compression of the intrarenal microcirculation. Prolonged vasoconstriction of afferent arterioles with a decrease in filtration pressure in the glomeruli is inevitably accompanied by subsequent ischemia of the medulla. It was found that RCS, even isosmolar, despite moderate diuresis and natriuresis, also cause greater vacuolization of proximal tubular cells and promote erythrocyte aggregation compared to other classes of contrasts. From this, it was concluded that not only the osmolarity of the contrast medium, but also the increased viscosity of isoosmolar agents and erythrocyte aggregation in-

duced by PKC are critical determinants of the degree of cellular damage. At the same time, no correlation was found between the degree of vacuolization of tubular cells and a decrease in kidney function [7]. A certain role in the pathogenesis of acute renal failure is assigned to the ability of RCS to have a direct cytotoxic effect, proven at the level of tubular epithelial cells (vacuolization of epithelial cells of the proximal tubules, cell necrosis and interstitial inflammation) and independent of hypoxia. Structural damage to the cell surface is mainly due to dysregulation and damage to the actin cytoskeleton, loss of cell polarity. In addition, active transport of the contrast agent increases metabolic activity with increased energy expenditure by the tubular epithelium due to osmotic loading, causing oxygen depletion, which in turn leads to increased renal hemodynamic effects. Ischemic damage to the structure and function of the surface membrane of the epithelium of the proximal tubules is the main mechanism of acute cell and organ dysfunction. When the plasma membranes of tubular cells are damaged, their permeability to calcium increases, its intracellular concentration changes, which leads to an increase in constrictive stimuli on the vessels of the kidneys. But first of all, the nephrotoxicity of a contrast agent is determined by its osmolarity. According to chemical and pharmacological properties, radiopaque preparations can be divided into high-osmolar, low-osmolar and iso-osmolar; ionic and non-ionic, as well as monomers and dimers. which leads to increased constrictive stimuli on the vessels of the kidneys. But first of all, the nephrotoxicity of a contrast agent is determined by its osmolarity. According to chemical and pharmacological properties, radiopaque preparations can be divided into high-osmolar, low-osmolar and iso-osmolar; ionic and non-ionic, as well as monomers and dimers. which leads to increased constrictive stimuli on the vessels of the kidneys. But first of all, the nephrotoxicity of a contrast agent is determined by its osmolarity. According to chemical and pharmacological properties, radiopaque preparations can be divided into high-osmolar, low-osmolar and iso-osmolar; ionic and non-ionic, as well as monomers and dimers.

A meta-analysis of several randomized trials showed that the use of high-osmolar contrast agents increases the risk of complications more than the use of hypo- or iso-osmolar agents, especially among patients with severe comorbidities. Currently, the isoosmolar non-ionic dimer iodixanol (vasipak) is considered the safest contrast agent. The use of gadolinium-containing contrast agents used in MRI in X-ray studies as an alternative is not advisable, since they have a greater nephrotoxic effect than equivalent doses of iodine-containing contrast agents.

Toxicology of radiopaque agents in post-COVID-19 patients. The toxicity of RCS is determined by the structure of their molecule and its ability to dissociate into ions in an aqueous solution [2]. Until recently, only ionic or dissociating radiopaque agents (sodium amidotrizoate(urographin, verografin, etc.), which consist of salts that dissociate into cations and anions. They have a high osmolarity (5 times that of plasma) and are therefore also called high osmolar contrast agents and can cause local ion imbalance. When using them, side effects often develop, up to the most severe. Safer are non-ionic or non-dissociating, low-osmolar radiopaque agents (iohexol (omnipak), iopromide (ultravist), iodixanol (visipak)). They do not dissociate into ions, are characterized by a higher ratio of the number of iodine atoms to the number of drug particles per unit volume of the solution (that is, good contrast is provided by a lower osmotic pressure), iodine atoms are protected by hydroxyl groups, which reduces chemotoxicity. At the same time, the cost of low-osmolar radiopaque agents is several times higher than that of high-osmolar ones. In addition, radiopaque agents are divided according to their structure into monomeric and dimeric depending on the number of benzene rings with embedded iodine atoms [3]. When using dimeric preparations containing six instead of three iodine atoms in one molecule, a smaller dose of the drug is required, thereby reducing osmotoxicity. According to the mechanism of development, side effects are divided into:*anaphylactoid, or unpredictable*(anaphylactic shock, angioedema, urticaria, bronchospasm, hypotension);*direct toxic*(nephrotoxicity, neurotoxicity, cardiotoxicity, etc.);*local*(phlebitis, soft tissue necrosis at the injection site).

