New-onset diabetes after kidney transplantation: Incidence and associated factors

Vânia Gomes, Florbela Ferreira, José Guerra, Maria João Bugalho

Vânia Gomes, Florbela Ferreira, Maria João Bugalho, Endocrinology, Diabetes and Metabolism Department, Santa Maria Hospital, Lisbon 1649-035, Portugal

José Guerra, Nephrology and Kidney Transplantation Department, Santa Maria Hospital, Lisbon 1649-035, Portugal

ORCID numbers: Vânia Gomes (0000-0002-0750-5744); Florbela Ferreira (0000-0002-2347-3658); José Guerra (0000-0001-8544-5209); Maria João Bugalho (0000-0003-0357-7350).

Author contributions: Gomes V wrote the manuscript, collected the data and performed the data analysis; Guerra J collected the data; Guerra J, Ferreira F and Bugalho MJ reviewed the manuscript for important intellectual content; all authors participated in designing the study.

Institutional review board statement: This study was reviewed and approved by the Ethics Committee of Santa Maria Hospital (No. 406/17).

Informed consent statement: Informed consent was not required for study participation or data publication because the clinical data were collected from an institutional database and had been anonymized before analysis.

Conflict-of-interest statement: All authors declare no conflicts-of-interest in relation to this article.

Open-Access: This article is an open-access article which was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/.

Manuscript source: Invited manuscript

Correspondence to: Vânia Gomes, MD, Doctor, Endocrinology, Diabetes and Metabolism Department, Santa Maria Hospital, Avenida Professor Egas Moniz, Lisbon 1649-035, Portugal. vania.rodrigues.gomes@gmail.com Telephone: +351-912-993251

Received: March 22, 2018
Peer-review started: March 23, 2018
First decision: May 8, 2018
Revised: May 24, 2018
Accepted: June 13, 2018
Article in press: June 13, 2018
Published online: July 15, 2018

Abstract

AIM
To determine the incidence and associated factors of new-onset diabetes after transplantation (NODAT) in a Portuguese central hospital.

METHODS
This single-center retrospective study involved consecutive adult nondiabetic transplant recipients, who had undergone kidney transplantation between January 2012 and March 2016. NODAT was diagnosed according to the criteria of the American Diabetes Association. Data were collected from an institutional database of the Nephrology and Kidney Transplantation Department (Santa Maria Hospital, Lisbon, Portugal) and augmented with data of laboratorial parameters collected from the corresponding patient electronic medical records. Exclusion criteria were preexisting diabetes mellitus, missing information and follow-up period of less than 12 mo. Data on demographic and clinical characteristics as well as anthropometric and laboratorial parameters were also collected. Patients were divided into two groups: With and without NODAT - for statistical comparison.

RESULTS
A total of 156 patients received kidney transplant
during the study period, 125 of who were included in our analysis. NODAT was identified in 27.2% of the patients (n = 34; 53% female; mean age: 49.5 ± 10.8 years; median follow-up: 36.4 ± 2.5 mo). The incidence in the first year was 24.8%. The median time to diagnosis was 3.68 ± 5.7 mo after transplantation, and 76.5% of the patients developed NODAT in the first 3 mo. In the group that did not develop NODAT (n = 91), 47% were female, with mean age of 46.4 ± 13.5 years and median follow-up of 35.5 ± 1.6 mo. In the NODAT group, the pretransplant fasting plasma glucose (FPG) levels were significantly higher [101 (96.1-105.7) mg/dL vs 92 (91.4-95.8) mg/dL, P = 0.007] and pretransplant impaired fasting glucose (IFG) was significantly more frequent (51.5% vs 27.7%, P = 0.01). Higher pretransplant FPG levels and pretransplant IFG were found to be predictive risk factors for NODAT development [odds ratio (OR): 1.059, P = 0.003; OR: 2.772, P = 0.017, respectively].

CONCLUSION
NODAT incidence was high in our renal transplant recipients, particularly in the first 3 mo posttransplant, and higher pretransplant FPG level and IFG were risk factors.

Key words: New-onset diabetes after transplantation; Incidence; Kidney transplantation; Impaired fasting glucose; Immunosuppression

© The Author(s) 2018. Published by Baishideng Publishing Group Inc. All rights reserved.

