

K/DOQI Clinical Practice Guidelines Research Recommendations

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K/DOQI Clinical Practice Guidelines for Cardiovascular Disease in Dialysis Patients

Guideline 2: Coronary Artery Disease

Research Recommendations

- Prospective trials are needed to examine the accuracy of noninvasive imaging in dialysis patients and its utility for clinical management.

Guideline 3: Acute Coronary Syndromes

Research recommendations

- Clinical trials of Acute Coronary Syndrome (ACS) treatment are required that specifically target all ranges of Chronic Kidney Disease (CKD), including dialysis patients.

Guideline 4: Chronic Coronary Artery Disease

Research Recommendations

- Randomized trials of percutaneous coronary intervention (PCI) are required, using sirolimus-eluting or paclitaxel-eluting stents compared to coronary bypass surgery.

Guideline 5: Valvular Heart Disease

Research Recommendations

- Observational studies of the newer generation of bioprosthetic valves (e.g., stentless valves) are required.
- Studies on the timing of valve replacement in relation to survival will provide valuable information (e.g., do clinicians wait too long to refer patients for surgery?).

Guideline 6: Cardiomyopathy (Systolic or Diastolic Dysfunction)

Research recommendations

- More clinical trials on treatment of Congestive Heart Failure (CHF) in dialysis patients are required. A randomized, prospective trial on primary beta-blocker therapy to reduce the risk of CHF and death would be a worthwhile project in dialysis patients, especially in diabetics.
- Valuable information may be derived from a large longitudinal cohort study of echocardiographic changes in the incident chronic hemodialysis (HD) and peritoneal dialysis (PD) populations, in the modern era of cardiac therapeutics.

- Further large cross-sectional studies are required to examine the prevalence of cardiomyopathy in the chronic HD and PD populations.

Guideline 7: Dysrhythmia

Research recommendations

- Modifications in the Centers for Medicare and Medicaid Services (CMS) form are required to increase the accuracy of data capture for arrhythmias and near-fatal cardiac arrest in dialysis patients.
- Studies are needed to assess the outcome and the effectiveness of different preventive and treatment strategies to improve the dismal outcome of near-fatal arrhythmias in dialysis patients.
- There is a strong need to evaluate the mechanisms of sudden death in this population.

Guideline 8: External Defibrillation

Research recommendations

- Observational studies are required to examine mortality trends after the implementation of this guideline.

Guideline 9: Cerebrovascular Disease

Research recommendations

- Stroke risk is very high in the CKD population. Effective screening strategies do not exist, nor do studies assessing interventions. Studies addressing these issues are greatly needed.

Guideline 10: Peripheral Vascular Disease (PVD)

Research recommendations

- Further studies are warranted to examine the feasibility and effectiveness of ankle:brachial or toe:brachial indices as screening tests for asymptomatic PVD in reducing limb amputation rates.

Guideline 11: Diabetes

Research recommendations

- Long-term, randomized controlled trials are needed to strengthen the evidence for the direct application of the American Diabetes Association (ADA) recommendations to patients on dialysis.

- More research is needed on the effect of renal dietary restrictions in diabetic patients.

Guideline 12: Blood Pressure

Research recommendations

- More studies are necessary to better determine goal blood pressures in dialysis patients.
- Studies are needed to determine which antihypertensive drugs are best suited for dialysis patients.
- More studies are necessary to determine optimal dosing (dose and time of administration) of antihypertensive drugs in dialysis patients.
- Further studies are needed to ascertain the potential advantage of daily dialysis over dialysis performed 3 times weekly to achieve better blood pressure control and better cardiovascular outcomes.

Guideline 14: Smoking, Physical Activity, and Psychological Factors

Research recommendations

Smoking

- Studies are required in CKD patients to examine the pharmacokinetics/safety of pharmacotherapies known to be effective in smoking cessation.
- Randomized trials are needed to determine the most effective interventions for smoking cessation in dialysis patients.
- Randomized, controlled trials are needed to determine the effects of smoking cessation on cardiovascular and all-cause outcomes in dialysis patients.

Physical activity

- Randomized clinical trials are needed to study the effects of exercise training on cardiovascular risk in dialysis patients.
- Studies are required to determine the optimal exercise prescription and to develop practical ways of incorporating physical activity and assessment of physical functioning into the routine care of dialysis patients.
- Studies are needed to define the barriers to exercise in dialysis patients and to develop motivational strategies to increase participation in regular physical activity.
- Studies are required to determine how to effectively incorporate physical activity into the routine care of dialysis patients.

Psychological factors

- Research is needed to study the presence of psychological distress in dialysis patients.
- Further studies are required to examine the impact of psychological distress on cardiovascular functioning and outcomes in dialysis patients.

- Studies are required in dialysis patients to examine the impact of therapeutic interventions, which are used to treat psychological conditions associated with cardiovascular disease (CVD), on psychological states and cardiovascular events.

Guideline 15: Anemia

Research recommendations

- Studies are needed to determine the most appropriate hemoglobin value to reduce the risk of nonatherosclerotic heart disease.

Guideline 16: Arterial Stiffness, Vascular and Valvular Calcification, Calcium, Phosphorus and PTH

Research recommendations

- Further studies are required to examine the use of statins in patients with pulse pressure (PP) >60 mm Hg.
- Evaluation of interventions is needed that might prevent or reverse the decrease of vascular compliance in patients with increased pulse pressure (PP).
- The validity of the semi-quantitative estimation of vascular calcification as a predictor of survival requires confirmation in other centers. Evaluation of alternative methods for estimation of coronary artery calcification (e.g., multislice CT) is needed.

Section III. State of the Science: Novel and Controversial Topics in Cardiovascular Diseases

Intradialytic Hypotension

Research recommendations

- A randomized study in patients with intradialytic hypotension (IDH) is needed to assess the safety, efficacy, and cost-effectiveness of automated feedback systems that continuously adjust ultrafiltration rate, dialysate sodium, and dialysate temperature.
- Controlled studies are also needed to examine the use of continuous on-line hematocrit monitoring to calculate the rate of ultrafiltration and blood volume and impedance measurements in the assessment of actual dry weight and desired goal for ultrafiltration.

Troponin

Research recommendations

- A prospective, randomized clinical trial on troponin testing and clinical decision-making would provide valuable information.

- There is a need for prospective cohort studies on the correlation between troponin levels and the burden of Coronary Artery Disease (CAD), as well as fatal and nonfatal CAD-related and non-CAD-related events.

Inflammation

Research recommendations

- Future research should aim at finding the optimal “cut-off” point at which elevated C-reactive protein (CRP) predicts outcome in CKD.
- Studies are needed to investigate the possible interactions between the presence of inflammation and both traditional risk factors (such as dyslipidemia) and nontraditional risk factors (such as oxidative stress, vascular calcification, advanced glycation end-products and endothelial dysfunction) for atherosclerosis.
- Research is also required to investigate the impact of age, gender, physical activity, diet, race and genetic factors on the prevalence of inflammation in CKD.
- Nonpharmacological and pharmacological interventions for patients with signs of inflammation should be developed and evaluated for efficacy in reducing inflammation and improving clinical outcomes in this patient group.
- The independent role of potential proatherogenic inflammatory biomarkers such as CRP, fetuin-A, and interleukin-6 (IL-6), in the processes of atherogenesis and progression, need to be tested in the uremic milieu.

Oxidative Stress

Research recommendations

- Studies are needed to determine which surrogate marker of oxidative stress best predicts outcome in CKD patients.
- Further research is required to investigate the possible interactions between the presence of oxidative stress and both traditional risk factors (such as dyslipidemia) and non-traditional risk factors (such as inflammation, vascular calcification, advanced glycation end-products and endothelial dysfunction) for atherosclerosis.
- Studies are also needed to determine which oxidative stress pathway (i.e., nitrosative, chlorinated or carbonyl stress) is quantitatively the most important in CKD patients. Nonpharmacological (such as diet) and pharmacological (such as vitamin E and acetylcysteine) interventions for CKD patients with signs of increased oxidative stress should be developed and evaluated for efficacy in reducing oxidative stress and improving clinical outcomes in this patient group.

Omega-3 Fatty Acids

Research recommendations

- Studies are required to identify the essential fatty acid status of CKD patients, both progressive and for those on renal replacement therapy.
- Studies should also evaluate the interrelationships among ω -3 fatty acid supplementation, oxidative stress, CVD and dialysis therapy.
- Clinical trials are needed to evaluate the role of dietary fatty acid modification on CVD risk and outcomes in CKD patients on renal replacement therapy.
- Further clinical trials should evaluate current nutrition recommendations for the general population modified to the diet recommendations for CKD patients.

Homocysteine

Research recommendations

- Further data are required regarding the effect of vitamin therapy on clinical outcomes.
- Lipoprotein(a) (Lp(a)) and Apolipoprotein(a) (Apo(a)) Polymorphism
- Further large dialysis cohorts should investigate the value of Lipoprotein(a) (Lp(a)) concentrations and Apolipoprotein(a) (Apo(a)) phenotypes for risk assessment. This question should especially be addressed in PD patients as well as in various ethnicities.
- A possible interaction of various Apolipoprotein(a) (Apo(a)) isoforms with lipids and other cardiovascular risk factors should be investigated.
- Experimental therapeutic strategies to lower Lipoprotein(a) (Lp(a)) should be examined in randomized, controlled clinical trials, especially in high-risk populations such as dialysis patients.

Malnutrition

Research recommendations

- Studies are needed to identify the incidence of hypoalbuminemia due to visceral protein store depletion vs. hypoalbuminemia due to chronic inflammation.
- Effective nutrition and medical management interventions need to be identified that are specific for malnutrition vs. inflammation vs. metabolic challenges.
- Studies are also required to examine how long-term nutritional intervention affects cardiovascular risk and specific risk factors for accelerated atherosclerosis, such as oxidative stress and endothelial dysfunction, in CKD patients.

Family History and Genetics

Research recommendations

- The predictive value of family history of CVD should be investigated in patients with renal disease.
- Further large dialysis cohorts should investigate the value of Lipoprotein(a) (Lp(a)) concentrations and Apolipoprotein(a) (Apo(a)) phenotypes for risk assessment. This question should especially be addressed in PD patients as well as in various ethnicities. Arising candidate genes for CVD should be investigated in dialysis patients.

Menopause

Research recommendations

- Little is known regarding cardiovascular outcomes associated with menopause. Observational studies should assess the impact of menopause on CVD risk. Given that there are over 30,000 women with CKD treated with hormone replacement therapy (HRT), studies should assess if the use of HRT is associated with improved CVD outcomes.

Preventive Foot Care in Diabetes

Research recommendations

- Long-term studies are warranted to examine the effectiveness of screening with ABI, and early diagnosis of peripheral vascular disease (PVD), on reducing the development of critical limb ischemia and the rates of amputation.
- Randomized, controlled trials are needed to study the effects of antiplatelet agents and statins in asymptomatic and symptomatic PVD on the development of critical limb ischemia and the rates of amputation.

Aspirin

Research recommendations

- Randomized controlled trials of aspirin as primary or secondary prophylaxis in preventing cardiovascular events with attention to GI bleeding are warranted.
- The cost-effectiveness of aspirin (risk of GI bleeding versus reduction in cardiovascular events) needs to be studied.

K/DOQI Clinical Practice Guidelines on Hypertension and Antihypertensive Agents in Chronic Kidney Disease

Guideline 2: Evaluation of Patients with CKD or Hypertension

Research Recommendations

The current clinical questions related to essential hypertension are all areas that require further research in CKD. These questions cannot be answered unless patients with CKD are included in large randomized trials. Areas for investigation include:

- Studies on the effect of various clinical and genetic factors on the response to antihypertensive therapy, to determine what factors should be included in the evaluation.
- Studies on the relationship between levels of proteinuria and albuminuria, to simplify the detection, evaluation and management of CKD.
- Studies on the cost-effectiveness of various components of the evaluation and the frequency of follow-up.

Guideline 3: Measurement of Blood Pressure in Adults

Research Recommendations

There are many unanswered questions related to the measurement of blood pressure in the CKD population.

- Research should specifically be performed in the patients with CKD who have been documented to have abnormal vascular compliance, to determine if oscillometric monitors for casual measurements give accurate results. If differences are noted, oscillometric normal values should be developed as they were for ambulatory blood pressure monitoring (ABPM).
- Controlled trials need to be performed to determine if blood pressure management in CKD patients with ambulatory blood pressure monitoring (ABPM) is superior to casual blood pressure (CBP) guided therapy
- More research into the prognostic ability of self-monitored blood pressure (SMBP) is needed. A systematic attempt should be made to test all home blood pressure monitors for accuracy especially when used for patients with CKD.
- Should all patients with CKD, especially those with higher stages of CKD have ambulatory blood pressure monitoring (ABPM), even if normotensive, to determine the presence of dipper status?
- Does white-coat hypertension (WCH) predispose to sustained hypertension?
- Should the definition of white-coat hypertension (WCH) take into account sleep blood pressure measurements for CKD patients?

