Dilated Left Ventricular End-Diastolic Diameter Is a New Risk Factor of Acute Kidney Injury Following Coronary Angiography

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Purpose: Left ventricular end-diastolic diameter (LVEDD) is a common indicator in echocardiogram, and dilated LVEDD was correlated with left ventricular insufficiency. However, it is uncertain whether dilated LVEDD is associated with increasing the risk of contrast-associated acute kidney injury (CA-AKI) in patients with coronary artery disease (CAD).

Patients and Methods: We enrolled 8,189 patients with CAD undergoing coronary angiography (CAG) between January 2007 and December 2018. Patients were divided into two groups according to the LVEDD length (normal LVEDD: men: LVEDD ≤ 56 mm, women: LVEDD ≤ 51 mm; dilated LVEDD: men: LVEDD > 56 mm, women: LVEDD > 51 mm). The endpoints were CA-AKI (an increase in the serum creatinine (Scr) level by > 0.3 mg/dl or > 50% within the first 48 h after CAG; CA-AKI: an absolute Scr increase ≥ 0.5 mg/dl or a relative increase ≥ 25% within 72 h after contrast medium exposure). In-hospital dialysis, 30-day mortality, and 1-year mortality were contained as well. Univariate and multivariable logistic regressions were used to assess the association between LVEDD and CA-AKI.

Results: Among 8,189 participants (men: 76.6%, mean age: 64.4 ± 10.7 years), 1,603 (19.6%) presented with dilated LVEDD. In addition, the dilated LVEDD group indicated an elevation of CA-AKI (12.4 vs. 6.2%, p < 0.001) and CA-AKI (15.0 vs. 8.8%; p < 0.001) when compared with the normal group. According to multivariable logistic analysis, dilated LVEDD was an independent predictor of CA-AKI (adjusted odds ratio (aOR): 1.31; 95% confidence interval (CI): 1.06–1.61, p = 0.010) and CA-AKI (aOR: 1.32; 95% CI: 1.04–1.67; p = 0.020).
INTRODUCTION

Contrast-associated acute kidney injury (CA-AKI) is a common complication following coronary angiography (CAG) (1), which is associated with poor outcomes, including dialysis, longer duration of hospitalization, mortality, and increased health-care costs (2–5).

Left ventricular end-diastolic diameter (LVEDD) is a common and important indicator in echocardiogram, which reflects the size of cardiac as well as left ventricular function. It is associated with progressive left ventricular insufficiency (6–9). At the same time, dilated LVEDD is linked to a high risk for heart failure and cardiovascular outcomes (10, 11).

Previous studies have shown that cardiac dysfunction is closely related to the occurrence and development of CA-AKI (12). As a clinically significant index used to assess cardiac function, left ventricular ejection fraction (LVEF) has been proved an independent risk factor for postoperative CA-AKI (13, 14). Similarly, Liu et al. have demonstrated that left ventricular end-diastolic pressure (LVEDP), an indicator of cardiac function, is independently associated with increased risk of CA-AKI among patients undergoing CAG and percutaneous coronary intervention (15). Monitoring hemodynamic parameters, such as LVEDP, is an invasive and expensive test. LVEDD is a novel and convenient imaging predictor reflecting cardiac function, but it has not established a direct relationship between LVEDD and the occurrence of CA-AKI.

Therefore, the aim of our study was to investigate the association of LVEDD levels with CA-AKI in a large registry of patients with coronary artery disease (CAD), who underwent CAG.

MATERIALS AND METHODS

Study Design and Population

The data of this cohort was from the registry of Cardiorenal Improvement (CIN) study (ClinicalTrials.gov NCT04407936) at Guangdong Provincial People's Hospital in China. A total of 8,189 patients with CAD, who underwent CAG between January 2007 and December 2018, were included in the final analysis after excluding 51,478 patients for the following reasons: (1) lack of LVEDD examination \( n = 20,858 \); (2) lack of judgment of CA-AKI \( ^{0350} \) and CA-AKI \( ^{0525} \) \( n = 24,958 \); (3) lack of follow-up information \( n = 5,662 \) (Figure 1). This study was conducted in accordance with the Declaration of Helsinki and was approved by the Research Ethics Committee of Guangdong Provincial People's Hospital (No. GDREC2019555H).

