



Update of the KDOQI™ Clinical Practice Guideline for Diabetes and Chronic Kidney Disease

Running head: Diabetes Guideline Update

PUBLIC REVIEW DRAFT 2012

DISCLAIMER

SECTION I: USE OF THE CLINICAL PRACTICE GUIDELINE

This Clinical Practice Guideline document is based upon the best information available as of December 2011. It is designed to provide information and assist decisionmaking. It is not intended to define a standard of care, and should not be construed as one, nor should it be interpreted as prescribing an exclusive course of management. Variations in practice will inevitably and appropriately occur when clinicians take into account the needs of individual patients, available resources, and limitations unique to an institution or type of practice. Every health-care professional making use of these recommendations is responsible for evaluating the appropriateness of applying them in the setting of any particular clinical situation. The recommendations for research contained within this document are general and do not imply a specific protocol.

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REFERENCE KEYS

CURRENT CKD NOMENCLATURE USED BY KDOQI

CKD Categories	Definition
CKD	CKD of any stage (1–5), with or without a kidney transplant, including both non–dialysis dependent CKD (CKD 1–5ND) and dialysis-dependent CKD (CKD 5D)
CKD ND	Non–dialysis-dependent CKD of any stage (1–5), with or without a kidney transplant (i.e., CKD excluding CKD 5D)
CKD T	Non–dialysis-dependent CKD of any stage (1–5) with a kidney transplant
Specific CKD Stages	
CKD 1, 2, 3, 4	Specific stages of CKD, CKD ND, or CKD T
CKD 3-4, etc.	Range of specific stages (e.g., both CKD 3 and CKD 4)
CKD 5D	Dialysis-dependent CKD 5
CKD 5HD	Hemodialysis-dependent CKD 5
CKD 5PD	Peritoneal dialysis–dependent CKD 5

NOMENCLATURE AND DESCRIPTION FOR RATING GUIDELINE RECOMMENDATIONS

Within each recommendation, the strength of recommendation is indicated as **Level 1**, **Level 2**, or **Not Graded**, and the quality of the supporting evidence is shown as **A**, **B**, **C**, or **D**.

Grade	Implications		
	Patients	Clinicians	Policy
Level 1 “We recommend”	Most people in your situation would want the recommended course of action and only a small proportion would not.	Most patients should receive the recommended course of action.	The recommendation can be evaluated as a candidate for developing a policy or a performance measure.
Level 2 “We suggest”	The majority of people in your situation would want the recommended course of action, but many would not.	Different choices will be appropriate for different patients. Each patient needs help to arrive at a management decision consistent with her or his values and preferences.	The recommendation is likely to require a substantial debate and involvement of stakeholders before policy can be determined.

* The additional category “Not Graded” was used, typically, to provide guidance based on common sense or where the topic does not allow adequate application of evidence. The most common examples include recommendations regarding monitoring intervals, counseling, and referral to other clinical specialists. The ungraded recommendations are generally written as simple declarative statements, but are not meant to be interpreted as being stronger recommendations than Level 1 or 2 recommendations.

Grade	Quality of evidence	Meaning
A	High	We are confident that the true effect lies close to that of the estimate of the effect.
B	Moderate	The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.
C	Low	The true effect may be substantially different from the estimate of the effect.
D	Very low	The estimate of effect is very uncertain, and often will be far from the truth.

ABBREVIATIONS AND ACRONYMS

4D	Deutsche Diabetes Dialyse Studie
4S	Scandinavian Simvastatin Survival Study
ACCORD	Action to Control Cardiovascular Risk in Diabetes
ACE	Angiotensin-converting enzyme
ADA	American Diabetes Association
AddIT	Adolescent type 1 diabetes mellitus cardio-renal Intervention Trial
ADVANCE	Action in Diabetes and Vascular Disease: Preterax and Diamicron Modified Release Controlled Evaluation
ALERT	Assessment of Lescol in Renal Transplant trial
ALTITUDE	Aliskiren Trial in Type 2 Diabetes Using Cardio-Renal Endpoints
ARB	Angiotensin receptor blocker
AURORA	A study to evaluate the use of Rosuvastatin in subjects on regular hemodialysis: an assessment of survival and cardiovascular events
AVOID	Aliskiren in the Evaluation of Proteinuria in Diabetes
BP	Blood pressure
CARDS	Collaborative Atorvastatin Diabetes Study
CARE	Cholesterol and Recurrent Events
CI	Confidence interval
CKD	Chronic kidney disease
CVD	Cardiovascular disease
DAIS	Diabetes Atherosclerosis Intervention Study
DCCT	The Diabetes Control and Complications Trial
DKD	Diabetic kidney disease
DM	Diabetes mellitus
DPP-4	Dipeptidyl peptidase-4
EDIC	Epidemiology of Diabetes Interventions and Complications
eGFR	Estimated glomerular filtration rate
ESKD	End-stage kidney disease
FDA	Food and Drug Administration
FIELD	Fenofibrate Intervention and Event Lowering in Diabetes
GBM	Glomerular basement membrane
GFR	Glomerular filtration rate
GLP-1	Glucagon-like-peptide-1
GlycoHb	Glycohemoglobin
HbA1c	Hemoglobin A1c
HDL-C	High-density lipoprotein cholesterol
HOPE	Heart Outcomes Prevention Evaluation
HPS	Heart Protection Study
HR	Hazard ratio
JNC	Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure
KDIGO	Kidney Disease: Improving Global Outcomes
KDOQI™	Kidney Disease Outcomes Quality Initiative™
KQ	Key question
LDL-C	Low-density lipoprotein cholesterol
LIPID	Long-term Intervention with Pravastatin in Ischemic Disease
LPD	Lower-protein diet
LVH	Left ventricular hypertrophy
MICROHOPE	Microalbuminuria, Cardiovascular, and Renal Outcomes in Heart Outcomes Prevention Evaluation
NHANES III	Third National Health and Nutrition Examination Survey
NIH	National Institutes of Health
NKF	National Kidney Foundation
NPH	Neutral Protamine Hagedorn
RAS	Renin-angiotensin system
RR	Relative risk
SCr	Serum creatinine

SHARP	Study of Heart and Renal Protection
TBM	Tubular basement membrane
TNT	Treating to New Targets
UKPDS	UK Prospective Diabetes Study
USRDS	United States Renal Data System
VADT	Veterans Affairs Diabetes Trial
VA-HIT	Veterans' Affairs High-Density Lipoprotein Intervention Trial
vs	Versus
WOSCOPS	West of Scotland Coronary Prevention Study

EXECUTIVE SUMMARY

INTRODUCTION

Chronic kidney disease (CKD) is a worldwide public health problem that affects millions of people from all racial and ethnic groups. Diabetes is the leading cause of CKD, and the rapidly increasing prevalence of diabetes worldwide virtually assures that the proportion of CKD attributable to diabetes will continue to rise. Indeed, a recent report from the National Health and Nutrition Education Survey (NHANES) found that prevalence of diabetic kidney disease (DKD) increased steadily from 1988 through 2008, and the latest United States Renal Data System (USRDS) report indicates a ~30% increase in incidence of end stage kidney disease (ESKD) in persons with diabetes in the USA between 1992 and 2008 (1, 2).

In 1997, as part of an effort to address the growing problem of CKD, the National Kidney Foundation (NKF) established the Kidney Disease Outcomes Quality Initiative (KDOQI™) to develop clinical practice guidelines for the management of all stages of CKD (3). By 2007, with the publication of the KDOQI™ Clinical Practice Guidelines and Clinical Practice Recommendations for Diabetes and Chronic Kidney Disease (4), the KDOQI™ reached its primary goal of producing evidence-based guidelines on the aspects of CKD most likely to improve care for patients (5). To ensure that practitioners and patients benefit from the latest knowledge, an essential part of KDOQI™ activities is to provide regular updates of these guidelines.

Since publication of the diabetes guidelines in 2007, several large well-designed clinical trials have addressed management issues relevant to patients with diabetes and CKD. Findings from these trials suggest that the existing guideline recommendations for the management of hyperglycemia, hypertension, hyperlipidemia, and albuminuria may no longer accurately reflect current medical knowledge. To properly incorporate the new findings from these clinical trials and other recent studies into a guideline update, a systematic review of the new evidence was warranted to formally determine their applicability and methodologic quality.

This report describes updates of guidelines for the management of hyperglycemia, hyperlipidemia and albuminuria in patients with diabetes and kidney disease as a result of this systematic review. An update of the guideline for management of blood pressure is presently underway by Kidney Disease: Improving Global Outcomes (KDIGO), a sister organization managed by the NKF, but organized as an independent not-for-profit foundation governed by its own international board of directors. KDIGO was established to improve international cooperation in the development, dissemination, and implementation of clinical practice guidelines (6). KDOQI™ and KDIGO work in concert to expand the scope of guidelines relevant to the care of patients with CKD and improve the care of these patients worldwide (5).

METHODS

The guideline update effort was a voluntary and multidisciplinary undertaking that included input from NKF scientific staff, an evidence review team from the Minneapolis Veterans Administration Center for Chronic Disease Outcomes Research, and a Work Group of experts in relevant disciplines. The approach to the systematic literature review and the comprehensive findings prepared for this update was reported in detail elsewhere (7). Briefly, MEDLINE was searched to identify randomized controlled trials published between January 2003 and October 2010 that related to

albuminuria, glycemic and lipid management in patients with diabetes. All titles and abstracts were assessed for their appropriateness to address key questions that were developed by the multidisciplinary team and outlined in **Figure 1**. Study reference lists, reviews, and meta-analyses were evaluated and references to other clinical trials were elicited from members of the Work Group. Data from each study that pertained to study quality, trial characteristics, population characteristics, efficacy outcomes, withdrawals, and adverse events were extracted. Evidence tables were created to address the key questions. Study quality was rated as good, fair or poor according to criteria suggested by the Cochrane Collaboration, and included adequate allocation concealment, method of blinding, use of the intention-to-treat principle for data analysis, reporting of dropouts, and reasons for attrition.

KQ 1:	In patients with diabetes (type 1 or 2), with or without CKD, does intensive glycemic control (as defined by lower target glycosylated hemoglobin) improve health outcomes compared to controls?
KQ 2:	What harms result from more intense glycemic control in individuals with diabetes (type 1 or 2)?
KQ 3:	In patients with diabetes (type 1 or 2) and chronic kidney disease, what evidence is there for specific lipid management targets (defined as goals for total cholesterol, LDL, HDL, triglycerides) that improve health outcomes?
KQ 4:	Is there evidence for specific lipid altering agent use for patients with diabetes (type 1 or 2) and chronic kidney disease?
KQ 5:	What harms result from more intense lipid management or use of specific lipid altering agents in individuals with diabetes (type 1 or 2) and CKD?
KQ 6:	What interventions prevent incident albuminuria and/or progression of albuminuria in patients with diabetes mellitus in whom further reduction in blood pressure is not the specific treatment objective?
KQ 7:	Is albuminuria a valid surrogate for health outcomes in diabetes?

Figure 1. Key questions (KQ) to be addressed by the evidence review.

In formulating the guideline statements, separate Recommendation level (1 or 2) grades were assigned for each specific recommendation based on the overall quality of the evidence for a particular intervention and outcome (**Tables 1 and 2**) (8). The overall quality and strength of evidence was assessed using methodology developed by the Agency for Healthcare Research and Quality and the Effective Health Care Program. Quality of evidence ratings included four categories: 1) high confidence, which indicated that further research was unlikely to change the confidence in the estimate of effect; 2) moderate confidence, which indicated that further research may change the confidence in the estimate of effect; 3) low confidence, which indicated that further research would likely have an important impact on the confidence in the estimate of effect; and 4) insufficient, which indicated that the evidence was unavailable or did not permit a conclusion. The strength of guideline recommendations was determined by a four-tiered letter grade: A) high-quality evidence that the practice improves health outcomes; B) moderate-quality evidence; C) low-quality evidence; and D) very low quality evidence (8).

Table 1. Grade for the strength of recommendation in the Diabetes and Chronic Kidney Disease Guideline

Grade*	Implications		
	Patients	Clinicians	Policy
Level 1 'We recommend'	Most people in your situation would want the recommended course of action and only a small proportion would not.	Most patients should receive the recommended course of action.	The recommendation can be adopted as a policy in most situations.
Level 2 'We suggest'	The majority of people in your situation would want the recommended course of action, but many would not.	Different choices will be appropriate for different patients. Each patient needs help to arrive at a management decision consistent with her or his values and preferences.	The recommendation is likely to require debate and involvement of stakeholders before policy can be determined.