- The data that alterations in circadian blood pressure rhythms are related to end-organ damage are strong, but would they benefit from a large multicenter study in CKD characterized by CKD stages?
- Does the normalization of circadian blood pressure pattern confer any protection? How would this be accomplished? Are some antihypertensive agents superior in this regard? What should be the dosage timing?
- More research using ambulatory blood pressure monitoring (ABPM) to adjust antihypertensive therapy is required. Research into the mechanisms of the abnormal blood pressure patterns coupled to the increase in end-organ damage is required and may lead to the development of new therapies.

Guideline 4: Evaluation for Renal Artery Disease

Research Recommendations

- A long-term, randomized controlled trial (RCT) should be conducted to compare the effect of medical management versus percutaneous transluminal renal angioplasty (PTRA) with stenting on blood pressure control, progression of kidney disease, and cardiovascular morbidity and mortality. Such a trial should aim to answer the questions of who is the ideal candidate for interventional therapy, and what are the benefits, if any, of an invasive approach to renal artery disease (RAD).
- The clinical predictive index needs to be validated in a hypertensive population composed of African American, Hispanics, and native Americans as well as Caucasians.

Guideline 5: Education on Self-Management Behavior

Research Recommendations

It is necessary to establish optimal interventions that combine behavioral approaches with pharmacological therapies to reduce risk factors for hypertension. Particular attention must be paid to identifying which behavioral strategies are most effective in producing desired behavior change.

- Research should be done with the CKD population that relates to behavioral factors implicated in an individual's management of hypertension. This research should include lifestyle factors, such as obesity, alcohol, cigarette smoking, and inactivity; social and environmental variables, such as lack of social support, socioeconomic status, and ethnicity; and individual characteristics, such as personality and reaction to stress.
- Research is needed regarding effective strategies for maintaining long-term adherence to self-care requirements for prevention and treatment of hypertension.
- Research is needed regarding the most effective strategies for promoting self-management behavior in minority populations.
- The effect of low-dose, combination therapy on adverse effects of medication and, in turn, medication adherence, should be examined.

Guideline 6: Dietary and Other Therapeutic Lifestyle Changes in Adults

Research Recommendations

- Conduct randomized, controlled trials to determine optimal dietary patterns to reduce blood pressure and slow the progression of kidney disease.
- Perform research to determine the effects of sodium reduction on blood pressure in patients with CKD.
- Conduct outcome studies to determine the effectiveness and value of Medical Nutrition Therapy (MNT) in CKD.

Guideline 7: Pharmacological Therapy: Use of Antihypertensive Agents in CKD

Research Recommendations

- Additional clinical studies are needed on the treatment of hypertension in patients with CKD. The variation in blood pressure within the population and the time-to-time variation in blood pressure within an individual need to be determined to permit definition of the blood pressure goal for the population.
- The effect of blood pressure control on rates of CVD in patients with CKD needs to be ascertained.
- A comparison of the effects of different antihypertensive agents on cardiovascular events in patients with CKD needs to be determined.

Guideline 8: Pharmacological Therapy: Diabetic Kidney Disease

Research Recommendations

The following questions require additional study in diabetic kidney disease:

- What is the optimal dose of angiotensin-converting enzyme (ACE) inhibitors and angiotensin-receptor blockers (ARBs) for kidney disease protection?
- What is the possible protective role of ARBs and other classes of antihypertensive agents, either alone or in combination with ACE inhibitors, on slowing kidney disease progression and CVD?
- The question regarding the optimal level of blood pressure reduction for cardiovascular risk reduction will be answered in 2008 by the Anemia Correction in Diabetes (ACORD) trial. However, this may not answer the question about the optimal level of blood pressure to slow diabetic kidney disease progression.
- Finally, studies are needed to examine the relationship between magnitude of albuminuria reduction and reduction in kidney disease progression and CVD risk, and to determine the optimal "target value" for urine albumin excretion in diabetic kidney disease during treatment with ACE inhibitors and ARBs.

Guideline 9: Pharmacological Therapy: Non-Diabetic Kidney Disease

Research Recommendations

Recommended areas for future research include:

- Optimal dosage of ACE inhibitor therapy for kidney disease protection; potential protective effects of ARBs and other classes of antihypertensive agents, either alone or in combination with ACE inhibitors, on slowing kidney disease progression;
- Preferred agents for to slow kidney disease progression in patients without proteinuria.
- Optimal level of blood pressure control for various levels of protein excretion; development of more discriminating diagnostic techniques for differentiating between types of nondiabetic CKD;
- Optimal level of proteinuria to slow kidney disease progression ("proteinuria-guided therapy").

In all studies, if feasible, it would be preferable to focus on specific types (diagnoses) of CKD due to causes other than diabetes.

Guideline 10: Pharmacological Therapy: Kidney Disease in the Kidney Transplant Recipient

Research Recommendations

- Most kidney transplant recipients have CKD after transplantation. Kidney transplant recipients are an ideal population in which to study the effects of antihypertensive therapy on the progression of kidney disease and the risk of CVD. In these patients, the onset of kidney disease in the transplanted kidney is known, patients are treated in specialized centers, measurements of blood pressure and urine protein can be standardized by adherence to protocols, and study endpoints such as deterioration in GFR and graft loss are well defined.
- The relationship of immunosuppressive medications to levels of blood pressure, proteinuria, progression of CKD, and clinical CVD also needs to be studied. For example, the use of calcineurin-inhibitors impacts the development and severity of posttransplantation hypertension. The effect of antihypertensive agents may be different depending on the immunosuppressive regimen. When using protocols that avoid or minimize exposure to calcineurin inhibitors, the value of dihydropyridine calcium-channel blockers may not be as important.
- Finally, ambulatory blood pressure monitoring should be studied in this population since a disturbed day-night blood pressure rhythm is present and office blood pressure may not accurately reflect the burden of hypertension and its relationship to progression of kidney disease or CVD.

Guideline 11: Use of Angiotensin-Converting Enzyme Inhibitors and Angiotensin Receptor Blockers in CKD

Research Recommendations

- Additional clinical studies are needed for the treatment of hypertension using ACE inhibitors and ARBs in patients with CKD due to glomerular diseases.
- More studies are required with co administration of ACE inhibitors and ARBs.
- The specific dose of ACE inhibitors or ARBs that confers the optimum renoprotective effect remains unclear.
- Future controlled trials will need to compare the dose-response relationship of antihypertensive agents to their adverse effects in patients with CKD.
- Studies should also be designed to determine differences between agents of the same class and among agents from different classes.
- Epidemiological studies will need to determine risk factors for adverse event formation.

Guideline 12: Use of Diuretics in CKD

Research Recommendations

- Additional clinical studies are needed to determine whether differences exist amongst the various loop diuretics in how each influences blood pressure independent of volume loss.
- Moreover, additional studies are needed to determine if the blood pressure-lowering response to a loop diuretic is better with ACE inhibitors or ARBs.
- Future controlled trials will need to explore the relationship between CKD progression and the electrolyte changes that accompany loop diuretic administration.
- Studies should also be designed to evaluate the impact on calcium-phosphate balance and the triggering of secondary hyperparathyroidism from the hypercalciuria produced by loop diuretic treatment.
- Finally, more studies are needed with combination loop and thiazide diuretic therapy to determine if this is a more effective and/or safer approach than high-dose therapy with a loop diuretic alone and to determine which is the best thiazide diuretic to combine with a loop diuretic.

Guideline 13: Special Considerations in Children

Research Recommendations

- Studies to investigate the role of blood pressure management in children with CKD on progression of CKD and CVD need to be undertaken so that appropriate recommendations can be formulated.
- There is a major lack of studies to address the role of adequate blood pressure management in children with CKD, on progression of kidney disease, and on CVD.

- While studies in adults demonstrate that ACE inhibitors and ARBs are preferred antihypertensive agents in retarding the progression of CKD, no such studies exist in children. It is important to recognize that children are unique and that studies are required to assess the safety and efficacy of these and other antihypertensive agents on the progression of kidney disease and on somatic and kidney growth.
- Further studies of hypertension in CKD in children should include ABPM. It is a valuable clinical tool that can provide additional information about the alterations in blood pressure patterns observed in CKD and the prediction of CVD.

K/DOQI Clinical Practice Guidelines for Bone Metabolism and Disease in Chronic Kidney Disease

Guideline 1: Evaluation of Calcium and Phosphorus Metabolism

Research Recommendations

- Much work is needed to relate biochemical markers of bone turnover to osteodystrophy in CKD.
- The role of new parathyroid hormone (PTH) assays must be further defined.
- The usefulness of dual energy X-ray absorptiometry (DEXA) requires demonstration.
- Optimal clinical practice guidelines await outcome studies on the monitoring of osteodystrophy of CKD, and validating outcome data of the recommendations made in these guidelines.

Guideline 2: Assessment of Bone Disease Associated with CKD

Research Recommendations

- Considering the invasive nature of bone biopsy, there is a need to investigate whether other markers of bone disease could be developed to replace bone biopsy for the accurate diagnosis of bone disease in patients with chronic kidney disease.
- At the present time, there are not any noninvasive tests that have sufficient accuracy for the diagnosis of bone disease in CKD patients. The Work Group recommends that bone biopsy be used to accurately establish the diagnosis in CKD patients enrolled in clinical research protocols studying bone disease. These protocols may be designed to assess the sensitivity or specificity of other diagnostic tests, or to assess the effectiveness of various therapies. In either instance, accurate diagnosis of the bone disease is pivotal to the quality and utility of such studies.
- Most of the currently used PTH assays are purported to measure only the "intact" PTH molecule, consisting of 84 amino acids. Most of the biological activity of the PTH molecule resides in the N-terminal, and, in large part, in the amino acid residues in positions 1 to 7. It appears that many "intact PTH" assays also detect biologically inactive fragments of PTH formed from the amino acids in the 7 to 84 positions. This

phenomenon leads to spurious elevations in the levels of intact PTH in CKD patients, in that these patients do not have significant hyperparathyroid bone disease even though the PTH level is above normal. If clinicians attempt to maintain intact PTH levels of CKD patients in the "normal" range below 65 pg/mL (7.15 pmol/L), then some CKD patients have low levels of bone formation and adynamic bone disease. Hence, our current recommendations distinguish between the "desired target range" for intact PTH in CKD patients and the "normal range" that has been determined for patients with normal kidney function.

Guideline 3: Evaluation of Serum Phosphorus Levels

Research Recommendations

- Longitudinal studies of patients on dialysis are needed, evaluating the effects of controlling serum phosphorus in the target range on morbidity and mortality.

Guideline 4: Restriction of Dietary Phosphorus in Patients with CKD

Recommendations for Research

- There is a need for large, multi-center longitudinal studies evaluating the effects of dietary phosphate restriction (as opposed to only protein restriction) on nutritional status, growth in children, morbidity, mortality, bone disease, and progression of decline in kidney function. These studies should be conducted in patients with all stages of CKD beginning in Stage 2.

Guideline 5: Use of Phosphate Binders in CKD

Research Recommendations

- Longitudinal studies evaluating phosphate binders and their efficacy, side effects, and impact on morbidity and mortality are needed. Although the recently completed study demonstrated an advantage of sevelamer HCl compared to calcium-based phosphate binders in preventing progression of aortic and coronary arteries calcification, studies evaluating this positive effect on cardiovascular morbidity and mortality in dialysis patients are needed.

Guideline 6: Serum Calcium and Calcium-Phosphorus Product

Research Recommendation

- Further studies are required to find the appropriate reference range of serum calcium for different age, gender, and race in CKD patients and those treated with dialysis.
- Studies are needed to determine the appropriate calcium intake, the time in the course of CKD when calcium supplementation should be initiated, and the type of calcium

salts to be used. Also, studies are needed to further understand the relationship between Ca-P product and morbidity and mortality.

Guideline 7: Prevention and Treatment of Vitamin D Insufficiency and Vitamin D Deficiency in CKD Patients (Algorithm 1)

Research Recommendations

- Prospective, controlled clinical trials with the daily administration of ergocalciferol in a monthly amount equivalent to 1,000 to 2,000 IU/day, are clearly warranted in patients with CKD and those undergoing dialysis, to assess the effects on serum levels of intact PTH, serum 1,25(OH)₂D levels, and even BMD. With the higher fracture rates known to occur in patients with Stage 5 CKD, studies to evaluate measures to minimize early secondary hyperparathyroidism would be warranted.

Guideline 8: Vitamin D Therapy in CKD Patients

This Guideline encompasses 2 parts: Guideline 8A, which deals with active vitamin D sterol therapy in CKD Stages 3 and 4, and Guideline 8B, which deals with CKD Stage 5.

