REVIEW PAPER https://doi.org/10.61785/ael/199673


# Patient nutrition after kidney transplantation

Beata Januszko-Giergielewicz[1,2], Paulina Borek-Trybała[3,4]

1 Academy of Applied Medical and Social Sciences, Elbląg, Poland
2 Clinical Department of General Surgery, Liver Surgery and Transplantation Surgery, Antoni Jurasz University Hospital No. 1 in Bydgoszcz, Collegium Medicum in Bydgoszcz, Nicolas Copernicus University in Toruń, Poland
3 Independent Team of Dietitians, The University Clinical Centre in Gdańsk, Poland
4 University of Health in Gdańsk, Poland

**Publishing info**

Received: 2024-12-28
Accepted: 2024-12-30
Online first: 2024-12-31
Published: 2024-12-31

Keywords

nutrition therapy
kidney transplantation
immunosuppression
comorbidity



**Abstract**

**Introduction:** Kidney transplantation (KTx) constitutes the ultimate renal replacement therapy, ensuring the longest life expectancy for patients with chronic kidney disease (CKD) and its best quality. In addition to pharmacological treatment and immunosuppressive (IS) therapy, diet is an essential component of therapy for kidney transplant recipients.

**Aim:** The aim of this study was to provide a comprehensive analysis of nutrition-related issues in patients after KTx.

**Material and methods:** A review of the available research papers and monographs on nutrition after KTx published during the last 5 years was carried out.

**Results and discussion:** Nutrition of the patient after KTx is influenced by many factors, related to the overall treatment process. These include the recipient's baseline kidney disease, comorbidities, and nutritional parameters prior to transplant qualification, donor-dependent factors (e.g. infections), adequate preparation for surgery (prehabilitation), the course of surgery and its complications, as well as IS and its side effects.

**Conclusions:** (1) Nutrition after KTx constitutes a significant component of therapy and affects early and late treatment outcomes. (2) Nutrition of the patient after KTx should be adjusted to the patient's clinical status and nutritional parameters prior to and after surgery, as well as comorbidities. (3) When creating a nutrition-based treatment plan for patients after KTx, IS therapy, along with its complications and nutritional interactions, should always be considered.

Corresponding author: Beata Januszko-Giergielewicz, Academy of Applied Medical and Social Sciences, Lotnicza 2, 82-300 Elbląg, Poland.
E-mail: beatagiergielewicz@gmail.com

## 1. Introduction

Kidney transplantation (KTx) constitutes a well-documented and ultimate renal replacement therapy, ensuring the longest life expectancy for patients with chronic kidney disease (CKD) and its best quality.[1]

Kidneys are the most frequently transplanted organs in the world. In Poland, according to Poltransplant data, 977 kidneys were transplanted from deceased donors (DDs) and 78 from living donors (LDs) in 2023 alone, whereas approximately 1000 patients with CKD await KTx surgery annually.

The life expectancy of a kidney graft (KG) recipient is influenced by many factors dependent on both the donor and the recipient. As regards the latter, these factors include, i.a., comorbidities, the impact of immunosuppressive (IS) therapy, compliance with medical recommendations, lifestyle, and diet. The main causes of mortality in the group of patients after KTx are cardiovascular (CV) complications, cancer, and infections.[1]

The prognosis after KTx is also significantly affected by the transplantation method, with kidney transplant from the LDs being preferred. In this case, the mere possibility of performing the organ transplantation procedure as planned entails many advantages, including sufficient time for the optimal preparation of the recipient and the donor, also in terms of nutritional parameters.[1,2]

The qualification of a recipient for KTx can be carried out after the commencement of dialysis therapy or already during conservative treatment. The latter is the so-called preemptive KTx (PKTx). Having a potential LD for a recipient awaiting transplantation makes it possible to perform a PKTx before starting dialysis therapy. This contributes to avoiding the dialysis-associated complications, including malnutrition that worsens during the course of dialysis.[3]

Nutrition of the patient after KTx is influenced by many factors, related to the overall treatment process. These include the recipient's baseline kidney disease, comorbidities, and nutritional parameters prior to transplant qualification, donor-dependent factors (e.g. infections), adequate preparation for surgery (prehabilitation), the course of surgery and its complications, as well as IS and its side effects.[4] The most important of these relationships will be discussed subsequently.

## 2. Aim

The aim of this study was to provide a comprehensive analysis of nutrition-related issues in patients after KTx.

## 3. Material and methods

A review of the available research papers and monographs on nutrition after KTx published during the last 5 years was carried out. Considering the latest theses regarding dietary guidelines for the general population, particular subsections analyze nutrition therapy in patients after KTx depending on the period since surgery, IS, and comorbidities. The discussion emphasizes the importance of a holistic approach to patient therapy and, in particular, the relationships between adequate nutrition, lifestyle, physical activity, and the patient's mental state.