* The additional category 'Not Graded' was used, typically, to provide guidance based on common sense or where the topic does not allow adequate application of evidence. The most common examples include recommendations regarding monitoring intervals, counseling, and referral to other clinical specialists. The ungraded recommendations are generally written as simple declarative statements, but are not meant to be interpreted as being stronger recommendations than Level 1 or 2 recommendations.

Table 2. Grade for quality of evidence in the Diabetes and Chronic Kidney Disease Guideline

A: High quality of evidence. We are confident that the true effect lies close to that of the estimate of the effect.
B: Moderate quality of evidence. The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.
C: Low quality of evidence. The true effect may be substantially different from the estimate of the effect.
D: Very low quality of evidence. The estimate of effect is very uncertain, and often will be far from the truth.

Outcomes

The primary health outcome examined in this review was all-cause mortality. Secondary health outcomes included ESKD and cardiovascular death, non-fatal cardiovascular events, clinically significant retinopathy including vision loss, amputations, and symptomatic hypoglycemia of sufficient severity to require the assistance of another person. Intermediate outcomes examined included changes in the level of albuminuria and glomerular filtration rate, doubling of serum creatinine concentration, and progression to $\geq$ stage 4 CKD (7). The impact of treatments described in the recent clinical trials on these health and intermediate outcomes was assessed in formulating the guideline statements.

Nomenclature

Guideline statements have evolved since the publication of the original diabetes guideline. The moral imperative that clinicians "should" implement a particular treatment was replaced by "We recommend" if the strength of the recommendation was strong or moderately strong and "We suggest"

if the strength of the recommendation was weak (8). This change was made to reflect the uncertainties inherent to all research findings and the need to adjust any recommendations to the needs of the individual patient.

GUIDELINE STATEMENTS

The customary practice of the NKF when the original diabetes guideline was published was to divide the statements into clinical practice guidelines and clinical practice recommendations. The guideline statements were based on a consensus with the Work Group that the strength of the evidence was sufficient to make definitive statements about appropriate clinical practice. When the strength of the evidence was not sufficient to make such statements, the Work Group offered recommendations based on the best available evidence and expert opinion. The original document contained five clinical practice guidelines and four clinical practice recommendations; updates for two clinical practice guidelines and one clinical practice recommendation are reported herein. The NKF now combines these statements and refers to them all as a clinical practice guideline, while specifying the strength of each recommendation and its underlying quality of evidence. Hence, Clinical Practice Recommendation 1 in the original document is now referred to as Clinical Practice Guideline 6 in this update.

SUMMARY OF RECOMMENDATIONS

GUIDELINE STATEMENTS

Guideline 2: Management of Hyperglycemia and General Diabetes Care in CKD

Hyperglycemia, the defining feature of diabetes, is a fundamental cause of vascular target organ complications, including diabetic kidney disease (DKD). Intensive treatment of hyperglycemia prevents elevated albuminuria or delays its progression, but patients treated by approaches designed to achieve near normal glycemia are at increased risk of severe hypoglycemia. Evidence that intensive treatment has an effect on loss of GFR is sparse.

- 2.1 We recommend a target hemoglobin A1c (HbA1c) of ~7.0% to prevent or delay progression of the microvascular complications of diabetes, including DKD. (1A)
- 2.2 We recommend not treating to an HbA1c target of <7.0% in patients at risk of hypoglycemia. (1B)
- 2.3 We suggest a target HbA1c >7.0% in patients with co-morbidities or limited life expectancy. (2C)

Guideline 4: Management of Dyslipidemia in Diabetes and CKD

Dyslipidemia is common in people with diabetes and CKD. Cardiovascular events are a frequent cause of morbidity and mortality in this population. Lowering low-density lipoprotein cholesterol (LDL-C) with statin-based therapies reduces risk of major atherosclerotic events, but not all-cause mortality, in patients with CKD including those with diabetes.

- 4.1 We recommend using LDL-C lowering medicines, such as statins or statin/ezetimibe combination, to reduce risk of major atherosclerotic events in patients with diabetes and CKD, including those who have received a kidney transplant. (1B)
- 4.2 We recommend not initiating statin therapy in patients with diabetes who are treated by dialysis. (1B)

Guideline 6: Management of Albuminuria in Normotensive Patients with Diabetes

Treatments that produce a lasting decrease in urinary albumin excretion may slow the progression of DKD even in the absence of hypertension. However, most people with diabetes and albuminuria have hypertension. Management of hypertension is addressed in Guideline 3 and the KDIGO Clinical Practice Guideline for Management of Blood Pressure in Chronic Kidney Disease.

- 6.1 We recommend not using an angiotensin-converting enzyme (ACE) inhibitor or an angiotensin receptor blocker (ARB) in normotensive normoalbuminuric patients with diabetes. (1A)
- 6.2 We suggest use of an ACE inhibitor or an ARB in normotensive patients with diabetes and albuminuria levels ≥ 30 mg/g. (2C)

GUIDELINE 2: MANAGEMENT OF HYPERGLYCEMIA AND GENERAL DIABETES CARE IN CKD

Hyperglycemia, the defining feature of diabetes, is a fundamental cause of vascular target organ complications, including diabetic kidney disease (DKD). Intensive treatment of hyperglycemia prevents elevated albuminuria or delays its progression, but patients treated by approaches designed to achieve near normal glycemia are at increased risk of severe hypoglycemia. Evidence that intensive treatment has an effect on loss of GFR is sparse.

2.1: We recommend a target HbA1c of ~7.0% to prevent or delay progression of the microvascular complications of diabetes, including DKD. (1A)

The evidence that achieving a hemoglobin A1c (HbA1c) level of ~7.0% is able to prevent the microvascular complications of diabetes was presented in detail in the original KDOQI diabetes guideline (4). For type 1 diabetes, evidence from the Diabetes Control and Complications Trial (DCCT) (9, 10), as well as from a meta-analysis of a number of smaller studies that preceded the DCCT (11), established that this level of glycemic control decreases the risk of microalbuminuria and retinopathy compared to less stringent control. The beneficial effects of intensive therapy on these outcomes persisted during the long-term follow-up study of the DCCT subjects, called the Epidemiology of Diabetes Interventions and Complications (EDIC) Study. Despite the gradual narrowing of the difference in HbA1c levels between the two DCCT groups over the first two years in the follow-up period, and levels remaining near 8% for both groups for the subsequent 12 years, the reduction in risk of microvascular complications of diabetes persisted. (12). Similar benefits of glycemic control on the development of microalbuminuria in patients with type 2 diabetes were originally observed in three studies; the Kumamoto Study (13, 14), the United Kingdom Prospective Diabetes Study (UKPDS) (15, 16), and the Veterans Affairs Cooperative Study on Glycemic Control and Complications in Type 2 Diabetes Feasibility Trial (17). Intensive glycemic control also significantly reduced the development of macroalbuminuria in patients with type 1 diabetes, as shown in the DCCT/EDIC Study (9, 10, 12) as well as the similarly designed but smaller Stockholm study (18), and in those with type 2 diabetes, as shown in the Kumamoto study (13, 14) and the VA Cooperative Study (17). The UKPDS showed a trend toward decreased development of macroalbuminuria, but this result did not achieve statistical significance (15, 16).

Three new studies have added to the evidence that even more intensive glycemic control reduces the development of elevated albuminuria in patients with type 2 diabetes. In the Action in Diabetes and Vascular Disease: Preterax and Diamicon Modified Release Controlled Evaluation (ADVANCE) trial, more intensive control that achieved an HbA1c of 6.5%, compared with standard control (HbA1c 7.3%) was associated with a 21% reduction in new onset or worsening nephropathy defined by new onset macroalbuminuria, doubling of serum creatinine, need for kidney replacement therapy, or death due to kidney disease (4.1% vs. 5.2%). Additionally, intensive glycemic control reduced development of macroalbuminuria by 30% (2.9% vs. 4.1%), and development of new onset microalbuminuria by 9% (23.7% vs. 25.7%) (19). The Action to Control Cardiovascular Risk in Diabetes (ACCORD) study similarly showed that more intensive control, achieving an HbA1c of 6.3%, compared with standard control (HbA1c 7.6%), resulted in a 32% reduction in the development of incident macroalbuminuria (2.7 vs. 3.9%) and a 21% reduction in the development of incident microalbuminuria (12.5% vs. 15.3%) (20). In the Veterans Affairs Diabetes Trial (VADT), more intensive glycemic control that achieved an HbA1c of 6.9% compared with standard control (HbA1c 8.4%) resulted in a 37% reduction in macroalbuminuria (7.6% vs. 12.1%) and a 32% reduction in microalbuminuria (10.0% vs. 14.7%) (21).

A few long-term observational cohort studies and secondary or post hoc analyses of interventional studies using ACE inhibitors (ACE-I) or ARBs found that poorer glycemic control is associated with a greater rate of fall of GFR in patients with type 1 diabetes (22-26). Most of the prospective, randomized studies used as evidence for the effect of glycemic control on kidney function are limited by the small numbers of patients reaching this intermediate outcome. However, the EDIC/DCCT follow-up study recently reported that 2.0% (1.6/1000 person-years) of participants in the previously intensive treatment group and 5.5% (3.0/1000 person-years) of those in the previously conventional treatment group developed sustained eGFR measurements <60 ml/min/ m^2 with a relative risk reduction of 50% ($p=0.006$); there were similar relative risk reductions for single eGFR measurements <45 ml/min/ $1.73m^2$ (50%, 1.6/1000 person-years versus 2.5/1000 person-years, $p=0.045$) and <30 ml/min/ $1.73m^2$ (44%, 0.8/1000 person-years versus 1.5/1000 person-years, $p=0.088$) and for ESKD (51%, 0.5/1000 person-years versus 1.1/1000 person-years, $p=0.098$) (27). For patients with type 2 diabetes, intensive treatment in the UKPDS was associated with a 67% risk reduction for a doubling of plasma creatinine levels at 9 years (0.71% of the intensive group and 1.76% of the conventional group, $p=0.027$) (15). None of the three more recent studies mentioned above (ADVANCE, ACCORD, VADT) showed significant benefits of more intensive glycemic control on creatinine-based estimates of GFR (19-21).

Accordingly, the evidence that intensive glycemic control reduces the microvascular complications of diabetes is based almost exclusively on prevention of microalbuminuria (a predictor of actual complications), reduced progression to macroalbuminuria, and on prevention of retinopathy. Evidence for the prevention of other intermediate microvascular outcomes, including declining estimated GFR (eGFR) and doubling of serum creatinine, is sparse. Although there is no evidence that intensive glycemic control slows progression to the clinical endpoint of ESKD, it is likely that if the earlier manifestations of nephropathy are reduced (i.e., albuminuria and earlier-stage CKD), then the eventual outcome of ESKD will also be reduced. However, such assumption presumes that benefits of intensive glycemic control are not outweighed by harms and that patients survive to reach ESKD.

2.2: We recommend not treating to an HbA1c target of $<7.0\%$ in patients at risk of hypoglycemia. (1B)

The major risk for patients attaining HbA1c levels $<7.0\%$ is hypoglycemia. This risk is particularly evident for patients with type 1 diabetes being treated with insulin (9, 18, 28). Although the Kumamoto Study and UKDPS also demonstrated an increased risk in those with type 2 diabetes being treated with insulin (14, 15), the magnitude of the risk was considerably less. The UKPDS also showed that sulfonylureas are associated with a small risk of hypoglycemia (15). The three most recent clinical trials (ADVANCE, ACCORD, and VADT) all showed substantial increases (range 1.5 – 3 fold) in severe and non-severe hypoglycemia among patients with type 2 diabetes with more intensive therapy. Targets for conventional and intensive glycemic therapy and the mean achieved HbA1c levels in these clinical trials are shown in Table 3. Intensifying glycemic control beyond current conventional management did not result in decreased risk of composite cardiovascular endpoints in any of these studies (19, 21, 29). Moreover, there was an increase in all-cause mortality in the intensively treated group compared to the conventionally treated group in the ACCORD study (29). The reasons for this finding are uncertain, although further analysis showed that increased mortality was not directly attributable to hypoglycemia (30). Therefore, lowering HbA1c to levels $<7.0\%$ is not recommended in patients with diabetes who are at risk for hypoglycemia, particularly those being treated with insulin or sulfonylureas. Moreover, the risk of hypoglycemia is increased in patients with diabetes with CKD, especially for those with substantial decreases in eGFR (CKD stages 4 and 5).

