Kidney Function Change after Transcatheter Aortic Valve Replacement in Patients with Diabetes and/or Hypertension

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Abstract

Background

The kidney function change after Transcatheter Aortic Valve Replacement (TAVR) in diabetes and/or hypertension patients is currently unknown.

Methods

A total of 242 severe Aortic Stenosis patients with diabetes mellitus and/or hypertension who underwent TAVR were analyzed. Patients were categorized into 3 groups based on the percent change [(discharge eGFR – baseline eGFR) x 100/baseline eGFR] in eGFR: improved ≥ 10%, no change, and declined ≥ 10%.

Results

Of these patients, 93 (38.4%) had an improvement in eGFR ≥ 10%, 117 (48.3%) had no changes, and 32 (13.2%) had a decline in eGFR of more than 10%. Patients with unchanged kidney function may be with lower STS scores (5.09 [3.58–8.34] % vs. 7.04 [4.52–9.91] % vs. 7.41 [3.52–10.97] %, p = 0.003), and lower perivascular disease (14.5% vs. 26.9% vs. 40.6%, p = 0.003) when compared with improved and declined kidney function patients, respectively. Patients with improved kidney function had lower eGFR (45.0 [33.9–60.3] mL/min/1.73 m^2 vs. 57.4 [43.4–70.7] mL/min/1.73 m^2 vs. 56.6 [44.2–76.8] mL/min/1.73 m^2, p = 0.000), and lower LVEF (55.1 [40.9–62.0] % vs. 60.4 [53.4–66.1] % vs. 59.9 [52.9–67.8] %, p = 0.002) than the unchanged or declined group, respectively. Moreover, patients with worsening kidney function had higher rate of in-hospital (12.5% vs. 1.7% vs. 0%, p = 0.002) and 30-day (15.6% vs. 1.7% vs. 0%, p = 0.000) mortality. Independent predictors of eGFR changes were STS scores, LVEF, baseline eGFR, and unplanned cardiopulmonary bypass.

Conclusions

Nearly 40% of diabetic and/or hypertensive patients experience an intermediate improvement after TAVR. Patients with declining renal function suffer more terrible outcomes in mortality.

Background

Aortic Stenosis is a progressive heart valve disease in older patients. According to the survey in the western country, the prevalence of the AS is nearly 6.4% in patients over 75 years old [1]. Transcatheter aortic valve replacement has been an alternative method for AS patients with prohibitive, high and moderate risk for surgical valve replacement [2–7]. Recently, TAVR has expanded to low-risk patients [8, 9]. Previous studies had described that concomitant baseline kidney dysfunction made up a higher

proportion of TAVR patients reaching up to nearly 66% [10, 11]. Pre-existing kidney dysfunction is hence a concern in patients who will undergo TAVR procedure, as it has been associated with a 2- to 6- fold increase in both short- and long-term mortality [10–13]. The majority of patients will benefit from the TAVR procedure with the recovery of the kidney function. TAVR procedure will release the obstruction of the left ventricle caused by severe AS and the increased cardiac output may be responsible for the recovery of the kidney function reasonably [14, 15]. A national survey conducted in 2013 revealed approximately 120 million patients in China have chronic kidney disease (CKD) representing a prevalence of 10.8% but the awareness of CKD (10.04%) remains low in China [16, 17]. In developed countries, CKD is most commonly attributed to diabetes and hypertension [18]. Few studies had reported the kidney function change after TAVR in baseline CKD patients [19–21]. However, no study has been focused on the kidney function change after TAVR in these diabetic and hypertensive population. Therefore, we aimed to investigate the kidney function change during the TAVR procedure in patients with diabetes and/or hypertension.

Methods

STUDY DESIGN AND PATIENT POPULATION.

A total of 410 consecutive severe Aortic Stenosis patients who underwent TAVR procedure were included from March 1, 2013, to May 30, 2019, who had self-expandable, balloon-expandable, and mechanical valves. After excluding the patients with baseline dialysis, severe kidney dysfunction (CKD stage 5: eGFR < 15 ml/min), and patients who died within 48 hours, 399 patients were enrolled in the study. Preoperative assessment was done comprehensively and TAVR procedures were determined by an interdisciplinary heart team. The study was approved by the local medical ethics committee of our hospital and carried out according to the principles of the Declaration of Helsinki. All patients provided written informed consent for TAVR and the use of anonymous clinical, procedural, and follow-up data for research.

