

New-onset diabetes after transplantation: focus on strategies to reduce risk



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Practice Points

- New-onset diabetes after transplantation (NODAT) is one of the major medical complications associated with solid-organ transplantation.
- Risk factors for NODAT are both transplant specific and nonspecific.
- There are important similarities and differences between NODAT and diabetes mellitus that prevent simple translation of research findings between the two.
- Appreciation of non-modifiable NODAT risk factors will help devise individualized immunosuppressant regimens that balance the risks of graft rejection and cardio-metabolic complications.
- An understanding of modifiable NODAT risk factors should guide clinical decision-making processes to help reverse, attenuate or delay the onset or progression of NODAT.

SUMMARY New-onset diabetes after transplantation (NODAT) is a major and frequent complication post-solid-organ transplantation with significant adverse outcomes associated with its development. Focus amongst transplant clinicians has shifted towards strategies to both predict and prevent the onset of NODAT. Our approach to this problem must incorporate both transplant-specific and nonspecific strategies and appreciate the differences between NODAT and diabetes mellitus with regards to pathophysiology, risk factors, clinical course and management. The complexity of these patients warrants cooperation between clinicians involved within both fields of transplantation and diabetes. This article aims to discuss current strategies to reduce the risk of NODAT and proposes future directions for clinical research.

New-onset diabetes after transplantation (NODAT) is a major medical complication associated with solid-organ transplantation, with many adverse clinical outcomes attributed to its development [1–4]. Owing to its considerable prevalence amongst transplant recipients, with up to half of all nondiabetic transplant recipients (range: 2–53%) likely to be diagnosed

with NODAT [5], the associated risk of morbidity, mortality, cost and adverse impact on patient quality of life (see **Figure 1**), attenuating the future risk of developing NODAT has become a clinical priority amongst transplant clinicians. Although there are parallels between such strategies in the transplant recipient and those in the general population, we should hesitate to

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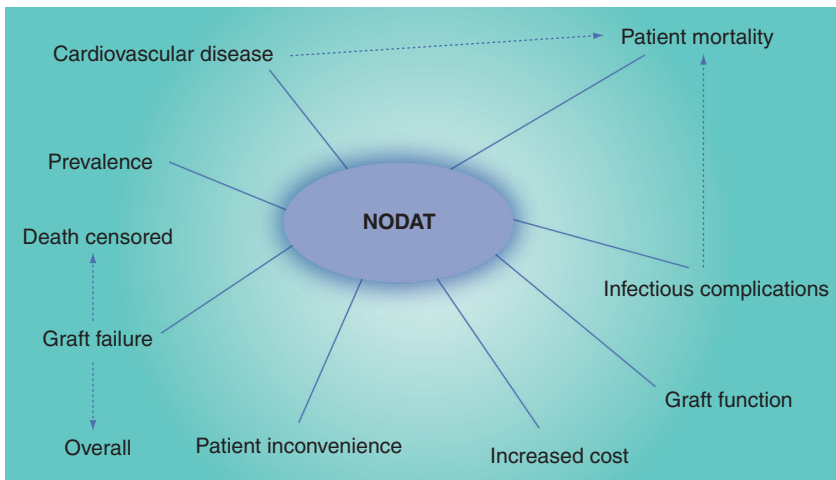


Figure 1. Why reduce the risk of new-onset diabetes after transplantation?
 NODAT: New-onset diabetes after transplantation.

simply translate strategies from one population to another. NODAT and diabetes mellitus have many similarities but there are also important clinical and pathophysiological differences [2] that make transplant recipients a unique high-risk population (see Table 1). Although some of these individuals would have developed diabetes mellitus regardless of solid-organ transplantation, the transplant event itself provides a trigger and exacerbates underlying risk (e.g., similar to gestational diabetes) that justifies the term new-onset diabetes after transplantation (superseding the previously used term post-transplant diabetes mellitus).

