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Heart failure and left ventricular dysfunction in older patients with chronic kidney disease: the China Hypertension Survey (2012–2015)

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Abstract

Background Heart failure (HF) is a leading cause of hospitalization and mortality for older chronic kidney disease (CKD) patients. However, the epidemiological data is scarce. We aimed to determine the prevalence of left ventricular (LV) dysfunction and HF, and to explore the risk factors for HF among those patients. **Methods** This is a cross-sectional analysis of the China Hypertension Survey conducted between October 2012 and December 2015. A total of 5,808 participants aged ≥ 65 years were included in the analysis. Self-reported history of HF and any other cardiovascular diseases was acquired. 2-D and Doppler echocardiography were used to assess LV dysfunction. CKD was defined as either estimated glomerular filtration rate (eGFR) < 60 mL/min per 1.73 m^2 or urinary albumin to creatinine ratio (ACR) ≥ 30 mg/g. **Results** Among CKD patients aged ≥ 65 years, the weighted prevalence of HF, heart failure with preserved ejection fraction (HFpEF), heart failure with mid-range ejection fraction (HFmrEF), and heart failure with reduced ejection fraction (HFrEF) was 4.8%, 2.5%, 0.8%, and 1.7%, respectively. The weighted prevalence of HF was 5.0% in patients with eGFR < 60 mL/min per 1.73 m^2, and was 5.9% in patients with ACR ≥ 30 mg/g. The prevalence of LV systolic dysfunction was 3.1%, and while it was 8.9% for moderate/severe diastolic dysfunction. Multivariate analysis showed that smoking was significantly associated with the risk of HF. Furthermore, age, smoking, and residents in rural areas were significantly associated with a risk of LV diastolic dysfunction. **Conclusions** The prevalence of HF and LV dysfunction was high in older patients with CKD, suggesting that particular strategies will be required.

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Keywords: Chronic kidney disease; Heart failure; Left ventricular dysfunction; Older population

1 Introduction

Heart failure (HF) is a global pandemic in healthcare affecting approximately 26 million people worldwide and is increasing in incidence and prevalence.[1,2] Recently, we reported that the prevalence of HF was 1.3% in the Chinese adult population aged 35 years or older,[3] suggesting that the overall prevalence of HF increased by 44% during the past 15 years.[4] Most patients with HF are elderly, constituting up to 80% of patients. Chronic HF is the leading cause of hospitalization for those over the age of 65 and represents a significant clinical and economic burden.[5] Elderly patients show a different clinical profile when compared with younger patients. In particular, elderly patients with HF often present with complex comorbidities, such as chronic kidney disease (CKD). HF is a leading cause of morbidity and mortality in patients with CKD, and the population of CKD patients with concurrent HF continues to grow.[6] The presence of one condition appears to accelerate the presentation and progression of the other; having both conditions increases the risk of hospitalization, rehospitalization, need for intensive care or kidney replacement therapy, and death.[7] However, epidemiological information

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on HF in patients with CKD in low- and middle-income countries, including in China, is scarce.

World Health Organization reported that the proportion of the population aged 60 years and over in China will increase from 12.4% in 2010 to 28% in 2040.[8] Given the much faster aging in China, and poor prognosis of HF in older patients with CKD, it is important to understand the epidemiological characteristics of HF in older patients with CKD, including the prevalence and risk factors. This will help guide the strategies for HF prevention and management, and the allocation of medical resources in China and low- and middle-income countries. We, therefore, used a large nationally representative sample of the Chinese population from the China Hypertension Survey (CHS) study to determine the prevalence of left ventricular (LV) dysfunction and HF and to explore the import risk factors for HF in older patients with CKD.

2 Methods

2.1 Study population

The CHS study was conducted between October 2012 and December 2015, and the design was published previously.[3,9,10] Briefly, a stratified, multistage random sampling method was used to obtain a nationally representative sample of the general Chinese population aged 15 years or older. All 31 provinces in mainland China were covered in this survey. For this substudy, all selected urban and rural areas were stratified into eastern, middle and western regions again according to both geographical locations as well as economic level. Using the simple random sampling method, 16 cities and 17 counties were selected, including seven cities and seven counties from eastern regions, six cities and six counties from middle regions, and three cities and four counties from western regions. Next, at least three communities or villages were randomly selected from each region. Participants with certified documents from the Administration of Households of the local government were enrolled to exclude immigration effects. To meet the designed sample size of 35,000 participants aged ≥ 35 years and to take non-response into account in the survey, 56,000 subjects were randomly selected and invited. Among these, 34,994 responded positively with a response rate of 62.5%. In the current study, a total of 5,808 individuals aged 65 or older with complete data on HF, education attainment, smoking status, consumption of alcohol, coronary artery disease (CAD), diabetes, CKD, and dyslipidemia, were eligible for analysis.[3] This study was approved by the Ethics Committee of Fuwai Hospital (No.2012-402) and written informed consent was obtained from each participant before data collection.

