ACUTE KIDNEY INJURY AFTER PRIMARY TOTAL HIP REPLACEMENT

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ABSTRACT

Surgical interventions that do not directly affect the urinary system can cause excretory dysfunction of kidneys.

The aim. *To establish the prevalence, risk factors and clinical significance of acute kidney injury after primary hip replacement performed in the clinic of the Irkutsk Scientific Centre of Surgery and Traumatology.*

Materials and methods. *We carried out a retrospective analysis of the case histories of 109 patients who underwent primary total hip replacement under conditions of subarachnoid anesthesia in the clinic of the Irkutsk Scientific Centre of Surgery and Traumatology in 2021.*

Results. *Postoperative changes in serum creatinine in 8 patients of the study group met the KDIGO (The Kidney Disease: Improving Global Outcomes) criteria for acute kidney injury. Initial indicators of renal excretory function in the subgroup with acute kidney injury were not different from those in the entire group.*

Statistically significant correlation was established between acute kidney injury and indicators of oxygen-carrying capacity of blood – initial and minimal postoperative hemoglobin concentration.

Acute kidney injury in patients of the study group had a minimal effect on the clinical course of the early postoperative period. None of the patients required renal replacement therapy, re-transfer from the specialized unit to the intensive care unit or any specific treatment. The duration of postoperative stay of patients with acute kidney injury in the clinic did not increase.

Conclusions. *Acute kidney injury was detected in 7.3 % of patients who underwent primary total hip replacement. Risk factors for the development of postoperative acute kidney injury in patients of the study group included relatively low initial and minimal postoperative blood hemoglobin concentrations, which may indicate prerenal mechanism of acute kidney injury pathogenesis. Implementation of the main steps of the "renal protocol" in patients with initial glomerular filtration rate over 45 ml/min/1.73 m^2 allows avoiding the development of severe clinically significant forms of postoperative acute kidney injury and complications associated with it in the early postoperative period of primary total hip replacement.*

Key words: *acute kidney injury, primary hip replacement, blood hemoglobin concentration*

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ОСТРОЕ ПОВРЕЖДЕНИЕ ПОЧЕК ПОСЛЕ ПЕРВИЧНОГО ТОТАЛЬНОГО ЭНДОПРОТЕЗИРОВАНИЯ ТАЗОБЕДРЕННОГО СУСТАВА

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РЕЗЮМЕ

Оперативные вмешательства, напрямую не затрагивающие мочевыделительную систему, могут вызывать нарушение экскреторной функции почек.
Цель исследования. *Установить распространённость, факторы риска и клиническую значимость острого повреждения почек после первичного эндопротезирования тазобедренного сустава у пациентов клиники ФГБНУ «Иркутский научный центр хирургии и травматологии» (ИНЦХТ).*
Материалы и методы. *Ретроспективному анализу подвергнуты истории болезни 109 пациентов, которым в 2021 г. в клинике ИНЦХТ в условиях субарахноидальной анестезии выполнено оперативное вмешательство в объёме первичного тотального эндопротезирования тазобедренного сустава (ТЭТС).*
Результаты исследования. *У 8 пациентов исследуемой группы послеоперационная динамика показателей креатинина в сыворотке крови соответствовала критериям KDIGO (The Kidney Disease: Improving Global Outcomes) острого повреждения почек (ОПП). Исходные показатели экскреторной функции почек в подгруппе ОПП были не хуже, чем во всей группе.*
Статистически значимая корреляция установлена между ОПП и показателями кислородной ёмкости крови – исходной и минимальной послеоперационной концентрацией гемоглобина.
ОПП у пациентов исследуемой группы после первичного ТЭТС оказывало минимальное влияние на клиническое течение раннего послеоперационного периода. Ни одному из пациентов не потребовалось проведение заместительной почечной терапии, повторный перевод из профильного отделения в палату интенсивной терапии и реанимации, специфическое лечение. Продолжительность послеоперационного пребывания пациентов с ОПП в клинике не увеличивалась.
Выводы. *Острое повреждение почек выявлено у 7,3 % пациентов, перенёсших первичное ТЭТС. Факторами риска развития послеоперационного ОПП у пациентов исследуемой группы были относительно низкие показатели исходной и минимальной послеоперационной концентрации гемоглобина крови, что может свидетельствовать в пользу преренального механизма патогенеза ОПП. Реализация основных положений «ренального протокола» у пациентов с исходной скоростью клубочковой фильтрации более 45 мл/мин/1,73 м^2 позволяет избежать развития тяжёлых клинически значимых форм послеоперационного ОПП и связанных с ним осложнений в раннем послеоперационном периоде первичного ТЭТС.*