Clinical characteristics of contrast-induced nnephropathy, in patients who have undergone COVID-19. With the development of acute renal failure syndrome due to the use of contrast, first of all, it is necessary to exclude alternative causes of its occurrence - atheroembolism syndrome, which can develop after angiography, ischemic nephropathy, nephrotoxic effects not associated with the administration of contrast, etc. After the introduction of RCS, a short-term increase in creatinine levels is possible after 24 h, however, this does not yet mean the development of CIN. With the development of the latter, the serum creatinine level increases by 0.5 mg / dl or more. In most cases, CIN manifests as a neoliguric and asymptomatic transient acute decrease in kidney function. The maximum peak of serum creatinine concentration is noted on the 3-5th day and usually returns to the initial level within 10-14 days, but can last up to 3 weeks. In some cases, oliguric acute renal failure occurs and hemodialysis may be required. The peak serum creatinine concentration in oliguric AKI usually persists for 5–10 days and returns to baseline after 14–21 days. Mortality in this group of patients is significantly higher than in non-oliguric acute renal failure. It must be emphasized that the degree of increase in serum creatinine has prognostic value for both

short-term and long-term prediction of adverse outcomes.

Changes in urinalysis in CIN are nonspecific. In a number of observations, there are: turbidity of urine, its dirty brown color, minimal proteinuria in the absence of hematuria, granular casts, epithelial cells of the renal tubules, amorphous sediment, urate and oxalate crystals. In most patients, the excreted sodium fraction is less than 1%.

Rifle criteria. The system of such criteria, proposed by ADQI experts, received the abbreviation RIFLE

(rifle - rifle,*English*):

Risk (risk),

Injury (damage),

Failure (insufficiency),

Loss (loss of kidney function),

ESRD (end stage renal disease - the final stage of kidney disease; terminal renal failure - ESRD - according to domestic terminology).

Representatives of three nephrological associations (ASN, ISN and NKF) and the European Society of Intensive Care Medicine at a meeting in Vicenza (Italy) proposed the concept of "*acute kidney injury"*(AKI — acute kidney injury — AKI) [11]. The first results of the work of this group were published in 2007 and touched upon the issues of clarifying diagnostic criteria and stratifying the severity of AKI. Risk factors for contrast-induced nephropathy may be related to RCD and/or directly to the patient [4,5].*With radiocontrast agents:*their osmolarity, large volume, route of administration, re-application after 72 hours, and complications from the previous application.*Directly with the patient:*1) previous renal failure; 2) diabetes mellitus with renal insufficiency; 3) decrease in effective intravascular volume (heart failure (NYHA class III and IV), myocardial infarction, liver cirrhosis, nephrotic syndrome, diuretics (especially furosemide), abdominal fluid loss, dehydration); 4) prolonged hypotension (concomitant use of a diuretic and ACE inhibitors); 5) metabolic disorders (diabetes mellitus, hyperuricemia, hypercalcemia, hypercholesterolemia); 6) multiple myeloma; 7) nephrotoxic drugs (non-steroidal anti-inflammatory drugs, aminoglycosides, amphotericin B, cyclosporine A, platinum-based drugs, sulfonamides); 8) old age; 9) arterial hypertension; 10) anemia; 11) proteinuria; 12) sepsis; 13) atopic allergy. The standard critical level of normal kidney function has long been considered a serum creatinine concentration of 1.5 mg/dL (132.8 μmol/L) or an estimated GFR of 60 mL/min [8]. The European Society for Urogenital Radiology (ESUR, ESUR) recommends slightly different indicators: serum creatinine - more than 120 μmol / l, GFR - less than 50 ml / min / 1.73 m2 of body surface area. The CI-AKI Consensus Working Panel agreed that the risk of CI-AKI becomes clinically significant at serum creatinine ≥ 115 μmol/L in men and ≥ 88.4 μmol/L in women [9]. serum creatinine - more than 120 μmol/l, GFR - less than 50 ml/min/1.73 m2 of body surface area. The CI-AKI Consensus Working Panel agreed that the risk of CI-AKI becomes clinically significant at serum creatinine ≥ 115 μmol/L in men and ≥ 88.4 μmol/L in women [9]. serum creatinine - more than 120 μmol/l, GFR - less than 50 ml/min/1.73 m2 of body surface area. The CI-AKI Consensus Working Panel agreed that the risk of CI-AKI becomes clinically significant at serum creatinine ≥ 115 μmol/L in men and ≥ 88.4 μmol/L in women [9].