2.2 Data collection

A standardized questionnaire developed by the coordinating center, Fuwai Hospital (Beijing, China), was administered by trained staff to obtain information on demographic characteristics and social-economic factors. Height was measured without shoes using a standard right-angle device and a fixed measurement tape (to the nearest 0.5 cm), and weight was measured without heavy clothing using an OMRON body fat and weight measurement device (V-body HBF-371, OMRON, Kyoto, Japan). Body mass index (BMI) was calculated as the weight divided by the square of the height (kg/m^2) for each participant. Blood pressure (BP) was measured with the OMRON HBP-1300 professional portable blood pressure monitor (OMRON, Kyoto, Japan) three times on the right arm supported at heart level after the participant was sitting at rest for five minutes, with 30 s between each measurement with an observer present. For each participant, a self-reported history of HF and any other cardiovascular diseases was acquired. In addition, ten HF symptoms were collected, including four typical symptoms (reduced ability to exercise; dyspnea when you exert yourself; swelling in your legs, ankles, and feet; dyspnea when you lie down) and six less typical symptoms (worse cough, especially when you are lying down or when you exert yourself; increased need to urinate at night; rapid or irregular heartbeat; feeling depressed; feeling severe thirst; and swelling of your abdomen).

The echocardiograms were obtained using a commercially available Doppler ultrasonography, with a 3.0-MHz transducer using M-mode, 2-dimensional, spectral Doppler and color Doppler transthoracic echocardiography with participants in the supine position. It was performed by certified physicians, who received a one-month training before the study on the standardization of quantifying cardiac chambers. 2D images were acquired and measured in the parasternal (standard long- and short-axis images) and apical views (2-, 4-chamber and apical long-axis images). A total of 16 echocardiographic parameters were obtained from each participant, including the left ventricular ejection fraction (LVEF). The biplane method of disks (Simpson's rule) was explored to assess the LVEF.[11] Grading diastolic dysfunction was based on the recommendations for the evaluation of left ventricular diastolic function by echocardiography.[12] Three physicians specialized in echocardiography read and analyzed the echocardiograms. If any question or uncertainty arose, the other two specialists were consulted.

2.3 Survey outcome definitions

HF was diagnosed according to the recommendation of the European Society of Cardiology[13,14] with minor modifications. HF was defined as follows: patients with a self-reported history of HF; ejection fraction (EF) < 50% and at least six HF symptoms; or moderate/severe diastolic dysfunction, at least six HF symptoms, and EF ≥ 50%. Heart failure with preserved ejection fraction (HFpEF) was defined as EF ≥ 50%, heart failure with reduced ejection fraction (HFrEF) was defined as EF < 40%, and LVEF in the range of 40%–49% was defined as heart failure with mid-range ejection fraction (HFmrEF). In a sensitivity analysis, at least three out of four typical HF symptoms were used to define HF.

To facilitate comparison with previous studies, LV systolic dysfunction was defined as EF < 50%, and moderate/severe dysfunction was defined as EF < 40% in the primary analyses.[15] In subsidiary analyses, EF < 52% for men and EF < 54% for women was graded as abnormal LV systolic function.[16] The LV diastolic dysfunction was classified as mild or grade I (impaired relaxation pattern), moderate or grade II (PNF), and severe or grade III (restrictive filling) according to the joint recommendations of the American Society of Echocardiography and the European Association of Cardiovascular Imaging.[12]

CAD was defined as previous myocardial infarction, surgery or coronary revascularization. Participants with a fasting plasma glucose level ≥ 7.0 mmol/L and/or who were receiving antidiabetic medications were defined as having diabetes. Dyslipidemia was defined as any one of the following four conditions: total cholesterol ≥ 6.2 mmol/L; triglycerides ≥ 2.3 mmol/L; low levels of high-density lipoprotein cholesterol < 1.0 mmol/L; or high levels of low-density lipoprotein cholesterol ≥ 4.1 mmol/L.[17] CKD was defined as either decreased estimated glomerular filtration rate (eGFR) < 60 mL/min per 1.73 m^2 or urinary albumin to creatinine ratio (ACR) ≥ 30 mg/g according to Kidney Disease Improving Global Outcomes guidelines.[18]