ENDPOINTS DEFINITION.

The primary endpoint of the present study was all-cause mortality (including cardiovascular mortality) in the hospital and at 30 days. The secondary outcomes were perioperative morbidities and follow-up clinical outcomes defined according to the Valve Academic Research Consortium (VARC)-2 criteria [22].

DATA COLLECTION AND DEFINITION.

Data collection included baseline characteristics, procedural data, and pre-discharge outcome. Baseline characteristics consisted of baseline clinical, laboratory, echocardiographic, and computed tomographic data. Patient’s comorbidities were obtained using the definitions according to the Society of Thoracic Surgeons data collection system and VARC-2. Perioperative morbidities and follow-up clinical outcomes were defined per criteria defined by VARC-2. Kidney function tests were performed before and after TAVR

procedure in all patients. The Cockcroft gault formula was used to estimate the Glomerular filtration rate (eGFR) at baseline and postprocedural for all patients. Patients were divided into three groups according to the percent change [(discharge eGFR – baseline eGFR)/baseline eGFR] * 100% in eGFR post-TAVR. Patients with improved, declined, and no kidney function change represented with ≥ 10%, < -10%, and between − 10% and 10% percent change in EFGR consecutively. Patients were classified as having diabetes mellites (DM) and/or hypertension (HTN) if they had been diagnosed with either condition at baseline, as reported on the “diagnosed conditions” electronic case report form.

STATISTICAL ANALYSIS.

Continuous variables following normal distribution were presented as mean ± SD and compared using the analysis of variance (ANOVA). Otherwise, the skewed variables were presented as median [interquartile range, IQR] and the Kruskal-Wallis test was used. Categorical data were presented as count (percentages) and compared with the chi-square test. $P < 0.05$ was considered statistically significant. Statistical analysis was performed using SPSS software (version 20.0, SPSS Inc., Chicago, Illinois) and the figure was performed in GraphPad Prism (version 6.0, GraphPad Software, San Diego, California).

Linear regression models were used to analyze the predictors of eGFR changes between pre-discharge and baseline [(discharge eGFR – baseline eGFR)/baseline eGFR]. The multivariable models were built by the stepwise selection, with candidate variables being selected if they were of clinical interest or satisfied for the entry criterion of $P < 0.10$ in the univariable analysis. Variables were entered with entry/stay criteria of 0.05/0.1 in a forward stepwise fashion.

Results

Of 399 patients who had TAVR from March 1, 2013, to May 30, 2019, diabetic and/or hypertensive patients were estimated up to be 242 (60.7%). Among these 242 diabetic and/or hypertensive patients, 93 patients (38.4%) had an improvement in eGFR ≥ 10%, 117 patients (48.3%) had no changes and 32 patients (13.2%) had a declined eGFR of more than 10%. In other 157 non diabetic or hypertensive patients, 77 patients (49.0%) had an improvement in eGFR ≥ 10%, 68 patients (43.3%) had no changes and 12 patients (7.6%) had a declined eGFR of more than 10%. The kidney function change between these diabetic and/or hypertensive patients and non-diabetic or hypertensive patients was on the very borderline of significance ($p = 0.059$). The eGFR change of two groups were showed in Fig. 1. The baseline demographics and clinical characteristics of diabetic and/or hypertensive patients in this study was shown in Table 1. There was no significant difference observed for age, sex, BMI, NYHA III or IV, and proportion of DM and/or HTN. Patients with declined and improved kidney function had a significantly higher STS scores when compared with unchanged kidney function patients (7.41 [3.52–10.97] and 7.04 [4.52–9.91] vs. 5.09 [3.58–8.34], $p = 0.003$). The Peri-Vascular Disease was higher in declined kidney function patients when compared with improved and unchanged patients (40.6% vs. 26.9% and 14.5%, $p = 0.003$). The previous history of smoke, dyslipidemia, Diabetes Mellitus, Atrial Fibrillation, COPD, PCI, and

other clinical diseases did not differ significantly. The patients with improved kidney function had higher creatinine (93.0 [74.5–121.0] umol/L vs. 75.0 [61.5–94.5] umol/L vs. 66.5 [54.3–95.3] umol/L, p = 0.000) and lower eGFR (45.0 [33.9–60.3] mL/min/1.73 m^2 vs. 57.4 [43.4–70.7] mL/min/1.73 m^2 vs. 56.6 [44.2–76.8] mL/min/1.73 m^2 p = 0.000) than patients with unchanged and declined kidney function.

