Metabolic Syndrome, ESRD, and Death in CKD


Summary

Background and objectives Previous studies reported an association between metabolic syndrome, incident CKD, and proteinuria. This study examined the associations between metabolic syndrome and its components with ESRD and death among those patients with stages 3 and 4 CKD (estimated GFR=15–59 ml/min per 1.73 m²).

Design, setting, participants, & measurements Patients with stages 3 and 4 CKD (n=25,868) who had data relating to metabolic syndrome and were followed in our health care system were identified using an electronic medical record-based registry. Cox proportional hazards models and competing risk analyses were used to study the associations between metabolic syndrome, its components (elevated BP, low HDL cholesterol, elevated serum triglycerides, impaired glucose metabolism, and obesity), and all-cause mortality and ESRD while adjusting for demographics, comorbid conditions, use of relevant medications, and renal function.

Results Sixty percent of the study population (n=15,605) had metabolic syndrome. In the multivariate-adjusted analysis, presence of metabolic syndrome was associated with an increased risk for ESRD (hazard ratio=1.33, 95% confidence interval=1.08, 1.64) but not death (hazard ratio=1.04, 95% confidence interval=0.97, 1.12) during a mean follow-up of 2.3 years. Among the individual components of metabolic syndrome, impaired glucose metabolism, elevated triglycerides, and hypertension were associated with increased risk for ESRD, whereas low HDL cholesterol and impaired glucose metabolism were associated with higher risk of death.

Conclusions Presence of metabolic syndrome is associated with ESRD but not death in patients with stages 3 and 4 CKD.

Introduction

CKD and metabolic syndrome are major public health problems (1,2). Metabolic syndrome is a constellation of cardiovascular risk factors linked with obesity and insulin resistance, with an estimated prevalence of 20%–25% in the general population, and it is associated with an increased risk of coronary artery disease, stroke, and mortality (3–5). In the past, various diagnostic criteria have been proposed by different organizations for metabolic syndrome (6–8). Recent consensus definition for metabolic syndrome consists of elevated BP, dyslipidemia (low HDL cholesterol and elevated serum triglycerides), elevated fasting glucose (impaired fasting glucose or type 2 diabetes), and central obesity (9). Previous observational studies and their meta-analysis reported an association between metabolic syndrome and incident CKD, microalbuminuria, and proteinuria among different ethnic groups (10–13).

Studies examining the association between metabolic syndrome and the progression of CKD are limited. A secondary analysis of the African American Study of Kidney Disease and Hypertension trial showed a 31% increased risk of CKD progression or death with metabolic syndrome (14). A population-based study from Taiwan showed that the impact of metabolic syndrome on CKD progression is significant only in early-stage CKD (stages 1–3) but not late-stage and diabetic CKD patients (15). Thus, the association between metabolic syndrome and CKD progression remains unclear and has not been explored in a diverse population. Therefore, we examined the associations between metabolic syndrome, ESRD, and death among those patients with stages 3 and 4 CKD (estimated GFR [eGFR]=15–59 ml/min per 1.73 m²) followed in our health care system.

Materials and Methods

We conducted an analysis using our preexisting Electronic Health Record-based CKD registry. The development and validation of this registry at Cleveland Clinic have been described in detail previously (16).

Study Population

Patients who had at least one outpatient encounter with a Cleveland Clinic health care provider and two eGFR values <60 ml/min per 1.73 m² (the Chronic Kidney Disease Epidemiology Collaboration equation) >90 days apart were included (17). Patients ages <18 years and patients who were already diagnosed with ESRD needing dialysis or renal transplant were excluded. Patients who met the inclusion/exclusion criteria from
January 1, 2005 to September 15, 2009 were included in this analysis.

