ORIGINAL RESEARCH

Clinical study on feasibility and repeatability of left ventricular systolic function assessment in patients with chronic kidney disease using artificial intelligence-based automatic strain technique

Fang Tian, Zhuole Wu, Lianli Zhong, Jie Qiu, Haixia Tang*

Department of Ultrasonography, Hainan General Hospital, Hainan Affiliated Hospital of Hainan Medical University, Haikou, Hainan 570311, China

*** Corresponding Author: Haixia Tang**; E-mail: btxx0329@126.com

Abstract

Background

Cardiovascular damage is a common complication in patients with chronic kidney disease (CKD), and left ventricular longitudinal strain (GLS) is superior to LVEF in evaluating systolic function. However, it has not been widely adopted clinically because it requires proficiency and is time-consuming. This study aimed to investigate the feasibility, reproducibility, and predictive value of automated GLS compared with manual GLS, providing a reference for clinical evaluation and reduction of cardiovascular events in CKD patients.

Methods

A total of 285 CKD patients (aged 52 ± 12.85) without dialysis were enrolled from Hainan Provincial People's Hospital. GLS was measured using three methods on identical apical three-, two-, and four-chamber views: (1) fully automatic GLS analyzed by machine functions, (2) semi-automatic GLS corrected by researchers, and (3) manual GLS measured by experts. Five cases were excluded due to poor image quality. Clinical outcomes were followed up by telephone and outpatient visits.

Results

About 35% of automatic GLS results required manual correction, with significant differences among the three methods ($P < 0.01$). The correlation and consistency between semi-automatic and manual GLS were higher than those of automatic GLS ($P < 0.01$). During 2-year follow-up, 55 patients (19.6%) experienced cardiovascular events. Automated GLS predicted events but with lower accuracy than semi-automatic GLS. The analysis time for automatic (15.23 ± 0.75 s) and semi-automatic GLS (75.06 ± 19.01 s) was markedly shorter than manual analysis (236.81 ± 45.41 s, $P < 0.01$).

Conclusions

Automated GLS assessment in CKD patients is feasible and reproducible. As some images still require manual correction, the semi-automated approach currently offers the optimal balance between efficiency and predictive value.

Keywords: Echocardiography, two-dimensional speckle tracking imaging, longitudinal strain, automatic measurement

Introduction

Cardiovascular damage is a common complication in patients with chronic kidney disease (CKD)[1]. Conventional two-dimensional echocardiography primarily relies on left ventricular ejection fraction (LVEF) to assess systolic function. However, LVEF often remains within the normal range in CKD patients, resulting in limited sensitivity and specificity for detecting early cardiac impairment in this population. Previous studies have shown that left ventricular global longitudinal strain (LVGLS), measured via two-dimensional speckle tracking imaging (2D-STI), can identify early myocardial systolic dysfunction and is strongly associated with adverse cardiovascular outcomes in CKD patients. LVGLS also demonstrates superior prognostic value over LVEF in risk stratification[2-5].

Despite its potential, widespread clinical adoption of LVGLS has been hindered by the dependency on time-consuming manual analysis and the requirement for specialized expertise in image interpretation. This limits its feasibility in routine practice, particularly in high-volume or resource-constrained settings.

Recent advances in artificial intelligence have enabled the development of automated strain measurement software, which can rapidly and consistently track endocardial borders and compute GLS based on machine learning algorithms[6]. Such tools offer the promise of efficient, reproducible, and operator-independent strain assessment[7]. However, the feasibility, reproducibility, and prognostic significance of fully automated GLS measurement remain largely unestablished in the CKD population—a group at heightened cardiovascular risk yet underrepresented in cardiac imaging innovation studies.

Therefore, this study aims to evaluate the feasibility and reproducibility of automated GLS measurement compared with standard manual GLS analysis in CKD patients, and to determine its predictive value for cardiovascular events. Our findings may help bridge an important clinical gap by validating an accessible, efficient tool for early cardiac risk stratification, ultimately supporting timely intervention and improved cardiovascular outcomes in this vulnerable patient group.