Ключевые слова: *острое повреждение почек, первичное эндопротезирование тазобедренного сустава, концентрация гемоглобина крови*

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INTRODUCTION

Surgical interventions that do not directly affect the urinary system can cause excretory dysfunction of kidneys. The clinical and economic aspects of postoperative acute kidney injury (AKI) have been the cause of intense research attention. The relevance of the problem for modern surgery in general and for traumatology and orthopaedics in particular is confirmed by statistical data considering the worsening of formal indicators of the postoperative period – the frequency of postoperative complications, exacerbations of concomitant pathology, the duration of patients' stay in the intensive care unit (ICU) and hospital, re-hospitalisation, hospital mortality, and the cost of treatment [1–4].

"Acute kidney injury" (this term has replaced the previously used term "acute renal failure") refers to a sudden onset of renal dysfunction under the influence of any exo- or endogenous factors, limited in time to 7 days [5]. The absence of a clear AKI cause is not uncommon and indicates a multifactorial pathogenesis [6]. The commonly accepted criteria for AKI include increased serum creatinine concentration and decreased diuresis rate [5].

Literature suggests that even transient AKI has potential long-term consequences ranging from the development of chronic kidney disease (CKD) to increased hospitalization rates, short- and long-term mortality [6, 7].

As the problem is significant and there are no obvious solutions, the need for a specific multidisciplinary approach to prevent AKI in the perioperative period has been recognized [8].

THE AIM OF THE STUDY

To determine the prevalence, risk factors and clinical significance of acute kidney injury after primary hip arthroplasty in patients of the Irkutsk Scientific Centre of Surgery and Traumatology.

MATERIALS AND METHODS

The case histories of 109 patients who underwent surgical intervention for primary total hip replacement (THR) under subarachnoid anaesthesia at the clinic of the Irkutsk Scientific Centre of Surgery and Traumatology in 2021 were retrospectively analysed. Summary results are presented as median (Me), 25th (P_{25}) and 75th (P_{75}) percentiles.

As Table 1 summarizes, the study group was predominantly female; as a rule, patients had a physical status corresponding to ASA (American Society of Anesthesiologists) class 3 and were of elderly age.

TABLE 1

DISTRIBUTION OF PATIENTS BY SEX, AGE AND PHYSICAL STATUS

Indicators		Values
Age, Me (P_{25}; P_{75})		63 (56; 68)
Physical status according to ASA, Me (P_{25}; P_{75})		3 (3; 3)
Sex, *n* (%)	female	62 (57 %)
	male	47 (43 %)

The disease that caused surgical intervention was idiopathic deforming osteoarthritis in the majority of cases (Table 2).

TABLE 2

PATHOLOGY FOR WHICH THE PATIENTS OF THE STUDY GROUP UNDERWENT SURGERY

Pathology	*n* (%)
Idiopathic deforming arthrosis	97 (89 %)
Femoral neck fracture	11 (10.1 %)
Rheumatoid arthritis	1 (0.9 %)

During pre-hospital examination, patients were expectedly diagnosed with concomitant age-related somatic pathology, most often arterial hypertension, chronic gastritis, coronary heart disease (CHD), and diabetes mellitus (Table 3). Number of nosologies of comorbidities per patient is 2 (1; 3).