Definitions and Outcome Measures

Renal Function. We applied the Chronic Kidney Disease Epidemiology Collaboration equation to patients who had two serum creatinine levels measured 90 days apart as of January 2005 in our health care system. All creatinine measurements were performed by the modified kinetic Jaffé reaction using a Hitachi 747–200 Chemistry Analyzer (1996–2001) or a Hitachi D 2400 Modular Chemistry Analyzer thereafter (Roche Diagnostics, Indianapolis, IN) in our laboratory. Urinary protein studies were not available for the entire study population. Therefore, to be comprehensive and reflect clinical practice, patients who had urine dipstick measurements, urine albumin-to-creatinine ratio, urine protein-to-creatinine ratio, and 24-hour urine studies were included to assess whether they had proteinuria. The following cutoffs were considered in determining whether someone had proteinuria: presence of $\geq1+$ proteinuria in dipstick studies, $>30$ mg/g in urine albumin-to-creatinine ratio and urine protein-to-creatinine ratio studies, and $>30$ mg proteinuria in 24-hour studies. Urine dipstick studies were performed using multistix reagent strips (SIEMENS). Urine albumin was measured by immunoturbidimetric assay with antigen excess check, and urine creatinine was measured using a multistep enzymatic procedure that produces a quinone imine chromogen on the Roche Modular platform in our laboratory.

Demographics, Comorbid Conditions, and Laboratory Parameters. Demographic variables, such as age, sex, and race/ethnicity, were extracted from the Electronic Health Records. Comorbid conditions were defined using prespecified criteria and previously validated (16). Serum triglycerides and HDL cholesterol were measured using an enzymatic colorimetric test run on the Roche Modular platform for all the study participants at different sites in our health care system. Within- and-between-run precision of human serum for triglyceride is stated at 1.5% and 1.8%, respectively, and within- and-between-run precision of human serum for HDL cholesterol is stated at 0.95% and 1.3%, respectively. In our health care system, lipid profiles are customarily obtained in the fasting state using a standard protocol.

Metabolic Syndrome. Metabolic syndrome was defined as the presence of three or more of the following components: body mass index (BMI) $\geq30$ kg/m$^2$, serum triglyceride level $\geq150$ mg/dl, HDL $\leq50$ mg/dl in women and $<40$ mg/dl in men, hypertension (BP $>130/85$ mmHg or on antihypertensive medications), and impaired glucose metabolism (presence of diabetes, use of oral hypoglycemics, or blood glucose level $>200$ mg/dl) (9). Because fasting blood glucose was not available, we included both the drug treatment for diabetes and physician diagnosis of diabetes in addition to blood glucose values to identify those patients with impaired glucose metabolism as suggested in the consensus definition (9). Similarly, it is recommended to consider BMI $\geq30$ kg/m$^2$ as a risk factor in the absence of waist circumference data, because this value approximates a waist circumference $>102$ cm in men and $>88$ cm in women.

Outcome Measures. The primary outcomes of interest were all-cause mortality and ESRD, which were ascertained from linkage of our registry with the Social Security Death Index and United States Renal Data System. Patients were followed from their date of inclusion in the registry until September 15, 2009.

Statistical Analyses

Baseline characteristics between CKD patients with and without relevant data relating to metabolic syndrome components were compared using chi-square and t tests for categorical and continuous variables, respectively. Similarly, baseline characteristics between CKD patients with and without metabolic syndrome were also compared. To evaluate whether survival and ESRD among persons with CKD were associated with metabolic syndrome, we used Kaplan–Meier plots and log-rank tests with entry into the registry as time of origin. Because ESRD and death are competing events, we fitted cumulative incidence functions that adjust for competing risks and compared these results with the traditional cause-specific analysis. In addition, a separate analysis that included all deaths (both before and after ESRD) was also conducted.