Research methods

Objects

A total of 280 patients with CKD who were treated in Hainan Provincial People's Hospital from July 2020 to January 2022 were selected (15 patients with CKD2, 65 patients with CKD3, 90 patients with CKD4 and 110 patients with CKD5), all of whom did not receive dialysis treatment. Patients who have congenital heart disease, valvular disease, cardiomyopathy, coronary heart disease and other serious heart disease, severe pulmonary hypertension, emergency hemodialysis indications, malignant tumors or other life expectancy of less than two years were excluded. All objects had follow-up data and echocardiographic images for strain analysis. All the included patients gave informed consent and this research was approved by the hospital ethics committee. At the beginning of the study, general clinical data such as age, gender, body surface area, heart rate, blood pressure, blood glucose and blood lipid were collected. All objects of research were followed up for 2 years by telephone and outpatient review. The primary ending at 2 years was death, and secondary endings included admitted for heart failure, stroke, and nonfatal myocardial infarction.

Echocardiography

Standard two-dimensional transthoracic and Doppler echocardiography was performed by two experienced sonographers (each with >5 years of experience) using the same equipment (Epic CvX; Philips Medical Systems, Andover, MA). Patients were positioned in the left lateral decubitus position with simultaneous electrocardiographic monitoring. To optimize image quality, patients were instructed to breathe quietly and briefly hold breath when necessary. Measurements included left atrial diameter, left ventricular diameter, interventricular septal thickness, left ventricular posterior wall thickness, left ventricular mass index, and left ventricular ejection fraction. Dynamic images of the left ventricular long-axis, four-chamber, and two-chamber views were acquired over three consecutive cardiac cycles. In full-volume mode, clear endocardial visualization was ensured, and apical four-chamber three-dimensional echocardiographic images were obtained. All two-dimensional (2D) and three-dimensional (3D) echocardiographic acquisitions adhered to the guidelines of the American Society of Echocardiography[8]. The examining physicians were blinded to the clinical characteristics of the subjects.

GLS was derived from apical long-axis, four-chamber, and two-chamber views by an experienced sonographer blinded to clinical data. Measurements followed the recommendations of the European Association of Cardiovascular Imaging/American Society of Echocardiography/Industry Task Force to Standardize Deformation Imaging[9].

Fully automated GLS: Using the on-machine function AutoStrain LV, the software automatically tracked endocardial boundaries and calculated GLS without any manual intervention.

Semi-automated GLS: Following the initial automated tracking and calculation, the operator reviewed the tracking quality. Manual correction was performed if the automatically generated region of interest (ROI) did not adequately align with the endocardial border, or if tracking dropout or obvious drift was observed in one or more myocardial segments. Adjustments included repositioning the ROI boundary to better match the endocardial contour and ensuring consistent myocardial coverage throughout the cardiac cycle.

Manual GLS: Using the on-machine function aCMQ, the operator manually placed points at the mitral annulus and apical endocardium at end-systole in the apical long-axis view. The software then generated an initial ROI, whose width was manually adjusted to match myocardial thickness. The aortic valve closure time was accurately identified. The software tracked myocardial motion frame-by-frame within the ROI. The same process was repeated for the four-chamber and two-chamber views, with manual refinement of the endocardial boundary as needed.

GLS measurement time: Fifty patients were randomly selected to record the time required for each GLS measurement method. The measurement time was defined as the duration from initial selection of the three standard apical views to the point when the final GLS value was computed.

Reproducibility assessment: Another fifty CKD patients were randomly chosen to evaluate intra- and inter-observer variability using the same images. Intra-observer variability was assessed between two measurements performed by the same observer 30 days apart, with the observer blinded to prior results. Inter-observer variability was calculated between the first measurements of two independent investigators, both blinded to each other's results. All GLS analyses were performed by experienced sonographers.