Risk factors associated with radiopaque drugs. Among the risk factors associated with radiopaque preparations, the following can be distinguished: 1) the type of contrast agent (its osmolarity) and 2) the technology of application - volume (dose), route of administration, repeated use of the drug for a short period of time, the presence of complications in the previous application . The contrast agent is not reabsorbed in the renal tubules. The half-life of its intravascular use in patients with normal renal function is about 2 hours and 75% is excreted within 4 hours, and 98% of the prescribed dose is excreted within 24 hours. After approximately 150 minutes, the concentration of RCS rapidly decreases in patients with normal renal function, but in patients with severe renal impairment, this phase is delayed. Radiocontrast agents are classified into ionic and non-ionic, monomers and dimers. First-generation or high-osmolar ionic contrast media (osmolarity > 2000 mosm/kg H2O), such as diatrizoate, have the highest percentage of various adverse reactions (10–12% in patients with an uncomplicated anamnesis and up to 50% in patients at risk). Second generation contrast agents or nonionic, low osmolar, high viscosity (osmolarity 600–1000 mosm/kg H2O), such as iohexol and iopromide, have fewer adverse reactions, less acute toxicity, and are widely used in clinical practice. Various adverse reactions were noted in 1-3% of patients with an uncomplicated anamnesis and in 16% of patients at risk.

In a large randomized trial including 1196 patients, there was no difference in nephrotoxicity between high and low osmolar RCs in patients with intact kidney function (with and without diabetes mellitus). However, in patients with one or two risk factors, the use of low-osmolar monomeric RCs reduced the risk of CIN by 3.3 times. A meta-analysis of 31 randomized controlled trials including 5146 patients confirmed that low-osmolar RCs are less nephrotoxic than high-osmolar ones, especially in patients with pre-existing renal impairment, especially diabetic nephropathy.

Contrast agents of the third generation or non-ionic isosmolar (osmolarity 290 mosm/kg - isoosmolar blood at all concentrations) are the most modern class of radiocontrast agents (iodixanol -

vizipak). Visipak causes less osmotic diuresis, natriuresis and, accordingly, a smaller decrease in effective intravascular volume. When it is used, the level of blood pressure does not decrease, cardiac arrhythmias do not occur, and allergic reactions are rare [10]. The risk of nephrotoxicity associated with the administration of iodixanol has been studied in patients with varying degrees of risk of nephropathy. When comparing iodixanol with low-osmolar RCS in individuals with normal renal function, there was no difference in the incidence of nephropathy. The NEPHRIC multicentre study found that that in patients at risk (with renal failure in combination with diabetes and without diabetes) with the introduction of iodixanol, the likelihood of developing nephropathy was 11 times lower, and the incidence of serious cardiovascular complications was 45% less without additional preventive measures compared with low osmolar RKS. This study demonstrated that iodixanol has a more favorable safety profile in at-risk patients.