## 4. Results and discussion

### 4.1. Prehabilitation

When considering nutritional challenges faced by patients after KTx, attention should be paid to the adequate, holistic preparation of the recipient for the transplantation, the so-called prehabilitation. It embraces some crucial components such as dietary recommendations, physical activity, and psychological aspects, which collectively support patients in improving their general conditions and diminishing the risk of postoperative complications.[4–7] First, the patient's nutritional status should be assessed before the KTx procedure as it impacts significantly postoperative outcomes.[4] Both underweight (body mass index – BMI, less than 18) and overweight patients (BMI over 35) are at an increased risk of complications and mortality compared to normal weight patients. Malnutrition, leading to the loss of protein and energy, can limit the ability to synthesize new proteins, which in turn affects wound healing and immunity. Obesity increases the risk of delayed graft function (DGF) and surgical complications. Therefore, an optimal nutritional status should be maintained in all patients awaiting KTx.[8]

As part of prehabilitation, patients should aim to increase their protein intake, which can benefit regenerative and immune processes. It is recommended that protein intake should be in the range of 1.2–1.5 g/kg of body weight (bw) in every 24 h. Meat, fish, legumes, and dairy products are valuable and commonly available sources of protein.[4]

The patient's diet should be rich in nutrients, including vitamins and minerals that support the overall body condition and the immune system function. The diet should contain vitamin C, which is a critical factor for collagen synthesis and the body's immune functions,[9] and omega-3 fatty acids, which can reduce inflammation.

In the period of 7–14 days prior to transplantation, it is recommended to consider the introduction of Foods for Special Medical Purposes (FSMPs), which have an immunomodulating effect.[10] It is standard practice to administer glucose solutions 24 h before and on the day of surgery in order to maintain electrolyte balance, prepare the patient for anesthesia, reduce the risk of insulin resistance, prevent muscle catabolism, and ensure a better surgical stress response.[4]

Regular physical activity is an integral part of prehabilitation. Physical exercises enhance body performance, strength and muscle flexibility, which can remarkably improve both the course of the surgery and the postoperative rehabilitation process. It is recommended that patients engage in moderate physical activity for at least 150 minutes per week.[6,7]

Stress related to surgery and fear about the future can negatively affect a patient's mental health. Psychological support may include consultations with a psychologist/psychodietician and relaxation techniques such as meditation, mindfulness or deep breathing. Organized support groups offer the opportunity to share experiences and emotions with other patients in an analogous situation, which greatly improves the mood and increases the potential to deal with the disease.[5]

### 4.2. Nutrition after kidney transplantation

A successful transplantation procedure improves the patient's condition, wellbeing, and appetite, all of which offer the opportunity to benefit from a comprehensive diet. The patient after KTx can eat like a healthy individual for much of his or her life with the graft, following the principles of a balanced and rational diet. This is true both for patients receiving a well-functioning graft during conservative treatment and those undergoing KTx during dialysis therapy. In both cases, severe dietary restrictions prior to surgery substantially limit the patient's functioning.[2]

Nutritional intervention is needed at each stage of CKD. This applies in particular to protein intake. In patients with renal failure undergoing conservative treatment too high a supply of protein can generate an increase in glomerular filtration rate, proteinuria, blood pressure and, consequently, disease progression. During dialysis therapy, dietary recommendations stipulate a protein supply at the level advised for healthy people, and a high-protein diet in the case of peritoneal dialysis and/or complications of renal replacement therapy.

Dietary restrictions after a successful KTx do not greatly affect the recipient's quality of life. They are largely profiled to control complications of IS therapy, mainly a decreased immune function, disturbances in carbohydrates, lipids, and calcium-phosphate metabolism as well as increased blood pressure levels. Dietary recommendations differ in the perioperative period and in long-term care and need to be discussed separately, as outlined subsequently in the individual subsections.[2]

Preventing weight gain constitutes a significant challenge for therapeutic teams providing care to the kidney graft recipient. High doses of glucocorticosteroids (GCS), a component of IS protocols, generate excessive weight gain especially in the first year after KTx, and being overweight or obese is a common consequence of long-term use of these drugs.[11] This poses a serious clinical problem, as being overweight or obese is a documented risk factor for DGF and other complications. In addition, the numerous comorbidities in this population, i.e. diabetes mellitus, hypertension (HT), and history of CV incidents, impose the need to adapt the diet to the patient's individual clinical status. Therefore, the therapeutic team for the patient after KTx should include a dietician (psychodietician) to optimize dietary recommendations after KTx.

The main aspects of nutrition therapy at different stages after kidney transplantation are discussed in detail in the following subsections. A separate section is devoted to the issue of nutrition therapy tailored to the profile of comorbidities in the CKD patient after KTx.