Table 3. Target and achieved HbA1c levels in the intensively and conventionally treated groups of three recent clinical trials that examined different levels of glycemic control in patients with type 2 diabetes

Study	Intensive Treatment		Conventional Treatment	
	Target	Achieved	Target	Achieved
ADVANCE (19)	<6.5%	6.5%	unspecified	7.3%
ACCORD (29)	<6.0%	6.4%	7-9%	7.5%
VADT (21)	<6.0%	6.9%	<9%	8.4%

2.3: We suggest a target HbA1c >7.0% in patients with co-morbidities or limited life expectancy. (2C)

Several years of intensive glycemic control (HbA1c ~ 7%) are required before the benefits to retinopathy, nephropathy, neuropathy, and several manifestations of cardiovascular disease (CVD) become evident (9, 10, 15, 16). An even longer time period is necessary before changes in such intermediate outcomes translate into meaningful clinical endpoints, such as kidney failure, blindness, amputations, or cardiovascular events. Therefore, when instituting intensive therapy for hyperglycemia in patients with limited life expectancy, the potential benefits must be balanced against the risks, especially when insulin is administered. With intensified insulin treatment, increased risk of hypoglycemia is accompanied by weight gain as well as the cost and inconvenience of multiple injections and frequent blood glucose monitoring. In individuals 70-79 years of age who are taking insulin, the probability of falls begins to increase with HbA1c <7% (31). Moreover, in patients with type 2 diabetes, one study showed that the presence of co-morbidities abrogates many of the benefits of lower HbA1c levels on cardiovascular events (32). It is important to recognize that CKD characterized by substantial decreases in eGFR (CKD stages 4 and 5) is a major co-morbidity for patients with diabetes. Therefore, a target HbA1c of >7.0% is suggested for patients with clinically-significant co-morbidities, including advanced CKD, or limited life expectancy.

Importantly, risks of microvascular complications are amplified with progressively increasing levels of HbA1c. Therefore, moderately intensive glycemic control, albeit not overly intensive, is fundamental to optimal diabetes care. The achieved HbA1c values were 7.3-8.4% among the conventional treatment groups in the three most recent clinical trials of patients with type 2 diabetes (ADVANCE, ACCORD, and VADT). Patients treated in the conventional manner were less likely to experience hypoglycemia, while risks of major clinical endpoints (all-cause mortality, CVD mortality, non-fatal CVD endpoints, and loss of kidney function or ESKD) were similar to those treated intensively.

LIMITATIONS

Recommendations regarding glycemic control in patients with diabetes and CKD are based primarily on reductions in the appearance and progression of albuminuria, yet the relationship between elevated albuminuria and clinical endpoints is often discordant. Less is known about appropriate glycemic control in patients with diabetes and more advanced CKD, because no prospective, randomized clinical trials evaluating the level of glycemic control on health outcomes have been carried out in patients with CKD Stages 3 – 5. Extended follow-up of patients with type 1 diabetes in

DCCT/EDIC showed a small beneficial effect of prior intensive therapy on later CKD endpoints but the numbers of patients were small. A recent observational, claims-based study in people with type 1 or type 2 diabetes and CKD (33) reported a U-shaped relationship between HbA1c level and risk of death, with deaths increasing significantly for HbA1c levels below 6.5% and above 8% over nearly 4 years of follow-up. Risks of doubling of serum creatinine, ESRD, CVD events, and hospitalization increased in a graded manner with higher levels of HbA1c.

HbA1c levels of ~7-9% are associated with better outcomes for survival, hospitalization, and CVD in patients on hemodialysis in some (34-38) but not all observational studies (39, 40); however, this relationship has not been tested in prospective, randomized studies. Nevertheless, patients with diabetes who are treated by dialysis or kidney transplant may continue to benefit from good glycemic control because of reductions in eye and neurologic outcomes. Complicating glycemic management in patients with diabetes and advanced CKD, however, are the many new medicines now available for glycemic control; some which are potentially useful and others which are harmful due to reduced clearance of the drug or its metabolites by the kidneys.

IMPLEMENTATION ISSUES

Special Considerations in Advanced CKD

The risk of hypoglycemia is increased in patients with substantial decreases in eGFR (CKD stages 4 and 5) for two reasons: (1) decreased clearance of insulin and of some of the oral agents used to treat diabetes and (2) impaired renal gluconeogenesis. With reduced kidney mass, the amount of gluconeogenesis carried out by the kidney is decreased (41). This reduction in gluconeogenesis may reduce the ability of a patient who is becoming hypoglycemic as a result of excessive insulin/oral agent dosing or lack of food intake to defend against hypoglycemia. However, this effect is difficult to quantify. About one-third of insulin degradation is carried out by the kidneys and impairment of kidney function is associated with a prolonged half-life of insulin. Patients with type 1 diabetes receiving insulin who have significant creatinine elevations (mean 2.2 mg/dl) have a 5-fold increase in the frequency of severe hypoglycemia (42, 43). Therefore, it is imperative that patients being treated intensively monitor their glucose levels closely and reduce their doses of medicine as needed to avoid hypoglycemia.

Progressive falls in kidney function result in decreased clearances of the sulfonylureas or their active metabolites (44-46), necessitating a decrease in drug dosing to avoid hypoglycemia. **Table 4** provides recommendations for drug dosing of medicines used to treat hyperglycemia in patients with CKD. First generation sulfonylureas (e.g., chlorpropamide, tolazamide and tolbutamide) should be avoided altogether in patients with CKD, as these agents rely on the kidney to eliminate both the parent drug and active metabolites, resulting in increased half-lives and the risk of hypoglycemia. Of the second-generation sulfonylureas (e.g., glipizide, glyburide and glimepiride), glipizide is the preferred agent as it does not have active metabolites and does not increase the risk of hypoglycemia in patients with CKD. An increase in the levels of the active metabolite of nateglinide occurs with decreased kidney function (47, 48), but this increase does not occur with the similar drug, repaglinide (49). On the other hand repaglinide can accumulate when the GFR ≤ 30 ml/min/1.73m² (49). Although hypoglycemia has not been demonstrated to increase substantially with progressive falls in GFR (49, 50), it would seem prudent to start with a 0.5 mg dose of repaglinide with each meal and titrate upwards cautiously when the GFR is <30 ml/min/1.73m². Similarly, nateglinide should be used with caution when the GFR is <30 ml/min/1.73m², starting with 60 mg at meals and cautiously titrating upwards.

Table 4. Dose adjustment for insulin compounds and oral medicines for diabetes in CKD

Medication Class	CKD stages 3, 4 and 5 ND
Insulin	
Glargine	No advised dose adjustment*
Detemir	No advised dose adjustment*
Neutral Protamine Hagedorn (NPH)	No advised dose adjustment*
Regular	No advised dose adjustment*
Aspart	No advised dose adjustment*
Lispro	No advised dose adjustment*
Glulisine	No advised dose adjustment*
First-generation sulfonylureas	
Acetohexamide	Avoid use
Chlorpropamide	GFR 50-80 ml/min/1.73m ² : reduce dose 50%, GFR <50 ml/min/1.73m ² : avoid
Tolazamide	Avoid use
Tolbutamide	Avoid use
Second-generation sulfonylureas	
Glipizide	No dose adjustment
Glimepiride	Start conservatively at 1 mg daily
Glyburide	Avoid use
Gliclazide	No dose adjustment
Meglitinides	
Repaglinide	If GFR <30 ml/min/1.73m ² start conservatively at 0.5 mg with meals
Nateglinide	If GFR <30 ml/min/1.73m ² start conservatively at 60 mg with meals
Biguanides	
Metformin	Do not use if SCr ≥1.5 mg per dl in men, ≥1.4 mg per dl in women or eGFR <60 ml/min/1.73m ² **
Thiazolidinediones	
Pioglitazone	No dose adjustment
Rosiglitazone	No dose adjustment
Alpha-glucosidase inhibitors	
Acarbose	Avoid if GFR<30 ml/min/1.73m ²
Miglitol	Avoid if GFR<30 ml/min/1.73m ²
DPP-4 inhibitor	
Sitagliptin	GFR >50 ml/min/1.73m ² : 100 mg daily GFR 30-50 ml/min/1.73m ² : 50 mg daily GFR <30 ml/min/1.73 m ² : 25 mg daily
Saxagliptin	GFR >50 ml/min/1.73m ² : 5 mg daily GFR ≤50 ml/min/1.73m ² : 2.5 mg daily
Linagliptin	No dosage adjustment
Incretin mimetic	
Exenatide	Not recommended in GFR <30 ml/min/1.73m ²
Liraglutide	Not recommended in GFR <60 ml/min/1.73m ²
Amylin analog	
Pramlintide	No dose adjustment
Dopamine receptor agonist	
Bromocriptine mesylate	Not studied in patients with reduced GFR

*Adjust dose based on patient response

**These levels are controversial (see text)

Metformin does not cause hypoglycemia. Lactic acidosis, however, is a rare and serious side effect of metformin use, which can occur when toxic levels of metformin accumulate. Metformin is cleared by the kidney, thus its use in CKD is restricted. A Food and Drug Administration (FDA) mandated black-box warning exists regarding the risk of lactic acidosis with metformin use. The FDA guidelines indicate that metformin should not be used in men with a serum creatinine of ≥ 1.5 mg/dl or women with a serum creatinine of ≥ 1.4 mg/dl. It is also reasonable to consider a GFR-cutoff for metformin use as well, since serum creatinine can translate into different eGFR levels depending on weight, race or age. The clearance of metformin decreases by about 75% when the GFR is <60 ml/min/1.73m² without further change when the GFR declines to 30 ml/min/1.73m² (51); however, serum concentrations of metformin at both of these lower GFR levels are only about two-fold higher than in normal kidney function and these levels are still only about 3% of those found in patients with true metformin-associated lactic acidosis (51, 52). In studies of patients continuing to receive metformin with GFR levels in the 30 – 60 ml/min/1.73m² range, lactic acidosis is still exceedingly rare even in the presence of comorbid conditions like congestive heart failure, chronic obstructive pulmonary disease, and liver disease (53, 54). Given the marked clinical benefit of metformin, a restriction to the creatinine cutoffs listed above or to a GFR cutoff of <60 ml/min/1.73m² has been called into question (55, 56), so that at present the exact GFR cut-off for metformin use to avoid lactic acidosis is controversial. A recent review proposed that metformin use be reevaluated when GFR is <45 ml/min/1.73m² and stopped when <30 ml/min/1.73m²; this advice was adopted by the British National Formulary (57, 58).

The thiazolidinediones, pioglitazone and rosiglitazone, do not lead to hypoglycemia and are metabolized by the liver and thus can be used in CKD. However, fluid retention is a major limiting side effect and they should not be used in advanced heart failure and CKD. They have been linked with increased fracture rates and bone loss (59); thus the appropriate use in patients with underlying bone disease (such as renal osteodystrophy) needs to be considered. In September, 2010, the FDA restricted use of rosiglitazone based on information linking the medication to increased cardiovascular events (60). Rosiglitazone should only be used in individuals who cannot control their blood glucose levels with other agents after appropriate documentation by the physician and a clear understanding of the risks by the patient.

Acarbose, a disaccharidase inhibitor, is only minimally absorbed, but with reduced kidney function, serum levels of the drug and its metabolites increase significantly. Although no adverse effects have been reported, its use in patients with a GFR <26 ml/min/1.73m² is not recommended (61). Miglitol has greater systemic absorption and undergoes kidney excretion, and it should not be used in patients with GFR <25 ml/min/1.73m² (61).

The dipeptidyl peptidase (DPP) 4 inhibitors, sitagliptin, saxagliptin, and linagliptin decrease the breakdown of the incretin hormones, such as glucagon-like peptide 1 (GLP-1), and improve both fasting and post-prandial glucose levels. All can be used in CKD patients but sitagliptin and saxagliptin need downward dose adjustments as detailed in **Table 4**.

Exenatide and liraglutide are injectable incretin mimetics and facilitate insulin secretion, decrease glucagon secretion, delay gastric emptying and cause early satiety. Although their use is associated with pancreatitis in some patients, the overall frequency of pancreatitis with their use is not greater than in patients with diabetes using other agents. Exenatide is excreted by the kidneys, and its clearance is reduced by 36% with a GFR of 45 ml/min/1.73m² and by 64% with a GFR of <30 ml/min/1.73m² (62). Therefore, exenatide is not recommended for use with a GFR <30 ml/min/1.73m². Furthermore, exenatide has been associated with acute kidney injury or acceleration of CKD progression in case reports (63, 64). Liraglutide is fully degraded elsewhere in the body, and the kidneys are not a major organ of elimination (65). In single dosing, there is no effect on the area under

the curve in subjects with stages 4 and 5 CKD (65). However, there are few data on long term use and the manufacturer recommends avoiding this medicine when GFR is $<60 \text{ ml/min/1.73m}^2$ (57).