Core tip: New-onset diabetes mellitus after transplantation (NODAT) is a major complication of kidney transplant. The aim of this study was to evaluate the incidence and associated factors of NODAT among kidney transplant recipients in a single center. A total of 125 patients transplanted at Santa Maria Hospital (Lisbon, Portugal) were assessed, and NODAT was identified in 27.2%. The median time to diagnosis was 3.68 ± 5.7 mo after transplantation and most patients (76.5%) developed NODAT in the first 3 mo posttransplant. Higher pretransplant fasting plasma glucose level and pretransplant impaired fasting glucose were predictive risk factors for NODAT development.

Gomes V, Ferreira F, Guerra J, Bugalho MJ. New-onset diabetes after kidney transplantation: Incidence and associated factors. World J Diabetes 2018; 9(7): 132-137 Available from: URL: http://www.wjgnet.com/1948-9358/full/v9/i7/132.htm DOI: http://dx.doi.org/10.4239/wjd.v9.i7.132

INTRODUCTION
New-onset diabetes after transplantation (NODAT) is a frequent metabolic complication of kidney transplantation, and associated with increased morbidity and mortality[1-2]. However, due to the absence of a standard definition of NODAT, it has been difficult to determine a reliable incidence rate. The first International Consensus Guidelines published in 2003 for the diagnosis and management of NODAT were updated in 2014 and advocate the World Health Organization (WHO) and American Diabetes Association (ADA) criteria for the diagnosis of diabetes mellitus (DM) and impaired glucose tolerance (IGT)[3,4]. Recent studies using these criteria found incidences of NODAT to be 7%-30% in the first year after transplant[5-8].

Increased insulin resistance and impaired insulin production are likely to contribute to the development of NODAT[9]. Both traditional type 2 DM and transplant-related risk factors affect this condition[9]. The NODAT risk factors can be categorized into three groups: Non-modifiable, modifiable and potentially modifiable[10]. The non-modifiable factors include age, race/ethnicity, family history of DM, male recipient sex, the presence of certain human leukocyte antigens (HLAs; such as HLA A30, B27 and B42), increased HLA mismatches, donor-recipient mismatch, deceased donor kidney, male donor sex and history of acute rejection[10]. Polycystic kidney disease may confer an increased risk of NODAT, although results of the related studies remain conflicting[11]. On the other hand, the modifiable risk factors comprise obesity and type of immunosuppressive agents used to prevent or treat rejection. Finally, the potentially modifiable risk factors include pretransplant impaired fasting glucose (IFG) or IGT, and infection with hepatitis C or cytomegalovirus (CMV)[10].

The aim of this study was to evaluate the incidence of NODAT and its associated factors among kidney transplant recipients who were treated in a transplant center of a central Portuguese hospital.

MATERIALS AND METHODS
This is a single-center retrospective study of consecutive adult nondiabetic patients, who underwent kidney transplant between January 2012 and March 2016 at Santa Maria Hospital, Lisbon, Portugal. Data were collected retrospectively from an institutional database created by the Nephrology and Kidney Transplantation Department and completed with data for laboratorial parameters collected from the respective patients’ electronic medical records, in agreement with our institutional ethical recommendations.

Inclusion and exclusion criteria
NODAT was diagnosed according to the ADA criteria (2017), which involves the following: Symptoms of diabetes (i.e., polyuria, polydipsia or unexplained weight loss) plus random plasma glucose of ≥ 200 mg/dL; fasting plasma glucose (FPG) of ≥ 126 mg/dL, with fasting defined as no caloric intake for at least 8 h; and 2-h plasma glucose of ≥ 200 mg/dL during an oral glucose tolerance test (OGTT). IFG was defined as FPG
between 100 mg/dL and 125 mg/dL\textsuperscript{[3]}. In the first 3 mo after transplant, glycated hemoglobin was not used as diagnostic criteria, since its validity can be affected by the processes of new hemoglobin synthesis and glycation in the posttransplant setting\textsuperscript{[12]}. The OGTT is considered the gold standard for diagnosing NODAT, enabling the identification of more patients than FPG measurement alone; likewise, it allows for diagnosis of IGT\textsuperscript{[4]}. However, in our kidney transplantation center, the OGTT is not routinely performed in transplant recipients. The NODAT diagnosis was established when the immunosuppressive therapy and kidney allograft were stable and in the absence of acute infections or other stress factors, in order to exclude patients who developed transient hyperglycemia in the early posttransplant period\textsuperscript{[4]}.