Publication of NODAT consensus guidelines in 2003 provided transplant clinicians with clarification regarding screening, diagnosis and management options [6]. Prior to 2003 the diagnosis of NODAT lacked consistency owing to variable diagnostic criteria, center demographics and evolving immunosuppression regimens. The 2003 guidelines provided a consensus amongst transplant clinicians to adopt current American Diabetes Association (ADA) guidelines for the diagnosis of NODAT in line with the diagnosis of diabetes mellitus, and outlined treatment pathways with regards to management. However, in the current climate of new pharmacotherapy and clinical evidence, these guidelines are in need of urgent update with regards to preventative strategies. The purpose of this article is to review the transplantation literature, with the aim of discussing the evidence base behind strategies to reduce the risk of NODAT, and to suggest future directions.

The aim is to assist clinicians in their attempts to devise focused and targeted risk-attenuation strategies for the development of NODAT in these high-risk patients. In the first half, the discussion will focus on how to predict the risk of developing NODAT. In the latter half of the article, the discussion will discuss strategies to attenuate or delay the development of NODAT and the evidence base for such therapeutic measures (see Figure 2).

Prediction of NODAT

■ **Risk factors**

Risk factors for the development of NODAT, both modifiable and non-modifiable, that are either transplant specific or nonspecific have been the subject of a recent comprehensive review [7] and are shown in Box 1. The importance of documenting these risk factors cannot be overstated. Knowledge of non-modifiable risk factors is important as it will allow individualization of immunosuppression to balance both graft and cardio-metabolic outcomes. Modifiable risk factors aid both prediction and prevention of NODAT and will be discussed in the second half of the article under preventative measures. In the context of predicting the risk of NODAT, it would be logical to assume a greater number of risk factors represents a higher likelihood of developing NODAT. In the general population, there are a variety of predictive risk factor models available that have epidemiologically demonstrated the ability to predict for the future risk of Type 2 diabetes mellitus [8]. No similar predictive models exist for a transplant-specific setting and it would be clinically advantageous to devise a specific NODAT predictive model for transplant recipients.

■ **Abnormal glucose metabolism**

Close surveillance of abnormal glycemia, regardless of timing or duration in the context of transplantation, identifies an individual with a heightened risk for the subsequent development of NODAT. Cosio *et al.* demonstrated an almost linear relationship between increasing levels of pre-transplantation fasting glycemia and subsequent post-transplantation risk of either impaired fasting glucose or NODAT [1]. From a postoperative perspective, Chakker *et al.* recently demonstrated a relationship between inpatient hyperglycemia immediately post-transplantation and subsequent risk of developing NODAT [9]. Patients who

maintained normoglycemia whilst in hospital only had a 4% risk of NODAT at 1-year post-transplantation, in contrast with a 30% risk of NODAT for individuals with inpatient hyperglycemia requiring insulin therapy (patients with noninsulin-requiring hyperglycemia had an intermediate risk of developing NODAT of 18%). The considerable risk associated with insulin-requiring hyperglycemia is important as the authors have previously published work demonstrating that 66% of nondiabetic renal transplant recipients required insulin therapy upon discharge post-transplantation [10], although such percentages of insulin-on-discharge have not been observed from my own personal experience. Therefore the occurrence of hyperglycemia in any recipient post-transplantation, even if short term and self-limiting, should alert the clinician to the high-risk status of that individual for the subsequent development of NODAT. It should be highlighted that even self-limiting hyperglycemia that satisfies a diagnosis of diabetes but resolves should be classed as an episode of NODAT in accordance with the 2003 consensus guidelines, to allow appropriate risk stratification to be implemented to attenuate future NODAT risk.

■ **Oral glucose tolerance tests**

The oral glucose tolerance test (OGTT) should be considered the gold-standard diagnostic test post-transplantation on current evidence and diagnostic criteria are similar to the general population as suggested by the ADA (see **Table 2**). Its advantage lies in the ability to identify both fasting and postprandial hyperglycemia. Both are associated with disparate risks for development of diabetes and cardiovascular disease in

the general population [11–13] due to their distinct pathophysiologies [14], with postprandial hyperglycemia having greater predictive power [11,15,16]. Similar epidemiological data for the predictive power of postprandial glucose is not available in transplant recipients and it remains to be seen whether postprandial hyperglycemia is a stronger risk factor than fasting hyperglycemia for clinical outcomes such as NODAT and cardiovascular disease post-transplantation.