Guideline 8A: Active Vitamin D Therapy in Patients with Stages 3 and 4 CKD (Algorithm 2)

Research Recommendations

- Further trials with longer-term treatment (24 months or longer) in larger numbers of patients are needed to satisfy the concern about the safety of the therapy with vitamin D sterols. *Trials with the newer vitamin D sterols which may be less calcemic will be of great interest.* An ideal goal of such treatment would be to reduce serum levels of intact PTH with little or no change in serum levels of calcium. Studies should evaluate the effect on bone, in particular to ascertain whether improvement in bone mineral content or in histological features of hyperparathyroid bone disease could be achieved. Investigational Review Boards may feel that it is inappropriate to withhold vitamin D therapy in placebo-controlled studies. However, comparisons of newer vitamin D sterols with calcitriol, alfacalcidol, or even ergocalciferol, at 50,000 IU monthly, would be ideal. It is apparent that the ideal target for serum levels of intact PTH that should be sought are not established, and biopsy evaluations in such trials with correlations between intact PTH or whole PTH levels with new assays of PTH (see discussion in Guidelines 1 and 2) and skeletal findings would be ideal. Also, in the trials that have been published, it would be useful if the data were reanalyzed to evaluate the relationship between serum levels of intact PTH and the degree of parathyroid bone disease found on biopsy in relation to the degree of impairment of kidney function.

Guideline 8B: Vitamin D Therapy in Patients on Dialysis (CKD Stage 5)

Research Recommendations

- Trials that compare different vitamin D sterols in patients with end-stage kidney disease are needed. Also, prospective trials are needed to evaluate the effect of pulse-dose calcitriol or other vitamin D sterol on bone, with study of the relationship between serum levels of intact PTH and bone turnover using double tetracycline, to assess a possibly important side-effect of vitamin D treatment.
- Moreover, little is known about the ideal target for serum levels of intact PTH during treatment with vitamin D. It is possible that the incidence of adynamic bone will increase substantially if vitamin D sterols are employed in patients who have only modest elevations of intact PTH levels.
- Studies are needed to examine the value of bone markers and to assess the relationship between the so-called "whole PTH molecule," "intact PTH," and bone histomorphometry during vitamin D treatment. Large studies that evaluate fracture rates should include data on previous vitamin D therapy in an effort to identify whether vitamin D treatment can modify the high incidence of fractures noted in end-stage kidney disease patients.

Guideline 9: Dialysate Calcium Concentrations

Research Recommendations

There is a basic conflict in calcium pathophysiology that needs to be resolved in CKD patients, i.e., the conflict between adequate suppression and control of PTH, and excessive calcium loading resulting in tissue injury. The resolution of this conflict will involve carefully designed trials to assess basic issues currently being widely discussed.

- Prospective long term studies of calcium balance and the accelerated atherosclerosis of CKD patients need to be coordinated to find the proper calcium balance that does not worsen these problems in patients.
- The regulation of PTH remains a challenge. Studies need to be done to determine what level of PTH is best (in terms of osteodystrophy) in the dialysis population. Once that is determined, the best ways to achieve the desired result will need to assess the coordination of the various biochemical and other approaches to PTH control, including dialysate calcium level.
- An acceptable balance between adequate control of PTH/bone disease and avoidance of accelerated atherosclerosis needs to be determined. Studies to define this balance will be both difficult and tedious.

Guideline 10: β_2 -Microglobulin Amyloidosis

Research Recommendations

- Long-term studies of the role of various dialysis membranes and other novel therapies are clearly warranted. However, the overall mechanism of the pathogenesis of the disease also requires further research so that more specific therapies can be developed.

Guideline 11: Aluminum Overload and Toxicity in CKD

Research Recommendations

- Longitudinal studies with the measurement of serum aluminum at 6-monthly intervals from the very outset of dialysis, combined with a subsequent desferrioxamine (DFO) test and bone biopsy in randomly selected patients and others chosen because serum aluminum levels rise $>40 \mu\text{g/L}$, could provide information on the “peak” aluminum levels at which there may be a risk of aluminum loading or the development of aluminum bone disease.
- Limited long-term trials with very low doses of aluminum gels, which remain the most “potent” of phosphate binders, would be useful. Such doses, however, almost certainly would need to be combined with another type of phosphate-binding agent.
- Large, prospective, long-term trials with the use of “low doses” of aluminum gels as phosphate binders would be useful. Those who remain convinced that low doses of aluminum are safe (and there remain some with this viewpoint) should seem compelled to design such trials to prove the point. Whether low doses of aluminum gels might be effective and safe when they are given in combination with continued “minidoses” of desferrioxamine (DFO) treatment would be useful to consider for a prospective trial, particularly with the growing concern about potential risks of calcium-based phosphate binders.

Guideline 12: Treatment of Aluminum Toxicity (Algorithm 8 and Algorithm 9)

Research Recommendations

- With the great reduction of incidences of aluminum toxicity, large clinical trials to evaluate its treatment are not likely to occur or to be possible. Some nephrologists still believe that certain “low doses” of aluminum gels are indeed both safe and effective to control serum phosphorus levels. It would be well to establish long-term, prospective trials in such patients to assess the safety of the treatment in comparison to other nonaluminum-based phosphate binders. There is little doubt that aluminum-based phosphate binders are more potent and effective in binding dietary phosphate, in comparison to similar doses of other phosphate-binding agents.

- Very small and uncontrolled trials indicate that it is possible to give aluminum-based binders combined with very small doses of desferrioxamine (DFO) (<1 mg/kg), and the investigators reported a slow, gradual reduction of plasma aluminum levels during such treatment. Others have shown that desferrioxamine (DFO) in doses of 0.5 to 1.0 mg/kg increases the ultrafilterable (and hence the dialyzable) level of plasma aluminum in dialysis patients with elevated plasma aluminum levels. These data provide the background for a potential prospective trial that could test the safety and effectiveness of aluminum gels combined with repeated, very low doses of desferrioxamine (DFO) in comparison to other nonaluminum-based phosphate binding agents.
- Investigators with interest in aluminum toxicity and its treatment need to collect additional series and cases where the desferrioxamine (DFO) is given in "low" doses of 5 mg/kg BW or even less. Recognizing whether cases of mucormycosis will be seen with such doses and use of high-efficiency dialyzers is also needed.
- In a population with substantial numbers of patients with aluminum overload and minimal symptoms, controlled trials comparing total aluminum withdrawal with desferrioxamine (DFO) treatment would be worthwhile to prove the advantage of DFO treatment over total withdrawal of exposure to aluminum.

Guideline 13: Treatment of Bone Disease in CKD

Research Recommendations

- Studies are needed to evaluate the changes in bone histology, PTH, and its fragments with the available vitamin D analogs and other therapeutic approaches.
- Aluminum accumulation in bone has become much less frequent with cessation of use of aluminum-containing phosphate binders. Unfortunately, the binders which have largely replaced aluminum have not proven completely satisfactory. Studies need to be conducted to determine whether there is a threshold of kidney function below which aluminum-based phosphate binders might be acceptable, and whether there are other substances besides citrate that increase intestinal aluminum absorption. Most importantly, studies evaluating the efficacy and safety of nonaluminum-containing and calcium-based binders are needed.
- The long-term safety of lower dialysate calcium concentration for treatment of adynamic bone disease, that is the risk of development of osteoporosis, needs to be carefully studied. Moreover, agents with a potential to increase bone turnover (eg, PTH) or newer vitamin D analogs need to be studied as candidates for treatment of adynamic bone disease. Manipulation of the calcium receptor with either calcilytics (which stimulate PTH release) or calcimimetics (which suppress PTH, but increase the amplitude of PTH cycling) may also become important therapeutic agents. Trials with some of these approaches are already underway, while others are planned for the future.

Guideline 14: Parathyroidectomy in Patients with CKD

Research Recommendations

- The monitoring and control of hyperparathyroidism remains a difficult problem and further information is needed in several areas. Correlations of PTH values with bone histology are necessary in the current era. New assays of PTH need to be evaluated for their clinical utility. The appropriate target values for PTH that are achieved by medical therapy need to be defined and related to bone histology. The appropriate target values for PTH during the course of CKD at various stages of kidney dysfunction need to be defined. Comparative studies of medical and surgical therapy would be of interest. Novel approaches to the control of hyperparathyroidism will be forthcoming.

Guideline 15: Metabolic Acidosis

Research Recommendations

- Areas for future research into the effects of chronic metabolic acidosis and osteodystrophy should include a fuller understanding of the calcium-vitamin D-PTH and the growth hormone - insulin-growth-factor-1 axes in humans with CKD at the level of bone. The role of newer therapeutic agents for osteoporosis, such as bisphosphonates, selective estrogen-receptor modulators, or isoflavones in patients with CKD, with or without chronic metabolic acidosis, remains unknown and deserves exploration.

Guideline 16: Bone Disease in the Kidney Transplant Recipient

Research Recommendations

- Much research is needed into all aspects of post-transplant osteodystrophy, including its pathogenesis and treatment. Most of the recommendations for management of post-transplant osteodystrophy require additional clinical trials. Clinical trials comparing alternative potentially beneficial therapies, alone or in combination, should be conducted in this important population.

K/DOQI Clinical Practice Guidelines for Chronic Kidney Disease: Evaluation, Classification, and Stratification

Guideline 1: Definition and Stages of Chronic Kidney Disease

Research Recommendations

- The Workgroup acknowledges that the proposed definition and classification chronic kidney disease and stages is arbitrary and can be refined by further research.
- The normal range for glomerular filtration rate (GFR) was defined using a relatively small number of individuals. It would be useful to conduct a large cross-sectional study of GFR in general population, across the full range of age, gender, race, ethnicity, protein intake, with adjustment for other factors, including high blood pressure, diabetes, and other conditions that affect GFR. This study would permit validation of prediction equations based on serum creatinine or other filtration markers within the normal range of GFR.
- The outcomes of individuals with various stages of chronic kidney disease are not defined. A cohort study of patients with chronic kidney disease would enable definition of the relationship between factors and outcomes of stages of chronic kidney disease. This would be particularly useful in defining the relationships among stages of chronic kidney disease, progression of chronic kidney disease, initiation and progression of cardiovascular disease, health service utilization, and barriers to care.
- Age-related rise in blood pressure and decline in GFR may be responsible for a large number of individuals in Stage 3 (GFR 30 to 59 mL/min/1.73 m²). There are even more individuals with high blood pressure and decreased GFR (GFR 60 to 89 mL/min/1.73 m²), who have not been classified as having chronic kidney disease. It would be useful to conduct cross-sectional and cohort studies of elderly individuals with normal and abnormal blood pressure and GFR to assess the effect of high blood pressure and decreased GFR in this population.

Guideline 2: Evaluation and Treatment

Research Recommendations

- Much research is needed to define diagnostic and therapeutic strategies to reduce adverse outcomes of chronic kidney disease at each stage of disease. It will also be important to assess the effect of implementing these guidelines on the outcomes of chronic kidney disease.

Guideline 3: Individuals at Increased Risk of Chronic Kidney Disease

Research Recommendations

- Implementation of these guidelines will require education of all health care providers about risk factors for chronic kidney disease and methods of testing. The Seventh Report of the Joint National Committee for the Prevention, Evaluation, Detection and Treatment of High Blood Pressure (JNC-VII) and the American Diabetes Association have issued recommendations for the evaluation of patients with high blood pressure and diabetes, respectively, for chronic kidney disease. However, as indicated in Table 42, a large number of individuals without high blood pressure and diabetes may also be at increased risk. Thus, it will be important to test a larger population than currently targeted, which would increase the cost of health care.
- The increased health care costs that would follow implementation of a screening program for chronic kidney disease may well require a more solid base of evidence than is currently available. The Work Group recommends development of a clinical practice guideline focused on this issue in order to develop specific recommendations for evaluating adults for chronic kidney disease. In the past, universal screening was not recommended because of the low prevalence of chronic kidney disease and the lack of treatments to improve outcomes. Data provided in these guidelines suggests that the prevalence of earlier stages of chronic kidney disease is higher than previously known and that earlier detection and treatment to prevent or delay the loss of kidney function and development of cardiovascular disease in chronic kidney disease. If sufficient information is not available to assess the value of testing individuals at increased risk, or of universal screening, the Work Group suggests that research on evaluation programs should be conducted

Guideline 4: Estimation of GFR

Research Recommendations

Estimating GFR

- Although existing equations based on serum creatinine provide an excellent cost-effective method for estimating GFR, their precision is limited. New methods are needed, particularly for detecting mild and moderate kidney disease, but their value in terms of bias, precision, and practicality should be well tested in large samples of subjects with and without kidney disease. In adults, new measures will have to perform substantially better than the 12.1% median difference (~90% of estimates within 30%) from GFR obtained with serum creatinine, age, sex, and race using the MDRD Study equation. In children, standardization of creatinine measurement across studies, use of gold standard GFR measures for reference, and inclusion of larger samples of children of different ages and ethnicities will allow refinement of the constants which should be used in estimating GFR in future modifications of the Counahan-Barratt or Schwartz formula.

- While the MDRD Study equation has many advantages, it needs further validation. In particular, further studies should focus on individuals with diabetes, mild decreases in kidney function or normal GFR, Mexican-Americans (whose average serum creatinine is lower than Caucasians), and non-US populations. The extent to which averaging multiple estimates improves precision needs further study. Including a direct measure of body composition by bioelectric impedance or dual-energy X-ray absorptiometry scanning may provide promising directions for improving on the prediction of GFR using serum creatinine.

