Diabetes & Metabolic Syndrome: Clinical Research & Reviews 13 (2019) 612–615

Contents lists available at ScienceDirect

Diabetes & Metabolic Syndrome: Clinical Research & Reviews

journal homepage: www.elsevier.com/locate/dsx

Original Article

Chronic kidney disease among US adults with type 2 diabetes and cardiovascular diseases: A national estimate of prevalence by KDIGO 2012 classification

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ARTICLE INFO

Article history:
Received 5 October 2018
Accepted 2 November 2018

Keywords:
Chronic kidney disease
Type 2 diabetes
Cardiovascular disease
Prevalence

ABSTRACT

Aim: Data on prevalence of chronic kidney disease (CKD) among US adults with type 2 diabetes (T2D) and cardiovascular diseases (CVD) are limited. The aim of this study was to provide such estimates for T2D, both overall and in those with CVD.

Materials and methods: Using the NHANES 2007–2014 data, we conducted a cross-sectional analysis of an adult sample with diagnosed and undiagnosed T2D, aged ≥18 years. CVD was defined based on self-reported personal interview data on a broad range of health conditions—congestive heart failure, coronary heart disease, angina, stroke, or heart attack. T2D was defined as diagnosed T2D (self-reported provider diagnosis) and undiagnosed T2D (FPG ≥126 mg/dL or HbA1c ≥ 6.5% without self-reported diagnosis). Participants who started insulin within a year of T2D diagnosis, or were pregnant at the time of health examination were excluded. Appropriate sample weights were used to provide a national estimate.

Results: The prevalence of moderate to severe renal impairment based on eGFR below 60 ml/min/1.73 m^2 among T2D was 18.0%. The prevalence of mild renal impairment was 36.9%: 28.3% with UACR<30 mg/g, 7.0% with UACR ≥30–300 mg/g and 1.6% with UACR >300 mg/g. For T2D and CVD subgroup, the prevalence was 33.6% for moderate to severe renal impairment and 42.8% for mild renal impairment.

Conclusions: This study confirms the high prevalence of CKD in patients with multiple comorbidities: T2D and CVD. It also provides estimates of the prevalence of CKD categories based on KDIGO 2012 classification for US adults with T2D.

1. Introduction

Chronic kidney disease (CKD) is an increasing public health issue and often occurs in the context of multiple comorbidities [1]. The Kidney Disease: Improving Global Outcomes (KDIGO) 2012 Clinical Practice Guideline recommends that CKD is classified based on cause, estimated glomerular filtration rate (eGFR) category, and albuminuria category [2].

Prevalence of CKD in the US adult general population is 14.8% [3]. However, data on the prevalence of CKD among US adults with type 2 diabetes (T2D) and cardiovascular diseases (CVD) are limited. Using a nationally representative sample, our study sought to provide a national estimate of prevalence of CKD in US adults aged ≥18 years with T2D, both overall and in those with CVD, based on KDIGO 2012 classification.

2. Methods

The National Health and Nutrition Examination Survey (NHANES) 2007–2014 were used for this study. NHANES is a cross-sectional survey designed to monitor the health and nutritional status of the representative samples of non-institutionalized civilian US population [4].

All NHANES participants aged 18 years or older, with complete

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https://doi.org/10.1016/j.dsx.2018.11.026
1871-4021/

demographic data, laboratory data, and information about T2D and CVD required for this study were included in the analysis.

CKD was categorized based on the KDIGO classification by GFR and albuminuria categories. GFR categories were based on eGFR: G1 ≥ 90 ml/min/1.73 m^2 (normal to high); G2 60–89 ml/min/1.73 m^2 (mildly decreased); G3a 45–59 ml/min/1.73 m^2 (mildly to moderately decreased); G3b 30–44 ml/min/1.73 m^2 (moderately to severely decreased); G4 15–29 ml/min/1.73 m^2 (severely decreased); and G5 <15 ml/min/1.73 m^2 (kidney failure). eGFR was calculated using two equations: Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation and Modification of Diet in Renal Disease (MDRD) equation [5,6]. Albuminuria categories were based on the urine albumin to creatinine ratio (UACR): A1 < 30 mg/g (normal to mildly increased); A2 30–300 mg/g (moderately increased); and A3 > 300 mg/g (severely increased).