Cox proportional hazards models were used to assess the associations between metabolic syndrome, death, and ESRD while adjusting for age, sex, race, smoking, malignancy, congestive heart failure, cerebrovascular disease, coronary artery disease, chronic obstructive pulmonary disease, use of angiotensin-converting enzyme inhibitors/angiotensin receptor blockers, LDL cholesterol, hemoglobin, albumin, and eGFR. We checked the proportional hazards assumption of metabolic syndrome by inspection of log-negative log survival plots. We tested two-way interactions between metabolic syndrome and prespecified covariates in the adjusted model: age, sex, race, and eGFR. The interactions were not statistically significant, except for the interaction term for age in the ESRD model; 1% of patients had missing LDL, 18% of patients had missing hemoglobin, and 17% of patients had missing albumin data. Mean value imputation was used to include these patients in the adjusted model. An indicator for missing data on each variable was included as well. In the study population, 13,599 patients had at least one urinary protein measure, and a separate multivariate analysis, including proteinuria along with other previously mentioned variables, was also conducted. Lastly, we performed a logistic regression analysis to examine whether presence of metabolic syndrome was associated with proteinuria after adjusting for the covariates described above.

All data analyses were conducted using Unix SAS version 9.2 (SAS Institute, Cary, NC) and R 2.12.2 (The R Foundation for Statistical Computing, Vienna, Austria). The cmpsk package was used for competing risk analysis. This study was approved by the Cleveland Clinic Institutional Review Board.

Results

Baseline Patient Characteristics

Of 43,546 patients in our CKD registry (as of September 15, 2009), 25,868 (59%) patients had relevant data relating to the different components of metabolic syndrome and were included in this analysis. The primary reason for excluding other patients was lack of lipid profile measurement (Figure 1). About 60% of the study population
Patients died. The Kaplan–Meier reached ESRD. Overall (pre- and post-ESRD), 3504 participants died before ESRD, and 3345 participants died after ESRD data, during a median follow-up of 2.4 years (mean=2.2 years). Among those patients with metabolic syndrome during a median follow-up of 2.2 years (mean=2.3 years), 3345 participants died before ESRD, and 481 reached ESRD. Overall (pre- and post-ESRD), 3504 patients died. The Kaplan–Meier (data not shown) and competing risk analyses (Figure 2) showed no significant difference in overall mortality between those patients with and without metabolic syndrome. However, there were significantly higher rates of ESRD among those patients with metabolic syndrome than those patients without metabolic syndrome in both Kaplan–Meier (data not shown) (log rank P<0.001) and competing risk analyses (P<0.001) (Figure 2). Results were similar in both analyses.

In the Cox proportional hazards model, after covariate adjustment, presence of metabolic syndrome was not associated with pre-ESRD death, but it was associated with an increased hazard for ESRD (hazard ratio [HR]=1.33, 95% confidence interval [95% CI]=1.08, 1.64) (Table 2). An analysis of covariate-adjusted overall mortality (pre- and post-ESRD) provided similar results to the analysis including only pre-ESRD death, with an HR for patients having metabolic syndrome of 1.06 (95% CI=0.98, 1.13).

**Associations between Individual Components and Outcomes**

Among the individual components of metabolic syndrome, elevated serum triglycerides (HR=1.07, 95% CI=1.00, 1.15), impaired glucose metabolism (HR=1.67, 95% CI=1.36, 2.00), and hypertension (HR=1.83, 95% CI=1.04, 3.25) were associated with an increased risk for ESRD. Impaired glucose metabolism (HR=1.18, 95% CI=1.10, 1.27) and low HDL cholesterol (HR=1.10, 95% CI=1.02, 1.18) were associated with an increased hazard for death, whereas obesity (HR=0.85, 95% CI=0.79, 0.93) and hypertension (HR=0.81, 95% CI=0.68, 0.97) were associated with a lower hazard for death (Figure 3).

**Interaction with Age**

We found a significant interaction of age with metabolic syndrome in the ESRD model, indicating that the association between metabolic syndrome and ESRD increased with age (P<0.001). For example, for a CKD patient of 70 years (mean age of our study population), there was an estimated 50% increased hazard for ESRD (95% CI =1.18, 1.93), whereas this risk was not significant for those patients ages 50 years (HR=1.11, 95% CI=0.85, 1.45). The test of interaction between age and metabolic syndrome was not significant for mortality (P=0.91), suggesting that the association between metabolic syndrome and mortality does not differ by age in our study population.