TABLE 3

CONCOMITANT SOMATIC PATHOLOGY IN PATIENTS OF THE STUDY GROUP

Concomitant somatic pathology	Prevalence, *n* (%)
Arterial hypertension	81 (74.3 %)
Chronic gastritis	69 (63.3 %)
CHD	17 (15.6 %)
Diabetes mellitus	15 (13.8 %)
Chronic cholecystitis	8 (7.3 %)
LEVVD	4 (3.7 %)
Chronic pyelonephritis	1 (0.9 %)

Note: LEVVD – lower extremity varicose vein disease.

Using baseline and postoperative serum creatinine concentration values, glomerular filtration rate (GFR) was measured using the CKD-EPI formula as the most correct calculation method according to the KDIGO (The Kidney Disease: Improving Global Outcomes) recommendations [9].

Blood haemoglobin concentration was recorded: preoperatively and minimally during postoperative hospital follow-up. Tranexamic acid infusion of 15 mg/kg 10–20 min before the surgical procedure was administered for haemostatic purposes in case of absence of contraindications (5 patients had such contraindications). External perioperative blood loss (visually intraoperative haemorrhage in the aspirator plus postoperative drainage discharge) was considered. Peri-operative estimated blood loss was determined by the decrease in blood haemoglobin concentration [10].

Spearman's rank correlation method was used to establish a connection between the phenomena. The Wilcoxon test was used to assess the statistical significance of the differences between the indicators at different stages of the study; in case of multiple comparisons, the Bonferroni correction was used.

Statistical processing was performed using Statistica 10 software package (StatSoft Inc., USA).

The study was performed within the framework of the research work "Systemic approach in the development of personalized methods of diagnosis and treatment of patients with injuries and diseases of the musculoskeletal system" (state registration number 122022200210-2; approved by the Ethical Committee of the Irkutsk Scientific Centre of Surgery and Traumatology, Minutes No. 9 dated December 16, 2021), meets the ethical standards of the World Medical Association Declaration of Helsinki "Ethical Principles for Conducting Scientific Medical Research Involving Human Subjects" as amended in 2000 and the "Rules of Clinical Practice in the Russian Federation" approved by Order of the Ministry of Health of Russia No. 266 dated June 19, 2003.

STUDY RESULTS

Notwithstanding the fact that the diagnosis of renal pathology was preliminarily confirmed in only 1 patient, an initial decrease (from slight to moderate) in renal excretory function was revealed in the majority of patients in the study group (Table 4). If CKD levels above C3a or equivalently GFR < 45 ml/min/1.73 m^2 were detected at the outpatient preoperative stage, patients were referred for a consultation with a nephrologist to prescribe specific therapy.

Considered in a single array the data of the patients of the studied group are the evidence of at least preser-

TABLE 4

STRATIFICATION BY BASELINE GLOMERULAR FILTRATION RATE ACCORDING TO CHRONIC KIDNEY DISEASE CLASSIFICATION [11]

Stages of CKD	Global kidney function characteristics	GFR level, ml/min/1.73 m^2	Number of patients, *n* (%)
Norm or C1	High or optimal	> 90	34 (31.2 %)
C2	Slightly reduced	60–89	59 (54.1 %)
C3a	Moderately reduced	45–59	16 (14.7 %)
C3b	Significantly reduced	30–44	–
C4	Sharply reduced	15–29	–
C5	End-stage renal disease (ESRD)	< 15	–

TABLE 5

POSTOPERATIVE DYNAMICS OF GLOMERULAR FILTRATION RATE AND SERUM CREATININE CONCENTRATION

Follow-up period	GFR, ml/min/1.73 m^2		Creatinine, μmol/l	
	entire group	AKI sub-group	entire group	AKI sub-group
At baseline	80.8 (67.2; 91.0)	87.7 (77.1; 98.3)	79.0 (70.0; 90.0)	72.5 (50.1; 79.5)
Day 1	82.3 (67.4; 93.4) *p* > 0.05	**59.4 (56.9; 66.3)** ***p* = 0.027**	80.0 (66.0; 93.5) *p* > 0.05	**102.5 (85.8; 117)** ***p* = 0.028**
Day 5	**83.7 (69.4; 94.2)** ***p* = 0.014**	77.8 (56.9; 90.4) *p* > 0.05	**75.0 (64.0; 89.0)** ***p* = 0.039**	81.0 (63.8; 99.8) *p* > 0.05

vation of excretory renal function in the postoperative period and even of its statistically significant improvement by the day 5 of observation (Table 5).