Baseline Data Collection

The study data were derived from the Clinical Management System of the Guangdong Provincial People's Hospital's electronic health record, which contained details regarding demographics, medical history, laboratory tests, medications, and other clinical data. Senior cardiologists were responsible for the data quality control and periodical data verification. During the study period, the information on death event and date for each patient was retrieved from the Guangdong Public Security System, which was linked to CIN dataset by a unique identification number. CAG or percutaneous coronary intervention was performed according to the standard clinical practice guidelines (16–18).

LVEDD Measurement

Echocardiography was performed by trained cardiologists for all patients at the time of admission. LVEDD was measured using an M-mode scan of the parasternal long-axis view with a 2D image. When the M-mode cursor could not be aligned perpendicularly to the left ventricular long axis, LVEDD was measured directly on 2D images (19).

Study Endpoint and Definitions

The primary outcome was CA-AKI \( ^{0350} \), defined as an absolute increase in serum creatinine (Scr) \( \geq 0.3 \text{ mg/dl} \) or a relative increase in Scr levels \( \geq 50\% \) within 48 h after contrast medium exposure (20). The secondary clinical outcomes included CA-AKI \( ^{0525} \) (defined as an absolute increase in Scr levels \( \geq 0.5 \text{ mg/dl} \) or a relative increase in Scr levels \( \geq 25\% \) within 72 h after contrast medium exposure) (21), in-hospital dialysis, 30-day mortality, and 1-year mortality. CAD was confirmed by CAG and discriminated according to the 10th Revision Codes of the International Classification of Diseases (ICD-10; I20.xx–I25.xx, I50.0001, and I91.40001 et al.). Estimated glomerular filtration rate (eGFR) was estimated by the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation (22). CKD was defined as eGFR < 60 ml/min/1.73 m². Anemia was defined as a baseline hematocrit value < 39% for men and < 36% for women, according to the World Health Organization (WHO) criteria (23). The echocardiography examination was used to evaluate the LVEF and heart failure with reduced ejection fraction (HFrEF), which was defined as LVEF<40% (24).

Statistical Analysis

To investigate the relationship of elevated LVEDD levels for CA-AKI in patients with CAD, men and women were divided into normal LVEDD group and dilated LVEDD group (men: LVEDD \( \leq 56 \), and>56 mm; women: LVEDD \( \leq 51 \), and>51 mm, respectively) (25). We reported descriptive statistics by means

Conclusion: In conclusion, these results demonstrated that the dilated LVEDD was a significant and independent predictor of CA-AKI following CAG in patients with CAD. Further verifications are needed to verify the association between LVEDD and CA-AKI.

Keywords: acute kidney injury, dilated left ventricular end-diastolic diameter, predictor, coronary angiography, coronary artery disease
(SD), median [interquartile range (IQR)], or number and percentage as and when it was needed. Categorical variables were compared by Pearson chi-square test, and continuous variables by t-test. The association between different LVEDD levels and CA-AKI was tested by univariable and multivariable logistic regression. To investigate the relationship between LVEDD and LVEF, scatter plot and curve fitting were performed as shown in Supplementary Figure 1. All analyses were performed using R software (version 4.0.3; R Foundation for Statistical Computing, Vienna, Austria). A two-sided p < 0.05 indicated significance for all analyses.

RESULTS

Clinical Characteristics
After screening, a total of 8,189 CAD patients, who underwent CAG from January 2007 to December 2018, were included in this study. The mean age was (64.4 ± 10.7) years, and 6,273 patients (76.6%) were men. Patients were divided into two groups: 1,603 (19.6%) patients with dilated LVEDD (men: LVEDD>56 mm; women: LVEDD>51 mm), and 6,586 (80.4%) patients with normal LVEDD (men: LVEDD ≤56 mm; women: LVEDD ≤51 mm). Compared with the normal LVEDD group, the dilated LVEDD group was more likely to present with anemia, diabetes mellitus (DM), and reduced LVEF (<40%), and had worse renal function. All of the baseline clinical characteristics of the patients are shown in Table 1.