Data on demographic/clinical characteristics, anthropometric and laboratorial parameters included age at transplant, sex, race, weight, height, calculated body mass index (BMI), etiology of primary renal disease, pretransplant FPG, history of hepatitis C or CMV infection, acute rejection episodes, type of transplant (deceased or living donor), type of immunosuppressive drugs for induction and maintenance therapy, follow-up time, graft loss and death. Exclusion criteria were preexisting DM, missing information (i.e., pretransplant FPG) and follow-up period of less than 12 mo. A total of 156 patients were transplanted during the study period, and 125 of these were eligible for the study.

**Immunosuppression regimen**

All patients received induction therapy, consisting of either basiliximab (an interleukin-2 receptor monoclonal antibody; ATG; Protocol B). Prior to the transplant, all patients received tacrolimus at 0.2 mg/kg. For Protocol A, the patient was administered 20 mg basiliximab pretransplantation and at 4 d posttransplantation; these patients also received tacrolimus at 0.075 mg/kg every 12 h and mycophenolate mofetil (1500 mg pretransplantation, followed by 1000 mg every 12 h for 1 wk posttransplantation and then 500 mg every 12 h). For Protocol B, the patient was administered 1.5-2 mg/kg ATG pretransplantation; methylprednisolone (500 mg) before ATG and tacrolimus at 0.05 mg/kg every 12 h.

All patients received 500 mg methylprednisolone intraoperatively, followed by 1 mg/kg per day for 3 d postoperatively, with progressive tapering until reaching 25 mg/d by the end of the first month after transplant. The maintenance therapy comprised corticosteroids (prednisolone), tacrolimus and mycophenolate mofetil.

**Statistical analysis**

Data were analyzed with SPSS Statistics for Windows, version 20.0 (IBM Corp., Armonk, NY, United States). A biomedical statistician (Nilza Gonçalves, Instituto de Medicina Molecular, Faculty of Medicine, University of Lisbon, Portugal) reviewed the study’s statistics. For comparative analysis, the patients were divided into two groups: With and without NODAT. For continuous variables, differences were analyzed using the Mann-Whitney test (nonparametric data) and Student’s \( t \)-test (parametric data). For categorical variables, differences were analyzed using the \( \chi^2 \) test. Multivariate analysis was performed to identify potential risk factors for NODAT by using a logistic regression test. Data were expressed as mean ± SD or median (minimum and maximum) for continuous variables and as percentage for categorical variables. \( P \leq 0.05 \) was considered significant.

**RESULTS**

A total of 125 patients were enrolled for the analysis (mean age: 46.9 ± 12.9 years; 51.2% male). The majority of our patients were Caucasian, and the median follow-up was 35.7 ± 15.1 mo. NODAT was identified in 27.2% \( [n = 34; 95\% \text{ confidence interval (CI)}: 20.17\%-35.59\%] \) of the patients; the NODAT cases were 53% female and had mean age of 49.6 ± 10.8 years. The incidence of NODAT in the first year was 24.8% (95\%CI: 18.06%-33.05\%).

The median time to diagnosis was 3.68 ± 5.7 mo after transplantation, with the majority of patients (76.5\%) developing NODAT in the first 3 mo. NODAT diagnoses at the follow-up intervals of 3-6 mo, 6-12 mo and after 12 mo were 5.9%, 8.8% and 8.8%, respectively. The median follow-up for the NODAT group was 36.4 ± 2.5 mo. In the group that did not develop NODAT (\( n = 91 \)), 47\% were female and the mean age was 46.0 ± 13.6 years. The median follow-up was 35.5 ± 1.6 mo, which was not significantly different from that of the NODAT group (\( P = 0.774 \)).

Table 1 compares the clinical and laboratory parameters of patients who developed NODAT with those who did not (NODAT vs non-NODAT). During the follow-up period, 1 patient in the NODAT group and 2 patients in the non-NODAT group died. There was no graft loss in the NODAT group, as opposed to the 5 cases recorded for the non-NODAT group.

In the NODAT group, the pretransplant FPG levels were significantly higher [101 (96.1-105.7) mg/dL vs 92 (91.4-95.8) mg/dL, \( P = 0.007 \)] and the occurrence of pretransplant IFG was significantly more frequent (51.5\% vs 27.7\%, \( P = 0.01 \)). Furthermore, higher pretransplant FPG levels and pretransplant IFG occurrence were identified as predictive risk factors for NODAT development (odds ratio (OR): 1.059, \( P = 0.003 \); OR: 2.772, \( P = 0.017 \), respectively).