Overweight was defined as a BMI between 24.0 kg/m^2 and 27.9 kg/m^2, and obesity was defined as a BMI of 28.0 kg/m^2 or more.[19] Current smokers were defined as participants who have smoked at least 20 packs of cigarettes in their lifetime and who currently smoke cigarettes; former smokers were defined as participants who have smoked at least 20 packs of cigarettes in their lifetime, and who have quit smoking for at least one month, and never smokers were defined as participants who have never smoked a cigarette or who have smoked fewer than 20 packs of cigarettes in their entire lifetime. Current drinkers were defined as participants who consumed at least one alcoholic beverage per week in the past month.

2.4 Statistical analysis

Our study was designed to provide accurate estimates of the prevalence of HF and LV dysfunction in the general Chinese population aged ≥ 35 years. Sampling weights were calculated based on the 2010 China population census data and sampling scheme and included oversampling for specific age or geographic subgroups, nonresponse, and other demographic or geographic differences between the sample and the total population.[20] Adjustment for differential probabilities of selection and the complex sampling design was used to enhance the representativeness of the survey sample population. Variables were summarized using means for continuous data; frequencies, percentages, and proportions used for categorical data.

Two-tailed Student's *t*-tests and ANOVA were used to compare continuous variables, and Pearson's chi-square tests were used to compare categorical variables. The prevalence was weighted to represent the total Chinese population aged ≥ 65 years. The risk factors for HF and LV dysfunction were estimated by Logistic regression models with the Enter method, in which all potential risk factors, including age, sex, ethnicity, education attainment, BMI, smoking status, consumption of alcohol, BP, CAD, diabetes, and dyslipidemia, were included. All 95% confidence intervals (CI) for the parameters were estimated. A two-sided *P*-value < 0.05 was considered significant. Statistical analyses were conducted with SAS version 9.4 (SAS Institute INC, Cary, NC, USA) and Stata 12.1 (STATA Corp., TX, USA).

3 Results

A total of 5,808 participants aged ≥ 65 years (49.6% men and 50.4% women; 47.4% from urban areas and 52.7% from rural areas) were included in the analysis, of them, 862 participants were defined as CKD. The characteristics of participants by kidney damage were presented in Table 1.

Among CKD patients aged 65 years or older, the weighted prevalence of HF was 4.8%, and the weighted prevalence of HFpEF, HFmrEF, and HFrEF was 2.5%, 0.8%, and 1.7%, respectively (Table 2). The weighted prevalence of HF was similar between urban and rural residents (5.9% *vs.* 4.0%, *P* = 0.173), and men and women (6.3% *vs.* 3.7%, *P* = 0.114) (Table 2). The weighted prevalence of HF was 5.0% in patients with eGFR < 60 mL/min per 1.73 m^2 and the prevalence was 5.9% in patients with ACR ≥ 30 mg/g (Figure 1). The most present symptoms in patients with HF were "reduced ability to exercise" (54.9%), "shortness of breath when you exert yourself" (42.6%), and "increased need to urinate at night" (30.9%) (Figure 2).

The weighted prevalence of LV systolic dysfunction (EF < 50%) was 3.1%, and while it was 8.9% for moderate/severe diastolic dysfunction. The prevalence of LV systolic

Table 1. Characteristics of study participants.