Table 1
Baseline Characteristics

	Diabetes and/or hypertension			
	Improved n = 93	No change n = 117	Declined n = 32	p
Age (yrs)	79.0[74.0–82.0]	77.0[72.5–82.5]	78.0[72.3–82.0]	0.745*
Male	54(58.1)	68(58.1)	15(46.9)	0.509
BMI (kg/m^2)	23.23 ± 3.56	23.32 ± 3.20	23.74 ± 3.57	0.757
NYHA III/IV	85(91.4)	104(88.9)	28(87.5)	0.804
STS	7.04[4.52–9.91]	5.09[3.58–8.34]	7.41[3.52–10.97]	**0.003***
Smoker	12(12.9)	15(12.8)	2(6.3)	0.604
Dyslipidemia	24(25.8)	27(23.1)	6(18.8)	0.709
Diabetes and HTN				0.114
Diabetes Mellitus	11(11.8)	10(8.5)	5(15.6)	
Hypertension	53(57.0)	84(71.8)	16(50.0)	
Combined	29(31.2)	23(19.7)	11(34.4)	
PVD	25(26.9)	17(14.5)	13(40.6)	**0.003**
Atrial Fibrillation	17(18.3)	25(21.4)	2(6.3)	0.147
COPD	20(21.5)	24(20.5)	8(25.0)	0.864
Prior PCI	11(11.8)	19(16.2)	7(21.9)	0.381
Prior CABG	0(0.0)	0(0.0)	1(3.1)	0.132
Prior MI	2(2.2)	2(1.7)	0(0.0)	1.000
Prior PPI	2(2.2)	3(2.6)	1(3.1)	1.000
Prior Stroke	6(6.5)	9(7.7)	0(0.0)	0.159

* Kruskal-Wallis test was used

Data are presented as mean ± SD, median [IQR] or no. (%). AS, aortic stenosis; AVA, aortic valve area; BMI, body mass index; CABG, coronary artery bypass grafting; COPD, chronic obstructive pulmonary disease; EF, ejection fraction; eGFR, estimated glomerular filtration rate; GI, Gastrointestinal; HTN, hypertension; LA, left atrial; LVEDD, left ventricular end-diastolic diameter; MG, mean gradient; MI, myocardial infarction; NYHA, New York Heart Association; PASP, pulmonary artery systolic pressure; PCI, percutaneous coronary intervention; PPI, permanent pacemaker implantation; PVD, peripheral vascular disease; STS, Society of Thoracic Surgeons.

	Diabetes and/or hypertension			
Prior Angina	16(17.2)	21(17.9)	4(12.5)	0.816
Syncope	12(12.9)	8(6.8)	2(6.3)	0.302
GI Bleeding	2(2.2)	1(0.9)	2(6.3)	0.167
Pulmonary HTN	8(8.6)	5(4.3)	1(3.1)	0.434
Pure AS	57(61.3)	78(66.7)	26(81.3)	0.115
Creatinine(umol/L)	93.0[74.5–121.0]	75.0[61.5–94.5]	66.5[54.3–95.3]	**0.000***
eGFR	45.0[33.9–60.3]	57.4[43.4–70.7]	56.6[44.2–76.8]	**0.000***
EF (%)	55.1[40.9–62.0]	60.4[53.4–66.1]	59.9[52.9–67.8]	**0.002***
MG (mmHg)	53[41.0-65.8]	51.0[42.0–62.0]	57.0[45.0–69.0]	0.219*
AVA (cm^2)	0.55[0.43–0.71]	0.64[0.50–0.75]	0.52[0.44–0.68]	**0.028***
Vmax	4.79[4.21–5.30]	4.70[4.20–5.20]	4.96[4.34–5.23]	0.365*
LVEDD	5.14 ± 1.04	4.93 ± 0.76	4.79 ± 0.89	0.095
LA	4.30 ± 0.68	4.24 ± 0.72	4.17 ± 0.60	0.606
PASP	37.5[31.0-54.5]	34.0[29.3–45.8]	38.0[29.0–51.0]	0.299*
* Kruskal-Wallis test was used				
Data are presented as mean ± SD, median [IQR] or no. (%). AS, aortic stenosis; AVA, aortic valve area; BMI, body mass index; CABG, coronary artery bypass grafting; COPD, chronic obstructive pulmonary disease; EF, ejection fraction; eGFR, estimated glomerular filtration rate; GI, Gastrointestinal; HTN, hypertension; LA, left atrial; LVEDD, left ventricular end-diastolic diameter; MG, mean gradient; MI, myocardial infarction; NYHA, New York Heart Association; PASP, pulmonary artery systolic pressure; PCI, percutaneous coronary intervention; PPI, permanent pacemaker implantation; PVD, peripheral vascular disease; STS, Society of Thoracic Surgeons.				