Patients diagnosed with NODAT were more frequently of African origin (29.4\% vs 22\%), presented a trend for higher age (49.6 ± 10.8 years vs 46.0 ± 13.6 years) and BMI (25.2 ± 4.0 kg/m\(^2\) vs 24.5 ± 4.4 kg/m\(^2\)), as well as a higher frequency of hepatitis C infection (2.9\% vs 1.1\%), CMV infection (97\% vs 93\%), acute rejection (14.7\% vs 8.8\%) and deceased donor (100\% vs 91.2\%), although none of these parameters...
Table 1  Clinical and laboratory parameters

|                        | NODAT group | Non-NODAT group | P   |
|------------------------|-------------|-----------------|-----|
| No. of patients        | 34 (27.2%)  | 91 (72.8%)      |     |
| Age at transplant (yr) | 49.6 ± 10.8 | 46.0 ± 13.6     | 0.165 |
| Female sex             | 53% (18/34) | 47% (43/91)     | 0.571 |
| Race                   |             |                 |     |
| Caucasian              | 70.6% (24/34) | 78% (71/91)   | 0.387 |
| African                | 29.4% (10/34) | 22% (20/91)    |     |
| Body mass index (kg/m²) | 25.2 ± 4.0 | 24.5 ± 4.4      | 0.418 |
| Pre-transplant FPG (mg/dL) | 101 (96.1-105.7) | 92 (91.4-95.8) | 0.007 |
| Pretransplant IFG      | 51.5% (17/33) | 27.7% (23/83) | 0.01 |
| Hepatitis C infection  | 2.9% (1/34) | 1.1% (1/91)     | 0.472 |
| CMV infection          | 97% (33/34) | 93% (82/88)     | 0.672 |
| Acute rejection        | 14.7% (5/34) | 8.8% (8/91)     | 0.338 |
| Type of transplant     |             |                 |     |
| Deceased donor         | 100% (34/34) | 91.2% (83/91) | 0.106 |
| Living donor           | 0% (0/34) | 8.8% (8/91)     |     |
| Follow-up (mo)         | 36.4 ± 2.5 | 35.5 ± 1.6      | 0.774 |

CMV: Cytomegalovirus; FPG: Fasting plasma glucose; IFG: Impaired fasting glucose; NODAT: New-onset diabetes after transplantation.

reached statistical significance. The most frequent etiology of end-stage renal disease was hypertensive nephropathy (n = 7) in the NODAT group and polycystic kidney disease (n = 17) in the non-NODAT group.

In the NODAT group, induction therapy comprised ATG in 6 patients and basiliximab in 28; in the non-NODAT group, 24 patients received ATG and 67 received basiliximab. No statistically significant difference was found between the two groups for the induction therapies used (P = 0.309). In both groups, maintenance therapy consisted of immunosuppression with corticosteroids, tacrolimus and mycophenolate mofetil. Of the 34 patients diagnosed with NODAT, 44.1% (n = 15) needed oral hypoglycemic agents, 26.5% (n = 9) needed insulin and 5.9% (n = 2) were administered combined therapy (insulin and oral hypoglycemic agents). In the remaining 23.5% of the patients (n = 8), diabetes was controlled with diet and exercise alone.

DISCUSSION

Kidney transplant, besides being more cost-effective than dialysis, improves patient survival[13]. Nevertheless, NODAT is a frequent complication of kidney transplantation and is associated with poorer outcomes, increased risk of infectious and cardiovascular complications and reduced rates of patient and graft survival[5,14].

The reported incidence of NODAT has varied broadly between studies, probably due to the use of diverse diagnostic criteria, intensity of routine screening and follow-up length[15]. Furthermore, variability in the immunosuppressive protocols used in different transplant centers could influence the calculated incidence rates of NODAT. For instance, it is known that tacrolimus is more diabetogenic than cyclosporine[16]. Recent studies using the WHO/ADA criteria reported that 7%-30% of nondiabetic kidney transplant recipients develop NODAT in the first year after transplant[5-6]. In our study, NODAT was diagnosed in 34 patients (27.2%), with an incidence of 24.8% in the first year after transplant. Therefore, our findings are in agreement with previous studies. NODAT occurrence reportedly peaks in the first 3-6 mo posttransplant[17,18]. Studies have also shown that the incidence is higher when higher dosages of immunosuppressive medications are used[17]. After the 3-6 mo period, the annual incidence of diabetes is comparable to that observed in pretransplant patients[17,18]. In the present study, the median time to diagnosis was 3.68 ± 5.7 mo, with the majority of patients (76.5%) developing NODAT in the first 3 mo, which is also consistent with the literature.