Pramlintide is an injectable amylin analog available as a complement to insulin therapy and normally it is given with each meal. Although pramlintide is metabolized and eliminated predominantly by the kidneys, it has a wide therapeutic index and dosage adjustments are not usually required in the presence of mild-to-moderate decreases in GFR. However, use of pramlintide is not recommended for patients with CKD stage 4 or greater.

Bromocriptine mesylate is a dopamine agonist that is predominantly metabolized in the liver and only 2-6% appears in the urine. No studies evaluating the safety of this medicine in patients with reduced GFR have been performed; therefore it should be used with caution in CKD.

Assessment of Glycemic Control

Inaccuracy of the HbA1c measurement in reflecting ambient glucose concentrations may hinder good glycemic control in patients with progressive kidney disease. Factors that may contribute to falsely decreased values include a reduced red blood cell lifespan, transfusions, and hemolysis. On the other hand, falsely increased values may occur due to carbamylation of the hemoglobin and acidosis. However, Morgan et al found that the relationship between HbA1c and glucose levels was not different between patients with normal kidney function and those with kidney failure (creatinine mean of 6.6 mg/dl), but some hemodialysis patients had lower than expected HbA1c levels relative to the ambient glucose concentrations (66). Opposite findings for dialysis patients were reported by Joy et al (67); an HbA1c increase of 1% correlated with a change in mean glucose of 20 mg/dl in hemodialysis patients and 30 mg/dl in those with normal kidney function. Studies published since the release of the previous KDOQI diabetes guidelines contributed further to our understanding of the relationship between HbA1c and glucose in advanced CKD. Inaba et al (68) found lower correlation of plasma glucose levels with HbA1c levels in patients with diabetes on hemodialysis ($r = 0.520$) compared to those with normal kidney function ($r = 0.630$) and they also had shallower regression slopes (0.012 vs. 0.021). Riveline et al (69) also found a shallower regression slope for hemodialysis patients compared to those without DKD and at lower levels of glucose ($<160 \text{ mg/dl}$ and HbA1c $<7.5\%$); hemodialysis patients tended to have higher glucose levels for a given HbA1c, whereas at higher levels the correlations were similar. When patients with CKD stages 3 and 4 were evaluated, glucose levels were also found to be very slightly higher than expected for given HbA1c levels (70). Iron supplementation or erythropoietin administration lead to a modest fall of 0.5 – 0.7% in HbA1c along with the rise in total hemoglobin in patients with advanced CKD. These effects are likely due to the formation of new red cells and to alterations in hemoglobin glycation rates (68, 71). Importantly, all of these studies show a very wide variability in the glucose/HbA1c relationship (66-71). The modest changes with decreasing eGFR from 75 down to $15 \text{ ml/min/1.73m}^2$, and even with hemodialysis, do not appear to be of clinical significance compared to the wide inter-individual variability. Neither peritoneal nor hemodialysis acutely change HbA1c levels (72). Fructosamine (glycated albumin) correlates either more poorly (66, 67, 69) or better (68, 70) with blood glucose than HbA1c in patients with stages 4 and 5 CKD. Nevertheless, a recent prospective study found that glycated albumin, which reflects glycemic control over a 2-week period, is a better predictor of mortality and hospitalizations than HbA1c in dialysis patients with diabetes (35). In summary, HbA1c remains the best clinical marker of long-term glycemic control, particularly if combined with self-monitoring of blood glucose, in patients with diabetes and CKD. Other markers such as glycated albumin that reflect glycemic control over a shorter period may be of greater value for predicting clinical outcomes in patients with advanced CKD.

GUIDELINE 4: MANAGEMENT OF DYSLIPIDEMIA IN DIABETES AND CKD

Dyslipidemia is common in people with diabetes and CKD. Cardiovascular events are a frequent cause of morbidity and mortality in this population. Lowering low-density lipoprotein cholesterol (LDL-C) with statin-based therapies reduces risk of major atherosclerotic events, but not all-cause mortality, in patients with CKD including those with diabetes.

4.1: We recommend using LDL-C lowering medicines, such as statins or statin/ezetimibe combination, to reduce risk of major atherosclerotic events in patients with diabetes and CKD, including those who have received a kidney transplant. (1B)

The evidence that lowering the LDL-C concentration reduces the risk of major atherosclerotic events in patients with diabetes and CKD (other than stage 5) was presented in detail in the original KDOQI diabetes guideline (4). Recommendations were based largely on four post hoc analyses (73-76) that reported results of lipid lowering therapy for a subpopulation of patients with CKD and diabetes compared with placebo (**Table 5**).

Table 5. Summary of four post hoc analyses reports of lipid lowering in people with diabetes mellitus (DM) and CKD

Study	# treated / # with DM and CKD	Randomized statin	CVD outcome vs placebo	Definition of kidney impairment	Kidney outcome vs. placebo
WOSCOPS, CARE, LIPID – Tonelli (76)	290 / 571	Pravastatin, 40 mg / day	All cause mortality 18% on pravastatin vs 19.2%. (Absolute reduction decreased from 6.4 to 3.5% comparing people with DM and CKD to those with neither). HR for CABG or PTCA 0.69 (0.47-1.01). HR for stroke = 1.12 (CI 0.63 to 1.97).	GFR <60 ml/min/1.73 m ² or GFR 60 – 89 ml/min/1.73m ² concomitant with trace or greater proteinuria on dipstick urinalysis	Not reported
4S – Chonchol (73)	105 / 200	Simvastatin, 20 mg / day	All cause mortality 13.5% on simvastatin vs 27.9%	GFR <75 ml/min/1.73m ²	Not reported
CARDS – Colhoun (74)	482 / 970	Atorvastatin, 10 mg / day	All cause mortality 5.6% on atorvastatin vs 6.1%. Stroke 1.2% on atorvastatin vs 3.1% on placebo. Unstable angina, ACS or revascularization 1.04% on atorvastatin vs 3.07% on placebo.	GFR <60 ml/min/1.73 m ²	20.5% regression from micro- to normoalbuminuria vs. 19.4%.
HPS – Collins (75)	142 / 310	Simvastatin, 40 mg / day	All cause mortality not reported.	creatinine >110 µmol/L (1.24 mg/dl) for women, and >130 µmol/L (1.47 mg/dl) for men	Significantly smaller fall in the GFR during follow-up (5.9 [0.1] vs. 6.7 [0.1] ml/min, difference –0.8 [0.2] ml/min; p=0.0003). This difference appeared to be slightly larger among those who had diabetes than among those who did not (–1.4 [0.4] ml/min vs. –0.5 [0.2] ml/min; heterogeneity p=0.08).

A new clinical trial has added to the evidence that LDL-C lowering reduces cardiovascular events in a wide range of patients with diabetes and CKD. The Study of Heart and Renal Protection (SHARP) trial (77) randomized 9438 participants ≥ 40 years old with CKD (mean eGFR of 27 ml/min/1.73m²) to receive simvastatin 20 mg plus ezetimibe 10 mg daily or placebo, and followed them for 5 years. Thirty-three percent of the patients (n=3023) were receiving maintenance dialysis at randomization and 23% (n=2094) of the participants had diabetes, with equal proportions in the simvastatin plus ezetimibe and placebo groups. Statin plus ezetimibe therapy was associated with a significant 17% relative risk reduction of the primary outcome of major atherosclerotic events (coronary death, MI, non-hemorrhagic stroke, or any revascularization) compared with placebo, HR = 0.83 (95% CI, 0.74 – 0.94). This finding was attributable in large part to significant reductions in non-hemorrhagic stroke and arterial revascularization procedures. There was no reduction in the risk of all-cause mortality, and among the patients with CKD not treated by dialysis at randomization (n=6247), treatment with simvastatin plus ezetimibe did not reduce the frequency of doubling of the baseline serum creatinine concentration or progression to ESKD. Although the study was not powered to reliably estimate the effect of treatment on primary outcomes among clinical subgroups, the proportional effect on major atherosclerotic events did not appear to differ between those with or without diabetes.

The Assessment of Lescol in Renal Transplant (ALERT) trial (78) examined the effect of statin therapy on cardiovascular risk reduction in 2102 patients with functioning kidney transplants who were followed for 5-6 years. Fluvastatin therapy (40-80 mg/day), compared with placebo, was associated with a significant 35% relative reduction in the risk of cardiac death or definite nonfatal myocardial infarction, HR = 0.65 (95% CI, 0.48 – 0.88). The study included a pre-specified analysis for a subset of 396 patients with diabetes, of whom 197 were randomized to fluvastatin and 199 to placebo. In this subset, the benefit was similar in magnitude as in the overall cohort, but was not statistically significant, HR = 0.71 (95% CI, 0.41 – 1.21), suggesting limitations of under-powering due to small sample size. Given these limitations and the lack of a significant interaction between diabetes and treatment assignment for the primary outcome, the Work Group based its recommendation for statin treatment in kidney transplant patients on the overall results from the ALERT study.

Accordingly, the evidence that treatment with statin or statin/ezetimibe combination improves health outcomes is based primarily on prevention of CVD events. There is no evidence from these trials that such treatment improves kidney disease outcomes, including doubling of serum creatinine or progression to ESKD, or all-cause mortality.

4.2: We recommend not initiating statin therapy in patients with diabetes who are treated by dialysis. (1B)

Results of the Die Deutsche Diabetes Dialyse Studie (4D) (79) motivated the recommendation regarding statin treatment in patients with type 2 diabetes on maintenance hemodialysis in the original KDOQI diabetes guideline (4). Concerns that the results of 4D were attributable to the futility of a single intervention in such high-risk patients inspired A Study to Evaluate the Use of Rosuvastatin in Subjects on Regular Hemodialysis (AURORA) (80), a clinical trial that randomized 2776 patients on hemodialysis to rosuvastatin 10 mg a day and placebo. Only 26% of the patients in AURORA had diabetes. As found in 4D, AURORA reported no significant effect of statin therapy on the primary cardiovascular outcome that included cardiac death or non-fatal myocardial infarction and fatal or non-fatal stroke, either in the overall study population or in the subgroup of patients with diabetes. A subsequent post-hoc analysis of the participants with diabetes in AURORA (81) found that treatment with rosuvastatin significantly reduced the risk of a redefined end point of cardiac death or non-fatal myocardial infarction by 32%, but significantly increased the risk of hemorrhagic stroke by more than

5-fold. Although the number of hemorrhagic strokes among participants with diabetes in AURORA was small and the overall stroke rate did not differ by treatment group, the finding is concerning, since the original report from the 4D trial found that treatment with atorvastatin was associated with 2-fold increase in fatal stroke (79). A recent post-hoc analysis of the 4D trial (82) found that fatal and nonfatal cardiac events were significantly reduced if the pretreatment LDL-C was >145 mg/dl. Although these post-hoc analyses provide a different look at the data from the previous studies, they must be viewed as hypothesis-generating, and therefore, do not alter the main message of the guideline update, which is based on the primary pre-specified outcomes from these clinical trials.

The SHARP trial (77) indicated that risk for the primary outcome of major atherosclerotic events other than death was reduced by simvastatin/ezetimibe combination among a wide range of patients with CKD. Yet, the “subgroup” of over 3000 patients on dialysis did not show a statistically significant reduction in risk of the primary outcome. The SHARP investigators advocate that this group is still likely to benefit because of lack of statistical heterogeneity. However, even as a subgroup, this is still the largest trial of LDL cholesterol-lowering conducted to-date in patients on dialysis. Taking into account the 4D and AURORA trials along with the SHARP data, overall evidence to support a favorable effect of initiating LDL-cholesterol lowering treatment on atherosclerotic events in dialysis patients is lacking. Moreover, since most of the clinical CVD events experienced by hemodialysis patients with diabetes are vascular deaths, for which statins provide little or no benefit as illustrated in the SHARP trial (77), the Work Group concluded that the available evidence continues to support the recommendation that statin therapy not be initiated in dialysis patients with diabetes. Whether previously treated patients should be continued on statin therapy once they commence dialysis, or not, has not been studied, and as such, data are insufficient to provide guidance for this group.

LIMITATIONS

With the exception of SHARP, data to support recommendations for LDL cholesterol-lowering come from post-hoc subgroup analyses of clinical trials that included CKD patients with and without diabetes. Nevertheless, a growing body of evidence demonstrates a clear benefit of statin therapy on clinical CVD events among patients with diabetes and across a wide range of CKD stages, perhaps with the exception of those on dialysis. Of note, the Adolescent type 1 diabetes mellitus cardio-renal Intervention Trial (AddIT) (83) is under way, and will provide data on the effectiveness of atorvastatin and quinalapril to prevent cardiovascular and kidney complications in adolescents with type 1 diabetes.