**Subgroup Analyses**

In a subgroup of patients who had at least one urinary protein study (n=13,599, 52%), the association between metabolic syndrome and ESRD was attenuated and no longer statistically significant with adjustment for proteinuria (HR=1.28, 95% CI=0.98, 1.60). There was no association between metabolic syndrome and all-cause mortality (pre-ESRD) in this model (HR=1.04, 95% CI=0.94, 1.40).

Presence of proteinuria was significantly associated with ESRD (HR=2.87, 95% CI=2.19, 3.76) and mortality (HR=1.45, 95% CI=1.31, 1.60) in these models.

**Metabolic Syndrome and Proteinuria**

Metabolic syndrome was associated with significantly higher odds of having proteinuria after covariate adjustment (odds ratio=1.84, 95% CI=1.68, 2.03).

**Discussion**

Metabolic syndrome is widely prevalent among those patients with stages 3 and 4 CKD. In our study, the presence of metabolic syndrome was associated with ESRD but not death. The associations between individual components of metabolic syndrome and outcomes also varied. These findings have significant clinical importance, because individual components of metabolic syndrome, metabolic syndrome itself, and CKD in the US population and across the globe are increasing (2).
We noted a higher prevalence (60%) of metabolic syndrome in CKD patients similar to the data from the Chronic Renal Insufficiency Cohort study (prevalence rate of 65%), because these patients have higher prevalence of the individual risk factors of metabolic syndrome (18). In the secondary analysis of the African American Study of Kidney Disease and Hypertension trial (n=842), metabolic syndrome was associated with a 31% increased risk (95% CI=1.03, 1.70) for the composite study end point of decrease in GFR of 50% or 25 ml/min per 1.73 m², ESRD, or death (14). However, the associations were attenuated when adjusted for proteinuria (HR=1.16, 95% CI=0.90, 1.50). Recent data from Taiwan reported that the association between metabolic syndrome and kidney disease progression is significant only in the nondiabetic early-stage CKD population and not stages 3 and 4 CKD population (15). Our analysis shows that, in a diverse CKD population, metabolic syndrome is associated with ESRD. However, we also noted that the association between metabolic syndrome and ESRD was attenuated when adjusted for proteinuria. Metabolic syndrome and its components lead to the development of proteinuria, which in turn, leads to progression of kidney disease and development of ESRD (19,20). Hence, it may not be appropriate to adjust