The clinical benefit of identifying postprandial hyperglycemia with an OGTT pre-transplantation has been demonstrated by Bergrem and colleagues [17], where a diagnosis of impaired glucose tolerance pretransplantation was associated with a 26% increased risk of developing post-transplantation hyperglycemia. The advantage of an OGTT post-transplantation has been confirmed in a number of publications [18,19], as it can provide greater predictive power than fasting glucose alone by unmasking NODAT with postprandial glucose assessment.

■ **Glycated hemoglobin**

The role of the A1c assay from a screening and risk stratification perspective remains controversial in the general population, with an additional layer of complexity in the context of transplantation. Hoban *et al.* have previously demonstrated glycated hemoglobin to be superior to fasting glucose as a screening test for NODAT in renal transplant recipients [20]. Sharif and Baboolal have commented on the benefits and caveats of utilizing the A1c assay in the context of transplantation [21]. Notably, the accuracy of the assay will be mitigated in the setting of myelotoxic immunosuppression and post-transplantation anemia. However,

Table 1. Comparison of Type 2 diabetes mellitus with new-onset diabetes after transplantation.

Comparator	Type 2 diabetes mellitus	NODAT
Diagnosis	ADA criteria	2003 Consensus guidelines (incorporating ADA criteria)
Pathophysiology	Combination of β-cell dysfunction in context of insulin resistance	Combination of β-cell dysfunction in context of insulin resistance (exacerbated by immunosuppression)
Risk factors	General (e.g., age, obesity, family history and ethnicity)	General (but lack of evidence for some traditional risk like family history) Transplant specific
Management	Clinical evidence from randomized controlled trials	No randomized controlled trials available to guide management
Complications	Micro- and macro-vascular complications well documented	Unclear if similar degree or severity of complications

ADA: American Diabetes Association; NODAT: New-onset diabetes after transplantation.

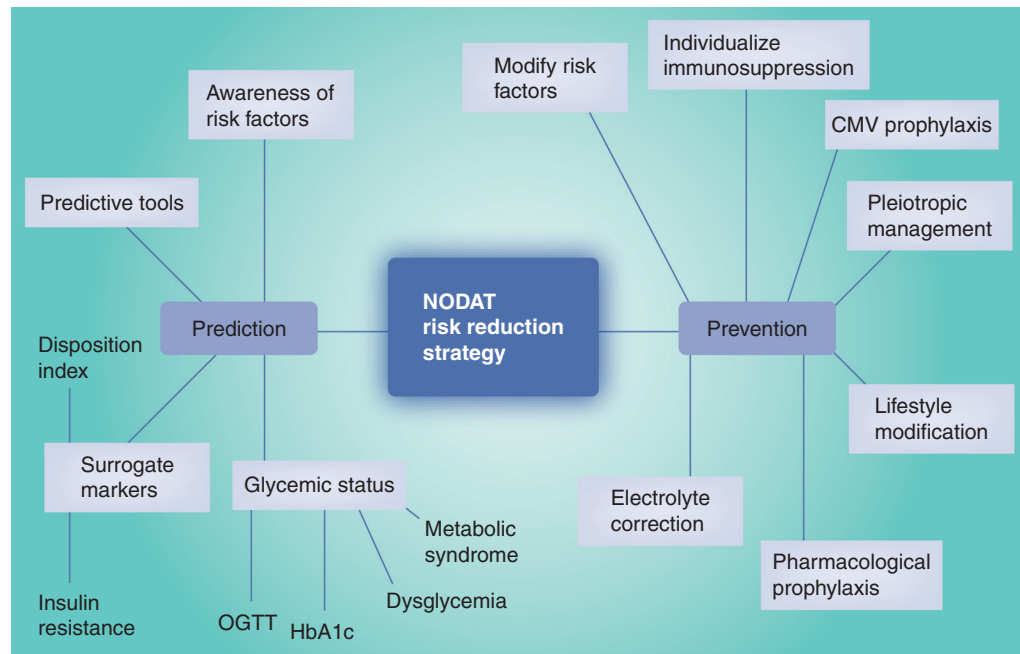


Figure 2. Strategies to reduce risk of new-onset diabetes after transplantation.
 CMV: Cytomegalovirus; NODAT: New-onset diabetes after transplantation; OGTT: Oral glucose tolerance test.

the benefits are likely to outweigh the limitations and further work is required to validate the use of the assay for screening and diagnosis in a post-transplantation setting.