Other lipid altering medicines may also be of value in the management of patients with diabetes and CKD, but the Work Group concluded that the available evidence for these medicines was not yet sufficient to make specific management recommendations. Randomized treatment trials that examined the effect of fibrates relative to placebo in patients with diabetes and CKD are summarized in **Table 6** (84-86). The Veterans’ Affairs high-density lipoprotein intervention trial (VA-HIT) (86) found evidence that gemfibrozil reduces risk of major cardiovascular events (fatal coronary heart disease, nonfatal myocardial infarction, and stroke) by 42% compared with placebo (RR=0.58; 95% CI, 0.38 to 0.89) in a post hoc analysis of 297 individuals with low eGFR (GFR <75 ml/min/1.73m²) and diabetes. The Diabetes Atherosclerosis Intervention Study (DAIS) (84) and the Fenofibrate Intervention and Event Lowering in Diabetes (FIELD) study (85, 87) reported that fenofibrate treatment significantly lowered the risk of developing new onset microalbuminuria compared with placebo (RR=0.87 in patients with type 2 diabetes; 95% CI, 0.77-0.97). Fenofibrate also promoted regression from microalbuminuria to normoalbuminuria (RR=1.15; 95% CI, 1.04-1.28, n= 2260, 2 trials), but did not change the risk of progression from microalbuminuria to macroalbuminuria (RR=1.07; 95% CI, 0.43-2.63, 1 trial, n=97). There is moderate evidence that fenofibrate decreases risk of progression from normoalbuminuria to microalbuminuria and leads to regression of microalbuminuria to

normoalbuminuria compared with placebo in patients with type 2 diabetes. None of the trials of fibrate therapy in diabetes published since the original guideline reported CVD or kidney disease outcomes for the subgroup of patients with CKD.

Table 6. Fibrate treatment in patients with DM and CKD

Study	# treated / # with DM and CKD	Randomized statin	CVD Outcome	Regression from micro-to normoalbuminuria
VA-HIT – Tonelli (86)	136 / 297	Gemfibrozil, 600 mg BID	Composite Outcome 26.5% (36/136) in the gemfibrozil treated group vs. 41.0% (66/161) in the placebo	Not reported
FIELD – Davis (85, 87)	4895 / 9795	Fenofibrate, 200 mg / day (mean dose)	Not reported	47% (462/983) in the fenofibrate group vs. 39.3% (400/1017) in the placebo group
DAIS –Ansquer (84)	155 / 314	Fenofibrate, 200 mg / day	Not reported	37.7% (20/53) in the fenofibrate group vs. 34.1% (15/44) in the placebo group

IMPLEMENTATION ISSUES

Reduced dosing of statins and fibric acid derivatives is generally recommended for patients with advanced CKD. On the other hand, increased dosing of statin therapy may be beneficial in some patients with diabetes and CKD. The Treating to New Targets trial (TNT) (88) reported a benefit for secondary prevention of major cardiovascular events from treatment with atorvastatin, 80 mg/day compared with atorvastatin, 10 mg/day, in 546 patients with diabetes and CKD and pre-existing coronary artery disease over 5 years of follow-up. The risk of stroke was 4.8% (13/273) for the higher dose, compared with 7.3% (20/271) for the lower dose. There was no reduction in all-cause mortality.

Higher statin doses, however, are associated with an increased risk of myopathy (89), particularly among patients with reduced kidney function (90), signifying that treatment regimens require modification in advanced CKD. Therefore, reliance less on higher dosing of statins and more on combination therapy to reduce LDL-C is an attractive strategy. The SHARP trial (77) addressed this issue by using lower dose simvastatin (20mg/day) and adding the cholesterol-absorption inhibitor ezetimibe (10 mg/day) to achieve an average LDL-C reduction of about 1 mmol/L.

Of note, the U.S. FDA issued a Safety Announcement in June 2011 that recommends limited use of the highest approved dose of simvastatin (80 mg) because of increased risk of myopathy. Simvastatin 80 mg should be used only in patients who have been taking this dose for 12 months or more without evidence of muscle injury. Simvastatin 80 mg should not be started in new patients, including patients already taking lower doses of the drug. In addition to these new limitations, FDA is requiring changes to the simvastatin label to add new contraindications (concurrent cyclosporine or gemfibrozil use) and dose limitations for use with other medicines such as calcium channel blockers or amiodarone. Further information can be obtained at the FDA website (fda.gov/Drugs/DrugSafety).

GUIDELINE 6: MANAGEMENT OF ALBUMINURIA IN NORMOTENSIVE PATIENTS WITH DIABETES

Treatments that produce a lasting decrease in urinary albumin excretion may slow the progression of DKD even in the absence of hypertension. However, most people with diabetes and albuminuria have hypertension. Management of hypertension is addressed in Guideline 3 and the KDIGO Clinical Practice Guideline for Management of Blood Pressure in Chronic Kidney Disease.

6.1: We recommend not using an ACE inhibitor (ACE-I) or an ARB for the primary prevention of DKD in normotensive normoalbuminuric patients with diabetes. (1A)

There is currently strong evidence that use of agents that block the renin angiotensin system (RAS) do not prevent the development of microalbuminuria or biopsy-assessed diabetic glomerulosclerosis in normoalbuminuric normotensive patients with type 1 diabetes, at least over a study duration of 4-5 years (91-93).

Studies in normoalbuminuric normotensive patients with type 2 diabetes are fewer but also show no benefit (91, 94). For normoalbuminuric patients with type 2 diabetes and hypertension, or pre-existing CVD, use of ACE inhibitors with or without diuretics reduces the absolute risk of developing microalbuminuria by between 2-4% over 4-5 years (95-97). However, these studies used a variety of definitions of microalbuminuria, were often based on single urine samples taken at 1-2 year intervals, and were not tested for a durable effect vs. a transient hemodynamic effect of RAS blockade. More stringent definitions of microalbuminuria using multiple timed collections at more frequent intervals revealed incidence rates of 3-4% per annum (91, 97) less than half that reported by studies using less stringent definitions such as MICROHOPE (96) and ADVANCE (95). Thus, the evidence does not support a clinical benefit of intervention to prevent the intermediate outcome of persistent microalbuminuria or the changes in kidney structure associated with DKD.

6.2: We suggest use of an ACE inhibitor or an ARB in normotensive patients with diabetes and albuminuria levels ≥ 30 mg/g. (2C)

There are no long-term studies that show a benefit of treatment with RAS blocking agents on CKD progression or health outcomes in normotensive patients with diabetes and microalbuminuria. In hypertensive type 1 and type 2 patients with diabetes, RAS blocking agents prevent development of macroalbuminuria, but even after two or more years of treatment, albuminuria increases soon after the withdrawal of these drugs (98). This observation calls into question the durability of the treatment effect on underlying disease processes.

For patients with macroalbuminuria and moderately reduced eGFR, there is strong evidence showing that ACE inhibition in type 1 (99) and ARBs in type 2 (100, 101) diabetes confer benefit in terms of loss of GFR (both rates of decline in eGFR and doubling of baseline serum creatinine) and ESKD, but few of these patients are normotensive. Furthermore, there are no long-term studies that examine the renoprotective efficacy of ACEI in type 2 or ARBs in type 1 diabetes.

Fundamental to the interpretation of all of these studies is the definition of hypertension, which is currently under review by KDIGO and the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC). Early studies in “normotensive” patients with

type 1 diabetes used definitions of the upper limit of normal for blood pressure that would now be considered hypertension. The meta-analysis published by the ACE Inhibitors in Diabetic Nephropathy Trialist Group (102) included studies in patients with type 1 diabetes whose upper limit of baseline blood pressures at inclusion ranged from 145-160mm Hg systolic and 90-120mm Hg diastolic. These investigators also did not report correction for systolic pressure, only for diastolic. Moreover, preferred statistical approaches to controlling for the effects of blood pressure are debatable, and as such, are not established methodologies.

LIMITATIONS

Past recommendations regarding management of albuminuria in patients with diabetes assumed that the appearance of microalbuminuria signaled an inevitable progression to macroalbuminuria. There is increasing evidence, however, of spontaneous remission of microalbuminuria in up to 40% patients with type 1 diabetes (103, 104), while about 30-40% remain microalbuminuric and do not progress to macroalbuminuria over 5-10 years of follow-up (105). Whether this observation reflects a better understanding of the natural course of albuminuria in diabetes or is, in part, a response to treatment is uncertain, but the adoption of a blanket policy for the use of RAS blocking drugs in these patients has made it difficult to explore other potential therapies and hindered studies of the natural history of early diabetic nephropathy.

The use of albuminuria as a surrogate marker of benefit of intervention in DKD was the subject of an FDA/NKF symposium in 2008 (106). Major questions were raised about how to define abnormal albuminuria; at what level should intervention take place; how many tests over what period of time would be required before intervention should commence; what would be regarded as an adequate response to intervention and how would this be defined; and how would long term benefit be measured? The conference produced a consensus report that concluded that the evidence was not strong enough to use changes in albuminuria as an adequate surrogate endpoint of long term kidney benefit in people with diabetes or other kidney disease.

A major confounding problem with interpreting studies of intervention in the course of DKD is changing natural history. In the 1970's, the median time to ESKD from the development of overt (dipstick positive) proteinuria in type 1 diabetes was <7 years (107); it is now >14 years (105). The incidence of ESKD in type 1 diabetes from Finland is now only 7.8% at 30 years duration (108). Recent data from the DCCT/EDIC cohort shows a 10 year incidence of 3% for ESKD in 325 patients with incident microalbuminuria during the course of the study (105). Thus, intervention studies with benefit in terms of health outcomes related to kidney disease as their primary end point could require many years of observation, and be costly in terms of resource. For these reasons, such studies are unlikely to be performed. In clinical practice, changes in eGFR and albuminuria are suggested to be used together to monitor kidney status, even in the absence of conclusive evidence that they predict precisely long-term reduction in risk of actual health outcomes such as ESKD.

IMPLEMENTATION ISSUES

Dosages for ACE inhibitors or ARBs

In normotensive persons with diabetes and albuminuria the target dose of ACE inhibitors or ARBs is unknown. In the absence of side effects or adverse events (e.g., hyperkalemia or acute kidney injury) the Work Group suggests titration up to the maximum approved dose for the treatment of hypertension.

Cautions about usage of ACE inhibitors and ARBs

The use of a combination of ACEI and ARBs as a dual blockade of the RAS cannot be recommended at present. At least 1 clinical trial has shown an increase in adverse events, particularly impaired kidney function and hyperkalemia, compared to either agent alone, despite a reduction in albuminuria using combination therapy (109, 110).

The use of ACEI and ARBs in early pregnancy is reportedly associated with harm to the fetus (neonatal acute kidney injury; lung toxicity; skull hypoplasia; congenital malformations of the cardiovascular system, central nervous system, and kidney) (111), although more recent studies have not confirmed these risks (112, 113). The FDA is currently reviewing its advice on the use of these agents in the first trimester.

Newer Agents that Target the RAS

One 6-month phase 2 study of Aliskiren in the Evaluation of Proteinuria in Diabetes (AVOID) reported a further reduction of albuminuria with the addition of the direct renin inhibitor aliskiren to losartan in type 2 patients with microalbuminuria (114). A phase 3 study, Aliskiren Trial in Type 2 Diabetes Using Cardio-Renal Endpoints (ALTITUDE), was subsequently initiated in 3 groups of patients with type 2 diabetes: 1) albuminuria ≥ 200 mg/g; 2) eGFR < 60 and ≥ 30 ml/min/1.73m² with albuminuria ≥ 20 mg/g and < 200 mg/g; 3) eGFR < 60 and ≥ 30 ml/min/1.73m² with CVD. However, ALTITUDE was stopped early due to therapeutic futility and increased risk of stroke and adverse events including hyperkalemia, hypotension, and ESKD or death due to kidney disease. Given these findings, dual blockade of the RAS with direct renin inhibition and either ACE-I or ARB cannot be recommended. Indeed, the manufacturer (Novartis) recommends that aliskiren be stopped in diabetic patients treated with ACEI or ARB.

DISCUSSION

Earlier and more aggressive therapeutic intervention is believed to be responsible, at least in part, for the general decline in the incidence of ESKD attributable to diabetes among several racial and ethnic groups in recent years (2). Encouraged by these observations and by the results of previous trials using less aggressive endpoints, several large, well-designed clinical trials were conducted among patients with diabetes to determine whether even earlier or more intensive therapy might further reduce the frequency of CKD and important health outcomes of CKD, including ESKD. Results from these trials suggest that “more is not always better”, as such interventions often did not improve clinical outcomes, and in some settings were actually harmful. After examining the new evidence, the Work Group moved each guideline to a more conservative position than was taken in the original guideline published in 2007.