T2D consisted of both self-reported diagnosed T2D and undiagnosed T2D. NHANES participants who self-reported T2D were identified by the answer "yes" to the question "Have you ever been told by a doctor or other health professional that you have diabetes or sugar diabetes". Undiagnosed T2D was defined by fasting plasma glucose (FPG) ≥126 mg/dL or HbA1c ≥ 6.5% among participants who did not report a previous diabetes diagnosis during the interview. Participants with type 1 diabetes, defined as a patient started insulin within a year of diabetes diagnosis, or participants who were pregnant at the time of health examination were excluded from the analysis.

Participants with CVD were identified based on self-reported responses to interview questionnaires on coronary heart disease, angina, heart attack, heart failure or stroke (i.e. ever told they had coronary heart disease, angina, heart attack, heart failure or stroke), or the presence of Grade 1 or Grade 2 angina as defined by the Rose questionnaire and captured in the Cardiovascular Disease and Health interview [7].

The prevalence of eGFR and UACR categories (and 95% confidence intervals) was calculated among US adults with T2D. A subgroup analysis was conducted among the US T2D population with CVD. The observations were weighted to account for the complex sampling design of NHANES and to project the estimates to the entire US population [8]. Statistical analyses were conducted using SAS, version 9.4.

3. Results

The NHANES 2007–2014 sample included a total of 3271 adults with T2D, yielding a national projected population estimate of 23.6 million. Based on the national estimates, 52.8% of US adults with T2D were male, 37.4% were aged ≥65 years old, and 60.3% were Non-Hispanic whites (Table 1).

The prevalence of moderate to severe renal impairment based on eGFR below 60 ml/min/1.73 m^2 using CKD-EPI equation was 18.0%: 10.4% with Stage 3a, 5.4% with Stage 3b, and 2.2% with Stage 4 or 5. The prevalence of mild renal impairment (stage 2, eGFR = 60–89 ml/min/1.73 m^2) was 36.9%: 28.3% with UACR<30 mg/g (normal to mildly increased albuminuria), 7.0% with UACR ≥ 30–300 mg/g (moderately increased albuminuria) and 1.6% with UACR >300 mg/g (severely increased albuminuria) (Table 2). The prevalence of CKD based on eGFR was slightly higher using the MDRD equation compared to CKD-EPI. Using the MDRD equation, the prevalence was 20.0% for moderate to severe renal impairment and 44.1% for mild renal impairment (Table 3).

Approximately 24.4% of individuals with T2D have CVD. For the T2D and CVD subgroup, the prevalence of moderate to severe renal impairment was 33.6% (Stage 3a: 16.1%; Stage 3b: 12.3%; Stage 4 or 5: 5.2%). The prevalence of mild renal impairment (Stage 2) was 42.8%, including 29.0% with UACR<30 mg/g, 11.8% with UACR≥ 30–300 mg/g and 2.1% with UACR >300 mg/g (Table 4). The prevalence of CKD based on eGFR using MDRD equation provided similar results (Table 4).

Table 1
Demographic characteristics of NHANES projected national estimates of US adults with T2D, overall and with CVD, NHANES 2007–2014.

	T2D overall		T2D and CVD	
	N[a]	Percent (SE)	N[a]	Percent (SE)
Sex				
Male	12,444,790	52.8 (1.2)	3,159,820	54.9 (2.2)
Female	11,138,965	47.2 (1.2)	2,599,252	45.1 (2.2)
Age				
18–64 years	14,775,271	62.7 (1.1)	2,262,843	39.3 (2.2)
65–74 years	5,154,823	21.9 (0.9)	1,848,575	32.1 (2.2)
≥75 years	3,653,661	15.5 (0.7)	1,647,655	28.6 (1.9)
Ethnicity				
Non-Hispanic whites	14,221,480	60.3 (1.1)	3,952,458	68.6 (1.8)
Non-Hispanic black	3,562,525	15.1 (0.6)	782,752	13.6 (1.1)
Mexican American	2,382,769	10.1 (0.5)	374,169	6.5 (0.7)
Other Hispanic	1,413,512	6.0 (0.4)	255,509	4.4 (0.6)
Others	2,003,470	8.5 (0.6)	394,184	6.8 (1.2)
Total	23,583,755	100.0	5,759,072	100.0

CVD = cardiovascular diseases; SE = standard error of percent, T2D = type 2 diabetes.
[a] Projected to national estimate.