Values for echocardiographic parameters did not differ between three groups for transvalvular mean gradient, max transvalvular velocity, left atrial size, left ventricular size, and pulmonary artery systolic pressure besides aortic valve area and LVEF. The improved kidney function patients had lower LVEF (55.1 [40.9–62.0] % vs. 60.4 [53.4–66.1] % vs. 59.9 [52.9–67.8] %, p = 0.002) when compared with the unchanged and declined kidney function patients. Moreover, the unchanged kidney function patients had higher aortic valve area (0.64 [0.50–0.75] cm^2 vs. 0.55 [0.43–0.71] cm^2 vs. 0.52 [0.44–0.68] cm^2, p = 0.028) when compared with the improved and declined kidney function patients. All baseline characteristics of patients were showed in Table 1.

The three groups had no difference in contrast volume used, fluoroscopy time, procedural time, and hospital stay. The intensive care unit stay was also comparable without statistically significant (1[0–1]

days vs. 0[0–1] days vs. 0[0–1] days, p = 0.062). However, for prevalence of blood transfusion, the declined kidney function patients may have higher rate than the other two groups (21.9% vs. 6.0% vs. 17.2%, p = 0.015). The declined kidney function patients had higher frequency of new pacemaker implantation (25.0% vs. 9.4% vs. 9.7%, p = 0.075) than the unchanged and improved kidney function groups, but did not reach statistical significance. More of a concern, patients with declined kidney function had higher rate of in-hospital mortality (12.5% vs. 1.7% vs. 0%, p = 0.002) and 30-day mortality (15.6% vs. 1.7% vs. 0%, p = 0.000) which was mainly caused by in-hospital (6.3% vs. 1.7% vs. 0%, p = 0.068) and 30-day (9.4% vs. 1.7% vs. 0%, p = 0.009) cardiovascular mortality (Table 2).

Table 2
Peri-procedural and follow-up clinical outcomes

	Diabetes and/or hypertension			
	Improved n = 93	No change n = 117	Declined n = 32	p
Contrast volume(ml)	125[110–156]	120[108–150]	120[98–150]	0.524*
Fluro time(min)	22[18–33]	22[18–32]	27[16–32]	0.911*
Procedural time(min)	83[55–119]	70[49–110]	95[60–133]	0.229*
Proglide	84(90.3)	107(91.5)	25(78.1)	0.133
ICU stay(days)	1[0–1]	0[0–1]	0[0–1]	0.062*
Hospital stay(days)	8[7–11]	8[7–10]	9[7–14]	0.115*
Stroke	2(2.2)	3(2.6)	3(9.4)	0.156
Blood transfusion	16(17.2)	7(6.0)	7(21.9)	**0.015**
Vascular Complication	4(4.3)	7(6.0)	3(9.4)	0.507
New Af	5(5.4)	6(5.1)	1(3.1)	0.861
New Pacemaker	9(9.7)	11(9.4)	8(25.0)	0.075
Unplanned CPB	4(4.3)	1(0.9)	2(6.3)	0.113
Mortality				
In-hospital	0(0.0)	2(1.7)	4(12.5)	**0.002**
30-day	0(0.0)	2(1.7)	5(15.6)	**0.000**
Cardiovascular Mortality				
In-hospital	0(0.0)	2(1.7)	2(6.3)	0.068
30-day	0(0.0)	2(1.7)	3(9.4)	**0.009**
* Kruskal-Wallis test was used				
Data are presented as median [IQR] or no. (%). Af, atrial fibrillation; CPB, cardiopulmonary bypass; ICU, intensive care unit.				