### Table 1. Characteristics of patients with and without metabolic syndrome at the time of being classified as CKD

<table>
<thead>
<tr>
<th>Variable</th>
<th>Metabolic Syndrome Present (n=15,605)</th>
<th>Metabolic Syndrome Absent (n=10,263)</th>
<th>Metabolic Syndrome Data Not Available (n=17,678)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>71.0±10.9</td>
<td>74.4±11.3</td>
<td>73.1±12.5</td>
</tr>
<tr>
<td>Man, n (%)</td>
<td>7212 (46.2)</td>
<td>4638 (45.2)</td>
<td>7752 (43.9)</td>
</tr>
<tr>
<td>African Americans, n (%)</td>
<td>1899 (12.2)</td>
<td>1214 (11.8)</td>
<td>2100 (11.9)</td>
</tr>
<tr>
<td>Diabetes, n (%)</td>
<td>6969 (44.7)</td>
<td>709 (6.9)</td>
<td>1458 (8.2)</td>
</tr>
<tr>
<td>Hypertension, n (%)</td>
<td>15,422 (98.8)</td>
<td>9303 (90.6)</td>
<td>13,631 (77.1)</td>
</tr>
<tr>
<td>Coronary artery disease, n (%)</td>
<td>4699 (30.1)</td>
<td>2355 (22.9)</td>
<td>1610 (9.1)</td>
</tr>
<tr>
<td>Cerebrovascular disease, n (%)</td>
<td>1791 (11.5)</td>
<td>1089 (10.6)</td>
<td>840 (4.8)</td>
</tr>
<tr>
<td>Congestive heart failure, n (%)</td>
<td>1614 (10.3)</td>
<td>766 (7.5)</td>
<td>941 (5.3)</td>
</tr>
<tr>
<td>Malignancy, n (%)</td>
<td>2957 (18.9)</td>
<td>2100 (20.5)</td>
<td>5168 (29.2)</td>
</tr>
<tr>
<td>Smoking (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>13,216 (84.7)</td>
<td>8697 (84.7)</td>
<td>10,474 (59.2)</td>
</tr>
<tr>
<td>Smoke</td>
<td>1172 (7.5)</td>
<td>667 (6.5)</td>
<td>1045 (5.9)</td>
</tr>
<tr>
<td>Missing</td>
<td>1217 (7.8)</td>
<td>899 (8.8)</td>
<td>6159 (34.8)</td>
</tr>
<tr>
<td>CKD stages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 3a (GFR=45–59 ml/min per 1.73 m²)</td>
<td>10,399 (66.6)</td>
<td>7269 (70.8)</td>
<td>10,273 (58.1)</td>
</tr>
<tr>
<td>Stage 3b (GFR=30–44 ml/min per 1.73 m²)</td>
<td>4012 (25.7)</td>
<td>2373 (23.1)</td>
<td>5463 (30.9)</td>
</tr>
<tr>
<td>Stage 4 (GFR=15–29 ml/min per 1.73 m²)</td>
<td>1194 (7.7)</td>
<td>621 (6.1)</td>
<td>1942 (11.0)</td>
</tr>
<tr>
<td>Number of encounters in Electronic Health Record</td>
<td>56.3±43.2</td>
<td>47.3±37.8</td>
<td>31.6±36.3</td>
</tr>
<tr>
<td>Body mass index (%; kg m²)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;18.5</td>
<td>56 (0.36)</td>
<td>166 (1.6)</td>
<td>301 (1.7)</td>
</tr>
<tr>
<td>18.5–24.9</td>
<td>1940 (12.4)</td>
<td>3571 (34.8)</td>
<td>4592 (26.0)</td>
</tr>
<tr>
<td>25–29.9</td>
<td>4483 (28.7)</td>
<td>4783 (46.6)</td>
<td>5522 (31.2)</td>
</tr>
<tr>
<td>30–34.9</td>
<td>4939 (31.7)</td>
<td>785 (7.6)</td>
<td>3133 (17.7)</td>
</tr>
<tr>
<td>35–39.9</td>
<td>2219 (14.2)</td>
<td>268 (2.6)</td>
<td>1395 (7.9)</td>
</tr>
<tr>
<td>≥40</td>
<td>1501 (9.6)</td>
<td>146 (1.4)</td>
<td>976 (5.5)</td>
</tr>
<tr>
<td>Missing</td>
<td>467 (3.0)</td>
<td>544 (5.3)</td>
<td>1759 (10.0)</td>
</tr>
<tr>
<td>Albumin (g/dl)</td>
<td>4.2±0.42</td>
<td>4.2±0.40</td>
<td>3.9±0.55</td>
</tr>
<tr>
<td>Hemoglobin (g/dl)</td>
<td>13.0±1.7</td>
<td>13.1±1.6</td>
<td>12.6±1.9</td>
</tr>
<tr>
<td>Serum triglycerides (mg/dl)</td>
<td>278.8±226.4</td>
<td>143.7±84.2</td>
<td>NA</td>
</tr>
<tr>
<td>HDL cholesterol level (mg/dl)</td>
<td>39.7±11.0</td>
<td>55.4±14.7</td>
<td>NA</td>
</tr>
<tr>
<td>Use of angiotensin-converting enzyme inhibitors/angiotensin receptor blockers (%)</td>
<td>12,024 (77.1)</td>
<td>6000 (58.5)</td>
<td>8311 (47.0)</td>
</tr>
<tr>
<td>Use of antihypertensives (%)</td>
<td>14,471 (92.7)</td>
<td>8159 (79.5)</td>
<td>11,943 (67.6)</td>
</tr>
<tr>
<td>Use of statins (%)</td>
<td>11,584 (74.2)</td>
<td>5818 (56.7)</td>
<td>6109 (34.6)</td>
</tr>
<tr>
<td>Use of fibrates (%)</td>
<td>2018 (12.9)</td>
<td>289 (2.8)</td>
<td>687 (3.9)</td>
</tr>
<tr>
<td>Proteinuria,a n (%)</td>
<td>2648 (30)</td>
<td>834 (17.5)</td>
<td>2105 (29.1)</td>
</tr>
</tbody>
</table>