■ **Metabolic syndrome**

The metabolic syndrome is proposed as a cluster of known cardiovascular risk factors, inter-related by a common but speculative pathophysiological defect that symbolizes a heightened metabolic burden. The syndrome is not a disease itself but a marker of metabolic disturbance and a potential risk assessment tool for the development of diabetes and cardiovascular disease. The role of the metabolic syndrome is controversial with regards to NODAT risk stratification. Diagnosing metabolic syndrome in the context of solid-organ transplantation is associated with numerous adverse clinical outcomes and has been the subject of a comprehensive review article [22]. Notably, it is unclear whether there are pathophysiological differences between the metabolic syndrome in the general versus transplant population. There is emerging evidence of the utility of the metabolic syndrome in risk stratifying transplant recipients for future risk of NODAT, whether it is diagnosed pretransplantation [23] or post-transplantation [24]. Whether labeling

transplant recipients with the metabolic syndrome has any clinical benefit over and above the presence of its individual components is unclear, but from an epidemiological viewpoint it certainly identifies high-risk patients who may merit further investigation or closer monitoring.

■ **Insulin resistance indexes**

New-onset diabetes after transplantation is characterized by the development of insufficient insulin secretion by the pancreatic β cell to compensate for the concomitant degree of insulin resistance [25–27]. Therefore, the development of insulin resistance is one of the early pathophysiological defects on the spectrum of dysglycemia and easy identification of deteriorating insulin resistance may be clinically advantageous. Gold standard techniques for assessing insulin sensitivity, such as euglycemic clamps or frequently sampled, intravenous glucose tolerance tests, are laborious and expensive academic tools. However, there are numerous surrogates available for estimation of insulin resistance in the context of transplantation, of which McAuley’s index (calculated as: $\exp [2.63 - 0.28 \ln (\text{insulin [in microunits per milliliter]}) - 0.31 \ln (\text{triglycerides [in millimoles per liter]})]$) has been validated as one of the strongest

correlates (correlation r values ranging from 0.32–0.61; $p < 0.05$) [28,29]. Clinical application of these surrogates are lacking and there is no evidence to suggest continuous monitoring of these surrogates predicts for the development of NODAT.

■ Disposition index

Although surrogate insulin resistance indexes could be useful as screening tools, screening of this pathophysiological phenomenon may be difficult to interpret in isolation. As previously highlighted, NODAT develops due to β -cell dysfunction in the context of insulin resistance. This relationship is quantitatively represented as a mathematical constant (rectangular hyperbola) and qualitatively called the disposition index. In the context of falling insulin sensitivity (increasing insulin resistance), the pancreatic β cell secretes more insulin to compensate in a reciprocal relationship. Despite these metabolic upheavals, the disposition index will remain constant and the patient remains normoglycemic. Only if the pancreatic β cells fails to adequately compensate for the degree of insulin resistance will the metabolic inter-relationship between insulin secretion and sensitivity fail and the disposition index falls, heralding the onset of hyperglycemia [26,30].

Therefore, as a more integrated representation of glycemic metabolism, surrogate markers for the disposition index itself may be better suited to track the evolution of glycemic abnormalities. In the general population, Utzschneider and colleagues demonstrated a surrogate for the disposition index that predicted for the development of future diabetes mellitus over and above that predicted by postprandial glucose [31]. In the transplant population, Sharif *et al.* have produced a surrogate formula for the disposition index ($DI = \text{Insulin}_0 \times [3.33/(\text{glucose}_0 - 3.5)] \times \exp [2.63 - (0.28 \times \ln \{ \text{insulin}_0 / 6.945 \}) - (0.31 \times \ln \text{triglycerides}_0)]$), calculated in standard international units, which correlates well with the intravenous glucose tolerance test-derived disposition index, is statistically consistent with a mathematical hyperbola and is valid in subgroups of transplant recipients [32]. The advantage of the Sharif index compared with the Utzschneider index is the ability to utilize fasting rather than postprandial blood sampling. There is evidence that a high carbohydrate–low glycemic index diet in the general population

can modify the disposition index in patients with impaired glucose tolerance [33]. However, clinical application of this experimental surrogate post-transplantation is awaited and it remains to be seen whether serial monitoring of the disposition index is clinically advantageous.