Perioperative blood loss expectedly led to the development of mild anemia: hemoglobin concentration decreased from the initial 134 (125; 143) g/L to 116 (107; 124) g/L on the day 1 and to 112 (102; 119) g/L on the day 5 of follow-up.

The estimated (according to the decrease in haemoglobin concentration) perioperative blood loss in the study group was 989 (809; 1350) mL or 18 % (16 %; 23 %) of the circulating blood volume (CBV). In the meantime, external perioperative blood loss was much lower, 200 (100; 320) mL or 4 % (2 %; 6 %) of the CBV; the clinical value of this indicator in most cases is very low [10]. Erythrocyte suspension transfusion was performed intraoperatively in 1 (0.9 %) patient and in another 2 (1.8 %) patients postoperatively.

In other words, in general, the system of perioperative anaesthesia support in total hip replacement works effectively.

In 8 (7.3 %) patients of the study group, however, the postoperative dynamics of serum creatinine values met the KDIGO criteria for acute kidney injury (Table 5). A statistically significant increase in creatinine concentration and corresponding decrease in GFR were observed in all of these patients on the first day after surgery, with subsequent recovery on the day 5 of follow-up.

Of particular note is the fact that baseline renal excretory function in the AKI subgroup was at least as good as in the whole group (not statistically significant).

To determine the influence of possible risk factors in postoperative AKI development, a correlation analysis was performed (Table 6).

No statistically significant relationships were found between postoperative AKI on the one hand and age, sex, and calculated blood loss on the other.

Statistically significant correlation was established between the fact of postoperative AKI development and blood oxygen capacity indices – initial and minimal postoperative haemoglobin concentration.

In the AKI subgroup, the estimated blood loss was 1098 (949; 1217) mL or 21 % (19 %; 24 %) of the CBV. The minimum postoperative hemoglobin values were not critical and amounted to 99 (95; 105) g/L. Of significance, no transfusion was performed on any of the patients in the AKI subgroup. No AKI and oliguria were observed in patients of the subgroup on the day 1 after surgery; diuresis on the background of perioperative infusion was 1600 (1600; 2700) mL.

Bone cement containing gentamicin was used for implant fixation in 41 (37.6 %) patients of the study group. In the AKI subgroup, cemented endoprosthetic components were implanted in 3 (37.5 %) of 8 patients. In summary, the results of this study do not provide a reasonable conclusion about the possible effect of potentially nephrotoxic components of bone cement on the development of postoperative AKI.

AKI in patients of the study group after primary THR had minimal effect on the clinical course of the early postoperative period. None of the patients required renal replacement therapy, repeated transfer from the specialized department to the intensive care and intensive care unit, or specific treatment. The correction of postoperative therapy consisted in the cancellation of drugs with nephrotoxic effect (most often non-narcotic analgesics were prescribed instead of non-steroidal anti-inflammatory drugs (NSAIDs) for pain relief). The duration of postoperative stay of AKI patients in the clinic did not increase.