Definition of “Normal” GFR Across Ages and Ethnicities

- The definition of decreased GFR relies on an understanding of the “normal” GFR range. The amount of data in healthy individuals of different ethnicities and children is limited. GFR may differ across ethnic groups but data are very sparse. It is also unknown to what extent a mild decrease in GFR among individuals without hypertension is indicative of kidney disease or “normal” aging.

Prediction Equations for Creatinine Excretion

- It would be useful in clinical practice to be able to estimate creatinine excretion from physiologic variables related to creatinine generation and extra-renal elimination, such as age, gender, race, body size, and GFR. This might be done in cross-sectional studies that measured these physiologic variables as well as 24-hour urine creatinine excretion. This would allow improved estimates of daily excretion of some urine solutes from measurements of solute-to-creatinine ratio in spot urine samples. estimates of daily excretion of some urine solutes from measurements of solute-to-creatinine ratio in spot urine samples.

Guideline 5: Assessment of Proteinuria

Research Recommendations

- Evaluate novel approaches to measuring urine and blood abnormalities which may predate and possibly predict proteinuria/albuminuria. Examples include elevated levels of beta -2-microglobulin and other tubular proteins in the urine of diabetic patients. Additional efforts should be instituted to identify constituents present in blood and/or urine that indicate normal kidney function with high specificity.
- It would be useful to conduct prospective trials of the long-term efficacy of antihypertensive medications that reduce albumin/protein excretion in kidney disease. These studies should incorporate better procedures to examine the efficacy of sustaining kidney function in advanced kidney disease and in reducing the incidence of cardiovascular disease in patients with kidney disease.
- It would also be useful to determine the relationships between factors that may affect albumin/protein excretion and also increase the risk of macrovascular disease (eg, glucose intolerance/diabetes mellitus, rising blood pressure, elevated lipid levels, and obesity) and progressive kidney failure.

Guideline 6: Markers of Chronic Kidney Disease other than Proteinuria

Research Recommendations

- Novel and expanded uses of established methodologies (such as Doppler or functional MRI) should be pursued in clinical research studies. Several novel urinary markers show promise of noninvasive demonstration of kidney damage or prediction of disease progression. None appears to be ready at this time for widespread application in clinical practice. Longitudinal and follow-up studies are necessary to verify whether abnormal NAG and possibly retinol-binding protein excretion in normoalbuminuric diabetic patients reliably predict later development of microalbuminuria and diabetic nephropathy. Similar studies are needed to confirm whether increased beta-2-microglobulin excretion predicts development of kidney failure in patients with idiopathic membranous nephropathy. Longitudinal studies of urinary excretion of specific cell types (macrophages, natural killer (NK) cells, podocytes) in diabetic nephropathy, Henoch-Schönlein nephropathy, and IgA nephropathy are also necessary in order to confirm preliminary findings that cyturia is strongly associated with activity in these diseases. Preliminary work on the urinary excretion of podocyte-specific marker proteins such as podocalyxin and nephrin should be validated by further studies.

Guideline 7: Association of Level of GFR with Hypertension

Research Recommendations

- A broad set of recommendations for research on high blood pressure in chronic kidney disease was developed by the NKF Task Force on Cardiovascular Disease in Chronic Renal Disease. Recommendations for observational studies are reproduced in Table 74 and for clinical trials in Table 75.

Guideline 8: Association of Level of GFR with Anemia

Research Recommendations

Clearly, more information is needed on hemoglobin levels in chronic kidney disease—especially in patients in the early stages of kidney disease and as kidney function declines. Future studies should include:

- Evaluation of the relationships between erythropoietin levels, hemoglobin and iron stores in patients with chronic kidney disease at each stage of the disease
- Description of changes in these hematological parameters in specific subgroups, such as diabetics and patients with failing transplant grafts
- Evaluation of the impact of treatment of anemia in stages of kidney disease prior to dialysis (CKD Stages 1-4) on kidney function decline, cardiac function, and general well-being

- Economic evaluations of therapeutic strategies which include maintenance of hemoglobin versus correction from low levels at different stages of chronic kidney disease.

Guideline 9: Association of Level of GFR with Nutritional Status

Research Recommendations

- Although the data presented herein is compelling, more research, especially prospective studies evaluating the impact of kidney disease on nutritional parameters, is needed. Importantly, studies to define the optimal methods to evaluate nutritional status in chronic kidney disease patients are critical. Prospective studies evaluating the impact of different levels of nutritional status on subsequent outcome in chronic kidney disease patients should also be performed. Finally, prospective studies evaluating the impact of intensive nutritional counseling on nutritional status and possibly clinical outcome in chronic kidney disease patients should be carried out.

Guideline 10: Association of Level of GFR with Bone Disease and Disorders of Calcium and Phosphorus Metabolism

Research Recommendations

- Much of the available information regarding abnormalities of mineral metabolism is derived from studies of patients with kidney failure or severely decreased kidney function. Clearly, more information is needed on the abnormalities of bone mineral metabolism among patients with earlier stages of chronic kidney disease. Moreover, research on outcomes related to abnormal mineral metabolism or bone disease is lacking in both patients with mildly, as well as severely decreased kidney function. In addition to bone complications, there is increasing evidence relating abnormal calcium-phosphorus metabolism and hyperparathyroidism to vascular calcification and cardiovascular complications.
- The relationship between levels of the available markers, and levels of kidney function, should be more accurately characterized. In addition, the relationship between such levels and kidney function should be separately studied among patients with additional risks of bone complications, that is, patients treated for prolonged periods with corticosteroids and transplant recipients.
- Research should also focus on the impact of interventions on levels of available markers and outcomes, specifically of interest would be comparing patients cared for by nephrologists with those not under the care of nephrologists, patients treated for some specified period of time for hyperparathyroidism compared to those not treated, and patients treated with corticosteroids compared to those never treated with such drugs.

Guideline 11: Association of Level of GFR with Neuropathy

Research Recommendations

- Much of the available information regarding neuropathy is derived from studies of patients with kidney failure. More information on neuropathy among patients with chronic kidney disease with earlier stages of chronic kidney disease may provide other means to follow progression of chronic kidney disease. In addition, if neuropathy were to be more carefully described and noted to have a high prevalence in earlier stages of chronic kidney disease and a relationship to kidney function, treatments to delay its progression could be considered.
- The relationship between subjective and objective measures of neuropathy, and levels of kidney function, should be more accurately characterized. In addition, the relationship between neuropathy and kidney function should be separately studied among patients with additional risks of neuropathy, such as diabetics and patients with amyloidosis.

Guideline 12: Association of Level of GFR with Indices of Functioning and Well-Being

Research Recommendations

- Research in dialysis patients has shown that functioning and well-being pre-treatment may predict post-treatment outcomes. Therefore, large-scale longitudinal studies are needed to evaluate the relationship between GFR and all domains of functional status and well-being throughout the course of progression of kidney disease. More research should be undertaken using the recommended standardized instruments and their outcomes compared. Whenever specific medications could affect outcomes, usage should be assessed. Because conditions such as anemia, bone disease, cardiovascular, disease, and diabetes can affect functioning and well-being, researchers need to study whether appropriate management of these conditions improves functioning and well-being. Finally, researchers need to examine the effectiveness of rehabilitation interventions in earlier stages of chronic kidney disease. Doing so could provide further scientific evidence for the relationship of kidney function and treatment on patients' risk of dysfunction, hospitalization, and death and increase understanding of what interventions improve functioning and well-being and reduce the burden of chronic kidney disease on the patient, his or her family, and society.

Guideline 13: Factors Associated with Loss of Kidney Function in Chronic Kidney Disease

Research Recommendations

- It is evident that there is a large amount of data in studies of varying size and quality regarding the impact of underlying conditions, patient characteristics, and

interventions. However, there are certain factors whose impact has not been conclusively determined, such as dietary protein intake, hyperlipidemia, and anemia and their treatment. Proteinuria as a risk factor deserves special consideration. Antihypertensive agents, especially ACE-inhibitors and angiotensin-receptor blockers, reduce proteinuria and slow the progression of kidney disease. However, the role of proteinuria per se has not been adequately studied. There is a need to develop alternative therapies to reduce urine protein.

- Many of the conclusions regarding the impact of factors unrelated to intervention, such as age, gender, race, and cause of kidney disease, come from “small” interventional trials. Similarly, in the case of the impact of blood pressure control, conclusions largely come from the observations that patients with lower blood pressures have improved outcomes. In the case of cause of kidney disease, the conclusion that certain causes are associated with faster rates of progression come from the comparison of studies of single causes, using diverse methods to measure or estimate GFR. A noninterventional prospective cohort study including sufficient numbers of patients with all causes of kidney disease, undergoing similar testing for level of kidney function, would be ideal to evaluate the impact of cause of kidney disease on the rate of decline in GFR. Alternatively, a sufficiently large prospective interventional trial could achieve a similar goal.

Guideline 14: Association of Chronic Kidney Disease with Diabetic Complications

Research Recommendations

- Much of the understanding about the relationships between diabetic nephropathy and cardiovascular disease, retinopathy, and neuropathy comes from studies in Caucasians. Yet the epidemic of diabetes affects many racial/ethnic groups worldwide. Since race/ethnicity may influence not only the risk of diabetes, but the severity and type of diabetic complications that develop, further characterization of the impact of diabetes in different populations is needed. Further characterization of these relationships in the elderly is also needed. Moreover, the extent to which aggressive treatment of diabetic complications modulates the progression of kidney disease needs to be examined, since recent studies suggest that improvements in the treatment of cardiovascular disease in patients with type 2 diabetes have contributed to an increase in diabetic kidney failure.

Guideline 15: Association of Chronic Kidney Disease with Cardiovascular Disease

Research Recommendations

- A large prospective multi-ethnic cohort study involving patients with Stage 3 and 4 chronic kidney disease is necessary to further examine the impact of “traditional” and “kidney disease-related” risk factors on incident cardiovascular disease. Emphasis should be placed on the recognition of potentially modifiable risk factors. Such a

- study could also determine the time course of cardiovascular disease in the chronic kidney disease population.
- A predictive clinical tool, using kidney disease stage and diagnosis, risk factors, and/or other variables, should be developed to better predict risk in patients with chronic kidney disease.
 - Standards for the measurement of kidney function and albuminuria in observational and controlled trials should be established.

K/DOQI Clinical Practice Guidelines for Managing Dyslipidemias in Chronic Kidney Disease

Research Recommendations

There are reasonable doubts as to whether trial results from the general population are applicable to all patients with CKD. It is beyond the scope of these guidelines to recommend all research that should be conducted in patients with dyslipidemia and CKD, or to design clinical trials. However, it is apparent that some questions are particularly well suited for study (Table 42), although these recommendations are not meant to be endorsements for specific protocols.

Table 42. Intervention Trials That Are Needed in Patients with Chronic Kidney Disease.

Population	Primary Intervention	Lipid Profile	Primary Endpoints
Stages 1-4 CKD	Statin	Any lipid profile, or ↑ LDL	ACVD, and/or Decline in GFR
Stages 1-4 CKD	Fibrate	↑ Triglycerides with ↑ non-HDL cholesterol	ACVD, and/or Decline in GFR
Hemodialysis	Statin, or Sevelamer hydrochloride	Any lipid profile	ACVD
Hemodialysis	Statin, or Fibrate, or Sevelamer hydrochloride	↑ Triglycerides with ↑ non-HDL cholesterol	ACVD
Peritoneal Dialysis	Statin	Any lipid profile, or ↑ LDL	ACVD
Transplant	Statin	Any lipid profile, or ↑ LDL	ACVD, and/or Decline in GFR

- **For children with CKD and/or a functioning kidney transplant, prospective cohort studies with long-term follow-up are recommended to determine:**
 1. The prevalence of dyslipidemias at all stages of CKD over time
 2. The associations between dyslipidemias and subsequent ACVD

- **For children with CKD and/or a functioning kidney transplant, phase I and phase II trials, and pharmacokinetic dosing studies are recommended to establish the safety and lipid-lowering efficacy of agents (*including, but not limited to*):**
 1. Bile acid sequestrants, eg, colesevelam
 2. Cholesterol uptake inhibitors, eg, ezetimibe
 3. Statins
 4. Fibrates
 5. Nicotinic acid
 6. Sevelamer hydrochloride
 7. Appropriate lipid-lowering drug combinations

- **For adults with CKD and/or a functioning kidney transplant, phase I and phase II trials and pharmacokinetic dosing studies are recommended to establish the safety and lipid-lowering efficacy of new agents (*including, but not limited to*):**
 1. Colesevelam
 2. Cholesterol uptake inhibitors, eg, ezetimibe
 3. Appropriate lipid-lowering drug combinations

- **For patients with Stages 1-4 CKD, these and other appropriate studies are recommended to determine whether:**
 1. A statin safely reduces the incidence of ACVD and all-cause mortality in patients with any lipid profile.
 2. A statin safely reduces the rate of decline in GFR in patients with any lipid profile.
 3. A statin safely reduces the incidence of ACVD and all-cause mortality in patients with LDL ≥ 100 mg/dL (≥ 2.59 mmol/L).
 4. A statin safely reduces the rate of decline in GFR in patients with LDL ≥ 100 mg/dL (≥ 2.59 mmol/L).
 5. A fibrate safely reduces the incidence of ACVD and all-cause mortality in patients with triglycerides ≥ 200 mg/dL (≥ 2.26 mmol/L) and non-HDL cholesterol ≥ 130 mg/dL (≥ 3.36 mmol/L).
 6. A fibrate safely reduces the rate of decline in GFR in patients with triglycerides ≥ 200 mg/dL (≥ 2.26 mmol/L) and non-HDL cholesterol ≥ 130 mg/dL (≥ 3.36 mmol/L).