Prevention of NODAT

■ Tailored immunosuppression

As previously discussed, an awareness of risk factors for NODAT is important for predicting the likelihood of its development [7]. An understanding of non-modifiable risk factors allows individualization of immunosuppressive regimens prior to transplantation, balancing the efficacy of graft survival with minimization of complications. In the current era of

Box 1. Risk factors for new-onset diabetes after transplantation.

Non-modifiable

- Age
- Ethnicity
- Family history of diabetes mellitus?
- *Cause of end-stage renal failure*
- Gender?
- *HLA mismatch?*
- Genetics
- *Innate immunity*
- *Donor characteristics?*
- Education

Modifiable

- Previous stress diabetes
- Obesity
- Metabolic syndrome
- Pre-transplant triglycerides
- *Cytomegalovirus*
- *Hepatitis C*
- *Immunosuppression*
 - Tacrolimus
 - Cyclosporin
 - Sirolimus
 - Corticosteroids
- *Rejection episodes?*
- Antihypertensives
 - β -blockers
 - Thiazide diuretics
- Biochemical abnormalities
 - Magnesium
 - Uric acid?
- Glomerular filtration rate?

Italics represent transplant-specific risk factors.

Table 2. Diagnosis of prediabetes based upon fasting glucose and oral glucose tolerance test (WHO).

Glycemic state	0 h glucose (mmol/l)	2 h glucose (mmol/l)
Normal	<6.1	<7.8
IFG	6.1 [†] –6.9	–
IGT	–	7.8–11.0
NODAT	>6.9	>11.0

[†]5.6–6.9 mmol/l with American Diabetes Association.
 IFG: Impaired fasting glycemia; IGT: Impaired glucose tolerance; NODAT: New-onset diabetes after transplantation.

immunosuppression there exists a variety of regimens providing comparable graft survival that could be appropriate for such patients at high risk of developing NODAT [34]. Examples of strategies with less diabetogenicity currently available include the use of cyclosporin rather than tacrolimus as the calcineurin inhibitor of choice [35], corticosteroid avoidance [36] or corticosteroid-sparing regimens [37]. The task for transplant clinicians is to balance the benefits of less diabetogenic immunosuppression with the potential increased risk of rejection with these strategies. Calcineurin inhibitor-free immunosuppression is one option but has its limitations. Transplant recipients poorly tolerate mTOR inhibitors and incidentally these agents are themselves associated with a risk of NODAT [38]. Newer immunosuppressant agents such as belatacept and tasocitinib are on the horizon, and awaiting regulatory approval, and have been shown to be less diabetogenic with equivalent graft survival, albeit at risk of increased allograft rejection [39,40].

Obesity/metabolic syndrome

Obesity, either alone or as a constituent of the metabolic syndrome, is one of the most important risk factors for the development of NODAT [23]. Putative evidence links pathophysiological mechanisms such as obesity, inflammation and adipocyte dysfunction as risk factors for NODAT [41]. A focus on obesity is important as it is common post-transplantation and associated with detrimental patient and graft outcomes [42]. However, there is currently no evidence to suggest pharmacologically or surgically targeting obesity post-transplantation has any favorable metabolic effects from a glycemic point of view.

With regards to the metabolic syndrome, although it has shown to be a useful risk stratification tool, it remains debateable whether the diagnosis provides any additional therapeutic

advantage over its individual components. Controversy remains as to the merit of the metabolic syndrome [43,44] and what value it has as a therapeutic target. Until a definitive underlying pathophysiological mechanism is elucidated, the metabolic syndrome is likely to remain an epidemiological rather than a clinical or therapeutic tool.