In multivariable linear models, age, male, STS score, peri-vascular disease, baseline LVEF, aortic valve area, baseline LVEDD, baseline eGFR, pre-discharge intensive care unit stay, blood transfusion, new pacemaker implantation, and unplanned cardiopulmonary bypass before discharge were included. In these models, STS score (p = 0.000), LVEF (p = 0.000), baseline eGFR (p = 0.000), and Unplanned

Cardiopulmonary Bypass (CPB) (p = 0.001) were the independent predictors of eGFR change between before discharge and baseline (Table 3).

Table 3
Univariate and Multivariate Predictor of changes of eGFR

Predictor	Univariate Predictor			Multivariate Predictor*		
	Coefficients	Standard error	P value	Coefficients	Standard error	P value
Age	-0.002	0.003	0.505			
Male	0.038	0.035	0.282			
STS	0.005	0.005	0.265	-0.020	0.005	0.000
PVD	-0.033	0.042	0.433			
EF	-0.007	0.001	0.000	-0.006	0.001	0.000
AVA	0.018	0.071	0.802			
LVEDD	0.073	0.019	0.000			
eGFR	-0.004	0.001	0.000	-0.005	0.001	0.000
Pre-discharge ICU stay	-0.001	0.006	0.927			
Blood transfusion	-0.036	0.053	0.497			
New pacemaker	-0.085	0.055	0.119			
Unplanned CPB	0.191	0.104	0.067	0.371	0.110	0.001
*Stepwise selection was used to do the multivariable linear regression						
CPB, cardiopulmonary bypass; EF, ejection fraction; eGFR, estimated glomerular filtration rate; LVEDD, left ventricular end-diastolic diameter.						

Discussion

To our knowledge, this is the first study investigated the prognosis of the kidney function change in patients with DM and/or HTN undergoing TAVR procedure. We found that 1). Declined kidney function patients were associated with higher mortality significantly in hospital and at 30 days; 2). Improved kidney function is ubiquitous in baseline diabetic and/or hypertensive patients, with a higher STS score, lower LVEF, and smaller aortic valve area, though the prevalence of improved population was lower than no diabetic or hypertensive population; 3). The STS score, LVEF, baseline eGFR, and bleeding are the independent predictors of improved versus declined kidney function after TAVR.

Prevalence

In the present study, 38.4% of diabetic and/or hypertensive patients had an improvement in kidney function which was lower than 49.0% in no diabetic or hypertensive patients. The previous study observed the 52% incidence of improved kidney function in baseline renal dysfunction patients after TAVR [20, 21]. Though the procedure itself may bring some risk to renal injury by the usage of contrast, nearly half of patients benefited more from the procedure. This phenomenon reveals that the release of pressure afterload by TAVR plays a more prominent role in the recovery of type 2 chronic cardiorenal syndrome whose cause may be multifactorial like reduced cardiac output, elevated venous pressure, renin-angiotensin-aldosterone system activation [23]. In our study, the observed rate of recovery kidney function was lower in diabetic and/or hypertensive patients. The phenome revealed that even in diabetic and/or hypertensive patients, whose comorbidities may influence the recovery of the kidney function benefited from TAVR procedure.

The presence of diabetes mellitus and/or hypertension has been associated with impaired kidney autoregulation, which was consistent with the previously reported study [24][25]. The pathophysiology mechanism may be related to the negative influence of DM and/or HTN on kidney autoregulation [26]. Aortic stenosis patients with uncontrolled hypertension or controlled hypertension by medication may have irreversible renal damage due to excessive activation of the renin-angiotensin-aldosterone system and decreased afferent arteriolar resistance [27][28]. Moreover, AS patients with DM came up, not only with more pronounced metabolic syndrome, but also with increased incidence of generalized atherosclerosis [29]. Though previously study by D. Schewel et al. couldn't find any evidence for influence of DM on the incidence of AKI, their data showed the numerically increased rate in AKI among those diabetic patients with severe renal failure (eGFR < 30 ml/min/1.86 m^2) [25]. A meta-analysis by Mina et al. showed DM was associated with increased AKI and 1-year mortality after TAVR [30]. Over all, it is reasonable that the rate of recovery kidney function was lower in diabetic and/or hypertensive patients when compared with previous studies.