Clinical Practice Guideline 2 was modified to recommend that a target HbA1c of $\sim 7\%$ is mainly useful to prevent or delay microvascular complications including DKD in both type 1 and type 2 diabetes. A recent series of three large clinical trials found nominal to no benefit of more intensive glycemic control (target HbA1c levels $< 7\%$) on macrovascular complications or clinical kidney disease endpoints (loss of function or requirements for dialysis or transplantation) in older people with established type 2 diabetes. Moreover, the risk of severe hypoglycemia was high (19-21). Therefore, a target HbA1c $< 7\%$ is not recommended for patients with diabetes at risk of hypoglycemia, a group that includes many in the CKD population. Finally, patients with diabetes and advanced CKD often have multiple co-morbidities or limited life expectancy that would nullify the potential benefits of intensive glycemic control. In such patients, a target HbA1c $> 7\%$ is suggested.

Clinical Practice Guideline 4 was updated to reflect the results of recent clinical trials of lipid-lowering therapies that included patients with diabetes and CKD. In particular, the SHARP trial added new data to support treatment with a statin-ezetimibe combination in patients with CKD at stages 3 and 4 as well as in those treated by dialysis (77). This treatment reduced risks of major atherosclerotic events, but not deaths or health outcomes related to kidney disease. Additionally, SHARP and AURORA expanded the knowledge base about initiating statins or statin-ezetimibe in patients with diabetes treated by hemodialysis (77, 80). Taken together, these data do not provide convincing evidence for benefits on overall clinical CVD events in this specific group. Guideline 4 no longer includes recommendations for an LDL-C concentration at which statin therapy should be initiated or a therapeutic target concentration to be achieved because the studies were not conducted in this manner and evidence is lacking to guide therapy by LDL-C concentration.

Clinical Practice Recommendation 1, now referred to as Clinical Practice Guideline 6, was revised to recommend that ACEI and ARBs not be used in patients with diabetes and CKD who have normal blood pressure and normoalbuminuria. Clinical trials of patients with either type 1 or 2 diabetes found these treatments did not reduce the development of elevated urinary albumin excretion or the structural evidence of DKD (91, 93). The use of ACEI or ARBs is still suggested in normotensive patients with diabetes and elevated albuminuria, but this suggestion is based on low-level evidence.

RESEARCH RECOMMENDATIONS

These guideline updates, and the clinical trials on which they were based, illustrate the importance of continuing to conduct research that challenges or expands established clinical practice. As stated in the original guideline, uncertainty is an immutable element of all scientific research, and the establishment of a guideline should neither preclude nor render unethical further inquiry (4). Even as knowledge regarding approaches to managing diabetes to prevent or treat DKD and related complications has advanced substantially since the publication of the original KDOQI™ Clinical Practice Guidelines and Clinical Practice Recommendations for Diabetes and Chronic Kidney Disease, many essential questions remain to be answered. The original guideline publication provided a list of research suggestions that meaningfully informed the investigative agenda, one of many indications of the importance of these efforts. The present research recommendations arose directly from the guideline update process. The Work Group provided research suggestions they considered key to advancing knowledge concerning clinical care. These suggestions are arranged by topic area in order to link back to the specific guidelines. Some of the recommendations are not for new research studies per se, but are proposals for how research studies might be designed to enhance their value, validity, or generalizability.

Guideline 2: Management of Hyperglycemia and General Diabetes Care in CKD

1. Determine effects of glycemic control on early and late GFR loss and health outcomes of CKD. Evaluate different levels of glycemic control to optimize safety as well as clinical outcomes of survival, hospitalization, and CVD events in advanced CKD and/or ESKD.
2. Perform validation studies of HbA1c, glycated albumin, and potentially other markers of long-term glycemic control in patients with diabetes and various stages of CKD.
3. Assess metformin safety in patients with CKD stages 4 and 5.

Guideline 4: Management of Dyslipidemia in Diabetes and CKD

1. Perform clinical trials of statins for primary and secondary prevention of CVD, or patient level meta-analyses of completed studies, in patients with DM and CKD stages 1-4.
2. Conduct studies of other lipid-lowering agents for primary and secondary prevention of CVD, or patient level meta-analyses of completed studies, in patients with DM and CKD stages 1-4.
3. Establish LDL-C levels for treatment and initiation of therapy as well as targets for primary and secondary prevention in patients with diabetes by CKD stage.
4. Evaluate lipid-lowering therapy for CVD in patients with diabetes who are treated by hemodialysis or peritoneal dialysis, or who have received a kidney transplant.
5. Examine results of previous studies, e.g., SHARP, by CKD stage.

6. Examine data from completed clinical trials to assess effects of lipid lowering agents on outcomes such as albuminuria, eGFR, and ESKD in participants with diabetes.
7. Examine lipid-lowering therapy for CVD in adolescent patients with diabetes.

Guideline 6: Management of Albuminuria in Normotensive Patients with Diabetes

1. Durability of RAS inhibition for the delay in microalbuminuria onset should be tested by a treatment washout phase of at least two months duration.
2. Post-hoc adjustment for blood pressure differences may be fraught with faulty assumptions. Therefore, equivalent blood pressure levels are an important design element to be considered in future clinical trials that test specificity of a drug's mechanism of action independent of blood pressure effects.
3. Since the "endpoint" of preventing incident albuminuria derives validity from predicting increased risk of GFR loss, treatments to reduce albuminuria should not be offset by greater GFR decline. Measurement of GFR (e.g., eGFR or other methods) should be performed as a companion to albuminuria. In clinical trials to demonstrate prevention of elevated albuminuria, the demonstration of normoalbuminuria at baseline should follow washout of at least of two months duration from previous RAS blockade, with careful blood pressure (BP) control by alternative antihypertensive agents. This approach is necessary to avoid randomization of participants in whom albuminuria is already present, but masked by RAS treatment, an effect which may be posited in several studies where there was rapid progression to microalbuminuria in the first few months after randomization to placebo.
4. Given the limitations of albuminuria as an outcome measure and the recent consensus panel's recommendation against acceptance of albuminuria as a surrogate outcome (106), studies are needed to evaluate durability of effects on urinary albumin excretion. The categorization of albuminuria outcomes should be based on a minimum of two of three consecutive urine samples being in the same category (115).
5. Consider an indication for regulatory approval based on demonstration of a lasting reduction in urinary albumin excretion, but conditional upon firm commitment to continue long-term studies to determine effects on GFR loss and clinically relevant outcomes.
6. Evaluate the relative roles of ACE inhibitors, ARBs, renin blockers, and mineralocorticoid receptor blockers on progression of DKD in patients with albuminuria.
7. Kidney biopsy outcomes based on carefully measured structural variables that correlate strongly with GFR loss may reduce the duration of primary prevention or early intervention DKD clinical trials (93). Consider enzyme replacement for Fabry's Disease as an example (116).

8. Clinical trials represent important opportunities to advance knowledge beyond addressing the primary hypotheses themselves. Protocols should include plans for acquiring and banking blood, urine, DNA, and other samples for eventual biomarker discovery and validation. Consider the DCCT as an example (117).

CONCLUSION

This update to the KDOQI™ Clinical Practice Guidelines and Clinical Practice Recommendations for Diabetes and Chronic Kidney Disease reflects our understanding of the present state of knowledge. Many questions about optimal management of DKD remain unanswered and numerous new ones have arisen. The research recommendations described above are intended to guide forthcoming research agendas and, hopefully, lead to results that further advance knowledge and inform future updates. Ultimately, the goal of this quest is to deliver optimal care that improves and prolongs the lives of people with diabetes and CKD.

ACKNOWLEDGMENTS

Guideline recommendations included in this Update were originally published in the American Journal of Kidney Diseases in 2007 and were reproduced with permission from the National Kidney Foundation.

We thank Drs. Michael Rocco and Jeffery Berns for their careful review of this manuscript; and Kerry Willis, Emily Howell and Michael Cheung from the National Kidney Foundation for help coordinating the work of the group and preparing the manuscript.

The Work Group is indebted to the evidence review team from the Minneapolis Veterans Administration Center for Chronic Disease Outcomes Research, who worked tirelessly to assemble the evidence and creatively to synthesize the information. The Work Group appreciates the careful review of the draft guideline and suggestions for improvement by external reviewers. Each comment was carefully considered and, whenever possible, suggestions for change were incorporated into the final report. As a result, this Update of the KDOQI™ Clinical Practice Guideline for Diabetes and Chronic Kidney Disease is the product of the Work Group, the Evidence Review Team, the NKF, and all those who contributed their effort to improve the updated guideline.

The following individuals provided written review of the draft guidelines. Participation in the review does not necessarily constitute endorsement of the content of the report by the individuals or the organization or institution they represent (to be compiled).

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Rudolf W. Bilous, MD, is Professor of Clinical Medicine and Honorary Consultant Physician at the University of Newcastle, UK. He received his fellowship from the Royal College of Physicians in London. From 1985 to 1987, he served as the Juvenile Diabetes Foundation International (JDFI) Post-Doctorate Fellow at the University of Minnesota and the National Institutes of Health (NIH) Fellow at Guy's Hospital in London from 1980 to 1982. He is currently serving as the Specialty Advisory Committee Chair for Endo/Diabetes of the Joint Committee for Higher Medical Training, as well as the Chairman of Professional Advisory Council Executive of Diabetes —UK (formerly the British Diabetic Association). Dr Bilous is also the President of the European Diabetic Nephropathy Study Group, and his research interest is focused on diabetic nephropathy and clinical diabetes, including hypertension. Grant/ Research Support/ Consultant: received travel bursaries from Boehringer Ingelheim and speakers fees from Roche, Boehringer Ingelheim, Novo Nordisk and Animas Corp.

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Andrew Narva, MD, has served as Director of the National Kidney Disease Education Program at the National Institute of Diabetes and Digestive and Kidney Diseases since 2006. From 1981 to 2006 he worked as a physician for the Indian Health Service (IHS) providing direct care to American Indian patients with kidney disease throughout New Mexico as the Albuquerque Area Nephrologist and providing technical consultation and support to all IHS areas and to tribes as the Chief Clinical Consultant for Nephrology for IHS. He has served as a member of the Medical Review Board of End-Stage Renal Disease Network 15, the NKF Kidney Early Evaluation Program, and on the Steering Committee for the National Quality Forum Renal Endorsement Maintenance Project. Dr Narva serves on the Expert Panel on Clinical Guidelines on High Blood Pressure (JNC 8) and the Working Group on CKD, International Federation of Clinical Chemistry and Laboratory Medicine. Dr Narva reported no relevant financial relationships.

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Kumar Sharma, MD, F.A.H.A., is Professor of Medicine and Director of the Center for Renal Translational Medicine at the University of California, Los Angeles. Dr Sharma has maintained a strong clinical practice with a focus on patients with type 1 and type 2 diabetes and kidney disease. He has conducted NIH-funded and industry supported investigator-initiated clinical trials. He has a major interest in the development of clinical biomarkers of kidney disease progression. His research efforts have focused on the pathogenesis of diabetic kidney disease (diabetes nephropathy, DN). His laboratory helped define the central role of the cytokine Transforming Growth Factor- β (TGF- β) in DN using cell culture and animal models and translated these findings to the human condition. These studies contributed to the development of the highly innovative anti-fibrotic approaches (e.g., Pirfenidone) that are currently being tested in clinical research trials under Dr Sharma's guidance. Recently, Dr Sharma has focused his attention on the contribution of the kidney to systemic complications in diabetes and obesity. His group was the first to describe the role of adiponectin on podocyte function and has also focused on the role of energy metabolism (via AMPK) on development of kidney disease. His group has also used novel genomic, proteomic, and metabolomic methods for clinical applications and for kidney disease. The goal of his research efforts is to develop new diagnostic and therapeutic approaches for personalized medicine in diabetes complications and kidney disease. Grant/ Research Support: Abbott Consultant: Johnson & Johnson; Pfizer.