### 4.3. Goals of nutrition therapy depending on time since surgery

Nutrition therapy (nutrition-based treatment plan) after KTx is divided into two key phases: the early phase, which lasts from the time of surgery until about 6 weeks afterwards, and the maintenance phase, which lasts from six weeks up to even several years after surgery.

Nutritional objectives in each of these phases are different due to the different metabolic needs of the body and the patient's clinical status.[12]

Table 1 presents detailed nutritional goals for both of these phases after KTx.

### 4.4. Early phase (0–6 weeks after KTx)

During this phase, it is crucial to support the function of the transplanted organ and minimize the risk of its acute rejection. In the first few weeks, patients are at a particular risk of malnutrition and electrolyte imbalance, as well as complications related to high doses of IS. A protein-rich diet (1.2–1.5 g/$kg_{bw}$ per 24 h) with

**Table 1. Nutritional goals depending on kidney transplant surgery timeframe.**

| Treatment phase | Period | Goals of nutrition therapy |
|---|---|---|
| Early phase | 0–6 weeks after KTx | To minimize the risk of graft rejection: support of immunosuppressive therapy effectiveness, prevention of gastrointestinal infections. |
| To prevent malnutrition: supply of nutrients (protein and energy). | | |
| To control electrolyte imbalance: stabilization of serum levels of potassium, sodium, and phosphorus. | | |
| To support tissue regeneration: a higher supply of proteins and vitamin C to promote wound healing. | | |
| Maintenance phase | from 6 weeks to some years after KTx | To optimize immunosuppressive therapy: diet adjustment to prevent side effects of immunosuppressants, i.e. obesity or hyperlipidemia. |
| To maintain adequate nutritional status: keeping body weight and total serum protein levels stable. | | |
| To prevent and/or treat comorbidities: diet adjustment to prevent hypertension, hyperlipidemia, diabetes. | | |
| To improve the quality of life: supporting the patient to maintain healthy eating habits in the long term in order to maintain both physical and mental wellbeing. | | |
| To prevent osteoporosis: adequate supply of calcium and vitamin D. | | |
| To prevent or treat post-transplant diabetes mellitus. | | |

Comments: KTx – kidney transplantation.

a high energy content is recommended to promote tissue healing and regeneration. A high-calorie diet is essential during this period to maintain muscle mass.

Balanced electrolyte ratios help to maintain homeostasis, which is crucial in the first weeks after KTx, when the graft has to adapt to new metabolic conditions. A close monitoring of serum IS drug levels and adjusting IS doses according to the protocol are also crucial in this period.

The European Society for Clinical Nutrition and Metabolism (ESPEN) guidelines recommend the early introduction of oral or enteral nutrition (EN) within the first 24 hours after organ transplantation, including KTx.[13] This recommendation is based on a strong expert consensus and has a high recommendation value.

It should be noted that EN does not affect the absorption and blood levels of tacrolimus (TAC), one of the crucial IS drugs administered after KTx.

If oral nutrition is insufficient, ESPEN recommends introducing EN or considering simultaneous parenteral nutrition (PN) if EN does not provide an adequate supply of nutrients.[13]

A major clinical concern is the reduced immunity resulting from the administration of powerful IS and the ease with which bacteria and other infectious agents can enter the organism via the digestive tract.

Recommendations for the prevention of gastrointestinal infections are:[14]

(1) Keeping hands clean (frequent handwashing) before and during food preparation and consumption.
(2) Following the principle of separate use of crockery and cutlery.
(3) Fruits and vegetables should be washed thoroughly under running water and peeled before being eaten or used for the preparation of meals.
(4) Fresh meat and eggs, from the moment of purchase through storage in the refrigerator, as well foods prepared from them, should be stored in airtight containers, separate from other products, and these containers should be disinfected after use.
(5) Separate cutting boards for fresh meat should be used and disinfected thoroughly after use.
(6) Meat should be cooked at 160–180°C.

These recommendations are most relevant in the initial period after KTx, nevertheless certain principles should be followed throughout the entire IS therapy.

Several types of food products should be avoided in the early post-transplant period as summarized in Table 2.

These products include tropical fruits, which are often a source of mold because of long transport and storage. Mold is dangerous for patients undergoing IS therapy and, in immunocompromised conditions, can cause dangerous complications, including fatal ones. Fungi, commonly referred to as mold, thrive in moist conditions, producing poisonous toxins called mycotoxins during the process of secondary metabolism. They cause acute or chronic poisoning (mycotoxicosis). More than 400 mycotoxins have now been isolated, the most well-known being patulin, which is found