DISCUSSION

Significant advances in surgical and anaesthetic technology have made replacement arthroplasty the treatment of choice, statistically significantly improving the quality of life of patients with a wide range of diseases and injuries of major joints of the lower extremity. The large array of total replacement arthroplasty surgeries of major joints of the lower extremity, as well as the global trend towards further increase in their number, provide an opportunity to reveal the patterns of influence of stereotypical trauma of the musculoskeletal system, which in essence is surgical intervention, on the life support systems of the organism. In contrast to unintentional injury, dur-

TABLE 6
THE RESULTS OF CORRELATION ANALYSIS

Risk factors	Correlation with AKI	*p*
Age	0.13	> 0.050
Sex	–0.03	> 0.050
Estimated blood loss, % CBV	0.12	> 0.050
Baseline blood hemoglobin	**–0.19**	**< 0.050**
Minimum postoperative blood hemoglobin	**–0.22**	**< 0.050**

ing surgical intervention the injury is inflicted under conditions of anaesthesia and blood loss compensation, which together avoid traumatic shock. The effects of musculoskeletal trauma on the body, however, are more complex, more multifaceted, and far from being limited to local destruction, nociceptive afferentation, and decreased circulating blood volume.

The risk of acute kidney injury is one of the non-obvious consequences of trauma and orthopaedic surgeries that affect the course of the postoperative period.

Literature data concerning AKI after orthopaedic interventions are extremely inconsistent [12].

First of all, the authors use at least three modern AKI criteria systems: RIFLE (Risk, Injury, Failure, Loss of kidney function, End-stage kidney disease) [13], AKIN (Acute Kidney Injury Network) [14] and KDIGO [9]. Comparing data from a small sample of a single-centre study with the results of a synthesis of data from regional and national registers is also a challenging task [12]. In addition, the database used may only cover patients with severe AKI, creating the illusion of low morbidity and high mortality [15]. KDIGO criteria were used in this study according to the current domestic guidelines [5].

The reported incidence of AKI after replacement arthroplasty of lower extremity joints varies from 0.16 to 19.9 % [12, 15, 16]. Meanwhile, studies using KDIGO criteria demonstrate serum creatinine dynamics corresponding to AKI closer to the upper limit of this interval – in 10–19.9 % of patients [12, 16]. Small single-centre studies tend to report higher AKI rates [12, 16]. Obviously, the true incidence of AKI according to KDIGO criteria in patients undergoing primary total major joint replacement arthroplasty of the lower extremity may be approximately 10 % [12].

According to the researchers, the risk factors for AKI after replacement arthroplasty of large joints of the lower extremity are: male gender; elderly age; obesity; low baseline hematocrit, blood haemoglobin and plasma albumin; concomitant diabetes mellitus, arterial hypertension, congestive heart failure, chronic obstructive pulmonary disease, liver pathology; auscultated preoperative heart murmurs; high ASA risk; use of renin-angiotensin system inhibitors; long duration of surgery; one-stage bilateral intervention; significant and prolonged postoperative decrease in blood haemoglobin level; perioperative blood transfusion; use of nephrotoxic drugs – vancomycin and gentamicin – for antibiotic prophylaxis [4, 12, 15–24].

There is evidence from a number of studies that a predictor of AKI after replacement arthroplasty of lower extremity joints is initially diagnosed CKD, most commonly defined as a decrease in calculated GFR rate less than 60 ml/min/1.73 m^2 [1, 16, 17, 19, 20, 23, 25, 26]. The incidence of postoperative AKI is increased 2.3–3.7-fold with initial CKD [17, 25, 26]. Even if the diagnosis of CKD is not definitively confirmed, a lower preoperative estimated GFR rate is associated with an increased risk of postoperative AKI [15]. Statistically, preoperative GFR rates of less than 60 mL/min/1.73 m^2 are accompanied by a 5- to 6-fold increase in the incidence of AKI [27].

GFR rate is used to stratify changes in renal function. Direct measurement of this indicator in clinical practice has been replaced by a calculated method for reasons of practicality, since direct measurement is time-consuming and expensive [15].

An apparently technically simple process of identifying patients with an initially reduced GFR rate is unexpectedly challenging in itself. The defined proportion of patients with baseline GFR rate reduction may differ significantly – by 7–8 times – which is depending on the formula used to calculate GFR rate [15]. This leads to significant discrepancies in the assessment of renal function, both at baseline and during postoperative follow-up, and thus to non-comparability of conclusions.