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KDOQI Leadership

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REFERENCES

1. de Boer IH, Rue TC, Hall YN, Heagerty PJ, Weiss NS and Himmelfarb J: Temporal trends in the prevalence of diabetic kidney disease in the United States. *JAMA* 305: 2532-2539, 2011
2. U.S Renal Data System, USRDS 2011 Annual Data Report: Atlas of Chronic Kidney Disease and End-Stage Renal Disease in the United States. National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, 2011.
3. Eknoyan G and Levin NW: Impact of the new K/DOQI guidelines. *Blood Purif* 20: 103-108, 2002
4. National Kidney Foundation: KDOQI Clinical Practice Guidelines and Clinical Practice Recommendations for Diabetes and Chronic Kidney Disease. *Am J Kidney Dis* 49: S1-S180, 2007
5. Rocco MV and Berns JS: KDOQI in the era of global guidelines. *Am J Kidney Dis* 54: 781-787, 2009
6. Eknoyan G, Lameire N, Barsoum R, et al.: The burden of kidney disease: improving global outcomes. *Kidney Int* 66: 1310-1314, 2004
7. Slinin Y, Ishani A, Rector T, et al.: Management of hyperglycemia, dyslipidemia, and albuminuria in patients with diabetes and chronic kidney disease: A systematic review for a clinical practice guideline for the National Kidney Foundation. In preparation, 2012
8. Uhlig K, Macleod A, Craig J, et al.: Grading evidence and recommendations for clinical practice guidelines in nephrology. A position statement from Kidney Disease: Improving Global Outcomes (KDIGO). *Kidney Int* 70: 2058-2065, 2006
9. The DCCT Research Group: The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. The Diabetes Control and Complications Trial Research Group. *N Engl J Med* 329: 977-986, 1993
10. The DCCT Research Group: Effect of intensive therapy on the development and progression of diabetic nephropathy in the Diabetes Control and Complications Trial. The Diabetes Control and Complications (DCCT) Research Group. *Kidney Int* 47: 1703-1720, 1995
11. Wang PH, Lau J and Chalmers TC: Meta-analysis of effects of intensive blood-glucose control on late complications of type I diabetes. *Lancet* 341: 1306-1309, 1993
12. Nathan DM, Zinman B, Cleary PA, et al.: Modern-day clinical course of type 1 diabetes mellitus after 30 years' duration: the diabetes control and complications trial/epidemiology of diabetes interventions and complications and Pittsburgh epidemiology of diabetes complications experience (1983-2005). *Arch Intern Med* 169: 1307-1316, 2009
13. Ohkubo Y, Kishikawa H, Araki E, et al.: Intensive insulin therapy prevents the progression of diabetic microvascular complications in Japanese patients with non-insulin-dependent diabetes mellitus: a randomized prospective 6-year study. *Diabetes Res Clin Pract* 28: 103-117, 1995
14. Shichiri M, Kishikawa H, Ohkubo Y and Wake N: Long-term results of the Kumamoto Study on optimal diabetes control in type 2 diabetic patients. *Diabetes Care* 23 Suppl 2: B21-29, 2000
15. UK Prospective Diabetes Study (UKPDS) Group: Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). UK Prospective Diabetes Study (UKPDS) Group. *Lancet* 352: 837-853, 1998
16. UK Prospective Diabetes Study (UKPDS) Group: Effect of intensive blood-glucose control with metformin on complications in overweight patients with type 2 diabetes (UKPDS 34). UK Prospective Diabetes Study (UKPDS) Group. *Lancet* 352: 854-865, 1998
17. Levin SR, Coburn JW, Abaira C, et al.: Effect of intensive glycemic control on microalbuminuria in type 2 diabetes. Veterans Affairs Cooperative Study on Glycemic Control

- and Complications in Type 2 Diabetes Feasibility Trial Investigators. *Diabetes Care* 23: 1478-1485, 2000
18. Reichard P, Nilsson BY and Rosenqvist U: The effect of long-term intensified insulin treatment on the development of microvascular complications of diabetes mellitus. *N Engl J Med* 329: 304-309, 1993
 19. Patel A, MacMahon S, Chalmers J, et al.: Intensive blood glucose control and vascular outcomes in patients with type 2 diabetes. *N Engl J Med* 358: 2560-2572, 2008
 20. Ismail-Beigi F, Craven T, Banerji MA, et al.: Effect of intensive treatment of hyperglycaemia on microvascular outcomes in type 2 diabetes: an analysis of the ACCORD randomised trial. *Lancet* 376: 419-430, 2010
 21. Duckworth W, Abraira C, Moritz T, et al.: Glucose control and vascular complications in veterans with type 2 diabetes. *N Engl J Med* 360: 129-139, 2009
 22. Breyer JA, Bain RP, Evans JK, et al.: Predictors of the progression of renal insufficiency in patients with insulin-dependent diabetes and overt diabetic nephropathy. The Collaborative Study Group. *Kidney Int* 50: 1651-1658, 1996
 23. Klein R, Klein BE, Moss SE, Cruickshanks KJ and Brazy PC: The 10-year incidence of renal insufficiency in people with type 1 diabetes. *Diabetes Care* 22: 743-751, 1999
 24. Mulec H, Blohme G, Grande B and Bjorck S: The effect of metabolic control on rate of decline in renal function in insulin-dependent diabetes mellitus with overt diabetic nephropathy. *Nephrol Dial Transplant* 13: 651-655, 1998
 25. Nyberg G, Blohme G and Norden G: Impact of metabolic control in progression of clinical diabetic nephropathy. *Diabetologia* 30: 82-86, 1987
 26. Parving HH, Rossing P, Hommel E and Smidt UM: Angiotensin-converting enzyme inhibition in diabetic nephropathy: ten years' experience. *Am J Kidney Dis* 26: 99-107, 1995
 27. de Boer IH, Sun W, Cleary PA, et al.: Intensive diabetes therapy and glomerular filtration rate in type 1 diabetes. *N Engl J Med* 365: 2366-2376, 2011
 28. The DCCT Research Group: Hypoglycemia in the Diabetes Control and Complications Trial. The Diabetes Control and Complications Trial Research Group. *Diabetes* 46: 271-286, 1997
 29. Gerstein HC, Miller ME, Byington RP, et al.: Effects of intensive glucose lowering in type 2 diabetes. *N Engl J Med* 358: 2545-2559, 2008
 30. Bonds DE, Miller ME, Bergenstal RM, et al.: The association between symptomatic, severe hypoglycaemia and mortality in type 2 diabetes: retrospective epidemiological analysis of the ACCORD study. *BMJ* 340: b4909, 2010
 31. Schwartz AV, Vittinghoff E, Sellmeyer DE, et al.: Diabetes-related complications, glycemic control, and falls in older adults. *Diabetes Care* 31: 391-396, 2008
 32. Greenfield S, Billimek J, Pellegrini F, et al.: Comorbidity affects the relationship between glycemic control and cardiovascular outcomes in diabetes: a cohort study. *Ann Intern Med* 151: 854-860, 2009
 33. Shurraw S, Hemmelgarn B, Lin M, et al.: Association between glycemic control and adverse outcomes in people with diabetes mellitus and chronic kidney disease: a population-based cohort study. *Arch Intern Med* 171: 1920-1927, 2011
 34. Drechsler C, Krane V, Ritz E, Marz W and Wanner C: Glycemic control and cardiovascular events in diabetic hemodialysis patients. *Circulation* 120: 2421-2428, 2009
 35. Freedman BI, Andries L, Shihabi ZK, et al.: Glycated albumin and risk of death and hospitalizations in diabetic dialysis patients. *Clin J Am Soc Nephrol* 6: 1635-1643, 2011
 36. Hayashino Y, Fukuhara S, Akiba T, et al.: Diabetes, glycaemic control and mortality risk in patients on haemodialysis: the Japan Dialysis Outcomes and Practice Pattern Study. *Diabetologia* 50: 1170-1177, 2007
 37. Kalantar-Zadeh K, Kopple JD, Regidor DL, et al.: A1C and survival in maintenance hemodialysis patients. *Diabetes Care* 30: 1049-1055, 2007

38. Oomichi T, Emoto M, Tabata T, et al.: Impact of glycemic control on survival of diabetic patients on chronic regular hemodialysis: a 7-year observational study. *Diabetes Care* 29: 1496-1500, 2006
39. Shurraw S, Majumdar SR, Thadhani R, Wiebe N and Tonelli M: Glycemic control and the risk of death in 1,484 patients receiving maintenance hemodialysis. *Am J Kidney Dis* 55: 875-884, 2010
40. Williams ME, Lacson E, Jr., Wang W, Lazarus JM and Hakim R: Glycemic control and extended hemodialysis survival in patients with diabetes mellitus: comparative results of traditional and time-dependent Cox model analyses. *Clin J Am Soc Nephrol* 5: 1595-1601, 2010
41. Gerich JE, Meyer C, Woerle HJ and Stumvoll M: Renal gluconeogenesis: its importance in human glucose homeostasis. *Diabetes Care* 24: 382-391, 2001
42. Hasslacher C and Wittmann W: [Severe hypoglycemia in diabetics with impaired renal function]. *Dtsch Med Wochenschr* 128: 253-256, 2003
43. Muhlhauser I, Toth G, Sawicki PT and Berger M: Severe hypoglycemia in type I diabetic patients with impaired kidney function. *Diabetes Care* 14: 344-346, 1991
44. Asplund K, Wiholm BE and Lundman B: Severe hypoglycaemia during treatment with glipizide. *Diabet Med* 8: 726-731, 1991
45. Jonsson A, Rydberg T, Sterner G and Melander A: Pharmacokinetics of glibenclamide and its metabolites in diabetic patients with impaired renal function. *Eur J Clin Pharmacol* 53: 429-435, 1998
46. Rosenkranz B, Profozic V, Metelko Z, Mrzljak V, Lange C and Malerczyk V: Pharmacokinetics and safety of glimepiride at clinically effective doses in diabetic patients with renal impairment. *Diabetologia* 39: 1617-1624, 1996
47. Inoue T, Shibahara N, Miyagawa K, et al.: Pharmacokinetics of nateglinide and its metabolites in subjects with type 2 diabetes mellitus and renal failure. *Clin Nephrol* 60: 90-95, 2003
48. Nagai T, Imamura M, Iizuka K and Mori M: Hypoglycemia due to nateglinide administration in diabetic patient with chronic renal failure. *Diabetes Res Clin Pract* 59: 191-194, 2003
49. Schumacher S, Abbasi I, Weise D, et al.: Single- and multiple-dose pharmacokinetics of repaglinide in patients with type 2 diabetes and renal impairment. *Eur J Clin Pharmacol* 57: 147-152, 2001
50. Hasslacher C: Safety and efficacy of repaglinide in type 2 diabetic patients with and without impaired renal function. *Diabetes Care* 26: 886-891, 2003
51. Sambol NC, Chiang J, Lin ET, et al.: Kidney function and age are both predictors of pharmacokinetics of metformin. *J Clin Pharmacol* 35: 1094-1102, 1995
52. Frid A, Sterner GN, Londahl M, et al.: Novel assay of metformin levels in patients with type 2 diabetes and varying levels of renal function: clinical recommendations. *Diabetes Care* 33: 1291-1293, 2010
53. Rachmani R, Slavachevski I, Levi Z, Zadok B, Kedar Y and Ravid M: Metformin in patients with type 2 diabetes mellitus: reconsideration of traditional contraindications. *Eur J Intern Med* 13: 428-433, 2002
54. Salpeter SR, Greyber E, Pasternak GA and Salpeter EE: Risk of fatal and nonfatal lactic acidosis with metformin use in type 2 diabetes mellitus. *Cochrane Database Syst Rev*: CD002967, 2010
55. Nye HJ and Herrington WG: Metformin: the safest hypoglycaemic agent in chronic kidney disease? *Nephron Clin Pract* 118: c380-383, 2011
56. Pilmore HL: Review: metformin: potential benefits and use in chronic kidney disease. *Nephrology (Carlton)* 15: 412-418, 2010
57. British National Formulary: www.bnf.org. Accessed November 15th, 2011.
58. Lipska KJ, Bailey CJ and Inzucchi SE: Use of metformin in the setting of mild-to-moderate renal insufficiency. *Diabetes Care* 34: 1431-1437, 2011
59. Grey A: Skeletal consequences of thiazolidinedione therapy. *Osteoporos Int* 19: 129-137, 2008
60. FDA Postmarket Drug Safety Information for Patients and Providers, FDA significantly restricts access to the diabetes drug Avandia.