**Table 2. Recommendations on how to avoid gastrointestinal infections after kidney transplantation.[14]**

| Recommendation | Description |
|---|---|
| Wash hands frequently and thoroughly. | Wash your hands thoroughly before preparing and eating food to prevent infection. |
| Check the tightness of packaging and expiry dates. | Make sure that the packaging is intact, and products are consumed before the expiry date to reduce the risk of poisoning. |
| Store raw animal foods separately. | Store raw meat, fish, and eggs separate from ready-to-eat foods to prevent cross-contamination. |
| Thorough thermal treatment of animal foods. | Cook meat, fish, and eggs to the right temperature (e.g. using a cooking thermometer) to terminate pathogens. |
| Wash and peel vegetables and fruits. | Wash vegetables and fruits thoroughly and, if possible, peel them to remove dirt and bacteria. |
| Avoid tropical fruits. | Tropical fruits can be difficult to wash thoroughly and carry a risk of infection. |
| Avoid products containing fresh eggs. | Do not eat mayonnaise, custard or ice cream containing raw eggs, which can be a source of salmonella. |
| Avoid blue cheese and unpasteurized dairy products. | Such products may contain Listeria monocytogenes that is particularly dangerous for organ transplant recipients. |
| Avoid ready-made salads and salad bars. | Ready-made foods may be subject to contamination and should not be consumed by transplant recipients. |
| Sanitize kitchen utensils and surfaces. | Regular sanitation of kitchen utensils and surfaces that have come into contact with raw products helps prevent infection. |

in bruised fruit. It is worth noting that mold very often develops inside the fruit, on the stones, even when the fruit itself looks healthy. Mycotoxins can also be found in damp rooms, especially artificially humidified and/or air-conditioned ones. Mycotoxin poisoning most often occurs after eating contaminated food, but the toxins also enter the body through inhalation and/or the skin.

Grapefruit should be completely excluded from the diet as grapefruit juice interferes with the metabolism of IS drugs. It is also crucial to exclude unpasteurized milk and blue cheese from the diet, which can provide a breeding ground for Listeria monocytogenes. Products prepared with raw eggs (ice cream, custards, mayonnaise) should also be avoided.

Meals should preferably be prepared at home, with fresh produce bearing an expiry date. Commonly accepted principles, as offered in the dietary recommendations, should be followed. It is advisable to avoid fast-food bars, where food is prepared hurriedly, from products of uncertain quality. In such places, thermal processing of meat may be insufficient, and salads may contain fruits and vegetables that are not adequately prepared to eliminate microorganisms such as bacteria or mold, with the addition of mayonnaise, cream, and sauces of indeterminate origin and uncertain quality.

### 4.5. Hypophosphatemia

When normal graft function is preserved, hypophosphatemia is often observed. This imposes a need to increase the phosphate content in the diet. This can be achieved by introducing lean meat, fish, skim milk, cottage cheese, and vegetables into the diet. If normal serum phosphate levels are not achieved, supplementation with pharmacological oral and parenteral phosphate preparations is necessary.[15]

### 4.6. Maintenance phase (from 6 weeks up to several years after KTx)

Once the patient's condition has been stabilized and the maintenance phase has begun, the nutritional goals are primarily to optimize the long-term IS therapy and its complications, to control body weight, and to prevent concomitant conditions, i.e. HT, hyperlipidemia or diabetes, which often develop or are exacerbated by IS.[12] Additionally, the diet should contain an adequate amount of energy to match the patient's physical activity and include a preventive dietary element for the development of CKD. In this phase the diet should be well balanced and adjusted to the patient's individual needs. Controlling protein supply is recommended at a level of approx. 0.8–1.0 g/kg$_{bw}$ per 24 h, which maintains a stable nutritional status without burdening the graft. The amount of protein should be adjusted to the actual CKD stage. Dietary recommendations for patients after KTx at each phase after surgery are collected in Table 3.

### 4.7. Side effects of IS drugs and their nutritional interactions

IS drugs are an essential component of therapy for kidney transplant recipients to prevent graft rejection. Although their administration has many benefits, it is also connected with a risk of side effects of IS therapy and nutritional interactions.

**Table 3. Dietary recommendations for patients after KTx.**

| Nutritional | Value |
|---|---|
| First 4-6 weeks after transplantation (EARLY PHASE) | |
| Protein | 1.2–1.5 g/kg bw/24h |
| Energy | 30–35 kcal/kg bw/24h |
| Over 4-6 weeks after transplantation (MAINTENANCE PHASE) | |
| Protein | 0.8–1.0 g/kg bw/24h – depending on eGFR. |
| Energy | Individually |
| Carbohydrates | 50% |
| Fats | 30% |
| Cholesterol | <300 mg/24h |
| Calcium | 1200 mg/24h |
| Phosphorus | 1200 mg/24h |
| Sodium | 2000 mg/24h |
| Physical activity | >30 min daily |

The most common side effects of IS drugs include:[16]

(1) Metabolic disorders, i.e. insulin resistance, diabetes, obesity and hyperlipidemia.
(2) Gastrointestinal dysfunction, i.e. nausea, vomiting, diarrhea, appetite fluctuations.
(3) Electrolyte imbalances, i.e. hyperkalemia, hypokalemia or hyponatremia.
(4) Increased infection risk – due to the suppression of the immune response, patients are more susceptible to gastrointestinal, respiratory, and other infections.
(5) Vitamins and minerals deficiency – IS drugs may affect vitamins and minerals absorption, which requires monitoring and supplementation when necessary.