- **For chronic hemodialysis patients, these and other appropriate studies are recommended to determine whether:**
 1. A statin safely reduces the incidence of ACVD and all-cause mortality in patients with any lipid profile.

2. A statin safely reduces the incidence of ACVD and all-cause mortality in patients with triglycerides ≥ 200 mg/dL (≥ 2.26 mmol/L) and non-HDL cholesterol ≥ 130 mg/dL (≥ 3.36 mmol/L).
 3. A fibrate safely reduces the incidence of ACVD and all-cause mortality in patients with triglycerides ≥ 200 mg/dL (≥ 2.26 mmol/L) and non-HDL cholesterol ≥ 130 mg/dL (≥ 3.36 mmol/L).
 4. Sevelamer hydrochloride safely reduces the incidence of ACVD and all-cause mortality in patients with triglycerides ≥ 200 mg/dL (≥ 2.26 mmol/L) and non-HDL cholesterol ≥ 130 mg/dL (≥ 3.36 mmol/L).
- **For chronic peritoneal dialysis patients, these and other appropriate studies are recommended to determine whether:**
 1. A statin safely reduces the incidence of ACVD and all-cause mortality in patients with any lipid profile.
 2. A statin safely reduces the incidence of ACVD and all-cause mortality in patients with LDL ≥ 100 mg/dL (≥ 2.59 mmol/L).
 - **For kidney transplant recipients, these and other appropriate studies are recommended to determine whether:**
 1. A statin safely reduces the incidence of ACVD and all-cause mortality in patients with any lipid profile.
 2. A statin safely reduces the rate of decline in GFR in patients with any lipid profile.
 3. A statin safely reduces the incidence of ACVD and all-cause mortality in patients with LDL ≥ 100 mg/dL (≥ 2.59 mmol/L).
 4. A statin safely reduces the rate of decline in GFR in patients with LDL ≥ 100 mg/dL (≥ 2.59 mmol/L).

NKF-K/DOQI Clinical Practice Guidelines for Hemodialysis Adequacy: Update 2006

Guideline 1: Initiation of HD

Research Recommendations

- It has been well shown that education and planning for kidney failure can improve patient outcomes, but optimal approaches have not been established. Answers to certain questions could help improve clinical outcomes while reducing costs. These questions include the approaches to education and planning for kidney failure in different demographic and cultural groups and their relative costs.
 1. How effective are video and internet-based educational materials?

2. Are computer-interactive programs helpful?
 3. How can nephrologists, nurses, social workers, dietitians, pharmacists, other professionals, and patient volunteers work together most effectively to educate new kidney patients and families?
 4. What is the best training for kidney patient educators?
 5. How much of the educational role should nephrologists delegate? For example, can earlier teaching about dietary potassium allow more extensive treatment with ACE inhibitors and ARBs in patients with CKD?
 6. Can new approaches to early dietary education yield improved volume and phosphorus control when patients reach kidney failure?
 7. What are the psychological and behavioral consequences of early education about the prospect of eventual organ failure and the shortened life expectancy associated with kidney failure?
- Estimation equations for GFR (Table 1, Guideline 1) should be examined in patients who produce unusually little creatinine, in particular, the elderly and patients with other chronic illnesses. A second important clinical group for which current estimating equations have not been validated is those with significantly decreased kidney perfusion, as occurs in patients with advanced heart failure.
 - Studies of the time to initiate replacement therapy are needed to determine the consequences of timing on survival, morbidity, and cost. Results of the Initiating Dialysis Early and Late (IDEAL) Study will be critical, but it seems unlikely to be definitive for all clinical subgroups. In view of racial differences in dialysis mortality rates, it seems plausible that response to early treatment might vary by race. The HEMO Study finding of differential dose effects in women also suggests the possibility that the response to early initiation also might vary by sex. Because of longer exposure to uremia, do patients with a slower decrease in GFR benefit from earlier initiation of kidney replacement therapy? Do patients with primary tubular disorders benefit from initiation of Kidney Replacement Therapy (KRT) at a higher level of GFR than patients with primary glomerular disorders? These questions should be addressed in particular groups of interest, including children and the elderly.
 - Less critical questions include measurement of patients' preferences (in the technical sense of utility) for the states of education vs. ignorance regarding prognosis and choices. It also would be important to understand demographic and cultural determinants of preference variation.
 - Finally, work is needed on the ethical implications of therapeutic attempts to influence patient preferences. These issues are all less critical as research priorities, not because they are less important, but because the findings are less likely to influence practice and policy in the short term.

Guideline 2: Methods for Measuring and Expressing HD Dose

Research Recommendations

- The ongoing Frequent HD Network will provide data that should be used to evaluate potential benefits of short-daily or nocturnal dialysis. If published uncontrolled studies showing better quality of life (QOL) are confirmed, efforts must be directed to provide more frequent dialysis in a less encumbering manner.
- The conductivity method promises to eliminate the need for drawing blood before and after dialysis and can be applied to each dialysis treatment. Objective studies are needed to correlate the delivered dose measured by using conductivity (ionic) dialysate methods with both eKt/V and $spKt/V$ determined by using classic blood-based methods. Testing is needed to show whether this method is a reliable substitute for the present technique.
- Tests of variance are needed for Kt/V measured in patients receiving daily dialysis treatments. Theoretically, the variance will be larger because measured blood urea nitrogen (BUN) values will be considerably lower and excursions from predialysis BUN to postdialysis BUN also will be lower, which reduces the power of kinetic modeling. How much lower and how much variance have not been determined in an experimental setting. This study can be done simply by drawing predialysis and postdialysis blood samples several days in succession. If blood-based measurements of Kt/V are found to be less reliable in these patients, dialysate methods may be required to measure the delivered dose. However, dialysate methods are intrinsically less accurate for measuring Kt/V than blood-based methods,³⁶⁴ so additional comparative studies will be required if the blood-based methods are found to be inadequate.

Guideline 3: Methods for Postdialysis Blood Sampling

Research Recommendations

- Because the amount of blood drawn from dialysis patients should always be minimized, it is desirable to minimize the volume of the discard sample when drawing blood from a venous catheter. Studies of how the ratio of discarded volume to catheter lumen volume affects BUN concentration would be of practical interest.
- Because timing may be different in smaller patients with shorter circuit pathways, validation of the stop-blood-flow method and stop-dialysate-flow method for determining dialysis dose in children requires future research.
- A study of needlestick injuries in dialysis clinics might help promote the use of blood-sampling procedures that do not involve use of exposed needles. This is an area of obvious importance and interest for which very few data are available.

Guideline 4: Minimally Adequate HD

Research Recommendations

- There are no reliable data regarding mortality that are not extremely susceptible to patient selection, and no RCT comparing mortality rates is foreseen in the near future. Whether more frequent dialysis reduces hospitalization rates may be answered by an RCT currently in progress (NIH Frequent HD Network trial), although this trial is underpowered to detect other than a very large reduction. However, it is powered to detect improvements in both QOL measures and left ventricular mass index; the latter is strongly related to “hard” cardiovascular outcomes.
- An alternative measure of dialysis dose in units measuring conductivity is $K_{\text{ecn}} \times T/V_{\text{ant}}$, where K_{ecn} is the conductivity-derived dialyzer clearance, T = session length, and V_{ant} = anthropometric volume. Studies are needed to determine whether adequacy determined serially using a conductivity standard is more or less variable, and more or less reliable, than adequacy determined based on classical urea kinetics with predialysis vs. postdialysis BUN measurements. Studies are also needed to determine whether much of the same information gleaned from monthly pre- and postdialysis BUN measurements in terms of PCR could be obtained using monthly predialysis BUN measurements only, and quarterly pre/post BUN values.
- Further study would look at the ratio of modeled to anthropometric volume, both cross-sectionally, and serially in large numbers of patients, and the possibility of dosing dialysis based on $K_{\text{ecn}} \times T/\text{BSA}$, where BSA is body surface area multiplied by a correction factor such that it would vary to the 2/3 power and in effect, reflect dosing based on body surface area.

Guideline 5: Volume and Blood Pressure Control

Research Recommendations

- The cost of dialyzer and blood tubing disposal has a direct impact on reuse, which reduces this provider burden. Aside from the biological hazard, recycling of dialyzer and tubing materials could reduce the requirement for disposal site space. Studies of the potential economic benefits are needed.
- Reuse of dialyzers and blood tubing may influence patient exposure to spalled particles, plasticizers, bore fluid, ethylene oxide, and other noxious manufacturing residuals from newly manufactured dialyzers. Studies should compare these exposures with the single-use situation when dialyzers and tubing are reused.
- More research should be devoted to reprocessing techniques for various types of dialyzer membranes made by different manufacturers, especially with regard to approaches involving heat and more biocompatible chemicals, such as citric acid.

Guideline 6: Preservation of Residual Kidney Function (RKF)

Research Recommendations

- Additional comparative studies of outcome in patients with and without RKF are needed.³⁵⁵ At the present time, many dialysis clinics do not measure RKF routinely and some do not measure it at all. Such studies would help resolve the critical question about the importance of RKF measurements. Perhaps even more helpful would be a controlled clinical trial in which the prescribed dialysis dose is adjusted or not in patients with significant RKF.
- Some studies have implicated contamination of the water used to prepare dialysate as a cause of dialysis morbidity and mortality. Other studies suggested that ultrapure dialysate helps preserve RKF.²³² Additional confirmatory studies are needed to determine whether introduction of ultrapure dialysate into routine clinical practice would help preserve RKF and improve such clinical outcomes as blood pressure control, nutritional status, and quality of life (QOL).
- A trial of ACE inhibitors or ARBs should be done to evaluate the effectiveness of such agents in preserving RKF.
- After dialysis therapy has started, diuretics often are prescribed for patients with good urine output to help with potassium balance and avoid excessive fluctuations in ECF volume and blood pressure. This practice may or may not help preserve RKF. Studies should address the effectiveness of various diuretic doses and whether diuretics should be advocated in patients with significant urine output to help preserve RKF.
- For patients in whom the targeted prescribed dialysis dose is based on RKF, there is an obvious need to measure RKF, but the optimum frequency of measurements has not been determined. The optimum frequency may depend on the type of kidney disease and the patient's history of its progression.
- Observational studies should include data to determine whether RKF serves to reduce fluctuations in serum potassium and bicarbonate concentrations and reduce ECF volume and blood pressure fluctuations.
- Some patients with slowly progressive kidney disease might benefit from incremental dialysis frequency (initiation of HD at a frequency < 3 times per week). Studies are needed to determine whether such a practice would help preserve RKF in patients with significant urine output and those with a marginally functional renal allograft.
- RKF imparts a stronger survival advantage than dose of dialysis. Investigations should explore potential kidney synthetic functions that, if preserved in the remnant kidney, may provide survival benefits not explained by level of GFR.

Guideline 7: Clinical Outcome Goals

Research Recommendations

- Additional studies are needed to validate the tools currently used to measure QOL and patient satisfaction within the diverse CKD stage 5 population. Interventions used to improve QOL and patient satisfaction should be evaluated to determine success in

- improving QOL, patient satisfaction, and clinical outcome. As standards of care are modified and new care strategies are introduced, there is need for periodic reassessment of the presently recommended dose of dialysis and its effect on patient mortality, hospitalization rates, QOL, patient satisfaction, and transplantation rates.
- There is a need for analysis of data linking clinical outcomes to recommended processes within the target goals. This would include analysis of the impact of specific KDOQI processes adjusting for established factors (eg, blood pressure control, hemoglobin A_{1c} [HbA_{1c}], lipid management, pharmacological therapy) that strongly influence clinical outcomes of HD patients. Periodically, there is a need for refining case-mix adjustments over time to reflect changes in relative contribution of traditional, nontraditional, and emerging risk factors as standards of care change.