4. Discussion and conclusions

This study applies a global classification of CKD to estimate the prevalence of renal impairment among the US population with T2D using a nationally representative sample. Bailey et al. [9] used NHANES 1999–2012 data and a similar staging of CKD and reported a slightly higher prevalence of CKD among the T2D population than our study. The study population from Bailey et al. was limited to

Table 2
Prevalence [% (95 CI)] of CKD among US adults with T2D, by eGFR (CKD-EPI) and Albuminuria Categories: KDIGO 2012 classification, NHANES 2007–2014.

GFR category, ml/min/1.73m^2 (CKD-EPI)		Albuminuria (UACR) category, mg/g			
		A1: <30	A2: 30-300	A3: >300	Total
		Normal to mildly increased	Moderately increased	Severely increased	
G1: ≥90	Normal or high	35.5 (33.2–37.8)	8.1 (6.8–9.3)	1.5 (1.0–2.0)	45.1 (42.7–47.4)
G2: 60-89	Mildly decreased	28.3 (26.2–30.5)	7.0 (5.8–8.1)	1.6 (1.1–2.1)	36.9 (34.6–39.2)
G3a: 45-59	Mildly to moderately decreased	7.3 (6.1–8.5)	2.4 (1.8–2.9)	0.7 (0.4–1.0)	10.4 (9.1–11.7)
G3b: 30-44	Moderately to severely decreased	2.6 (2.0–3.3)	1.8 (1.2–2.4)	1.0 (0.6–1.4)	5.4 (4.5–6.4)
G4: 15-29	Severely decreased	0.2 (0.1–0.4)	0.9 (0.5–1.3)	0.7 (0.4–1.1)	1.8 (1.3–2.4)
G5: <15	Kidney failure	0.01 (0–0.04)	0.1 (0–0.3)	0.3 (0.1–0.5)	0.4 (0.2–0.7)

CI = confidence interval; CKD = chronic kidney disease; CKD-EPI = Chronic Kidney Disease Epidemiology Collaboration; eGFR = estimated glomerular filtration rate; KDIGO=Kidney Disease Improving Global Outcomes; T2D = type 2 diabetes; UACR = urine albumin-to-creatinine ratio.

Table 3
Prevalence [% (95 CI)] of CKD among US adults with T2D, by eGFR (MDRD) and Albuminuria Categories: KDIGO 2012 classification, NHANES 2007–2014.

GFR category, ml/min/1.73m^2 (MDRD)		Albuminuria (UACR) category, mg/g			
		A1: <30	A2: 30-300	A3: >300	Total
		Normal to mildly increased	Moderately increased	Severely increased	
G1: ≥90	Normal or high	27.7 (25.7–29.8)	7.0 (5.8–8.1)	1.1 (0.8–1.5)	35.9 (33.6–38.1)
G2: 60-89	Mildly decreased	34.4 (32.1–36.7)	7.9 (6.7–9.1)	1.8 (1.2–2.4)	44.1 (41.8–46.5)
G3a: 45-59	Mildly to moderately decreased	8.9 (7.6–10.3)	2.6 (2.0–3.2)	0.9 (0.6–1.3)	12.5 (11.0–14.0)
G3b: 30-44	Moderately to severely decreased	2.6 (2.0–3.3)	1.8 (1.2–2.3)	0.9 (0.5–1.3)	5.3 (4.4–6.3)
G4: 15-29	Severely decreased	0.2 (0.1–0.4)	0.9 (0.5–1.2)	0.7 (0.4–1.1)	1.8 (1.2–2.3)
G5: <15	Kidney failure	0.01 (0–0.04)	0.1 (0–0.3)	0.3 (0.1–0.5)	0.4 (0.2–0.7)

CI = confidence interval; CKD = chronic kidney disease; eGFR = estimated glomerular filtration rate; KDIGO=Kidney Disease Improving Global Outcomes; MDRD = Modification of Diet in Renal Disease; T2D = type 2 diabetes; UACR = urine albumin-to-creatinine ratio.