Independent predictors of kidney function change

Alexis et al. found that female gender, baseline liver dysfunction, and preoperative left ventricular ejection fraction was associated with an immediately declining or improving kidney function in baseline renal dysfunction patients [20]. Data from the PARTNER 1 Trial and registry reported by Boehar et al. showed that female gender and baseline left ventricular mass are predictors of declined or improved kidney function [21]. Multivariable logistic regression in previous study by Azarbal et al found moderate to severe lung disease, eGFR < 50 ml/min, and previous aortic valve surgery were the independent predictors of acute kidney recovery, while patients with diabetes mellitus, baseline anemia, and STS > 6.1 were likely to develop acute kidney injury [19]. Though the included population were different, our study identified four independent predictors of improved versus declined eGFR in diabetic and hypertensive patients. We had

found lower STS, LVEF, baseline eGFR, and less unplanned CPB may give the potential improvement of kidney function.

Our study identified the patients with lower LVEF may be likely to improve kidney function after TAVR. This finding supports the concept that after the release of the pressure afterload, the LVEF recovered, and the low perfusion state in the kidney was eliminated. Therefore, it can be observed that lower LVEF patients had more prevalence of improved kidney function. Our findings are similar to previous results. Lower eGFR patients were more likely to develop kidney function improvement and higher STS scores may increase the risk of kidney function injury [19]. Thus, clinical avoidance of TAVR in these severe kidney dysfunction patients may not be reasonable given the enormous potential for improvement in this high-risk group. Moreover, it was reasonable that less unplanned CPB during the TAVR procedure may help the recovery of the kidney function. Unplanned cardiopulmonary bypass was one of the severe peri-procedural complications that was associated with acute kidney injury after cardiac surgery [31, 32]. The exposure of blood to non-endothelial lined surfaces during cardiopulmonary bypass can induce a systemic inflammatory response, coagulopathy, hemodilution, generation of thrombin, inflammatory reaction, and postoperative bleeding leading to declined kidney function [33].

Mortality

Findings from the present study showed the relationship between declined kidney function change and higher mortality in diabetic and/or patients who underwent TAVR. The previous study by Okoh et al. showed that in-hospital, 30-day and 1-year mortality was associated with declined kidney function change significantly [20]. All these results confirm the adverse effects of declined kidney function on mortality after TAVR [34–38]. Our study confirmed that the detrimental effect on all-cause and cardiovascular mortality persisted in diabetic and/or hypertensive patients.

Limitations

This study is a retrospective single-center study with a small number of patients and therefore there are still some limitations inherently present in such study. Patients with baseline eGFR < 15 ml/min and those on dialysis were excluded from the present study because the fluctuations in eGFR of these diabetic and/or hypertensive patients were not accurate. The present study only considered an immediate improvement change as improved or declined kidney function change in eGFR defined by pre-discharge value. Long-term follow-up was not considered in our study, which would have been valuable to be further studied whether it would persist in the long term as well. The study is likely not adequately powered to detect differences in some clinical endpoints in improved or declined kidney function group compared with the group who experienced no change for the limited number of patients. We used a clinically meaningful definition of improved or declined eGFR, but the other definition like absolute increase or decrease of serum creatinine of 0.3 mg/dl could also be used as the Valve Academic Research Consortium definition [22].

Conclusions

The frequency of recovery of kidney function in diabetic and/or hypertensive severe symptomatic AS patients was lower than no diabetic or hypertensive patients. Nearly 40% of diabetic and/or hypertensive patients experience an intermediate improvement after TAVR. Patients with declining renal function suffer more terrible outcomes in mortality, mainly in cardiovascular mortality.

Abbreviations

AS: Aortic stenosis:BMI:Body mass index; CKD:Chronic kidney disease; COPD:chronic obstruction pulmonary disease; DM:Diabetes mellitus; eGFR:Estimated glomerular filtration rate; HTN:Hypertension; LVEF:Left ventricular ejection fraction; MSCT:Multi-slice computed tomography; NYHA:New York heart association; PCI:Percutaneous coronary intervention; TAVR:Transcatheter aortic valve replacement; TTE:Transthoracic echocardiography.