Guideline 8: Pediatric HD Prescription and Adequacy

Research Recommendations

- The high rates of young adult HD patient cardiovascular mortality and morbidity, psychological illness, and unemployment compel pediatric HD patient study in the areas of inflammation, cardiovascular fitness, nutrition assessment and malnutrition treatment, and health-related QOL. Because many young adult patients are treated in pediatric programs and have the potential to develop morbidities in their pediatric years, there is a need to study these areas in pediatric patients. Measurement of HD small-solute clearance, preferably using either measured or validated estimated eKt/V, and nutrition, using nPCR, are critical to control for the dose of delivered dialysis and nutrition status in any pediatric HD outcome study. Recent recommendations from the European Pediatric Dialysis Working Group³⁵⁹ provide an excellent basis in terms of the current state of the art in pediatric HD practice, from which future research should emanate to improve the care of pediatric HD patients.
- Recent data from a small pediatric study showed benefits of daily nocturnal HD in children. Additional study of daily HD treatment schedules and technologies should be undertaken in children

NKF-K/DOQI Clinical Practice Guidelines for Peritoneal Dialysis Adequacy: Update 2006

Guideline 1: Initiation of Dialysis

Research Recommendations

- Although it is recognized that the patient's clinical condition at the start of Kidney Replacement Therapy (KRT) is an important predictor of outcome, there are no data to confirm whether an “earlier” (in terms of kidney progression) or a “healthier” (less

advanced comorbidities) start results in a survival advantage or just a lead-time bias. Furthermore, is the answer to that question dependent on prior rate of progression of kidney disease, cause of kidney disease, the same for different ethnic groups, or dependent on comorbidities present? Given the cost of Kidney Replacement Therapy (KRT) to society, it is important to know whether, in general, the timing of the start of dialysis therapy improves total lifespan or only increases time on dialysis therapy, but not total lifespan. If it is the latter, data to show that the patient otherwise would tend to be healthier with less hospitalization, better QOL, or rehabilitation also would be important to know.

- Much more research is needed regarding the impact on the patient of the period leading up to dialysis therapy and the period just after starting dialysis therapy. Additional research is needed on mood disorders, particularly depression and anger, that may develop during this period and the impact such disorders may have on outcomes after dialysis therapy is initiated.

Guideline 2: PD Solute Clearance Targets and Measurements

Research Recommendations

- It now is well documented that the presence of RKF offers the typical patient on Kidney Replacement Therapy (KRT) an important survival advantage. What is not known is why that is true. Is it caused by better blood pressure or volume control, more small-solute removal, removal of middle molecules, or some other poorly recognized function of metabolic or paracrine function of the kidney tubules? Additional research to define the effects of RKF would be most important. Results may influence clinical practice, guidelines on initiation of dialysis therapy (can it be done in an incremental manner?), and further determine how one best includes the residual kidney component of total solute clearance in dose calculations.
- As noted in the text of these guidelines, 2 recent prospective randomized trials suggested that, over the range of solute clearance studies and using current standard PD technologies (mainly continuous ambulatory peritoneal dialysis (CAPD)), trying to achieve higher solute clearance goals had little clinical benefit for the population as a whole. Therefore, considerably more research is needed in the area of adequacy of PD. Additional randomized trials, optimally multicentered, to examine different PD doses are needed to evaluate lower Kt/V_{urea} in populations with larger patients with more comorbidity. A study that compares a group that maintains a peritoneal Kt/V_{urea} of 1.7 from the start of dialysis therapy (disregarding RKF) with a group that has a total Kt/V_{urea} of 1.7 (kidney plus peritoneal, which would require starting PD therapy with a minimal prescription with subsequent adjustment upward as RKF is lost) would be helpful. In addition, a randomized trial of different levels of small-molecule clearances is needed specifically for anuric patients on PD therapy. Trials with a longer follow-up than 2 years with assessment of nerve conduction to evaluate for neuropathy would be helpful. Markers of middle-molecule clearances also should be obtained long term. A randomized study to evaluate the influence of middle-molecule clearance or of full- versus partial-duration day dwells on patient outcomes would be valuable.

- Trials are needed in APD, with both dry day and wet days. A trial that compares outcomes with beginning PD on APD with a dry day versus beginning PD with a wet day (controlling for peritoneal dose), with the subsequent adjustment of the prescription (including the addition of a wet day), would be informative in evaluating the potential benefit of a dry abdomen for part of the day on protection of the peritoneal membrane and immune function. Such a study would need to include markers of the peritoneal membrane, as well as determination of middle molecules and neuropathy.
- Studies must be designed that separate the effects of volume control from those of small-molecule clearances. It is clear from the studies that have been done that volume overload sometimes is a consequence of using a limited number of exchanges in continuous ambulatory peritoneal dialysis (CAPD) and perhaps a consequence of excessively short nighttime exchanges in APD, in which the ultrafiltration volume is likely to be 50% sodium free.
- Because increasing small-molecule clearance does not appear to be the path to improved survival, studies investigating other maneuvers to decrease mortality should be investigated. Attention should be focused on specific causes of mortality. These studies could include use of an ACE inhibitor in combination with a lipid-lowering drug versus ACE inhibitor alone, monthly follow-up to assess and adjust the prescription to maximize volume status versus less frequent visits, and to evaluate cardiovascular deaths. Anuric patients are more likely to die a sudden death.⁶⁹ Data from the same group indicate that hypokalemia is a risk factor for death; in this study, hypokalemia was defined by 3 measurements of potassium during 12 weeks, and sudden death was not more frequent in this group.²⁷⁰ Therefore, it seems possible that hypokalemia might be more common in anuric patients, possibly because of dietary and nutritional issues, and contribute to sudden death, but this needs to be studied.
- Another area that might prove fruitful to decrease morbidity and mortality is further research on decreasing the risk for, and managing, peritonitis. The risk for death related to peritonitis is variable from a low of 3% of deaths in Canada to 16.6% of deaths in Hong Kong.⁶⁹ Aggressive catheter removal for refractory peritonitis versus delayed catheter removal (in an attempt to decrease mortality related to peritonitis) may result in a decrease in peritonitis-related deaths. Peritonitis remains the leading cause of technique failure²⁷¹ and affects peritoneal function during the first year on PD therapy.²⁷² Additional research on training methods and exit-site care may prove fruitful.
- Last, studies of maneuvers to improve adherence with the prescription and diet are much needed in PD patients, especially in such countries as the United States, where adherence is less than optimal. Such maneuvers might include closer monitoring, treatment of depression, evaluation of supplies with home visits, etc.
- The presence of RKF was rather arbitrarily defined in this document by the Work Group as 100 mL of urine output per day. This was chosen because many of the studies on clearances chose 100 mL/d as the cutoff value. However, it is not clear that this is the most appropriate level of urine output to use, or even if urine volume, rather than measured GFR, would be preferable. Additional research is needed in this area.

Guideline 3: Preservation of Residual Kidney Function (RKF)

Research Recommendations

- Rigorous studies are needed to examine whether the use of radiocontrast dye affects RKF in dialysis patients and whether renoprotective strategies in the nondialysis population also apply to those on dialysis therapy. Although controversial, it was suggested that the rate of decrease in RKF in those on APD therapy compared with those on CAPD therapy is faster. More data are needed. Because of financial issues and ease of administration, use of aminoglycoside antibiotics for the treatment of peritonitis has been recommended. Therefore, data about whether long- or short-term use of aminoglycosides is associated with a more rapid decrease in RKF would be helpful. The USRDS analysis⁸⁰ showed an association between use of ACE inhibitors and also use of calcium channel blockers with better preservation of RKF. Subsequent studies examined ACE inhibitors and ARBs, but not the use of calcium channel blockers; therefore, additional studies are needed. Clinical evaluation of the continuing use of immunosuppressive therapy (other than calcineurin inhibitors) to maintain residual kidney allograft function in patients on dialysis therapy is lacking. Also unclear is whether the benefit of attaining normotension by vigorous ultrafiltration is offset by the decrease in RKF from the attendant volume depletion.
- Data for the effect of peritonitis on RKF are contradictory. Studies examining the impact of peritonitis, as well as the treatment approach, on RKF are needed. In particular, the severity of peritonitis may relate to loss of RKF with more severe episodes (for example, fungal or those caused by gram-negative bacilli) perhaps more likely leading to loss of RKF.

CPR for Guideline 3

- Current guidelines recommend assessing peritoneal transport status by using peritoneal equilibration test (PET). They subsequently recommend a hypertonic dwell (4.25% dextrose) to work up a patient with ultrafiltration failure. Studies that compare 1.36%/1.5% dextrose or 2.27%/2.5% dextrose PET with 3.86%/4.25% dextrose PET are minimal. Because the 3.86%/4.25% test is recommended for the workup of ultrafiltration failure, more comparison data are needed. Furthermore, most kinetic modeling programs use data from 2.27%/2.5% dextrose PET to predict solute clearance and ultrafiltration. One needs to evaluate whether current kinetic modeling programs are as accurate if 4.25% PET is used; alternatively, if not, one may want to develop programs that use 4.25% dextrose PET data specifically. Once done, the standard PET may be changed to a 4.25% dextrose PET.

Guideline 4: Maintenance of Euvolemia

Research Recommendations

- Randomized trials to determine optimal blood pressure targets for PD patients are required. Larger randomized trials looking at the effect of newer dialysis solutions on

- important patient outcomes also would be helpful. Studies looking at the relationship between peritoneal hypertonic glucose exposure and metabolic and cardiovascular outcomes, as well as patient survival, would be valuable.
- Euvolemia in home dialysis patients is not always readily achieved because patients may not be knowledgeable about this aspect of PD. A study examining training methods emphasizing evaluation of “euvolemia” as done by the patient on impact of blood pressure and volume status would be worthwhile. In addition, there are few, if any, studies of interventions to enhance patients' abilities to follow a rather rigorous diet in regard to sodium intake. Such studies should be undertaken.

Guideline 5: Quality Improvement Programs

Research Recommendations

- CQI programs were shown to improve specific outcomes for subgroups of patients, such as peritonitis rates, exit-site infection rates, technique failure rates, etc. It would be important to develop a better understanding about which factors also improve patient well-being and satisfaction with their modality. Current guidelines recommend assessing peritoneal transport status by using PET. They subsequently recommend a hypertonic dwell (4.25% dextrose) to work up a patient with ultrafiltration failure. Studies that compare 1.36%/1.5% dextrose or 2.27%/2.5% dextrose PET with 3.86%/4.25% dextrose PET are minimal. Because the 3.86%/4.25% test is recommended for the workup of ultrafiltration failure, more comparison data are needed. Furthermore, most kinetic modeling programs use data from 2.27%/2.5% dextrose PET to predict solute clearance and ultrafiltration. One needs to evaluate whether current kinetic modeling programs are as accurate if 4.25% PET is used; alternatively, if not, one may want to develop programs that use 4.25% dextrose PET data specifically. Once done, the standard PET may be changed to a 4.25% dextrose PET.
- Quality improvement programs are rather time consuming and therefore costly. A cost analysis of the impact of aggressive interventions by a program on outcomes should be carried out.

Guideline 6: Pediatric PD

Research Guidelines

- Pediatric data are sparse, in part because there are few clinical trials using RR for death as an outcome for adequacy. However, there are other important aspects of overall patient care that need to be considered and evaluated. These include the development of a simplified means to estimate glomerular rate in children that precludes the need for urine collection and that is accurate at low levels (stages 4 to 5 CKD) of kidney function, determination of adequate and optimal total solute clearance in children receiving PD, comparison of the impact of peritoneal solute clearance versus RKF on patient outcome, evaluation of PD and the longevity of

dialysis therapy on QOL of pediatric patients and their families, determination of the ability of icodextrin-based dialysis solutions to enhance ultrafiltration across the age/size spectrum of pediatrics, and evaluation of the safety and efficacy of ACE-inhibitor, ARB, and diuretic therapy in children with CKD stage 5 receiving PD.

K/DOQI Clinical Practice Guidelines for Vascular Access: Update 2006

Guideline 1: Patient Preparation for Permanent HD Access

Research Recommendations

- Studies are required to determine the optimal vascular mapping criteria based on outcome goals of working fistulae.
- Studies are needed to determine the optimal stratification of patients for fistula placement. Is there an age component to sizing of the artery and vein for fistula creation? Specifically, should the minimal vein diameter for such higher risk groups as female, diabetic, and elderly patients be larger to have acceptable working fistula outcomes?
- Randomized studies should be performed comparing 1-stage with 2-stage brachial basilic vein transposition fistula outcomes.
- Studies are needed to determine the optimal surgical techniques for fistula creation with outcomes to identify factors that minimize the development of surgical swing segment stenosis in fistulae.

Guideline 2: Selection and Placement of HD Access

Research Guidelines

- ***Patients should be considered for construction of a primary fistula after failure of every HD access.*** There is a paucity of information about the success of this strategy. If a forearm loop AVG is placed as initial access, does this lead to successful construction of elbow-level fistulae? How often? Do we need an RCT? In what patients would a graft before fistula be cost- and resource effective? None? Some? Would a PU “immediate use” type of graft be preferable to a catheter if one had to do immediate (ie, within days) dialysis?
- How often is primary conversion of dysfunctional grafts to fistulae successful? Is it affected by the previous history of thrombosis or angioplasty (if applicable)? What are the guidelines for number of angioplasties/thrombectomies performed before compromising the ability to convert to a fistula? What is the optimal timing for conversion?
- ***The preference for fistulae is based on lower morbidity associated with their creation and maintenance compared with other access types. Is this still true for the US CKD stage 5 population?***

- Has this remained true as the population has grown older and the health care system in the United States has been stretched? Late referrals, lower skill sets in the staff delivering dialysis and cannulating accesses, increased comorbidity in the United States compared with Europe, Japan, or Canada—do these factors influence the selection of initial access and the progression and choices among different access types?