Table 4
Subgroup analysis: Prevalence [% (95 CI)] of CKD among US adults with self-reported CVD and T2D, by eGFR (CKD-EPI/MDRD) and Albuminuria Categories: KDIGO 2012 classification, NHANES 2007–2014.

		Albuminuria (UACR) category, mg/g			
		A1: <30	A2: 30-300	A3: >300	Total
		Normal to mildly increased	Moderately increased	Severely increased	
GFR category, ml/min/1.73m^2 (CKD-EPI)					
G1: ≥90	Normal or high	17.2 (13.6–20.7)	4.8 (3.1–6.5)	1.6 (0.5–2.7)	23.6 (19.7–27.4)
G2: 60-89	Mildly decreased	29.0 (24.9–33.1)	11.8 (8.9–14.6)	2.0 (1.0–3.1)	42.8 (38.4–47.2)
G3a: 45-59	Mildly to moderately decreased	10.6 (8.0–13.3)	4.5 (2.8–6.1)	1.0 (0.3–1.7)	16.1 (13.0–19.2)
G3b: 30-44	Moderately to severely decreased	6.2 (4.2–8.3)	4.3 (2.8–5.8)	1.8 (0.7–2.8)	12.3 (9.6–15.0)
G4: 15-29	Severely decreased	0.5 (0.03–1.0)	1.9 (0.7–3.0)	2.0 (0.7–3.4)	4.4 (2.6–6.2)
G5: <15	Kidney failure	0	0.4 (0–1.2)	0.4 (0.1–0.7)	0.8 (0–1.7)
GFR category, ml/min/1.73m^2 (MDRD)					
G1: ≥90	Normal or high	15.3 (11.9–18.6)	4.3 (2.8–5.8)	1.0 (0.4–1.6)	20.6 (17.0–24.2)
G2: 60-89	Mildly decreased	27.8 (23.5–31.6)	12.3 (9.4–15.2)	2.2 (0.9–3.5)	42.1 (37.7–46.4)
G3a: 45-59	Mildly to moderately decreased	13.9 (10.7–17.1)	4.7 (3.1–6.4)	1.3 (0.4–2.1)	19.9 (16.4–23.5)
G3b: 30-44	Moderately to severely decreased	6.2 (4.2–8.3)	4.1 (2.7–5.6)	1.9 (0.8–3.0)	12.2 (9.6–14.9)
G4: 15-29	Severely decreased	0.5 (0.03–1.0)	1.8 (0.6–2.9)	2.0 (0.7–3.4)	4.3 (2.5–6.1)
G5: <15	Kidney failure	0	0.4 (0–1.2)	0.4 (0.1–0.7)	0.8 (0–1.7)

CI = confidence interval; CKD = chronic kidney disease; CKD-EPI = Chronic Kidney Disease Epidemiology Collaboration; CVD = cardiovascular diseases; eGFR = estimated glomerular filtration rate; KDIGO=Kidney Disease Improving Global Outcomes; MDRD = Modification of Diet in Renal Disease; T2D = type 2 diabetes; UACR = urine albumin-to-creatinine ratio.

diagnosed T2D with the age of onset >30 years, resulting in an older study population than ours. This may explain some of the differences observed [9].Our findings are consistent with a study of the prevalence of CKD in T2D conducted by Wu et al. with similar age group to our study [10]. However, Wu et al. did not provide the distribution of albuminuria categories in every eGFR category. Our study provides data among T2DM patients with CVD and undiagnosed T2D, which neither of the aforementioned two studies include [9,10].