■ **Virus infection**

Cytomegalovirus infection

Hjelmsaeth and colleagues have demonstrated an independent link between cytomegalovirus (CMV) infection and the development of NODAT, with putative mechanisms including direct virus-induced pancreatic β-cell damage [45]. This raises the possibility of prophylactic agents to prevent CMV infection also indirectly attenuating the risk of developing NODAT. Current transplantation practice is to administer 100 days of antiviral prophylaxis (e.g., oral valganciclovir) to patients at high risk for CMV (usually donor CMV positive and recipient CMV negative). The recent Improved Protection Against Cytomegalovirus in Transplant (IMPACT) study explored the benefits of utilizing a 200-day approach compared with 100 days in renal transplant recipients at high risk for NODAT [46]. Although there were advantages with regards to a reduced incidence of CMV with the prolonged 200-day prophylaxis, there was no significant difference in the secondary end point of incidence of NODAT (although the study was not adequately powered for this analysis). It should, however, be noted that not all groups have shown a link between CMV and NODAT and any putative link between the two remains pathophysiologically speculative [47].

Hepatitis C

Studies have shown that recipients with hepatitis C have a greater incidence of NODAT [48–50], although others have shown no statistically significant association and merely a trend [51]. Bloom *et al.* retrospectively performed multivariate logistic regression on 427 renal transplant recipients and identified hepatitis C as an independent risk factor, although a significant interaction existed between hepatitis C status and tacrolimus use [52]. The mechanism by which hepatitis C may cause NODAT is speculative but possible mechanisms suggested include impaired insulin action, defects in glucose

homeostasis secondary to liver disease or insulin resistance [52], with the latter emerging as the strongest causative factor [53]. This raises the possibility of antiviral treatment of hepatitis C attenuating the risk or progression of NODAT, although such evidence is lacking.

■ Correction of biochemical abnormalities

Biochemical abnormalities are common post-transplantation and likely secondary to both immunosuppression and tubular dysfunction (in the context of kidney transplantation). Van Laecke *et al.* demonstrated the detrimental effect of post-transplant hypomagnesemia on glucose metabolism in a retrospective single-center analysis of 254 renal transplant recipients [54]. Although this would suggest magnesium replacement may attenuate abnormal glucose metabolism, the authors paradoxically found the use of magnesium supplements to be associated with a risk of NODAT on a univariate analysis. Apart from hypomagnesemia, other common post-transplant biochemical abnormalities that may be associated with transplant-associated hyperglycemia include hyperuricemia and vitamin D deficiency [55]. Whether correction of any of these factors will attenuate abnormal glucose metabolism post-transplantation is unknown.

■ Antihypertensive therapy

The differing diabetogenicity of hypertensive agents is well documented in the general population, with β -blockers in particular noted for significant diabetogenic effects [56]. In the transplant population, Hjelmessaeth *et al.* observed detrimental effects of β -blockers and thiazide diuretics on glucose metabolism, although this proved nonsignificant in a multivariate analysis [57]. The pathophysiological effect of β -blockers on glucose metabolism post-transplantation may result from adipocyte dysfunction [58]. The choice of antihypertensive agents post-transplantation should be based on benefit on an individual basis but should acknowledge the possible diabetogenic risk attached to each agent in the context of pre-existing diabetic risk.

■ Lifestyle modification

Lifestyle modification has been shown to delay the onset of diabetes in nontransplant populations with abnormal glucose metabolism [59–62]. In a transplantation setting, Sharif *et al.* have demonstrated the successful use of aggressive

lifestyle modifications [63]. Renal transplant recipients with abnormal postprandial glucose metabolism on an OGTT (impaired glucose tolerance and NODAT, $n = 36$) were selected to have aggressive lifestyle modifications (dietician referral, graded exercise program and weight loss advice), whilst renal transplant recipients with normal postprandial glucose metabolism (normal and impaired fasting glucose, $n = 79$) received leaflets advocating healthy lifestyle modifications alone. The dietary meal framework was derived from Diabetes UK advice [101] and consisted of 50% carbohydrate, 25% protein (meat, fish and beans) and 25% fiber (fruit and vegetables). A graded exercise program was commenced with the aim of maintaining 2 h of endurance exercise (e.g., walking, jogging or swimming) per week. Dieticians monitored all dietary and exercise diaries with reinforcement of lifestyle modification advice.

The intensive regimen resulted in a statistically significant reduction in postprandial glucose levels (10.2 mmol/l to 8.7 mmol/l, $\Delta = -15\%$, $p = 0.012$) and improved reclassification of glycaemic status on re-evaluation by OGTT 6 months later. By contrast, simple lifestyle modification advice by leaflets alone in the group with normal glucose tolerance ($n = 79$) resulted in a significant deterioration of postprandial glucose levels (5.9 mmol/l to 6.6 mmol/l, $\Delta = +12\%$, $p = 0.001$) and worse glycaemic status reclassification on follow-up OGTT.