All variables are P<0.05 comparing metabolic syndrome data available versus not available, except African American. Continuous variables compared using t test, and categorical variables compared using chi-square test.

aData missing for 52% of study population.
for proteinuria in this analysis (causal pathway), and thus, the results of the analysis adjusted for proteinuria should be interpreted with caution. In addition, proteinuria data were not available for 48% of patients, and the effect estimate (although not statistically significant) still suggests that there is potential for harmful renal effects of metabolic syndrome in this cohort (HR=1.28, 95% CI=0.98, 1.60).

Numerous experimental and population-based studies have shown that insulin resistance and hypertension are associated with glomerular injury and glomerulosclerosis (21–23), and thus, as expected, impaired glucose metabolism and hypertension were associated with an increased risk for ESRD in this analysis. However, the relationship between other components, such as elevated serum triglycerides and ESRD, low HDL cholesterol, and all-cause mortality, is novel. Previous studies have examined the relationship between low HDL cholesterol, elevated serum triglycerides, and incident kidney disease (24,25). Although Hanai et al. (26) reported an association between low HDL cholesterol and progression of kidney disease, the observed relationship between serum triglycerides $>150$ mg/dl and ESRD in this study has not been reported before. We recently reported an increased risk for death among patients ages $<65$ years with serum triglycerides $\geq 200$ mg/dl (27). Cumulatively, these results might suggest the need for additional studies in this area. Low HDL cholesterol levels have been associated with increased cardiovascular disease and mortality in the general population, but interventional studies aimed to increase HDL levels failed to show any benefits (28,29). Hence, additional studies are warranted on this topic before any valid conclusions are drawn about HDL cholesterol and outcomes in CKD.

Obesity contributes to the development of CKD through different mechanistic pathways that include glomerular hyperfiltration, activation of the renin-angiotensin system, insulin resistance, and direct lipotoxicity (30). There was no association between obesity and ESRD in this analysis, and

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**Table 2.** Associations between metabolic syndrome and all-cause mortality (pre-ESRD) and ESRD among stages 3 and 4 CKD patients ($n=25,868$)

<table>
<thead>
<tr>
<th>Metabolic Syndrome Present Versus Absent</th>
<th>Unadjusted HR (95% CI)</th>
<th>Model A $\times$ HR (95% CI)</th>
<th>Model B $\times$ HR (95% CI)</th>
<th>Model C $\times$ HR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESRD ($n=481$)</td>
<td>1.89 (1.54, 2.33)</td>
<td>1.60 (1.30, 1.98)</td>
<td>1.53 (1.24, 1.89)</td>
<td>1.33 (1.08, 1.64)</td>
</tr>
<tr>
<td>All-cause mortality ($n=3345$)</td>
<td>0.96 (0.90, 1.03)</td>
<td>1.17 (1.09, 1.25)</td>
<td>1.07 (0.99, 1.15)</td>
<td>1.04 (0.97, 1.12)</td>
</tr>
</tbody>
</table>