Multiple risk factors have been identified. In our study, higher pretransplant FPG levels and occurrence of pretransplant IFG were predictive risk factors for NODAT development. Other researchers have reported abnormal glucose metabolism as a NODAT risk factor. For example, Cosio et al[19] reported that high pretransplant glucose levels represent a risk factor for NODAT at 1-year posttransplant. The risk was shown to increase as pretransplant FPG levels rose. Among patients with pretransplant IFG in that study, 70% had hyperglycemia at 1 year (IFG 43% and NODAT 27%). The strongest risk factor for NODAT seems to be age[20]. NODAT development is 2.2 times more likely to occur in patients with age above 45 years[21]. Another independent risk factor for NODAT is obesity or overweight status. Previous studies have reported a relative risk of 1.4 and 1.8 for patients with BMI between 25-30 kg/m² and > 30 kg/m², respectively[22]. We also found a trend for higher age and higher BMI in the NODAT group.

African-Americans have a 2-fold risk of developing NODAT compared to Caucasians. This finding can be, at least partly, related to immunosuppressive agents’ pharmacokinetics variation[15]. Hepatitis C and CMV infection are also associated with NODAT. Hepatitis C virus causes insulin resistance in the context of liver dysfunction, abnormalities in glucose metabolism and
pancreatic β cell dysfunction[23]. Similarly, lower median insulin release has been reported for patients with CMV infection, suggesting impaired pancreatic β cell function as a possible pathogenic mechanism[24].

History of acute rejection episodes requiring elevated doses of glucocorticoids, as well as the type of transplant (deceased donor), have also been implicated in risk of NODAT[22]. We found higher frequencies of African-origin individuals, hepatitis C infection, CMV infection, acute rejection and deceased donors in our NODAT group, as suggested in the literature; however, the differences did not reach statistical significance. The majority of NODAT patients in our study required treatment for diabetes, with most responding to oral hypoglycemic agents, followed by insulin, and few requiring combined therapy. Nearly a quarter of the patients were able to achieve diabetes control without medication, based on lifestyle modifications.

Some limitations exist in our study design that may impact the interpretation and/or generalization of our findings. This was a retrospective study with a relatively small sample, only reflecting a single center experience. Moreover, OGTT is not currently used in our center as a NODAT screening test, which is likely to lead to underestimation of its incidence in this cohort.

The incidence of NODAT in renal transplant recipients is high, particularly in the first 3 mo. Recognition of the associated factors may help to prevent this condition. Higher pretransplant FPG levels and occurrence of pretransplant IFG were predictive risk factors for NODAT development, indicating a need for periodic blood glucose screening in patients waiting for a transplant in order to identify those at risk. Using the same rationale as for type 2 DM, early identification of impaired carbohydrate metabolism in the posttransplant setting will allow implementation of lifestyle modifications in order to minimize progression to NODAT and its potentially severe complications.

ARTICLE HIGHLIGHTS

Research background
New-onset diabetes after transplantation (NODAT) is a common complication of kidney transplantation, correlated with poorer outcomes. Its incidence varies greatly between studies, and multiple risk factors have been associated with its onset.

Research motivation
Albeit a frequent complication of kidney transplant, very few studies of NODAT in the Portuguese population have been published.

Research objectives
To evaluate the incidence and associated factors of NODAT among kidney transplant recipients in a Portuguese hospital.

Research methods
Retrospective study of consecutive adult nondiabetic patients, who underwent kidney transplant between January 2012 and March 2016 in a central Portuguese hospital.

Research results
NODAT was identified in 27.2% of the kidney transplant recipients. The median time to diagnosis was 3.68 ± 5.7 mo after transplantation. Higher pretransplant fasting plasma glucose levels and occurrence of pretransplant impaired fasting glucose (IFG) were predictive risk factors for NODAT development.

Research conclusions
Periodical blood glucose screening in patients waiting for a kidney transplant is important to identify those at risk for and to minimize progression to NODAT and its potentially severe complications.