Characteristics	Normal (n = 4,946)	Kidney damage			Total (n = 5,808)
		eGFR < 60 mL/min per 1.73 m^2 (n = 744)	ACR ≥ 30 mg/g (n = 194)	Chronic kidney disease (n = 862)	
Mean age, yrs	74.9 (74.2–75.6)	74.8 (73.5–76.1)	72.4 (72.1–72.7)	74.8 (74.1–75.6)	72.4 (72.1–72.7)
Female, %	58.0 (53.0–62.9)	61.0 (50.2–70.8)	52.0 (48.5–55.4)	58.1 (53.3–62.7)	52.0 (48.5–55.4)
Mean body mass index, kg/m^2	24.5 (23.1–25.8)	25.0 (23.6–26.4)	24.0 (23.4–24.6)	24.5 (23.2–25.8)	24.0 (23.4–24.6)
< 18.5	5.5 (2.4–12.1)	3.0 (1.0–8.3)	5.5 (3.9–7.6)	5.3 (2.3–11.9)	5.5 (3.9–7.6)
18.5–23.9	41.3 (33.1–50.0)	40.1 (27.6–54.1)	46.8 (41.5–52.1)	41.3 (33.3–49.9)	46.8 (41.5–52.1)
24.0–27.9	35.4 (30.5–40.6)	30.4 (22.6–39.5)	34.3 (31.5–37.2)	34.7 (30.0–39.7)	34.3 (31.5–37.2)
≥ 28.0	17.8 (10.6–28.3)	26.5 (16.9–39.0)	13.5 (9.7–18.5)	18.6 (11.5–28.8)	13.5 (9.7–18.5)
Ethnicity (Han), %	91.7 (72.5–97.9)	94.3 (75.0–98.9)	93.5 (80.0–98.1)	91.9 (73.7–97.9)	93.5 (80.0–98.1)
Education attainment, %					
Elementary school	77.2 (59.6–88.6)	75.1 (58.7–86.5)	74.8 (64.2–83.0)	76.7 (59.9–87.9)	74.8 (64.2–83.0)
Middle high school	19.3 (10.3–33.2)	21.2 (11.9–34.9)	21.7 (15.0–30.5)	19.7 (10.9–32.8)	21.7 (15.0–30.5)
High school or above	3.5 (1.1–10.0)	3.7 (1.0–12.4)	3.5 (1.5–7.7)	3.6 (1.2–10.2)	3.5 (1.5–7.7)
Smoking, %					
Nonsmokers	72.9 (65.4–79.3)	77.8 (69.8–84.2)	72.4 (65.7–78.3)	73.7 (67.0–79.5)	72.4 (65.7–78.3)
Former smokers	9.6 (5.9–15.2)	9.3 (4.8–17.1)	8.3 (5.9–11.4)	9.6 (6.0–15.0)	8.3 (5.9–11.4)
Current smokers	17.5 (9.8–29.1)	12.9 (5.5–27.4)	19.3 (14.5–25.2)	16.7 (9.5–27.7)	19.3 (14.5–25.2)
Consumption of alcohol, %					
Non-drinkers	82.0 (78.5–85.0)	81.3 (74.7–86.5)	78.2 (70.4–84.5)	82.1 (78.7–85.0)	78.2 (70.4–84.5)
Former drinkers	7.0 (4.2–11.5)	9.5 (6.0–14.6)	7.9 (5.3–11.6)	7.5 (4.7–11.9)	7.9 (5.3–11.6)
Current drinkers	11.0 (6.8–17.3)	9.2 (4.3–18.7)	13.9 (9.1–20.7)	10.4 (6.5–16.3)	13.9 (9.1–20.7)
Hypertension, %	75.8 (69.2–81.4)	85.5 (74.8–92.1)	62.1 (58.8–65.2)	76.3 (70.0–81.7)	62.1 (58.8–65.2)
Coronary artery disease, %	3.2 (1.3–7.5)	2.2 (0.6–7.8)	1.4 (0.8–2.4)	3.0 (1.3–6.8)	1.4 (0.8–2.4)
Dyslipidemia, %	16.3 (10.9–23.6)	23.3 (12.2–39.9)	12.8 (9.0–17.9)	17.3 (11.3–25.6)	12.8 (9.0–17.9)
Diabetes, %	35.4 (23.8–48.9)	40.7 (26.2–57.1)	33.2 (26.6–40.6)	36.0 (25.0–48.7)	33.2 (26.6–40.6)
Urban, %	58.0 (27.8–83.2)	63.8 (42.1–81.0)	65.3 (45.2–81.1)	58.9 (30.5–82.4)	65.3 (45.2–81.1)

Data are presented as n (95% CI). All values were weighted to represent the total Chinese population aged 65 years or older based on 2010 Chinese census data. ACR: urinary albumin to creatinine ratio; eGFR: estimated glomerular filtration rate.

Table 2. Weighted prevalence of heart failure in patients with chronic kidney disease.