HR, hazard ratio; 95% CI, 95% confidence interval; model A, adjusted for age, sex, and race; model B, adjusted variables included in model A plus smoking, malignancy, congestive heart failure, cerebrovascular disease, coronary artery disease, chronic obstructive pulmonary disease, use of angiotensin-converting enzyme inhibitors/angiotensin receptor blockers, LDL cholesterol, hemoglobin, and albumin; model C, adjusted variables included in model B plus baseline estimated GFR.
obesity was associated with a lower risk for all-cause mortality. Visceral or abdominal adiposity, as measured by waist circumference, is associated with inflammation and might be a better predictor for mortality than BMI, which does not distinguish between fat and fat-free mass. Recently, Kramer et al. (31) reported differential associations between BMI and waist circumference with mortality in a large cohort of participants with CKD, and each 1-kg/m² increase in BMI was associated with 3% lower risk of death. Similar associations have been reported in renal transplant recipients (32). We did not have waist circumference details given the nature of the study population; however, the revised definitions of the National Cholesterol Education Program-Adult Treatment Panel III suggest using BMI to define metabolic syndrome when waist circumference data are not readily available, and this definition has been used in previous studies.

Several factors, including aging, genetic and environmental factors, and Western lifestyle that includes a high calorie diet and sedentary lifestyle, contribute to the increasing prevalence of metabolic syndrome. Low physical activity levels are common in those patients with CKD and are associated with death in the CKD population (33–35). Although available data support adopting exercise and intentional weight loss in this population, the quality of the available evidence on this topic is suboptimal (36,37). Our results add to the existing body of literature about the harmful effects of metabolic syndrome and support the need for studying the effects of increasing levels of physical activity and adopting a healthier lifestyle in this population (38).

Strengths of this analysis include the large sample size, diverse population, availability of both dialysis and mortality data for the study cohort, and use of competing risk models. Apart from the inherent bias of an observational study, our study is subject to other limitations. Mean follow-up was 2.3 years, and a longer follow-up might have shown a risk for mortality among those patients with metabolic syndrome. A significant interaction was noted in the Cox proportional hazards model of ESRD, suggesting that metabolic syndrome confers a higher risk for ESRD in older but not younger populations. This finding might be attributed to the nature of the CKD registry, and the inception point for the outcomes analysis was the date of inclusion in the CKD registry and not when the patient developed metabolic syndrome. We could not ascertain whether the blood glucose results available were fasting, thereby reducing the number of patients with impaired glucose metabolism or insulin resistance.

A significant portion of the potential study population did not have information to assess the presence of metabolic syndrome and were excluded from the analysis. It is possible that these patients are systematically different from our study population, and as such, results may lack complete external validity. Furthermore, although we were able to adjust for several confounding variables, we lacked data relating to physical activity, diet, socioeconomic status, family history of cardiovascular and kidney disease, and whether the components of metabolic syndrome were well controlled, which might influence the results. The lack of association between metabolic syndrome and mortality in this study should be interpreted with caution. It could be attributed to the inverse association noted with BMI, hypertension, and higher use of cardioprotective medications, such as statins and renin angiotensin blockers, in this population.

In summary, metabolic syndrome is widely prevalent and associated with ESRD but not mortality in a diverse

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**Figure 3.** Associations of individual components of metabolic syndrome with ESRD and mortality.

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nondialysis-dependent CKD population. The associations between the individual components of metabolic syndrome and outcomes varied, showing a need for additional investigation into the mechanisms. Furthermore, long-term studies to examine the relationship between metabolic syndrome and mortality in CKD patients are also warranted. Additionally, whether interventions, such as lifestyle modifications, can improve the risk associated with metabolic syndrome on kidney disease progression in those patients with CKD warrants additional study.

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Disclosures

None.

References


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