<http://www.fda.gov/Drugs/DrugSafety/PostmarketDrugSafetyInformationforPatientsandProviders/ucm226956.htm>

61. Snyder RW and Berns JS: Use of insulin and oral hypoglycemic medications in patients with diabetes mellitus and advanced kidney disease. *Semin Dial* 17: 365-370, 2004
62. Linnebjerg H, Kothare PA, Park S, et al.: Effect of renal impairment on the pharmacokinetics of exenatide. *Br J Clin Pharmacol* 64: 317-327, 2007
63. Johansen OE and Whitfield R: Exenatide may aggravate moderate diabetic renal impairment: a case report. *Br J Clin Pharmacol* 66: 568-569, 2008
64. Weise WJ, Sivanandy MS, Block CA and Comi RJ: Exenatide-associated ischemic renal failure. *Diabetes Care* 32: e22-23, 2009
65. Jacobsen LV, Hindsberger C, Robson R and Zdravkovic M: Effect of renal impairment on the pharmacokinetics of the GLP-1 analogue liraglutide. *Br J Clin Pharmacol* 68: 898-905, 2009
66. Morgan L, Marenah CB, Jeffcoate WJ and Morgan AG: Glycated proteins as indices of glycaemic control in diabetic patients with chronic renal failure. *Diabet Med* 13: 514-519, 1996
67. Joy MS, Cefalu WT, Hogan SL and Nachman PH: Long-term glycemic control measurements in diabetic patients receiving hemodialysis. *Am J Kidney Dis* 39: 297-307, 2002
68. Inaba M, Okuno S, Kumeda Y, et al.: Glycated albumin is a better glycemic indicator than glycated hemoglobin values in hemodialysis patients with diabetes: effect of anemia and erythropoietin injection. *J Am Soc Nephrol* 18: 896-903, 2007
69. Riveline JP, Teynie J, Belmouaz S, et al.: Glycaemic control in type 2 diabetic patients on chronic haemodialysis: use of a continuous glucose monitoring system. *Nephrol Dial Transplant* 24: 2866-2871, 2009
70. Freedman BI, Shihabi ZK, Andries L, et al.: Relationship between assays of glycemia in diabetic subjects with advanced chronic kidney disease. *Am J Nephrol* 31: 375-379, 2010
71. Ng JM, Cooke M, Bhandari S, Atkin SL and Kilpatrick ES: The effect of iron and erythropoietin treatment on the A1C of patients with diabetes and chronic kidney disease. *Diabetes Care* 33: 2310-2313, 2010
72. Saloranta C, Groop L, Ylinen K, Teramo K, Tolppanen EM and Tallgren LG: The usefulness of micro- and macrochromatographic determinations of glycohemoglobin in diabetic patients with nephropathy. *Clin Nephrol* 25: 186-192, 1986
73. Chonchol M, Cook T, Kjekshus J, Pedersen TR and Lindenfjeld J: Simvastatin for secondary prevention of all-cause mortality and major coronary events in patients with mild chronic renal insufficiency. *Am J Kidney Dis* 49: 373-382, 2007
74. Colhoun HM, Betteridge DJ, Durrington PN, et al.: Effects of atorvastatin on kidney outcomes and cardiovascular disease in patients with diabetes: an analysis from the Collaborative Atorvastatin Diabetes Study (CARDS). *Am J Kidney Dis* 54: 810-819, 2009
75. Collins R, Armitage J, Parish S, Sleight P and Peto R: MRC/BHF Heart Protection Study of cholesterol-lowering with simvastatin in 5963 people with diabetes: a randomised placebo-controlled trial. *Lancet* 361: 2005-2016, 2003
76. Tonelli M, Keech A, Shepherd J, et al.: Effect of pravastatin in people with diabetes and chronic kidney disease. *J Am Soc Nephrol* 16: 3748-3754, 2005
77. Baigent C, Landray MJ, Reith C, et al.: The effects of lowering LDL cholesterol with simvastatin plus ezetimibe in patients with chronic kidney disease (Study of Heart and Renal Protection): a randomised placebo-controlled trial. *Lancet* 377: 2181-2192, 2011
78. Jardine AG, Holdaas H, Fellstrom B, et al.: Fluvastatin prevents cardiac death and myocardial infarction in renal transplant recipients: post-hoc subgroup analyses of the ALERT Study. *Am J Transplant* 4: 988-995, 2004
79. Wanner C, Krane V, Marz W, et al.: Atorvastatin in patients with type 2 diabetes mellitus undergoing hemodialysis. *N Engl J Med* 353: 238-248, 2005
80. Fellstrom BC, Jardine AG, Schmieder RE, et al.: Rosuvastatin and cardiovascular events in patients undergoing hemodialysis. *N Engl J Med* 360: 1395-1407, 2009

81. Holdaas H, Holme I, Schmieder RE, et al.: Rosuvastatin in diabetic hemodialysis patients. *J Am Soc Nephrol* 22: 1335-1341, 2011
82. Marz W, Genser B, Drechsler C, et al.: Atorvastatin and low-density lipoprotein cholesterol in type 2 diabetes mellitus patients on hemodialysis. *Clin J Am Soc Nephrol* 6: 1316-1325, 2011
83. Adolescent type 1 Diabetes cardio-renal Intervention Trial Research Group: Adolescent type 1 Diabetes Cardio-renal Intervention Trial (AdDIT). *BMC Pediatr* 9: 79, 2009
84. Ansquer JC, Foucher C, Rattier S, Taskinen MR and Steiner G: Fenofibrate reduces progression to microalbuminuria over 3 years in a placebo-controlled study in type 2 diabetes: results from the Diabetes Atherosclerosis Intervention Study (DAIS). *Am J Kidney Dis* 45: 485-493, 2005
85. Davis TM, Ting R, Best JD, et al.: Effects of fenofibrate on renal function in patients with type 2 diabetes mellitus: the Fenofibrate Intervention and Event Lowering in Diabetes (FIELD) Study. *Diabetologia* 54: 280-290, 2011
86. Tonelli M, Collins D, Robins S, Bloomfield H and Curhan GC: Gemfibrozil for secondary prevention of cardiovascular events in mild to moderate chronic renal insufficiency. *Kidney Int* 66: 1123-1130, 2004
87. Keech A, Simes RJ, Barter P, et al.: Effects of long-term fenofibrate therapy on cardiovascular events in 9795 people with type 2 diabetes mellitus (the FIELD study): randomised controlled trial. *Lancet* 366: 1849-1861, 2005
88. Shepherd J, Kastelein JP, Bittner VA, et al.: Intensive lipid lowering with atorvastatin in patients with coronary artery disease, diabetes, and chronic kidney disease. *Mayo Clin Proc* 83: 870-879, 2008
89. Armitage J, Bowman L, Wallendszus K, et al.: Intensive lowering of LDL cholesterol with 80 mg versus 20 mg simvastatin daily in 12,064 survivors of myocardial infarction: a double-blind randomised trial. *Lancet* 376: 1658-1669, 2010
90. Link E, Parish S, Armitage J, et al.: SLCO1B1 variants and statin-induced myopathy--a genomewide study. *N Engl J Med* 359: 789-799, 2008
91. Bilous R, Chaturvedi N, Sjolie AK, et al.: Effect of candesartan on microalbuminuria and albumin excretion rate in diabetes: three randomized trials. *Ann Intern Med* 151: 11-20, 2009
92. The EUCLID Study Group: Randomised placebo-controlled trial of lisinopril in normotensive patients with insulin-dependent diabetes and normoalbuminuria or microalbuminuria. *Lancet* 349: 1787-1792, 1997
93. Mauer M, Zinman B, Gardiner R, et al.: Renal and retinal effects of enalapril and losartan in type 1 diabetes. *N Engl J Med* 361: 40-51, 2009
94. Haller H, Ito S, Izzo JL, Jr., et al.: Olmesartan for the delay or prevention of microalbuminuria in type 2 diabetes. *N Engl J Med* 364: 907-917, 2011
95. Patel A, MacMahon S, Chalmers J, et al.: Effects of a fixed combination of perindopril and indapamide on macrovascular and microvascular outcomes in patients with type 2 diabetes mellitus (the ADVANCE trial): a randomised controlled trial. *Lancet* 370: 829-840, 2007
96. Heart Outcomes Prevention Evaluation Study Investigators: Effects of ramipril on cardiovascular and microvascular outcomes in people with diabetes mellitus: results of the HOPE study and MICRO-HOPE substudy. *Lancet* 355: 253-259, 2000
97. Ruggerenti P, Fassi A, Ilieva AP, et al.: Preventing microalbuminuria in type 2 diabetes. *N Engl J Med* 351: 1941-1951, 2004
98. Andersen S, Brochner-Mortensen J and Parving HH: Kidney function during and after withdrawal of long-term irbesartan treatment in patients with type 2 diabetes and microalbuminuria. *Diabetes Care* 26: 3296-3302, 2003
99. Lewis EJ, Hunsicker LG, Bain RP and Rohde RD: The effect of angiotensin-converting-enzyme inhibition on diabetic nephropathy. The Collaborative Study Group. *N Engl J Med* 329: 1456-1462, 1993
100. Brenner BM, Cooper ME, de Zeeuw D, et al.: Effects of losartan on renal and cardiovascular outcomes in patients with type 2 diabetes and nephropathy. *N Engl J Med* 345: 861-869, 2001

101. Lewis EJ, Hunsicker LG, Clarke WR, et al.: Renoprotective effect of the angiotensin-receptor antagonist irbesartan in patients with nephropathy due to type 2 diabetes. *N Engl J Med* 345: 851-860, 2001
102. ACE Inhibitors in Diabetic Nephropathy Trialist Group: Should all patients with type 1 diabetes mellitus and microalbuminuria receive angiotensin-converting enzyme inhibitors? A meta-analysis of individual patient data. *Ann Intern Med* 134: 370-379, 2001
103. Hovind P, Tarnow L, Rossing P, et al.: Predictors for the development of microalbuminuria and macroalbuminuria in patients with type 1 diabetes: inception cohort study. *BMJ* 328: 1105-1109, 2004
104. Perkins BA, Ficociello LH, Silva KH, Finkelstein DM, Warram JH and Krolewski AS: Regression of microalbuminuria in type 1 diabetes. *N Engl J Med* 348: 2285-2293, 2003
105. de Boer IH, Rue TC, Cleary PA, et al.: Long-term renal outcomes of patients with type 1 diabetes mellitus and microalbuminuria: an analysis of the Diabetes Control and Complications Trial/Epidemiology of Diabetes Interventions and Complications cohort. *Arch Intern Med* 171: 412-420, 2011
106. Levey AS, Cattran D, Friedman A, et al.: Proteinuria as a surrogate outcome in CKD: report of a scientific workshop sponsored by the National Kidney Foundation and the US Food and Drug Administration. *Am J Kidney Dis* 54: 205-226, 2009
107. Watkins PJ, Parsons V and Bewick M: The prognosis and management of diabetic nephropathy. *Clin Nephrol* 7: 243-249, 1977
108. Finne P, Reunanen A, Stenman S, Groop PH and Gronhagen-Riska C: Incidence of end-stage renal disease in patients with type 1 diabetes. *JAMA* 294: 1782-1787, 2005
109. Kunz R, Friedrich C, Wolbers M and Mann JF: Meta-analysis: effect of monotherapy and combination therapy with inhibitors of the renin angiotensin system on proteinuria in renal disease. *Ann Intern Med* 148: 30-48, 2008
110. Mann JF, Schmieder RE, McQueen M, et al.: Renal outcomes with telmisartan, ramipril, or both, in people at high vascular risk (the ONTARGET study): a multicentre, randomised, double-blind, controlled trial. *Lancet* 372: 547-553, 2008
111. Cooper WO, Hernandez-Diaz S, Arbogast PG, et al.: Major congenital malformations after first-trimester exposure to ACE inhibitors. *N Engl J Med* 354: 2443-2451, 2006
112. Li DK, Yang C, Andrade S, Tavares V and Ferber JR: Maternal exposure to angiotensin converting enzyme inhibitors in the first trimester and risk of malformations in offspring: a retrospective cohort study. *BMJ* 343: d5931, 2011
113. Porta M, Hainer JW, Jansson SO, et al.: Exposure to candesartan during the first trimester of pregnancy in type 1 diabetes: experience from the placebo-controlled DIabetic REtinopathy Candesartan Trials. *Diabetologia* 54: 1298-1303, 2011
114. Parving HH, Persson F, Lewis JB, Lewis EJ and Hollenberg NK: Aliskiren combined with losartan in type 2 diabetes and nephropathy. *N Engl J Med* 358: 2433-2446, 2008
115. Caramori ML, Fioretto P and Mauer M: The need for early predictors of diabetic nephropathy risk: is albumin excretion rate sufficient? *Diabetes* 49: 1399-1408, 2000
116. Desnick RJ: Enzyme replacement therapy for Fabry disease: lessons from two alpha-galactosidase A orphan products and one FDA approval. *Expert Opin Biol Ther* 4: 1167-1176, 2004
117. Lin J, Glynn RJ, Rifai N, et al.: Inflammation and progressive nephropathy in type 1 diabetes in the diabetes control and complications trial. *Diabetes Care* 31: 2338-2343, 2008