Risk Factors Associated with Patients SURVIVED COVID-19. Factors that increase the risk of kidney damage to RCS include: previous renal dysfunction, diabetic nephropathy with renal failure, a decrease in effective intravascular volume, competitive use of nephrotoxic drugs, advanced age, and a number of others [8].

Other risk factors for the development of contrast-induced nephropathies. Despite a significant body of research, controversy and disagreement remain regarding risk factors for CIN, the use of contrast agents, and the nephrotoxic effects of radiopaque agents on the kidneys. In an attempt to document the current understanding of CIN and develop strategies to prevent this condition, the ECSD established the Committee on the Safe Use of Contrast Agents to focus on the effects of contrast agents on kidney function [4]. Based on the results of a questionnaire sent to ESUR members and experts in the field, predisposing and procedure-related risk factors were identified and simple guidelines for the use of contrast agents were published and can be found on the Internet at the ESUR website (www.esur.org).

Dose of contrast agents. Large volumes of contrast agents are associated with an increase in the prevalence of CIN. Experts in the field believe that smaller volumes of contrast agents needed for imaging should be used, since the risk of CIN increases with increasing doses of contrast agents, in particular, as was shown in the RECOVER study, with a volume of contrast agents ≥ 140 ml, the risk of developing CIN increases [five]. Contrast volume has been confirmed to be an independent risk factor for CIN. To date, there is no consensus on the optimal minimum dose of CV [4]. With intra-arterial administration of CA, calculations of possible limits were proposed based on the fact that the dose of CA in grams of iodine should be equal in digital terms to GFR (ml / min). For example, in a patient with a GFR of 60 ml/min, the estimated dose of CV at an iodine concentration of 320 is 187.5 ml.

Osmolarity of contrast agents. In patients with existing renal dysfunction, the risk of developing CIN was higher when high osmolar contrast agents were used compared to low osmolar contrast agents. To prevent the development of contrast-induced nephropathy, the ECSD recommends the use of low- or iso-osmolar contrast agents. A number of studies have shown that in high-risk patients, isosmolar contrast agents are less nephrotoxic than low-osmolar contrast agents, but along with this, there are a number of studies in which there was no significant difference between the isoosmolar drug and comparator drugs [10,11]. Further work is needed to confirm this position.

Type of contrast agent. Data from a number of studies indicate that the incidence of CIN with the use of low-osmolar contrast agents is lower than with the use of high-osmolar contrast agents in patients at risk for CIN. For example, in one large randomized trial, patients with kidney disease developed acute renal failure 3.3 times more often when they were injected with high-osmolar contrast agents (diatrizoate) rather than low-osmolar contrast agents (iohexol) [12,13]. We also compared the nephrotoxic effects of contrast agents with an osmolality equal to blood osmolality (iodixanol) with the effects of a low-osmolar contrast agent (iohexol) in patients with diabetes mellitus and impaired renal function who underwent coronary or aortofemoral angiography.p= 0.002) [9]. Moreover, the incidence of the most severe cases of contrast-induced nephropathies (increased SCr > 1 mg/dL, or > 88 μmol/L) was 0% in patients treated with isoosmolar CA compared with 15% in patients treated with low osmolar contrast agent. After this study, a large number of studies have been conducted to study the role of osmolarity in the development of CIN. One of them is the RECOVER study [5]. This study was designed to compare the nephrotoxicity of the isosmolar non-ionic dimer of iodixanol and the ionic dimer of ioxaglate. Patients received iodicanol or yoxaglat for coronary angiography. The primary point was to determine the frequency of CIN (an increase in [SCr] ≥ 25% or ≥ 0.5 mg / dL (44.2 mmol / L). The frequency of CIN in various groups of patients was also determined: with severe renal impairment (GFR < 30 ml / min), with diabetes, in patients who received large doses of CA (≥ 140 ml). According to the results of the study, the frequency of CIN was statistically significantly lower in the iodixanol group (7.9%) than in the ioxaglat group (17.0%;p= 0.021).