Modern domestic recommendations suggest calculating GFR rate using the CKD-EPI formula [5]. However, literature sources refer to GFR rate calculated according to the Mayo formula as a more accurate predictor of postoperative AKI [15].

This complexity and multifactorial nature of the pathogenesis of postoperative AKI predetermine the importance of the technologies used in the treatment process, which in turn may differ significantly from one medical centre to another. A consequence of this is the additional discrepancy in the reported incidence of postoperative AKI and the value of each orthopaedic clinic's experience.

More specifically, the introduction of technologies to optimize postoperative rehabilitation may have an impact on the incidence of postoperative AKI [3]. ERAS (Enhanced Recovery After Surgery) protocols are intended to minimize postoperative infusion, which may be associated with the development of AKI, especially since similar concerns have been raised in other surgical procedures [3, 28]. The undoubted achievements of ERAS associated with early patient mobilization and shorter hospital stays are coupled with reports of an increasing proportion of patients with abnormally low GFR rates postoperatively as new rehabilitation protocols are implemented [3, 29].

Generally, AKI is mainly likely to develop by a prerenal mechanism secondary to hypovolaemia as a result of renal ischaemia [3, 27]. Renal mechanisms, which may be mediated by direct damaging effects, also cannot be excluded [3].

The clinical significance of postoperative AKI has been the impetus for optimizing the perioperative management of patients in total joint replacement arthroplasty of the lower extremity.

The early detection of decreased renal excretory function has the potential to stratify the risks of complications before surgery and to modify the postoperative treatment programme [15].

The proposed perioperative "renal protocol" provides preoperative detection of CKD (GFR < 60 ml/min/1.73 m^2), as well as risk factors from comorbidities, correction of preoperative anaemia, restriction up to complete withdrawal of nephrotoxic drugs (NSAIDs, antibiotics, hypotensive drugs and diuretics), minimization of blood loss, control

of systemic hemodynamics and hydrobalance, postoperative GFR rate control [12, 30]. Implementation of the "renal protocol" serves to reduce the incidence of postoperative AKI and improve clinical and economic outcomes of treatment [30].

Referring to our own experience, the "renal protocol" for primary THR at the Irkutsk Scientific Centre of Surgery and Traumatology clinic includes:

- pre-hospital identification of patients with CKD, consultation with a nephrologist if CKD level is above C3a (GFR rate < 45 ml/min/1.73 m^2), treatment of concomitant pathology, restriction of nephrotoxic drugs (primarily NSAIDs);
- anaemia diagnosis and correction at the outpatient preoperative stage;
- perioperative hemodynamic control, minimization of hemorrhagia, timely effective replenishment of blood loss;
- use of subarachnoid anaesthesia with preserved consciousness, which leads to enteral replenishment of physiological fluid requirements immediately after the end of surgery and when the patient is admitted to the postoperative observation room;
- the cancellation of nephrotoxic drugs at the diagnosis of postoperative AKI.

Being clearly aware of the limitations in using the results of the present study (relatively small sample in one medical centre), we nevertheless consider it possible to formulate statements summarising our long-term experience (649 primary THR surgeries performed at the Irkutsk Scientific Centre of Surgery and Traumatology clinic in 2021 only).

CONCLUSIONS

Acute kidney injury was detected in 7.3 % of patients undergoing primary total hip replacement arthroplasty. Risk factors for the development of postoperative acute kidney injury in patients of the study group included relatively low baseline and minimal postoperative blood hemoglobin concentrations, which may indicate prerenal mechanism of acute kidney injury pathogenesis. Implementation of the main provisions of the "renal protocol" in patients with initial GFR rate more than 45 ml/min/1.73 m^2 allows to avoid the development of severe clinically significant forms of postoperative AKI and related complications in the early postoperative period of primary THR.

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Conflict of interest

The authors of this article declare the absence of a conflict of interest.

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