Nutritional interactions of IS drugs with some foods are an important issue.[17,18] Some foods may affect absorption and/or metabolism of IS drugs. Hence, exclusion of some products, depending on the administered IS therapy, is recommended. Detailed nutritional interactions of IS drugs are presented in Table 4.

### 4.8. Deterioration of the transplanted kidney function

Post-transplant kidney dysfunction (PTKD) is a serious clinical issue that may significantly affect the patient's clinical outcome and quality of life.[19]

The majority of recipients, even after the most successful KTx, remain in CKD stage 2, 3a or even 3b. Thus, the graft dysfunction may worsen over time, and these disorders may have both immunological and non-immunological mechanisms. Research studies have revealed that up to 20%–30% of patients may experience PTKD in the first 5 years after KTx.[19]

If the estimated glomerular filtration rate (eGFR) decreases, the introduction of a low-protein diet is recommended, as is the case in the CKD population during conservative treatment.[20]

### 4.9. Recommendations for protein restriction in CKD

According to KDIGO (Kidney Disease Improving Global Outcomes) guidelines of 2020,[20] patients with eGFR below 30 mL/min/1.73 m² (CKD stage G4–G5) should limit their protein consumption to 0.8 grams per kilogram of body weight daily. This is comparable to recommendations for healthy adults. However, the latest KDOQI guidelines of 2024 stress that a more rigorous approach involving a low-protein (0.55–0.60 g/$kg_{bw}$) or very low-protein diet (0.28–0.43 g/$kg_{bw}$), supplemented with keto analogues of amino acids, may be beneficial for patients with serious renal failure. Dietary protein restrictions should be controlled by specialists to avoid protein malnutrition, especially in elderly patients.

Plant-based diets, such as vegetarian, vegan or Mediterranean diets, have become popular due to their health benefits, including decreasing the risk of CKD development and cardiovascular events. Research studies suggest that plant-based diets, characterized by a lower protein content, may slow disease progression and reduce the risk of complications.[21,22]

Plant-dominant low-protein diet (PLADO) is a nutritional model in which plant-based protein constitutes 50% of total dietary protein content, with a simultaneous limitation of total protein content to 0.6–0.8 g/$kg_{bw}$. The main principles of PLADO include decreased animal-based protein consumption and increased plant-based products intake.[22]

### 4.10. Dietary recommendations for patients after KTx with comorbidities

#### Obesity

Weight gain after KTx, even in patients not previously burdened by this comorbidity, is common and poses

**Table 4. Interaction of IS drugs with food products.[17,18]**

| Immunosuppressant | Interaction with food | Result | Examples of food products |
|---|---|---|---|
| Ciclosporin | Elevated serum drug levels with grapefruit consumption. | Increased risk of adverse effects, i.e. kidney damage and hypertension. | Grapefruit and grapefruit juice |
| | Fats may increase absorption. | Possible elevated level of the drug in the blood. | Fat fish, plant oils |
| | Risk of elevated serum drug levels with turmeric consumption. | Inhibition of enzymes responsible for drug metabolism (CYP3A4). | Supplements and extracts containing turmeric |
| | **Herbs rich in coumarin may reduce drug absorption.** | Decreased serum drug level, increased risk of graft rejection. | **Hypericum, mint, chamomile** |
| Tacrolimus | Elevated serum drug levels with grapefruit consumption. | Increased risk of adverse effects. | Grapefruit and grapefruit juice |
| | Fiber-rich foods may reduce absorption. | Risk of lower drug levels and potential graft rejection. | Fruits, vegetables, whole-grain cereal products<br>*Practical advice: these foods should not be completely eliminated, but administering the drug together with meals rich in fiber should be avoided.* |
| | Risk of elevated serum drug levels with turmeric consumption. | Inhibition of enzymes responsible for drug metabolism (CYP3A4) | Supplements and extracts containing turmeric |
| | **Herbs rich in coumarin may reduce drug absorption.** | Decreased serum drug level, increased risk of graft rejection. | **Hypericum, mint, chamomile** |
| Azathioprine | Purine-rich foods may increase the risk of hepatotoxicity | Increased risk of adverse effects. | Red meat, seafood, sardines |
| | Garlic may affect azathioprine metabolism | Possible exacerbation of the drug effects | Garlic |
| Mycophenolate mofetil | Calcium may reduce absorption | Reduced drug efficacy | Dairy products, calcium supplements<br>*Practical advice: these products should not be eliminated completely, but administering the drug together with calcium-rich meals should be avoided.* |
| | Aluminum-containing supplements may reduce absorption. | Reduced drug efficacy. | Aluminum-containing preparations (e.g. certain painkillers) |
| Prednisone | Sodium intake increases the risk of fluid retention. | Increased blood pressure and risk of edema. | Salt, processed foods |
| | Alcohol increases adverse effects. | Risk of liver damage and gastrointestinal disorders. | Alcohol (beer, wine, spirits) |