Guideline 3: Cannulation of Fistulae and Grafts and Accession of HD Catheters and Port Catheter Systems

Research Recommendations

- Can intensive structured cannulation training lead to better access outcomes?
- Can increased remuneration for expert cannulators lead to better access outcomes?
- Can self-cannulation lead to better outcomes?

Guideline 4. Detection of Access Dysfunction: Monitoring, Surveillance, and Diagnostic Testing

Research Recommendations

- Studies are needed to compare outcomes of physical examination with “high-tech” methods in determining the best timing for intervention.
- The role of DDU as an intermediate diagnostic test should be examined to determine the “timing” for access intervention with percutaneous transluminal angioplasty (PTA) or surgery.
- There may be important differences in the susceptibility of grafts and fistulae to thrombosis as a function of absolute access flow or change in access flow over time. The “best” therapy for the access also may differ according to type. Future studies should carefully separate the surveillance data, type of intervention (PTA or surgical), response to therapy, and both short-term and long-term outcomes according to access type, either graft or fistula. Because more proximal accesses have greater flow rates, data also should be categorized to access location, primarily the feeding artery (radial or ulnar versus low brachial, high brachial, and axillary for the upper arm and femoral for the thigh).
- Studies are needed to establish objective criteria for endovascular intervention.

Guideline 5. Treatment of Fistula Complications

Research Guidelines

- The efficacy of physical examination in detecting abnormalities in accesses difficult to cannulate should be studied.

- Comparative trials are required to assess interventional versus surgical modalities to correct maturation failure with measurement of access flow longitudinally before and after correction.
- Studies should examine the effect of intervention on: recurrent stenosis, elastic recoil, and juxta-anastomotic stenoses.

Guideline 6. Treatment of AVG Complications

Assessing adequacy of the intervention.

- Is PTA an effective intervention for treatment of vascular access–related stenosis? We cannot answer this question. A fundamental problem is our inability to reliably predict the outcomes of our percutaneous and surgical interventions. The true determinants of HD graft patency and longevity remain unknown. It certainly is a complex and multifactorial process. The primary determinants of graft failure likely are regulated by both physiological and genetic factors and therefore are variable within the patient population. To add to the confusion, neointimal hyperplastic stenoses develop simultaneously and sequentially in multiple locations. Our success in treating 1 stenosis is negated by the rapid development of another lesion. And there is another important variable: delayed elastic recoil can cause rapid recurrence of the stenosis after an apparently successful angioplasty procedure. This phenomenon can occur minutes to hours after balloon dilation, and our anecdotal experience suggests that elastic recoil of a stenosis may happen after 10% to 15% of our angioplasty procedures. Our current challenge is to identify the determinants for successful angioplasty and optimize our techniques to improve our clinical outcomes. In addition, we need to develop pharmacological means to reduce/prevent the recurrence of neointimal hyperplasia after successful angioplasty.

Criteria for success.

- An end point is used to define the successful completion of a procedure. The definition of a successful procedure can be viewed from several different perspectives. For example, the end point for clinical success is alleviation of the patient's symptoms. Hemodynamic success is restoration of normal blood flow throughout the treated vascular segment. And for treatment of stenoses, the end point for anatomic success is less than 30% residual diameter reduction. These clinical, hemodynamic, and anatomic end points serve as the determinants of a successful endovascular intervention. Our clinical experience has shown that these commonly used end points are *unreliable* for predicting the long-term patency of an HD graft or fistula. Although we use end points to define immediate success, there is no postprocedural end point that correlates with long-term patency. Our inability to predict the long-term outcome of our endovascular procedures continues to frustrate both the physician and patient.
- After an endovascular intervention, the standard definition of anatomic success is a residual stenosis with less than 30% diameter reduction. Although there are well-recognized physiological concepts that support the use of 50% stenosis as the definition of a hemodynamically significant lesion, there is no such scientific basis

for the use of less than 30% residual stenosis to define a successful treatment. A consensus committee reached the value of 30% with representatives from interventional radiology and vascular surgery. This well-accepted standard end point (<30% residual stenosis) has no hemodynamic or physiological meaning. In addition, the residual stenosis does not allow for proper remodeling of the vein and may contribute to recurrence of stenosis. Therefore, it is not surprising that use of this parameter as a determinant of success is not predictive of the long-term patency of an HD graft or fistula. This poor correlation between degree of residual stenosis and subsequent patency was substantiated in a study that reported analysis of 96 interventions performed in native AVFs.⁶³⁰ After angioplasty, 17 lesions had greater than 30% residual stenosis and, by definition, had failed treatment. However, there was no difference in the long-term patency of this group compared with patients who had lesions with less than 30% residual stenosis on final fistulography.

- Obviously, criteria used for success need to be examined by well-designed outcome studies.

Multiple lesions and criteria for intervention.

- According to the KDOQI guidelines, lesions with less than 50% stenosis should not be treated. However, it is not uncommon for a graft or fistula to have multiple areas of endoluminal irregularity that, when measured individually, represent less than 50% stenosis and therefore should not be treated. However, a hemodynamic abnormality may still exist. The basic principles of hemodynamics state that the effects of multiple stenoses are additive, similar to an electrical circuit with a series of multiple resistors. Therefore, our current concepts that emphasize the evaluation of individual stenoses using anatomic criteria are flawed.
- New methods⁵⁴ that provide a more global assessment of the entire vascular access circuit suggest that subtle lesions can have substantial hemodynamic effects. The assessment of intragraft blood flow during angioplasty procedures may provide additional information regarding the hemodynamic importance of lesions that are greater than 30% but less than 50% stenosis.
- We need to identify physiological/objective criteria for successful intervention.

Clinical Practice Guidelines for Nutrition in Chronic Renal Failure

I. ADULT GUIDELINES

Guideline 1: Use of Panels of Nutritional Measures

Research Recommendations

- Studies are needed to determine the most effective combination of measures of nutritional status for evaluating protein-energy malnutrition.

Guideline 2: Panels of Nutritional Measures for Maintenance Dialysis Patients

Research Recommendations

- Research is necessary to identify and validate the following:
 1. The optimal panel of measures to screen for disorders in nutritional status.
 2. The optimal panel of measures for a comprehensive assessment of nutritional status.
 3. The optimal frequency with which these nutritional measures should be employed.
- More information is needed concerning the appropriate parameters to be used for assessment of body composition (eg, for expressing dual energy x-ray absorptiometry [DXA] measurements, anthropometry, and the creatinine index).
- Patient subgroups should be identified (eg, elderly, obese, severely malnourished, or physically very inactive individuals) for whom the use of specialized combinations of body composition measures are beneficial.

Guideline 3: Serum Albumin

Research Recommendations

- More information is needed concerning the relative contributions of nutritional intake and inflammatory processes to serum albumin concentrations.
- There is a need for a better understanding of the mechanisms by which hypoalbuminemia or the factors causing hypoalbuminemia lead to increased morbidity and mortality in dialysis patients.
- Studies are needed to assess whether and under what conditions nutritional intervention increases serum albumin concentrations in hypoalbuminemic dialysis patients.
- Will an increase in serum albumin levels induced by nutritional support reduce morbidity and mortality in persons undergoing dialysis?

Guideline 4: Serum Prealbumin

Research Recommendations

- What range of serum prealbumin concentrations is associated with optimal outcome?
- More information is needed concerning the relative contributions of nutritional intake and inflammatory processes to serum prealbumin levels.
- Data are needed concerning the mechanisms by which low serum levels of prealbumin lead to increased mortality in dialysis patients.
- Will nutritional intervention in malnourished hypoprealbuminemic dialysis patients increase serum prealbumin concentrations?

- Will an increase in serum prealbumin levels induced by nutritional support reduce morbidity and mortality in individuals undergoing dialysis?

Guideline 5: Serum Creatinine and the Creatinine Index

Research Recommendations

- The degree of correlation of the serum creatinine and creatinine index with skeletal muscle mass and dietary protein intake (DPI), and the sensitivity to change in these parameters of creatinine metabolism, need to be better defined.
- The relationship between the creatinine index and the edema-free lean body mass or skeletal muscle protein mass needs to be defined for ESRD patients.
- The rate of creatinine degradation in ESRD patients needs to be defined more precisely.
- The level of serum creatinine and the creatinine index associated with optimal nutritional status and lowest morbidity and mortality rates need to be defined.
- The relationships between other markers of protein-energy nutritional status (eg, serum albumin, prealbumin, or anthropometry) and serum creatinine or creatinine index are limited, somewhat contradictory, and need to be further examined.
- Whether nutritional interventions that increase serum creatinine or creatinine index will improve morbidity or mortality in malnourished dialysis patients should be tested.
- The effects of age, gender, race, and size of skeletal muscle mass on the relationship between the serum creatinine and the creatinine index on morbidity and mortality need to be examined.

Guideline 6: Serum Cholesterol

Research Recommendations

- What are the conditions under which serum cholesterol is a reliable marker of protein-energy nutrition? What can be done to increase the sensitivity and specificity of the serum cholesterol as an indicator of protein-energy nutritional status?
- The relationships between other markers of protein-energy nutritional status (eg, serum albumin or anthropometry) and serum cholesterol are limited, somewhat contradictory, and need to be better defined.
- How does nutritional intervention in malnourished dialysis patients affect their serum cholesterol concentrations?
- Recent data suggest that serum cholesterol exhibits a negative acute-phase response to inflammation.⁴² The relationship among serum cholesterol, nutritional status, and inflammation needs to be further investigated.
- Why does mortality increase when the serum cholesterol falls outside the 200 to 250 mg/dL range?
- More information is needed about the patterns of morbidity and mortality associated with abnormal serum cholesterol concentrations in dialysis patients. For example, in

- these individuals, is cardiovascular mortality directly related to the serum cholesterol level and are malnutrition and mortality from infection inversely related to the serum cholesterol level?
- Additional data investigating the relationships among serum cholesterol, protein-energy nutritional status, morbidity, and mortality are needed for persons undergoing PD.

Guideline 7: Dietary Interviews and Diaries

Research Recommendations

- Techniques to improve the reliability and precision of dietary interviews or diaries for MD patients are needed.
- Other less laborious and more reliable methods to estimate nutrient intake, particularly energy intake, are needed.
- Predictability of morbidity, mortality, or other clinical outcomes.

Guideline 8: Protein Equivalent of Total Nitrogen Appearance (PNA)

Research Recommendations

- There are still a number of technical problems with measuring PNA in individuals undergoing HD or peritoneal dialysis that engender errors and increase the costs of measurement. Research to decrease these sources of error would be useful.
- The mathematical relationship between PNA and protein intake in HD patients has not been well defined. A larger database to examine these relationships more precisely would be useful.
- More research into optimal methods for normalizing PNA to body mass would be valuable.

Guideline 9: Subjective Global Nutritional Assessment (SGA)

Research Recommendations

- The most effective technique for performing SGA needs to be identified. Is the currently recommended 4-item scale optimal? Should visceral proteins (eg, serum albumin, transferrin, and/or prealbumin) be added to the SGA? Should a standard reference of body mass be included (eg, BMI or % standard body weight (SBW))?
- The technique of SGA needs greater validation with regard to sensitivity, specificity, accuracy, intraobserver and interobserver variability, correlation with other nutritional measures, and predictability of morbidity, mortality, or other clinical outcomes.

Guideline 10: Anthropometry

Research Recommendations

- Age-, sex-, and race- or ethnic-specific desirable reference values for anthropometry obtained in large numbers of dialysis patients are needed.
- The risk of morbidity and mortality associated with different anthropometric measurements in dialysis patients should be determined.
- To determine whether anthropometry might be an acceptable intermediate outcome in nutrition intervention trials.
- Will improvement in anthropometric values through nutritional intervention be associated with decreased morbidity and mortality and enhanced quality of life in individuals undergoing dialysis?

Guideline 11: Dual Energy X-Ray Absorptiometry (DXA)

Research Recommendations

- The sensitivity and specificity of DXA as a marker of protein-energy nutritional status, and specifically body composition, need to be defined more precisely.
- Careful studies of the relationships between changes in more traditional markers of protein-energy nutritional status (eg, albumin, prealbumin, or anthropometry) and changes in body composition by DXA are needed.
- Whether DXA assessment of body composition might be an acceptable intermediate outcome in nutrition intervention trials needs to be determined.
- Whether DXA measurements correlate with morbidity and mortality in dialysis patients needs to be determined.