Our study has several limitations. Firstly, CVD were identified based on self-reported responses to interview questionnaires. Therefore, some CVD cases might have been missed because of lack of information (such as peripheral artery disease) in the questionnaire, resulting in some misclassification of CVD status. Secondly, the determination of the presence of kidney disease based on eGFR and albuminuria was made based on a single random sample of the laboratory values. Thirdly, NHANES only sampled noninstitutionalized adults. The findings may not be generalizable to nursing home adults where CKD prevalence is unknown but likely to be high. Lastly, the sample size for G5 (Kidney failure) category in our study is considered too small to produce statistically reliable estimates.

Our study provides the most recent estimates of the prevalence of CKD categories based on the eGFR categories and the distribution of albuminuria by severity within the categories of eGFR among US adults with T2D. Furthermore, the data confirms the high prevalence of CKD among the US population with multiple comorbidities—T2D and CVD, with 33.6% individuals having evidence of moderate to severe renal impairment, and 42.8% having mild renal impairment, based on the CKD-EPI equation. Current guidelines from the American Diabetes Association (ADA) and the European Association for the Study of Diabetes (EASD) on the management of hyperglycemia in patients with T2D recommend a stepwise and individualized treatment approach taking into account the adverse effects of antidiabetic medications, patient's age and comorbidities (such as cardiovascular diseases and kidney function) [11,12]. The information generated by our study is particularly useful to clinicians, policy makers, and entities focused on T2D population health management.

Disclosures

Tongtong Wang is an employee of Merck Sharp & Dohme Corp., a subsidiary of Merck & Co., Inc., Kenilworth, NJ, USA, and may own stock and/or hold stock options in the company. Robert Lubwama is an employee of Merck Sharp & Dohme Corp., a subsidiary of Merck & Co., Inc., Kenilworth, NJ, USA, and may own stock and/or hold stock options in the company. Hakima Hannanchi is an employee of Merck Sharp & Dohme Corp., a subsidiary of Merck & Co., Inc., Kenilworth, NJ, USA, and may own stock and/or hold stock options in the company. Kristy Iglay is an employee of Merck Sharp & Dohme Corp., a subsidiary of Merck & Co., Inc., Kenilworth, NJ, USA, and may own stock and/or hold stock options in the company. Carol Koro is an employee of Merck Sharp & Dohme Corp., a subsidiary of

Merck & Co., Inc., Kenilworth, NJ, USA, and may own stock and/or hold stock options in the company. Yuzhi Xi is supported by Merck Graduate Student Fellowship.

Compliance with ethics guidelines

This article is based on previously conducted studies using a Health Insurance Portability and Accountability Act of 1996 (US) (HIPAA) compliant database and does not involve any new studies of human or animal subjects performed by any of the authors.

Acknowledgements

Funding

This analysis and article processing charges were funded by Merck & Co, Inc., Kenilworth, NJ, USA.

Authorship

Tongtong Wang, Yuzhi Xi, Robert Lubwama, Hakima Hannanchi, Kristy Iglay, and Carol Koro meet the International Committee of Medical Journal Editors (ICMJE) criteria for authorship for this manuscript, take responsibility for the integrity of the work as a whole, and have given final approval to the version to be published.

Author contribution

Tongtong Wang, Yuzhi Xi, Robert Lubwama, Hakima Hannanchi, Kristy Iglay, and Carol Koro are responsible for the work described in this paper. Tongtong Wang, Robert Lubwama and Carol Koro conceived, designed, and/or planned the study. Yuzhi Xi, Robert Lubwama and Hakima Hannanchi analyzed the data. Tongtong Wang, Yuzhi Xi, Robert Lubwama, Hakima Hannanchi, Kristy Iglay, and Carol Koro interpreted the results. Tongtong Wang and Yuzhi Xi drafted the manuscript. Tongtong Wang, Yuzhi Xi, Robert Lubwama, Hakima Hannanchi, Kristy Iglay, and Carol Koro critically reviewed and/or revised the manuscript for important intellectual content. All authors provided final approval of the version to be published and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

The materials have been presented as posters at the ADA 78th Scientific Sessions, June 22–26, 2018. Orlando, Florida and at the 34th International Conference on Pharmacoepidemiology & Therapeutic Risk Management annual conference, August 22–26, 2018, Prague, Czech Republic.

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