Characteristics	HF	HF types		
		HFpEF	HFmrEF	HFrEF
Overall	4.8 (3.4–6.7)	2.5 (1.5–4.2)	0.8 (0.3–2.0)	1.7 (0.7–4.1)
Age, yrs				
65–74	3.9 (3.0–5.2)	2.6 (1.4–4.8)	0.8 (0.3–2.1)	0.8 (0.2–2.9)
≥ 75	5.6 (3.4–9.2)	2.5 (1.4–4.2)	0.8 (0.1–4.8)	2.7 (1.1–6.5)
P-value*	0.108		0.242	
Gender				
Men	6.3 (3.7–10.4)	3.6 (1.4–9.3)	0.5 (0.2–1.5)	2.2 (0.7–6.7)
Women	3.7 (2.3–5.8)	1.7 (0.7–4.2)	1.0 (0.2–4.0)	1.4 (0.6–3.4)
P-value*	0.114		0.442	
Region				
Urban	5.9 (3.7–9.4)	3.4 (1.5–7.5)	1.1 (0.2–5.5)	2.2 (1.0–5.0)
Rural	4.0 (2.4–6.3)	1.9 (0.8–4.3)	0.5 (0.2–1.6)	1.4 (0.3–6.3)
P-value*	0.173		0.472	

Data are presented as n (95% CI). All values were weighted to represent the total Chinese population aged 65 years or older based on 2010 Chinese census data. *Refers to Chi-square test was used to test whether distributions of categorical variables differ from each another. HF: heart failure; HFmrEF: heart failure with mid-range ejection fraction; HFpEF: heart failure with preserved ejection fraction; HFrEF: heart failure with reduced ejection fraction.

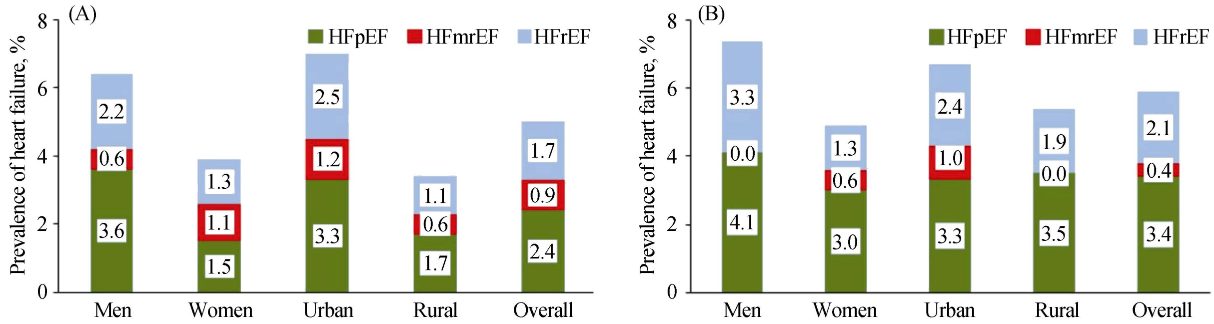

Figure 1. The prevalence of heart failure in patients with eGFR < 60 mL/min per 1.73 m^2 (A) and ACR ≥ 30 mg/g (B). ACR: urinary albumin to creatinine ratio; eGFR: estimated glomerular filtration rate; HFmrEF: heart failure with mid-range ejection fraction; HFpEF: heart failure with preserved ejection fraction; HFrEF: heart failure with reduced ejection fraction.

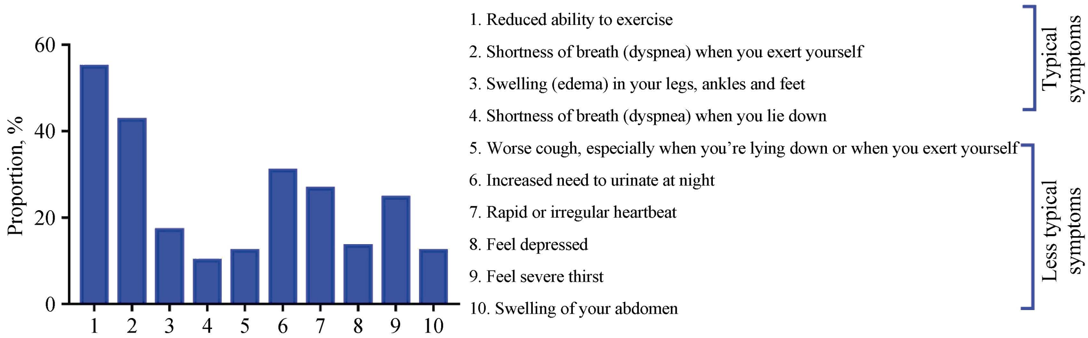

Figure 2. The signs and symptoms in heart failure among chronic kidney disease patients.

dysfunction increased with age (P < 0.05). Moderate and severe LV diastolic dysfunction was significantly higher in the men (P < 0.05), severe LV diastolic dysfunction was higher in the rural area (P < 0.05) (Table 3). According to the joint recommendations of the American Society of Echocardiography and the European Association of Cardiovascular Imaging, the prevalence of abnormal LV systolic function was 7.5% (supplemental material, Table 1S). In total, 86.1% of participants with LV dysfunction had mild LV diastolic dysfunction (Figure 3).