a major challenge for therapeutic teams. This results from the administration of GCS (initially in high doses) in IS protocols and increased appetite once uremic symptoms disappear.[11] Risk factors for obesity after KTx additionally include metabolic disorders, i.e. hyperglycemia, post-transplant diabetes mellitus (PTDM) or hyperlipidemia, largely caused by IS.

Due to the risks of weight gain after KTx and its adverse effects on the graft function, after the early postoperative period, in the long term, a patient after KTx should be on a low-calorie diet, accompanied by intensified physical activity.[6,11] Detailed dietary recommendations for obese patients after KTx are presented in Table 5.

### Hyperglycemia and diabetes

Hyperglycemia is commonly observed after KTx. It is mainly caused by an imbalance between insufficient insulin secretion, increased metabolism of this hormone, and tissue insulin resistance. IS drugs are an important link in affecting carbohydrate metabolism in patients after KTx. These drugs affect pancreatic β-cell function and peripheral tissue insulin sensitivity through multiple metabolic pathways. In particular, this refers to high doses of GCS, as well as calcineurin inhibitors (CNI), i.e. TAC i CsA (cyclosporine A), and proliferation signal inhibitors (sirolimus – SRL, everolimus – EVR). Drugs in the CNI group, despite their greater IS power, allowing for reducing GCS doses, have a strong diabetogenic effect. This effect is more expressed in the case of TAC as compared to CsA.[23]

Post-transplant hyperglycemia need not always be perpetuated. Within a few weeks or months after KTx it may be normalized without any treatment, although abnormal fasting glycemia may continue for quite some time. This is related to postoperative stress, high doses of GCS, management of acute rejection or the development of acute infection.

However, some patients are diagnosed with chronic glucose intolerance which, over time, can clinically

**Table 5. Modifications of dietary recommendations for kidney transplant recipients considering comorbidities (over 6 weeks).**

| Health status | Dietary recommendations |
|---|---|
| Diabetes | Limit simple carbohydrates and products with a high glycemic index. |
| | Choose complex carbohydrates (e.g. whole-grain cereal products). |
| | Control portions and consume meals regularly to keep blood glucose levels stable. |
| | Include dietary fiber to improve insulin sensitivity. |
| Obesity | Reduce dietary calorie content (25-30 kcal/kg bw), focus on a caloric deficit. |
| | Increase the consumption of low-calorie vegetables and fruits. |
| | Regular physical activity, adapted to the patient's capabilities. |
| Hypertension | Limit sodium consumption (up to 2 g daily), avoid processed food and fast-food. |
| | Increase potassium consumption (bananas, tomatoes, potatoes) to reduce blood pressure. |
| | Include products rich in fiber and unsaturated fats. |
| Hyperlipidemia | Limit saturated and trans fats (red meat, full-fat dairy products, processed food). |
| | Introduce unsaturated fats (fish, nuts, olive oil) into the diet. |
| | Increase the intake of soluble and insoluble fiber (fruits, vegetables, whole-grain cereals). |
| Metabolic syndrome | Combine recommendations for diabetes, obesity, and hyperlipidemia. |
| | Limit calories, simple carbohydrates, and saturated fats. |
| | Intensify physical activity and consume meals regularly. |
| Intensified physical activity | Increase the overall calorie intake to meet higher energy needs. |
| | Maintain an increased protein supply (1.2-1.5 g/kg bw, depending on activity level). |
| | Adequate hydration, especially before and after physical exercise. |

take the form of full-blown type 2 diabetes, referred to as post-transplant diabetes mellitus (PTDM). This term denotes newly diagnosed diabetes after transplantation, as well as undiagnosed diabetes prior to transplantation. It is estimated that approx. In total, 4%–23% of patients develop PTDM during the first year after KTx and approx. 25% of patients 3 years after surgery.[24]

PTDM develops in two distinct phases. During the first 6 months after KTx the risk for its development is highest. In the following years, the number of patients with PTDM increases along with the follow-up period.