Research perspectives
Clinicians should be aware of NODAT risk factors, namely pretransplant IFG, to perform a tighter surveillance of patients in these conditions. Multicentric studies are required to investigate other risk factors possibly implicated in NODAT development.

ACKNOWLEDGEMENTS
The authors thank Nilza Gonçalves for statistical analysis review.

REFERENCES
1. Langsford D, Dwyer K. Dysglycemia after renal transplantation: Definition, pathogenesis, outcomes and implications for management. World J Diabetes 2015; 6: 1132-1151 [PMID: 26322159 DOI: 10.4239/wjd.v6i6.11132]
2. Juan Khong M, Ping Chong Ch. Prevention and management of new-onset diabetes mellitus in kidney transplantation. Neth J Med 2014; 72: 127-134 [PMID: 24846925]
3. American Diabetes Association. 2. Classification and Diagnosis of Diabetes. Diabetes Care 2017; 40: S1-S24 [PMID: 27979989 DOI: 10.2337/dc17-S005]
4. Sharif A, Hecking M, de Vries AP, Perrini E, Hornum M, Rasoul-Rockenschaub S, Berlakovich G, Krebs M, Kautzky-Willer A, Scherthanner G, Marchetti P, Pacini G, Ojo A, Takahara S, Larsen JL, Budde K, Eller K, Pascual J, Jardine A, Bakker SJ, Valderhaug TG, Jenssen TG, Colhney S, Säemann MD. Proceedings from an international consensus meeting on posttransplantation diabetes mellitus: recommendations and future directions. Am J Transplant 2014; 14: 1992-2000 [PMID: 25307034 DOI: 10.1111/ajt.12850]
5. Gourishankar S, Jhangri GS, Tonelli M, Wales LH, Cockfield SM. Development of diabetes mellitus following kidney transplantation: a Canadian experience. Am J Transplant 2004; 4: 1876-1882 [PMID: 15476489 DOI: 10.1111/j.1600-6143.2004.00591.x]
6. Rodrigo E, Santos L, Piñera C, Millán JC, Quintela ME, Toyos C, Allende N, Gómez-Alamillo C, Arias M. Prediction at first year of incident new-onset diabetes after kidney transplantation by risk prediction models. Diabetes Care 2012; 35: 471-473 [PMID: 22279030 DOI: 10.2337/dc11-2071]
7. Yu H, Kim H, Baek CH, Baek SD, Jeung S, Han DJ, Park SK. Risk factors for new-onset diabetes mellitus after living donor kidney transplantation in Korea - a retrospective single center study. BMC Nephrol 2016; 17: 106 [PMID: 27473469 DOI: 10.1186/s12882-016-0321-8]
8. Patel S, Gohel K, Patel B. Incidences and risk factor for new onset diabetes after transplantation in live donor kidney transplantation: a prospective single centre study. Int J Pharm Pharm Sci 2016; 8: 230-233
9. Chakker A, Hanson RL, Raza SM, DiStefano JK, Millis MP, Heilman RL, Mulligan DC, Reddy KS, Mazur MJ, Hamawi K, Moss AA, Mekeel KL, Cerhan JR. Pilot study: association of traditional and genetic risk factors and new-onset diabetes mellitus following kidney transplantation. Transplant Proc 2009; 41: 4172-4177 [PMID: 20085362 DOI: 10.1016/j.transproceed.2009.08.065]
New-onset diabetes mellitus in transplant patients: an overview. Diabetes Metab Syndr Obes 2011; 4: 175-186 [PMID: 21760734 DOI: 10.2147/DMSO.S19027]

Cheungpasitporn W, Thongprayoon C, Vijayvargiya P, Anthanont P, Erickson SB. The Risk for New-Onset Diabetes Mellitus after Kidney Transplantation in Patients with Autosomal Dominant Polycystic Kidney Disease: A Systematic Review and Meta-Analysis. Can J Diabetes 2016; 40: 521-528 [PMID: 27184299 DOI: 10.1016/j.jcjd.2016.03.001]

Wilkinson A, Davidson J, Dotta F, Home PD, Keown P, Kibber B, Jardine A, Levitt N, Marchetti P, Markell M, Naicker S, O'Connell P, Schnitzler M, Standl E, Torregrosa JV, Uchida K, Valantine H, Villamil F, Vincenti F, Wissing M, Guidelines for the treatment and management of new-onset diabetes after transplantation. Clin Transplant 2005; 19: 291-298 [PMID: 15877787 DOI: 10.1111/j.1399-0012.2005.00359.x]