Declarations

Availability of data and materials

The data are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This study was approved by the Institutional Review Board of Second Affiliated Hospital of Zhejiang University School of Medicine. Written informed consent was obtained from all patients being included in the study.

Consent for publication

All authors reviewed and approved the final version of the manuscript and consented for publication.

Competing interests

The authors have no conflicts of interests to declare.

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None.

Authors' contributions

JQF and CJY designed the research. KDR and WBL conducted experiments. SN, XPL, LHW, QFZ, YXH, JBJ recruited patients, collected data and checked in the data. JQF and ZXC did statistical analysis. XBL and JAW made critical revision to the manuscript.

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Figures

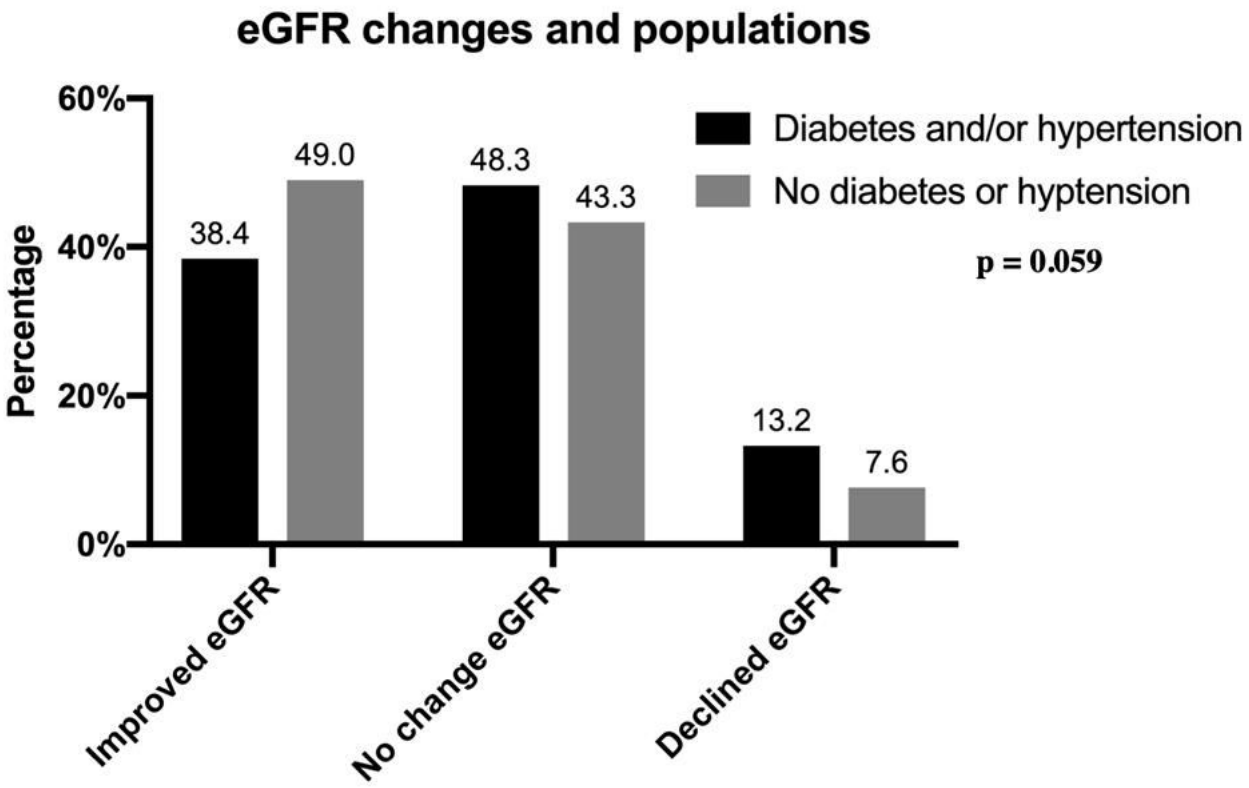

Figure 1

The percentage of eGFR changes in diabetic and/or hypertensive patients versus no diabetic or hypertensive patients