Table 3. Weighted prevalence of left ventricular dysfunction in patients with chronic kidney disease.

Characteristics	LV systolic dysfunction*		LV diastolic dysfunction*		
	40% ≤ EF < 50%	EF < 40%	Mild	Moderate	Severe
Overall	1.4 (0.8–2.7)	1.7 (0.7–4.1)	70.9 (52.5–84.2)	2.4 (1.4–4.1)	6.5 (2.2–17.9)
Age, yrs					
65–74	0.9 (0.4–2.2)	0.8 (0.2–2.9)	66.7 (44.5–83.3)	1.8 (0.8–3.9)	8.7 (2.7–24.4)
≥ 75	2.0 (1.0–4.2)	2.7 (1.1–6.5)	75.2 (59.3–6.7)	3.1 (1.2–7.7)	4.3 (1.5–12.0)
P-value**	0.029			0.059	
Gender					
Men	1.4 (0.6–3.2)	2.2 (0.7–6.7)	61.0 (40.3–78.4)	3.9 (2.1–7.1)	9.3 (3.2–24.3)
Women	1.5 (0.6–3.9)	1.4 (0.6–3.4)	78.0 (61.1–88.9)	1.3 (0.7–2.5)	4.5 (1.3–14.5)
P-value**	0.646			< 0.001	
Region					
Urban	1.3 (0.3–5.2)	2.2 (1.0–5.0)	87.5 (75.5–94.1)	2.7 (1.0–7.4)	2.7 (0.9–7.9)
Rural	1.6 (0.9–2.8)	1.4 (0.3–6.3)	59.2 (43.1–73.6)	2.2 (1.2–4.1)	9.2 (3.0–24.9)
P-value**	0.743			0.004	

Data are presented as n (95% CI). All values were weighted to represent the total Chinese population aged 65 years or older based on 2010 Chinese census data. *Refers to LV dysfunction was defined based on the echocardiographic data only. **Refers to Chi-square test was used to test whether distributions of categorical variables differ from each another. EF: ejection fraction; LV: left ventricular.

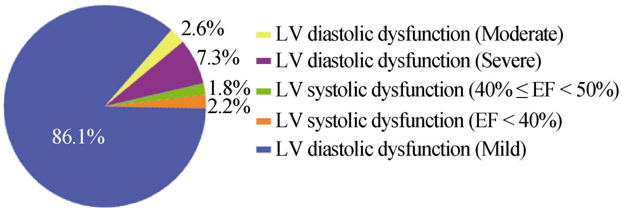

Figure 3. The proportion of subtype of left ventricular dysfunction in patients with kidney disease. EF: ejection fraction; LV: left ventricular.

Multivariate analysis showed that smoking was significantly associated with the risk of HF. Furthermore, age, smoking, and residents in rural areas were significantly associated with a risk of LV diastolic dysfunction (supplemental material, Table 2S).

4 Discussion

Our study showed, among CKD patients aged 65 years or older, the weighted prevalence of HF was 4.8% (an estimated 0.8 million), and the weighted prevalence of HFpEF, HFmrEF, and HFrEF was 2.5%, 0.8%, and 1.7%, respectively. Further, the prevalence of LV systolic dysfunction was 3.1%, and while it was 8.9% for moderate/severe diastolic dysfunction.

HF is highly prevalent in patients with CKD and end-stage renal disease, and is strongly associated with mortality in these patients.[21] In the Atherosclerosis Risk in Communities study reported that the incidence of HF was 3-fold higher in individuals with eGFR < 60 mL/min per 1.73 m^2, compared with the reference group with eGFR ≥ 90 mL/min per 1.73 m^2.[22] Our study showed that the prevalence of HF was 2-fold higher in patients with CKD compared with those without.