Guideline 12: Adjusted Edema-Free Body Weight (aBW_{ef})

Research Recommendations

- The use of the aBW_{ef} for assessment and prescription of nutritional intake must be validated.
- More precise and practical methods are needed for assessing the size of body water compartments and, in particular, undesirable increases or reductions in total body water, intracellular water, or extracellular or intravascular water.

Guideline 14: Treatment of Low Serum Bicarbonate

Research Recommendations

- The optimum serum bicarbonate and blood pH levels for dialysis patients need to be defined. There are data from individuals without renal insufficiency indicating that mid-normal or high normal blood pH range maintains better nutritional status than does the low-normal range.
- More research is needed on the long-term effects of correcting acidemia on clinical outcomes and particularly on intermediate nutrition-related outcomes as well as morbidity and mortality.

- The effect of correction of acidemia on muscle function and on beta-2 microglobulin metabolism needs more investigation.

Guideline 15: Dietary Protein Intake (DPI) in Maintenance Hemodialysis (MHD)

Research Recommendations

- More studies are needed on the relationship between the quantity and type of DPI and nutritional status, morbidity, mortality, and quality of life in HD patients. Long-term, randomized, prospective clinical trials would be particularly helpful in addressing these questions. To reduce the large costs for such studies, innovative investigational tools are needed.
- Information concerning dietary protein requirements of special subsets of HD patients is needed. Such subsets include individuals with protein-energy malnutrition (PEM) or low dietary energy intake (DEI), obese individuals, and the elderly.

Guideline 16: Dietary Protein Intake (DPI) for Chronic Peritoneal Dialysis (CPD)

Research Recommendations

- The research recommendations for management of dietary protein intake (DPI) for patients treated with maintenance peritoneal dialysis are similar to those for patients treated with HD.
- Studies to determine the optimum protein intake should be undertaken in subsets of PD patients, including those who are elderly, malnourished, obese, or who have a low energy intake or catabolic illness such as peritonitis.

Guideline 17: Daily Energy Intake for Maintenance Dialysis Patients

Research Recommendations

- Few studies have examined energy requirements of persons undergoing HD or PD. Hence, there is a great need for more research in this area. It would be of particular value to conduct both carefully controlled metabolic studies, as well as long-term, randomized outpatient clinical trials, particularly in which patients are randomly assigned to different energy intakes. It would be helpful to relate daily energy intake to morbidity, mortality, and quality of life scales, as well as to nutritional measures. To reduce the high cost and length of time to collect such data, innovative investigative tools to address these issues are needed.
- Studies are needed to assess the optimal energy requirements of subsets of dialysis patients (eg, individuals with protein-energy malnutrition (PEM), patients with superimposed catabolic illnesses, obese individuals, and elderly patients).

- Studies are needed to examine whether increasing energy intake of dialysis patients with protein or energy malnutrition would be beneficial to the patients.
- Assessment of energy intake is laborious, time-consuming, and therefore expensive. Developmental studies to create accurate and less costly methods for assessing energy intake are greatly needed.

Guideline 18: Intensive Nutritional Counseling With Maintenance Dialysis (MD)

Research Recommendations

- A better understanding of the effects of nutrition intervention counseling methods (including quality of life scales) on nutritional intake, nutritional status, morbidity, and mortality should be evaluated in dialysis patients.

Guideline 19: Indications for Nutritional Support

Research Recommendations

- Conduct a randomized clinical trial comparing oral nutritional supplements, tube feeding, and intradialytic parenteral nutrition (IDPN) in malnourished dialysis patients. Outcomes should include survival, morbidity, and quality of life as well as nutritional status.
- Research is needed to define the optimal composition of oral supplements, enteral nutrition, and intradialytic parenteral nutrition (IDPN) formulas for dialysis patients.
- Conduct studies of the indications for nutritional support in dialysis patients.
- Determine the optimal timing for intraperitoneal amino acids (IPAA) administration (eg, daytime CAPD versus nighttime withycler).
- Evaluate the effects of IPAA on physical function, hospitalization, and other clinical outcomes.
- Examine the clinical value and cost-effectiveness of nutritional support through hemodialysate.

Guideline 21: Energy Intake During Acute Illness

Research Recommendations

- Studies to define the optimal protein intake for the dialysis patients who are acutely ill are needed.
- The effects of different levels of protein intake on patient outcome and on nutritional markers are needed. Because increasing protein intake may alter dialysis requirements, the effect of higher levels of protein intake on the optimal dose of dialysis should be defined.

- The energy needs of acutely ill dialysis patients should be better defined. It would be particularly valuable to define how energy needs may vary with different protein and amino acid intakes.
- The development of simple and inexpensive methods for determining the energy expenditure in individual acutely ill patients would be very helpful.
- The optimal mixes of energy sources (ie, protein, amino acids, carbohydrates, and fat) for acutely ill dialysis patients should be defined.
- Studies are needed that examine which energy intakes are associated with the most optimal clinical outcomes.

Guideline 22: L-Carnitine for Maintenance Dialysis Patients

Research Recommendations

- Additional clinical trials in the area of erythropoietin-resistant anemia, carefully accounting for anticipated differences in response based on factors such as iron stores and the level of inflammatory mediators.
- Further definition of the L-carnitine response by taking an "outcomes" approach to patients treated with L-carnitine. Can patient subgroups be identified who are likely to respond to L-carnitine for one or more of its proposed indications? Are certain individuals uniform "responders" across indications (a "carnitine-deficient" phenotype) or do certain patient characteristics predict specific responses?
- A randomized clinical trial of L-carnitine in dialysis patients with cardiomyopathy and reduced ejection fraction.
- A randomized clinical trial of L-carnitine for the treatment of hyperlipidemia, restricted to patients with preexisting hyperlipidemia.

The constant used in this last equation (0.029 kg/mg/24 h) was derived from individuals without renal disease²³⁴ and should be reevaluated for ESRD patients; at least one study suggests that this constant is also applicable for dialysis patients. Skeletal or cardiac muscle protein intake as well as total protein intake can affect the creatinine index,^{235,236} and marked variations in these nutrients may therefore have major effects on the creatinine index. Thus, until the relationships between total protein intake and muscle intake and the creatinine index are well defined for ESRD patients, some caution must be exercised in interpreting the creatinine index, particularly if the diet of the individual in question is particularly high or low in these nutrients.

Guideline 23: Panels of Nutritional Measures for Nondialyzed Patients

Research Recommendations

- More sensitive and specific measures of protein-energy nutritional status in CKD/kidney failure patients need to be developed.
- Studies are needed to test whether monitoring nutritional status in individuals with progressive CKD/kidney failure by a combination of measures is beneficial for detecting and preventing malnutrition.

- Additional research is needed to define more accurately the combination of measures that provides the most useful information concerning the nutritional status of individuals with CKD/kidney failure.

Guideline 24: Dietary Protein Intake for Non-Dialyzed Patients

Research Recommendations

- Which subpopulations of patients with progressive chronic renal disease are particularly likely or unlikely to display slowing in the decline of their GFR with dietary protein restriction?
- Are there any additive benefits to prescribing both low protein diets and angiotensin converting enzyme inhibitors for patients with progressive chronic renal disease?

Guideline 25: Dietary Energy Intake (DEI) for Non-Dialyzed Patients

Research Recommendations

- Studies are needed to assess why spontaneous DEI is reduced in persons with kidney failure who are not undergoing dialysis.
- More data are needed on the energy requirements of clinically stable patients with CKD. There are very few data in this area.
- Data are also needed on the energy requirements of individuals with kidney failure who are obese or malnourished or who have associated catabolic illnesses.
- What techniques can be used to increase energy intake in individuals with CKD and kidney failure?

Guideline 26: Intensive Nutritional Counseling for Chronic Renal Failure (CRF)

Research Recommendations

- Why do apparently clinically stable patients with creatinine clearances under 50 mL/min often have decreased dietary protein and energy intakes and evidence of deteriorating nutritional status?
- What interventions are likely to prevent or reverse the developing PEM in these individuals?
- Will interventions that improve nutritional status reduce morbidity and mortality in these individuals?

Guideline 27: Indications for Renal Replacement Therapy

Research Recommendations

- Studies to assess the optimal timing and indications for commencing renal replacement therapy are needed.
- Serial evaluations of nutritional status in the course of these studies will help to determine whether initiation of dialysis indeed improves nutritional status.
- Studies should be conducted to determine whether any GFR level can be used to indicate when maintenance dialysis should be initiated.
- Whether earlier initiation of renal replacement therapy can prevent the development or worsening of PEM and its attendant complications needs to be evaluated in a controlled study.

II. PEDIATRIC GUIDELINES

Guideline 1: Patient Evaluation of Protein-Energy Nutritional Status

Research Recommendations

1. Investigation in the following areas to standardize interpretation in children with renal disease:
 - PNA
 - Subjective Global Assessment (SGA) for pediatric patients
 - Prealbumin

Guideline 2: Management of Acid-Base Status

Research Recommendations

- Studies are needed to delineate the role of acidosis on growth retardation in the setting of ESRD in children.
- Whether or not correction of acidosis may improve the poor response to recombinant human GH in pediatric patients treated with dialysis needs to be elucidated.

Guideline 3: Urea Kinetic Modeling

Research Recommendations

- Appropriate correlations between calculated and measured data need to be established. The impact of the PNA on growth needs to be better defined, and the need to normalize the data to some measure of body size must be assessed. Longitudinal data of PNA, along with dietary protein and energy intake, must be collected and correlated against accepted parameters of growth and nutritional status.
- There is a need for the development of a validated formula to calculate V in children treated with peritoneal dialysis. The reported studies described above calculated the urea volume of distribution based on formulas developed in normal children. It is not

- clear whether children with renal failure and on peritoneal dialysis are characterized by the same formula.
- Assess the ability of a kinetic model of solute removal for children treated with CAPD and automated peritoneal dialysis to accurately reflect the nutritional status of these patients and establish a valid model for children treated with all forms of peritoneal dialysis. The relationship between weekly creatinine clearance and weekly Kt/V for children treated with CAPD is not the same as that for children treated with automated peritoneal dialysis. Correlations may differ between modalities.

Guideline 4: Interval Measurements

Research Recommendations

- The use of bioelectrical impedance (BIA) and DXA technologies to measure body composition should be explored.
- The measurement of IGF-I or IGF-binding protein levels to reflect nutritional adequacy should be explored.
- The value of using a selective dietary interview/diary and the use of nPNA to assess DPI should be determined.

Guideline 5: Energy Intake for Children Treated With Maintenance Dialysis

Research Recommendations

- Given the lack of specificity of the recommended dietary allowance (RDA) for calories, and the fact that the RDA was devised to apply to a population of normal children, clearer data on the actual energy expenditure of children treated with dialysis are necessary. Indirect calorimetry can be utilized and resting energy and basal energy expenditure can be measured and compared with the RDA. The impact of the dialysis process on the children's energy expenditure should be assessed in this patient population. The availability of such information would allow a more appropriate initial diet prescription for such patients.
- Prospective interventional trials should be designed to better understand the impact of various energy intakes on growth and nutritional status.

Guideline 6: Protein Intake for Children Treated With Maintenance Dialysis

Research Recommendations

- What is the optimal DPI for a child on HD or peritoneal dialysis?
- What is the optimal ratio of protein to non-protein calories?
- How can the impact of interventions on protein intake best be monitored?

Guideline 7: Vitamin and Mineral Requirements

Research Recommendations

- The vitamin and mineral needs of children undergoing dialysis should be determined by prospective, longitudinal studies conducted in patients not yet receiving vitamin and mineral supplementation.

Guideline 8: Nutrition Management

Research Recommendations

- Would adaptation of an SGA tool specifically for the pediatric population be useful for evaluating nutrition status of children?
- Studies are needed to evaluate strategies to enhance compliance, with particular emphasis on the adolescent age group.

Guideline 9: Nutritional Supplementation for Children Treated With Maintenance Dialysis

Research Recommendations

- The use of amino acid-based peritoneal dialysis solutions is potentially an attractive means of nutrition support. Studies should be conducted to determine the optimal dialysate amino acid profile and whether the amino acids should be combined with dextrose for better utilization of the protein source. Even with the addition of both dextrose and amino acids to dialysate, the total tolerable osmolality of the dialysate solution prevents the solutions from providing much energy. Thus, the solutions are more effective at providing an adequate amino acid or protein load than a sufficient energy intake.
- The impact of this therapy on the nutrient intake of patients, solute clearance, and patient growth when used on a long-term basis also requires further study.

Guideline 10: Recommendations for the Use of Recombinant Human Growth

Research Recommendations

- Studies are needed to better define the response to recombinant hGH in patients treated with dialysis, and whether higher doses of recombinant hGH would have a beneficial effect on linear growth remains to be established.
- Although it is recognized that control of secondary hyperparathyroidism is important prior to the initiation of therapy with recombinant hGH, serum PTH levels increase during therapy with recombinant hGH despite treatment with calcitriol. Thus, further studies should define the appropriate serum PTH levels that correspond to indices of

bone remodeling during therapy with calcitriol and recombinant hGH in children treated with maintenance dialysis.