PTDM is one of the most common complications in patients after KTx and contributes to increased comorbidity and mortality rates in this patient group. It causes a 60% increase in the risk of myocardial infarction, a significant increase in the risk of cardiovascular incidents, including cerebral ones, as well as aortic and lower limb artery disease. The risk of infections, mainly urinary tract infections, also increases. PTDM is a strong predictor of a shorter graft survival as compared to recipients without diabetes. It notably diminishes graft function, assessed with serum creatinine levels, and increases the risk of acute rejection. For all these reasons, patients with hyperglycemia and diabetes require particular attention and precise dietary recommendations.[24]

When diagnosed with hyperglycemia or PTDM, the patient requires education as regards glycemia control (and self-control), introduction of nutrition therapy, intensified physical activity, and – if necessary – administration of drugs reducing serum glucose levels (oral antidiabetic drugs and/or insulin).[25] It is also necessary to adjust IS therapy to the patient's glycemic status. The modification involves mostly a reduction of GCS doses, considering IS protocol without GCS, and a substitution of a more diabetogenic TAC for CsA.

A carbohydrate-restricted diet is recommended (130–180 g per 24 h for a diet 2000 kcal), accompanied with limiting simple sugars. A combination of physical activity and loss of weight improves insulin resistance and β-cell function.[26] Nutritional principles for patients after KTx with hyperglycemia or diabetes are collected in Table 5.

### Hyperlipidemia

Dyslipidemia characterized by elevated levels of total cholesterol and LDL (low density lipoprotein) cholesterol is commonly found in patients after KTx.[26] It is considered a significant risk factor for atherosclerosis-related cardiovascular diseases. In approx. 60% of patients after KTx post-transplant lipid profile abnormalities are observed, and approx. 40% experience cardiovascular incidents within 36 months after KTx.

The reasons for this are complex and depend on the recipient's genetic and environmental factors, as well as administered IS drugs, in particular GCS, CsA, SRL, and EVR.

Elevated total cholesterol and atherogenic fractions of the lipid profile have been shown to be important predictors of serious CV complications and

mortality in patients after KTx. As in the general population, treatment of hyperlipidemia after KTx requires lifestyle modification, introduction of an appropriate diet, and administration of pharmacotherapy. Recipients after KTx should be qualified as high or very high cardiovascular risk patients, which implies achieving target LDL-cholesterol levels of less than 70 mg/dL or less than 55 mg/dL, respectively. It is important to determine the amount of lipid supply in the diet, which can help to normalize serum lipid levels after KTx.[26]

It is recommended to limit fats supply to the level of less than 20%, with the contribution of unsaturated fats less than 10% and cholesterol supply less than 500 mg per 24 h. The recommended level of total cholesterol of less than 200 mg/dL is achieved via nutrition therapy only in approx. 20% of the population of patients after KTx. Hence, nutrition therapy often needs to be combined with pharmacotherapy.

Dietary recommendations for hyperlipidemia are analogous with those for other patient groups and include the Mediterranean diet, rich in olive oil, marine fish, and polyunsaturated fatty acids. In addition, it is advised to consume large amounts of vegetables and plant-based rather than animal-based proteins.

### Conflict of interest
None declared.

### Funding
None declared.

## 5. Conclusions
(1) Nutrition after KTx constitutes a significant component of therapy and affects early and late treatment outcomes.
(2) Nutrition of the patient after KTx should be adjusted to the patient's clinical status and nutritional parameters prior to and after surgery, as well as comorbidities.
(3) When creating a nutrition-based treatment plan for patients after KTx, IS therapy, along with its complications and nutritional interactions, should always be considered.