Shivaswamy V, Boerner B, Larsen J. Post-Transplant Diabetes Mellitus: Causes, Treatment, and Impact on Outcomes. Endocr Rev 2016; 37: 37-61 [PMID: 26650437 DOI: 10.1210/er.2015-1084]

Caillard S, Eprinchard L, Perrin P, Braun L, Heibel F, Moreau F, Kessler L, Moulin B. Incidence and risk factors of glucose metabolism disorders in kidney transplant recipients: role of systematic screening by oral glucose tolerance test. Transplantation 2011; 91: 757-764 [PMID: 21336240 DOI: 10.1097/TP.0b013e31820f8877]

Palepu S, Prasad GV. New-onset diabetes mellitus after kidney transplantation: Current status and future directions. World J Diabetes 2015; 6: 445-455 [PMID: 25897355 DOI: 10.4239/wjd.v6.i3.445]

Luan FL, Steffick DE, Ojo AO. New-onset diabetes mellitus in kidney transplant recipients discharged on steroid-free immunosuppression. Transplantation 2011; 91: 334-341 [PMID: 21242885 DOI: 10.1097/TP.0b013e3182032c5f]

Ghisdal L, Van Laecke S, Abramowicz MJ, Vanholder R, Abramowicz D. New-onset diabetes after renal transplantation: risk assessment and management. Diabetes Care 2012; 35: 181-188 [PMID: 22187441 DOI: 10.2337/dc11-1230]

Mourad G, Glyda M, Albano L, Viklický O, Merville P, Tydén G, Mourad M, Löhmus A, Witzke O, Christiaans MHL, Brown MW, Undre N, Kazeem G, Kyppers DRJ; Advagraf-based immunosuppression regimen examining new onset diabetes mellitus in kidney transplant recipients (ADVANCE) study investigators. Incidence of Posttransplantation Diabetes Mellitus in De Novo Kidney Transplant Recipients Receiving Prolonged-Release Tacrolimus-Based Immunosuppression With 2 Different Corticosteroid Minimization Strategies: ADVANCE, A Randomized Controlled Trial. Transplantation 2017; 101: 1924-1934 [PMID: 27547871 DOI: 10.1097/TP.0000000000001435]

Cosio FG, Kadva Y, van der Velde M, Larson TS, Textor SC, Griffin MD, Stegall MD. New onset hyperglycemia and diabetes are associated with increased cardiovascular risk after kidney transplantation. Kidney Int 2005; 67: 2415-2421 [PMID: 15882287 DOI: 10.1111/j.1523-1755.2005.00349.x]

Rodrigo E, Fernández-Fresneda G, Valero R, Ruiz JC, Piñera C, Palomar R, González-Cotorruelo J, Gómez-Alamillo C, Arias M. New-onset diabetes after kidney transplantation: risk factors. J Am Soc Nephrol 2006; 17: S291-S295 [PMID: 17130277 DOI: 10.1681/ASN.2006080929]

Cosio FG, Pesavento TE, Osei K, Henry ML, Ferguson RM. Post-transplant diabetes mellitus: increasing incidence in renal allograft recipients transplanted in recent years. Kidney Int 2001; 59: 732-737 [PMID: 11168956 DOI: 10.1046/j.1523-1755.2001.059000.2732.x]

Kesiraju S, Paritala P, Rao Ch UM, Sahariah S. New onset of diabetes after transplantation - an overview of epidemiology, mechanism of development and diagnosis. Transpl Immunol 2014; 30: 52-58 [PMID: 24184293 DOI: 10.1016/j.trim.2013.10.006]

Markell M. New-onset diabetes mellitus in transplant patients: pathogenesis, complications, and management. Am J Kidney Dis 2004; 43: 953-965 [PMID: 15168375 DOI: 10.1053/j.ajkd.2004.03.020]

Hjelmesaeth J, Sagedal S, Hartmann A, Rollag H, Egeland T, Hagen M, Nordal KP, Jenssen T. Asymptomatic cytomegalovirus infection is associated with increased risk of new-onset diabetes mellitus and impaired insulin release after renal transplantation. Diabetologia 2004; 47: 1550-1556 [PMID: 15338129 DOI: 10.1007/s00125-004-0499-z]