Incidence of CA-AKI and Clinical Outcomes
Totally, 607 (7.4%) patients fulfilled the diagnostic criteria for CA-AKI, and the incidence of CA-AKI among the dilated LVEDD group was apparently higher than the normal group (12.4 vs. 6.2%; p < 0.001, Table 2). A similar result was observed.
Diuretics, n (%) 64.44 ± 10.73* 64.43 ± 10.78* 64.49 ± 10.52* 0.822
Age>75, n (%) 1,534 (18.73) 1,232 (18.71) 302 (18.84) 0.931
Male, n (%) 6,273 (76.60) 5,066 (76.92) 1,207 (75.30) 0.179

**Medical history**

AMI, n (%) 2,067 (25.27) 1,697 (25.05) 370 (23.08) 0.027
HT, n (%) 4,969 (60.74) 4,028 (61.23) 941 (57.80) 0.067
DM, n (%) 2,535 (30.99) 1,952 (29.67) 583 (36.37) <0.001
CHF, n (%) 1,374 (16.79) 807 (12.26) 567 (35.37) <0.001
HFrEF, n (%) 1,211 (14.86) 383 (5.85) 828 (51.72) <0.001
CKD, n (%) 432 (5.28) 293 (4.45) 139 (8.67) <0.001
Anemia, n (%) 3,488 (42.74) 2,695 (41.30) 773 (48.65) <0.001
PCI, n (%) 6,318 (77.15) 5,176 (78.59) 1,142 (71.24) <0.001

**Laboratory test**

Glut, mmol/L 7.59 ± 3.58* 7.50 ± 3.52* 7.96 ± 3.81* <0.001
HbA1c, % 6.63 ± 1.47* 6.59 ± 1.46* 6.77 ± 1.48* <0.001
HDLc, mmol/L 0.97 ± 0.25* 0.97 ± 0.25* 0.94 ± 0.25* <0.001
LDLC, mmol/L 2.80 ± 0.99* 2.80 ± 0.97* 2.79 ± 1.04* 0.513
H/GB, g/L 129.06 ± 18.80* 129.83 ± 18.06* 125.89 ± 21.28* <0.001
eGFR, ml/min/1.73 m² 67.73 ± 24.73 69.88 ± 24.10 58.91 ± 25.32 <0.001
LVEF, % 56.02 ± 13.42* 59.75 ± 10.66* 40.76 ± 12.74* <0.001
CMV, ml 154.88 ± 85.74* 156.24 ± 85.22* 149.33 ± 87.65* <0.004
Conversely, for age, gender, and hypertension, an absolute increase in serum creatinine ≥ 0.5 mg/dL or a decrease in serum creatinine ≥ 25% within 72 h after contrast medium exposure.

**Association of LVEDD with AKI**

Univariate logistic regression analysis indicated that the dilated LVEDD [odds ratio (OR): 2.1; 95% confidence interval (CI): 1.78–2.54; p < 0.001, Supplementary Table 1] was significantly associated with CA-AKI\(^{0525}\) after CAG. When using the criteria of CA-AKI\(^{0525}\), similar result was found (OR: 1.8; 95% CI: 1.57–2.16; p <0.001, Supplementary Table 1). In this study, age, anemia, CKD, DM, and HFrEF were also closely related to CA-AKI\(^{0350}\) and CA-AKI\(^{0525}\) (all p <0.001, Supplementary Table 1). After adjusting for related risk factors (age, gender, hypertension, acute myocardial infarction (AMI), CKD, HFrEF, DM, contrast medium volume (CMV) >200, and diuretics), dilated LVEDD [adjusted odds ratio (aOR): 1.3; 95% CI: 1.06–1.61; p = 0.010, Table 3] remained significantly associated with CA-AKI\(^{0350}\). Similar results were obtained in CA-AKI\(^{0525}\) (aOR: 1.32; 95% CI: 1.04–1.67; p = 0.020, Table 3).

**DISCUSSION**

To our knowledge, this is the first cohort study that investigates the relationship between LVEDD and CA-AKI in patients with CAD. The results of our study showed that dilated LVEDD was markedly related to the incidence of CA-AKI in patients with CAD, regardless of reduced LVEF.
A number of risk factors, such as laboratory examinations (Scr, age, and gender), comorbidities, and medications, have been confirmed to be associated with CA-AKI (26, 27). Some risk models, such as Merhan score and age, creatinine, and ejection fraction (ACEF) score, were commonly used to assess the risk of CA-AKI in clinical practice (28, 29). However, these methods were reviewed and contain multiple variables, which limits their clinical use. Therefore, it is necessary to explore a variable that is common and easy to access to determine the risk of AKI. The echocardiogram is readily available and widely used in the diagnosis of cardiovascular disease.