### References
1 Heleniak Z, Illersperger S, Małgorzewicz S, et al. Arterial stiffness as a cardiovascular risk factor after successful kidney transplantation in diabetic and nondiabetic patients. *Transplant Proc*. 2022;54(8):2205–2211. https://doi.org/10.1016/j.transproceed.2022.07.007.
2 Stoler ST, Chan M, Chadban SJ. Nutrition in the management of kidney transplant recipients. *J Ren Nutr*. 2023;33(6S):S67-S72. https://doi.org/10.1053/j.jrn.2023.07.001.
3 Rana Magar R, Knight SR, Maggiore U, et al. What are the benefits of preemptive versus non-preemptive kidney transplantation? A systematic review and meta-analysis. *Transplant Rev (Orlando)*. 2023;37(4):100798. https://doi.org/10.1016/j.trre.2023.100798.
4 Dempsey J, Hargrove T. Nutritional prehabilitation in kidney transplant candidates: A review. *Nutrients*. 2023;15(5):1200.
5 Kelleher CC, McMahon A. Psychosocial considerations in prehabilitation for renal transplantation. *Clin J Am Soc Nephrol*. 2023;18(6):879–885.
6 Surma S, Ciechanowski K. Physical activity and the risk and progression of chronic kidney disease [in Polish]. W: Więcek A, ed. *Advances in Nephrology and Hypertension*. Kraków: Medycyna Praktyczna. 2023;22:145–162.
7 Hayes L, Gibbons E. The Role of Exercise in Prehabilitation for Patients Undergoing Kidney Transplantation. *Transplant Proc*. 2022;54(7):1758-1764.
8 Streja E, Molnar MZ, Kovesdy CP, et al. Associations of pretransplant weight and muscle mass with mortality in renal transplant recipients. *Clin J Am Soc Nephrol*. 2011;6(6):1463–1473. https://doi.org/10.2215/cjn.09131010.
9 Bechara N, Flood VM, Gunton JE. A systematic review on the role of vitamin C in tissue healing. *Antioxidants (Basel)*. 2022;11(8):1605. https://doi.org/10.3390/antiox11081605.
10 Wilkins LR, Mikhail M. Immunomodulatory effects of nutritional support in transplantation: A systematic review. *Transplant Rev*. 2023;37(3):146–157.
11 Tantisattamo E, Kalantar-Zadeh K, Halleck F, Duettmann W, Naik M, Budde K. Novel approaches to sarcopenic obesity and weight management before and after kidney transplantation. *Curr Opin Nephrol Hypertens*. 2021;30(1):14-26. https://doi.org/10.1097/mnh.0000000000000673.
12 Fong JVN, Moore LW. Nutrition trends in kidney transplant recipients: The importance of dietary monitoring and need for evidence-based recommendations. *Front Med (Lausanne)*. 2018;5:302. https://doi.org/10.3389/fmed.2018.00302.
13 Weimanna A, Bragab M, Carli F. ESPEN practical guideline: Clinical nutrition in surgery. *ESPEN Guideline*. 2021;40(7):4745–4761. https://doi.org/10.1016/j.clnu.2021.03.031.
14 Gioco R, Corona D, Ekser B, et al. Gastrointestinal complications after kidney transplantation. *World*

*J Gastroenterol*. 2020;26(38):5797–5811. https://doi.org/10.3748/wjg.v26.i38.5797.

15 Chan M, Patwardhan A, Ryan C, et al. Caring for Australasians with renal impairment; Dietitians Association of Australia. Evidence-based guidelines for the nutritional management of adult kidney transplant recipients. *J Ren Nutr*. 2011;21(1):47–51. https://doi.org/10.1053/j.jrn.2010.10.021.

16 Meneghini M, Bestard O, Grinyo JM. Immunosuppressive drugs modes of action. *Best Pract Res Clin Gastroenterol*. 2021;54–55:101757. https://doi.org/10.1016/j.bpg.2021.101757.

17 Kardas P, Szewczyk T. Interactions of immunosuppressive drugs with food[in Polish]. In: Boniecka I, Lisik W, eds. *Dietetics in Transplantation*, Warszawa: Wydawnictwo Medyczne. 2022.

18 Wojciechowska J, Kwiatkowski S. The impact of diet on the effectiveness of immunosuppressive drugs [in Polish]. *Przegl Epidemiol*. 2021;75(3):321–328.

19 Pahl M, et al. Incidence and risk factors of post-transplantation kidney dysfunction in a cohort of kidney transplant recipients: a systematic review and meta-analysis. *Transplant Proc*. 2020;52(6):1894-1901.

20 Ikizler TA, Burrowes JD, Byham-Gray LD, et al. KDOQI Clinical Practice Guideline for Nutrition in CKD: 2020 Update. *Am J Kidney Dis*. 2020;76(Suppl. 1):S1–S107. https://doi.org/10.1053/j.ajkd.2020.05.006.

21 Chen H, Shen J, Xuan J, et al. Plant-based dietary patterns in relation to mortality among older adults in China. *Nat Aging*. 2022;2:224–230. https://doi.org/10.1038/s43587-022-00180-5.

22 Kalantar-Zadech K, Joshi S, Schlueter R. Plant-dominant low-protein diet for conservative management of chronic kidney disease. *Nutrients*. 2020;12(7):1931. https://doi.org/10.3390/nu12071931.

23 Hadj Ali I, Adberrahim E, Ben Abdelghani K, et al. Incidence and risk factors for post-renal transplant diabetes mellitus. *Transplant Proc*. 2011;43(2):568–571. https://doi.org/10.1016/j.transproceed.2011.01.032.

24 Małyszko J, Małyszko J. Diabetes in kidney transplant patients [in Polish]. *Terapia Nefrol Transplantol*. 2024;1(432):76-80.

25 Li J, CHong A, Carey S. Interwencje dietetyczne w profilaktyce i leczeniu cukrzycy u pacjentów po przeszczepie nerki – przegląd systematyczny. *Nefrologia (Carlton)*. 2022;27(3):269–280.

26 Chmielnicka K, Heleniak Z, Dębska-Ślizień A. Dyslipidemia in renal transplant recipiens. *Transplantology*. 2022;3(2):188–199. https://doi.org/10.3390/transplantology3020020.