The Chronic Renal Insufficiency Cohort Study found that less than a high school education, history of cardiovascular disease, diabetes mellitus, systolic BP, and waist circumference were significantly and independently associated with increased risk of HF in patients with CKD.[23] Besides these traditional risk factors,[24,25] cigarette smoking also has been associated with an increased risk of HF among the general population in previous cohort studies.[26] A previous study reported that smoking cessation varies by amount and duration of prior smoking may have different effects on the risk of HF.[27] In addition to vascular effects, smoking, via increased oxidative stress and inflammation, directly affects the myocardium leading to systolic and diastolic dysfunction. It also promotes other HF risk factors including BP, increased heart rate, diabetes, and atherosclerosis.[28] In this study, former smokers were significantly associated with HF, suggesting that smoking might be an important factor influencing the status of HF in older patients with CKD.

Either LV systolic or diastolic dysfunction can lead to clinically evident congestive HF.[29] LV dysfunction is observed even in patients with early stages of chronic kidney dysfunction.[30] Dounaevskaia, *et al*.,[31] in a hospital-based study, reported that the prevalence of moderate-severe LV systolic dysfunction in patients with advanced CKD was 8.8%. The prevalence of LV systolic and moderate/severe diastolic dysfunction has reached 3.1% and 8.9% in this study. The high prevalence of LV dysfunction combined with a significant increase of the elderly population, suggesting a huge burden potential in China and other low- and middle-income countries with similar characteristics.

4.1 Limitations

This study provides significant epidemiological knowledge of HF in older patients with CKD, however, it also has several limitations. One limitation is that not all factors influencing HF have been collected, such as genetic factors, sleep apnea, brain natriuretic peptide or N-terminal pro-brain natriuretic peptide. Another limitation is that it would be better to investigate the relationship between risk factors and HF in a cohort study rather than a cross-sectional study, so the explanation of results requires prudence.

4.2 Conclusions

In summary, our results showed that the prevalence of HF was 4.8% (estimated 0.8 million) among patients aged 65 years or older with CKD, and the prevalence of LV systolic and moderate/severe diastolic dysfunction has reached 3.1% and 8.9%. Our findings suggest that national strategies will be needed to reduce the burden of HF in older patients with CKD.

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References

1 Conrad N, Judge A, Tran J, *et al*. Temporal trends and patterns in heart failure incidence: a population-based study of 4 million individuals. *Lancet* 2018; 391: 572–580.
2 Savarese G, Lund LH. Global public health burden of heart failure. *Card Fail Rev* 2017; 3: 7–11.
3 Hao G, Wang X, Chen Z, *et al*. Prevalence of heart failure and left ventricular dysfunction in China: the China Hypertension Survey, 2012-2015. *Eur J Heart Fail* 2019; 21: 1329–1337.
4 Gu DF, Huang GY, He J, *et al*. [Investigation of prevalence and distributing feature of chronic heart failure in Chinese

adult population]. *Zhonghua Xin Xue Guan Bing Za Zhi* 2003; 31: 3–6. [In Chinese].

5 Azad N, Lemay G. Management of chronic heart failure in the older population. *J Geriatr Cardiol* 2014; 11: 329–337.

6 Tuegel C, Bansal N. Heart failure in patients with kidney disease. *Heart* 2017; 103: 1848–1853.

7 House AA, Wanner C, Sarnak MJ, *et al*. Heart failure in chronic kidney disease: conclusions from a Kidney Disease: Improving Global Outcomes (KDIGO) Controversies Conference. *Kidney Int* 2019; 95: 1304–1317.

8 World Health Organization. China country assessment report on ageing and health. World Health Organization of ageing and life-course Web site. https://www.who.int/ageing/publications/china-country-assessment/en/ (accessed November 20, 2019).

9 Wang Z, Zhang L, Chen Z, *et al*. Survey on prevalence of hypertension in China: background, aim, method and design. *Int J Cardiol* 2014; 174: 721–723.

10 Dong Y, Wang Z, Chen Z, *et al*. Comparison of visceral, body fat indices and anthropometric measures in relation to chronic kidney disease among Chinese adults from a large scale cross-sectional study. *BMC Nephrol* 2018; 19: 40.

11 Lang RM, Bierig M, Devereux RB, *et al*. Recommendations for chamber quantification: a report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. *J Am Soc Echocardiogr* 2005; 18: 1440–1463.

12 Nagueh SF, Appleton CP, Gillebert TC, *et al*. Recommendations for the evaluation of left ventricular diastolic function by echocardiography. *Eur J Echocardiogr* 2009; 10: 165–193.

13 Ponikowski P, Voors AA, Anker SD, *et al*. 2016 ESC guidelines for the diagnosis and treatment of acute and chronic heart failure: the Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC) Developed with the special contribution of the Heart Failure Association (HFA) of the ESC. *Eur Heart J* 2016; 37: 2129–2200.