■ Pharmacological prophylaxis for 'high risk' patients

Unlike in the general population [64–66], there is no evidence in the transplant population that the use of glucose-lowering agents as prophylaxis in patients deemed to be high risk for the development of NODAT or cardiovascular disease is beneficial. Randomized controlled trials targeting nondiabetic transplant recipients should be actively encouraged. In the context of overlapping metabolic disorders with shared pathophysiological mechanisms, it could be hypothesized that antiobesity or lipid-lowering agents may be beneficial owing to putative indirect effects on glucose metabolism, so-called pleiotropic effects.

■ Statins for pleiotropic benefits

Prasad *et al.* putatively suggested the link between the use of 3-hydroxy-3-methylglutaryl-coenzyme A reductase inhibitors (statins) and a

reduced incidence of NODAT in a retrospective analysis of 314 renal transplant recipients [67]. Based on this hypothesis, Sharif *et al.* conducted a randomized controlled, double-blind, placebo-controlled crossover study comparing the effects of rosuvastatin 10 mg once daily and placebo in 20 nondiabetic renal transplant recipients with an indication for statin treatment [68]. Physiological parameters of glucose metabolism were assessed with the use of a frequently sampled, intravenous, glucose tolerance test and a meal tolerance test at the end of a 12-week crossover in each arm. Despite being an effective lipid-lowering agent and with clinically but not statistically significant anti-inflammatory action, the study demonstrated no significant influence of short-term rosuvastatin treatment on any physiological parameters of pancreatic β -cell function and insulin sensitivity. It could be argued that the pleiotropic effects of statin treatment only manifest after long-term administration, but in the absence of any clear evidence this hypothesis remains pure speculation.

Conclusion

This article highlights our current understanding on the strategies available for predicting and preventing the development of NODAT. In view of the significant advances made in both our knowledge base and available pharmacological armamentarium, it provides a clinical update to outdated NODAT guidelines. Although there remains a lack of randomized controlled trials, clinicians are in a better position today to make informed decisions regarding the prevention, attenuation and management of transplant-associated hyperglycemia in a clinical setting. We hope the summary provided here not only guides risk reduction of NODAT, but inspires further research and clinical trials into preventative strategies focussing specifically on solid-organ transplant recipients.

New-onset diabetes after transplantation is a major complication of solid-organ transplantation with associated morbidity, mortality and financial cost. Appropriate risk stratification should lead to adequate strategies to attenuate the risk of the development of NODAT – this requires close attention to risk factors for NODAT on an individual basis. Attention must be given to targeted research on the pathophysiology, progression and management of NODAT as simple translation of clinical data from the general population may not be appropriate. With

patient expectations of a successful allograft heightened in the current era, focusing on attenuating the adverse complications of solid-organ transplantation, such as NODAT, will dominate the direction of transplantation medicine in the years to come.

Future perspective

Interest in this area is likely to direct attention to strategies attenuating the development of NODAT and focusing on how to predict and prevent NODAT. With regards to attenuating abnormal glycemic metabolism, it is clear that NODAT has many similarities but also important differences with diabetes mellitus and that simple translation of research from the general to transplant population should be avoided. Focused and targeted clinical trials are specifically required in this high-risk population to help guide strategies to both predict and prevent development of NODAT, including prophylaxis for high-risk recipients and targeting of obesity and the metabolic syndrome. Collaborations between transplant clinicians and diabetologists should therefore be encouraged to ensure transplant recipients receive optimum care for transplant-associated hyperglycemia. Evolving research domains such as utilizing genomics and genetic polymorphisms to identify high-risk population groups are likely to add to the knowledge base of NODAT risk stratification and will help shed light on some of the pathophysiological mysteries associated with the disease.

Transplant-specific randomized controlled trials are required to assess the potential for pharmacological prophylaxis to prevent the onset of NODAT in high-risk groups. Some agents such as metformin may be suitably attractive for their weight neutral properties, but close attention would need to be given to potential side effects. With the number of transplant recipients on the increase, future projects should be planned for by clinicians today.

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