Primary:	Secondary:
Determine CIN frequency (SC ≥ 0.5 mg/dl or ≥ 25% above baseline up to 3 days).	Average peak of contrast agents:
	determination of independent risk factors for CIN;
	frequency of serious cardiovascular adverse events (MACE) at the hospital stage and up to the 30th day after discharge;
	the quality of the obtained diagnostic information.

In addition, the incidence of CIN was statistically significantly lower in patients with impaired renal function (p= 0.023) with concomitant diabetes (p= 0.041). In the study "Comparison of the safety and efficacy of iodixanol and iopromide in patients with chronic renal failure: a randomized controlled trial" [7], the tasks were set to evaluate several endpoints when comparing isoosmolar iodixanol and low osmolar iopromide.

Based on the results of the study, the following conclusions were made.

The frequency of CIN was significantly lower in the iodixanol group compared to the iopromide group (5.7 vs. 16.7%;p= 0.011).

Prevention of contrast-induced nephropathiesincludes: 1) conducting a radiopaque procedure only for strict indications; 2) identification and stratification of risk factors for RCI; 3) an adequate choice of volume and type of contrast

nogo substance (it is better to use iso- or low-osmolar contrasts); 4) if possible, refusal of repeated and multiple X-ray contrast studies; 5) cancellation of nephrotoxic drugs before X-ray contrast examination; 6) if possible, the use of alternative imaging methods or alternative contrasts; 7) adequate hydration. Since the risk factors for the occurrence of CIN are very diverse, and the consequences are serious or even life-threatening, doctors need to take measures to prevent it. Although the optimal strategy to prevent CIN has not yet been fully defined, it is important to first identify high-risk patients. The most common ways to identify high-risk patients are a survey, a study of the medical history, measurement of serum creatinine before the administration of a contrast agent.

To prevent the development of CIN, patients must be adequately hydrated. Nephrotoxic drugs should be discontinued at least 24 hours before contrast agent administration. Since the nephrotoxic effect of the contrast agent is dose-dependent, it is recommended to use the lowest possible dose. Moreover, the choice of a suitable contrast agent is important. It has been shown that the frequency of CIN in patients with renal insufficiency and diabetes mellitus is lower when using isoosmolar contrast agents than when using low-osmolar ones (Iohexol). Some studies have shown that the administration of drugs from different pharmacological groups - calcium channel blockers, dopamine and N-acetylcysteine - reduces the incidence of CIN.

Recommendations for the prevention of contrast-induced nephropathies: 1) hydration: 3 ml/kg of isotonic sodium chloride solution one hour before the procedure and 1 ml/kg per hour during 6 hours after the procedure; 2) acetylcysteine (ACC): 600 mg × 2 times a day before and on the first day after the introduction of RCS; 3) in urgent situations: hydration with isotonic sodium chloride solution, ACC - 600 mg IV bolus before the procedure and 600 mg 2 times a day*per os*the next day after the procedure.

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КОНТРАСТ-ИНДУЦИРОВАННЫЕ НЕФРОПАТИИ У ПАЦИЕНТОВ, ПЕРЕНЕСШИХ COVID-19

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Резюме. *В течение последних 30 лет значительно увеличилось применение рентгеноконтрастных средств (РКС) при проведении урографии, ангиографии, компьютерной томографии и операционных процедур.Ежегодно в мире используется около 60 миллионов доз РКС, но, несмотря на использование более новых и менее нефротоксичных препаратов, риск контраст-индуцированной нефропатии (КИН) остается значительным, особенно среди пациентов с предшествующим нарушением функции почек. Контраст-индуцированная нефропатия является серьезной причиной острого поражения почек и представляет собой актуальную проблему в клинической практике. До настоящего времени остаются противоречия в понимании многих аспектов КИН.Однако, нынешняя ситуация при применении контрастных веществ у пациентов с COVID-19 и вызывая КИН стал актуальным вопросом у клиницистов и радиологов.*

Ключевые слова: *контраст-индуцированная нефропатия, рентген-контрастные средства, COVID-19.*