Left ventricle structural dilation used to be considered as the morphologic substrate of congestive heart failure (CHF) for the first time by a German pathologist Linzbach AJ (30). Using left ventricular dimensions in the risk stratification of patients will aid in the better identification of patients at risk for heart failure and mortality (11). Many studies have indicated that LVEDD dilation is implicated in the development of progressive left ventricular insufficiency and CHF (7, 9). Moreover, dilated LVEDD is associated with major adverse cardiovascular events in patients with heart failure and left ventricular systolic insufficiency (10). Moreover, it was also reported that left ventricular dilation could be used for identifying cardiac death and serious ventricular arrhythmias independently in left ventricular systolic insufficiency (6, 8). Our study suggests that an adjusted large LVEDD is still an independent factor associated with higher incidence of CA-AKI, even after adjusting for ejection fraction <40, which manifests left ventricular systolic insufficiency. It confirms that dilated LVEDD is an independent predictor for CA-AKI without relying on LVEF. Likewise, our study showed that there was no clear relationship between LVEDD and LVEF. The possible reason why related adverse events were caused by left ventricular dilation is that increased ventricular wall stress in the dilated ventricle causes a mismatch in cardiac afterload, which leads to hemodynamic changes and further cardiac and renal adverse events, such as CA-AKI.

Previous studies also have found that LVEDD level is a risk factor for mortality in patients with or without heart failure. Seko et al. retrospectively analyzed data from 4,444 patients, who underwent echocardiography, and found that LVEDD had a deleterious impact on long-term mortality after adjusting for age and body size (31). The conclusion was similar to the study conducted by Kajimoto K et al., which indicated that after adjustment for multiple comorbidities, men with an LVEDD of 61 mm had a significantly higher risk of the outcomes than men with an LVEDD <54 mm, although this conclusion was weakened among women (32). Our study also found that the group with higher LVEDD had worse outcome events and had a significantly higher incidence of CA-AKI than the normal group.

This study has several important clinical significances and research implications. As it was described above, LVEDD was reported to be an important factor of cardiac function. Our results demonstrated that dilated LVEDD was an independent predictor of CA-AKI among patients with CAD, even after adjusting for potential confounding factors. The outcome demonstrates that we should not only focus on LVEF in echocardiogram but also LVEDD. A routine pre-procedural LVEDD measurement may provide useful information for the cardiologist to identify the high risk for the incidence of AKI. The degree of prediction of AKI can also be improved by combining known risk factors. More attention should be given to patients with dilated LVEDD.

**Limitations**

This study has several limitations. First, this observational cohort was conducted in a single center that is located in southern China. However, Guangdong Provincial People's Hospital is the largest cardiovascular center in southern China. Moreover, the sample size included in the study is large enough and patients come from different regions, which provide the results with a certain degree of universality. Second, the velocity and volume of preoperative hydration may influence the incidence of CA-AKI, but they were unrecorded. Third, there are some confounding factors that have not been taken into consideration due to the lack of variables, such as body mass index (BMI), smoking, and other influencing factors. However, special attention was given to avoid biases by adjusting the results in accordance with comorbidities and clinically relevant in-hospital events. Finally, our database lacks information on hemodynamic disturbances, such as cardiogenic shock or the use of mechanical circulatory support, and coronary-artery-bypass-grafting (CABG) incidence following CAG. Therefore, we may fail to consider the impact of hemodynamic disturbances and post-contrast CABG on the results.

**CONCLUSION**

Our study found that dilated LVEDD may be remarkably related to an increased risk of CA-AKI following CAG in patients with CAD. LVEDD is an easily obtained indicator in echocardiogram, which can be performed before CAG to identify the risk of CA-AKI in patients with CAD. Precautionary measures should be taken in the perioperative period for patients with dilated LVEDD, who have a high risk for CA-AKI.

**DATA AVAILABILITY STATEMENT**

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/Supplementary Material.

**ETHICS STATEMENT**

The studies involving human participants were reviewed and approved by Research Ethics Committee of Guangdong Provincial People's Hospital. The patients/participants provided their written informed consent to participate in this study.

**AUTHOR CONTRIBUTIONS**

YL, JL, and JC contributed to supervision, mentorship, research idea, and study design. QL, SC, HH, WC, BW, WL, SY,
LL, MY, RT, ZH, and JD contributed to data acquisition. JL and YL contributed to data analysis/interpretation. SC and QL contributed to statistical analysis. All authors contributed important intellectual content during manuscript drafting or revision and accepts accountability for the overall work by ensuring that questions pertaining to the accuracy or integrity of any portion of the work are appropriately investigated and resolved.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcvm.2022.827524/full#supplementary-material

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