14 Dickstein K, Cohen-Solal A, Filippatos G, *et al*. ESC guidelines for the diagnosis and treatment of acute and chronic heart failure 2008: the Task Force for the diagnosis and treatment of acute and chronic heart failure 2008 of the European Society of Cardiology. Developed in collaboration with the Heart Failure Association of the ESC (HFA) and endorsed by the European Society of Intensive Care Medicine (ESICM). *Eur Heart J* 2008; 29: 2388–2442.

15 van Riet EE, Hoes AW, Wagenaar KP, *et al*. Epidemiology of heart failure: the prevalence of heart failure and ventricular dysfunction in older adults over time. A systematic review. *Eur J Heart Fail* 2016; 18: 242–252.

16 Lang RM, Badano LP, Mor-Avi V, *et al*. Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *J Am Soc Echocardiogr* 2015; 28: 1–39.e14.

17 Joint committee for guideline revision. 2016 Chinese guidelines for the management of dyslipidemia in adults. *J Geriatr Cardiol* 2018; 15: 1–29.

18 Stevens PE, Levin A, Kidney Disease: Improving Global Outcomes Chronic Kidney Disease Guideline Development Work Group Members. Evaluation and management of chronic kidney disease: synopsis of the kidney disease: improving global outcomes 2012 clinical practice guideline. *Ann Intern Med* 2013; 158: 825–830.

19 Chen CM, Kong LZ, for China Obesity Problem Working Group. In *Chinese adults guidelines for the prevention and control of overweight and obesity*, People's Medical Publishing House: Beijing, China, 2006.

20 Census Office of The State Council of China, Division of Population and Employment Statistics, National Bureau of Statistics of China. In *Tabulation on the 2010 population census on the People's Republic of China* [Online]; China Statistics Press: Beijing, China, 2012. https://www.stats.gov.cn/tjsj/pcsj/rkpc/6rp/indexch.htm (accessed May 20, 2012).

21 Segall L, Nistor I, Covic A. Heart failure in patients with chronic kidney disease: a systematic integrative review. *Biomed Res Int* 2014; 2014: 937398.

22 Kottgen A, Russell SD, Loehr LR, *et al*. Reduced kidney function as a risk factor for incident heart failure: the atherosclerosis risk in communities (ARIC) study. *J Am Soc Nephrol* 2007; 18: 1307–1315.

23 He J, Shlipak M, Anderson A, *et al*. Risk factors for heart failure in patients with chronic kidney disease: the CRIC (Chronic Renal Insufficiency Cohort) study. *J Am Heart Assoc* 2017; 6: e005336.

24 Avery CL, Loehr LR, Baggett C, *et al*. The population burden of heart failure attributable to modifiable risk factors: the ARIC (Atherosclerosis Risk in Communities) study. *J Am Coll Cardiol* 2012; 60: 1640–1646.

25 Mahmood SS, Wang TJ. The epidemiology of congestive heart failure: the Framingham Heart Study perspective. *Glob Heart* 2013; 8: 77–82.

26 Kamimura D, Cain LR, Mentz RJ, *et al*. Cigarette smoking and incident heart failure: insights from the Jackson Heart Study. *Circulation* 2018; 137: 2572–2582.

27 Ahmed AA, Patel K, Nyaku MA, *et al*. Risk of heart failure and death after prolonged smoking cessation: role of amount and duration of prior smoking. *Circ Heart Fail* 2015; 8: 694–701.

28 Gopal DM, Kalogeropoulos AP, Georgiopoulou VV, *et al*. Cigarette smoking exposure and heart failure risk in older adults: the Health, Aging, and Body Composition Study. *Am Heart J* 2012; 164: 236–242.

29 Gluba-Brzózka A, Michalska-Kasiczak M, Franczyk-Skóra B, *et al*. Markers of increased cardiovascular risk in patients with chronic kidney disease. *Lipids Health Dis* 2014; 13: 135.

30 Otsuka T, Suzuki M, Yoshikawa H, *et al*. Left ventricular diastolic dysfunction in the early stage of chronic kidney disease. *J Cardiol* 2009; 54: 199–204.

31 Dounaevskaia V, Yan AT, Charytan D, *et al*. The management of left ventricular systolic dysfunction in patients with advanced chronic kidney disease. *J Nephrol* 2011; 24: 41–49.