Statistical analysis

Continuous variables are expressed as mean ± standard deviation or median (IQR). Categorical variables are expressed as numbers (percentages). The normal distribution of the data was tested by Kolmogorov-Smirnov. One-way ANOVA and Tukey post Hoc test were applied to compare GLS obtained from three different measurement methods, and Bonferroni was used to correct multiple comparisons. Intra-observer and inter-observer repeatability tests were performed applying the repeated measures ANOVA, as expressed by the intra-group correlation coefficient (ICCs). Pearson correlation analysis was used to evaluate the correlation between GLS obtained by three different measurements. Bias and limits of agreement (LOA) between the two different measurements were assessed using Bland-Altman analysis. Receiver operating characteristic (ROC) curve analysis was used to calculate the area under the curve (AUC) for GLS measured by each method, and the best cutoff value for each variable to distinguish between cardiovascular adverse events was obtained from the ROC curve. The area of ROC curve was compared using Medcalc Version 22.0.2 (Medcalc Software, Ostend, Belgium), and the remaining statistical analysis was performed using SPSS version 27.0 (SPSS, Chicago, IL). The data was considered statistically significant if bilateral P value <0.05.

Results

General clinical data and baseline echocardiographic data are shown in Table 1.

Comparison of correlation and consistency between automatic, semi-automatic GLS and manual GLS three measurement methods is shown in Table 2.

Comparison of area under ROC curve between automatic and semi-automatic GLS and manual GLS: automatic GLS

Table 1 General clinical data and baseline echocardiographic data

Age (years of age)	51.10±12.62
Gender (male/female, n)	182/98
Body surface area (BSA, m^2)	1.63±1.72
Heart rate (times/min)	77.49±8.93
Systolic pressure (mmHg)	147.76±23.50
Diastolic pressure (mmHg)	87.15±15.13
Blood glucose (mmol/L)	6.35±3.13
Blood fat (mmol/L)	1.64±1.33
Left ventricular internal diameter (mm)	49.25±5.60
Left atrial diameter (mm)	37.84±5.44
Interventricular septal thickness (mm)	12.55±1.73
Left ventricular posterior wall thickness (mm)	12.25±1.7
Left ventricular mass index (LVMI, g/m^2)	102.49±24.82
left ventricular ejection fraction (LVEF, %)	59.63±7.08
Automatic GLS	-16.37±3.39
Semi-automatic GLS	-17.04±3.41
Manual GLS	-18.18±4.13

Table 2 Correlation and consistency comparison between automatic, semi-automatic GLS and manual GLS measurement methods

	r	p	Bias±LOA
Automatic and manual GLS	0.865	<0.001	0.71±3.4
Semi-automatic and manual GLS	0.720	<0.001	1.81±5.7
Semi-automatic and automatic GLS	0.769	<0.001	1.1±5.2

Table 3 Area under ROC curve of automatic GLS, semi-automatic GLS and manual GLS measurement methods

	AUC (95%CI)	GLS cutoff value (%)	Sensitivity (%)	Specificity (%)
Automatic GLS	0.753 (0.683-0.823)	-17.6	83.0	65.2
Semi-automatic GLS	0.858 (0.809-0.906)	-15.7	83.0	76.7
Manual GLS	9.828 (0.774-0.883)	-15.0	73.1	79.2

Table 4 Comparison of repeatability of automatic GLS, semi-automatic GLS and manual GLS measurement methods

	Intraclass correlation coefficient (ICC)	95% CI	P value
Intra-observer			
Automatic GLS	1	1.000-1.000	P=0.000
Semi-automatic GLS	0.958	0.928-0.976	P=0.000
Manual GLS	0.908	0.843-0.947	P=0.000
Inter-observer			
Automatic GLS	1	1.000-1.000	P=0.000
Semi-automatic GLS	0.912	0.851-0.949	P=0.000
Manual GLS	0.868	0.778-0.923	P=0.001

and manual GLS:P=0.0235, $P < 0.05$; Semi-automatic GLS and manual GLS: p=0.1331, $p > 0.05$; Automatic GLS and semi-automatic GLS: p=0.0007, $P < 0.05$, as shown in Table 3.

The comparison of repeatability between automatic and semi-automatic GLS and manual GLS three measurement methods is shown in Table 4.

Discussion

In this study, we validated the feasibility, repeatability, and prognostic value of AI based automated GLS measurement in patients with CKD. The main findings are as follows: (1) Automated and semi automated GLS measurements were time efficient and showed good reproducibility; (2) Semi automated GLS demonstrated higher correlation and agreement with manual GLS than fully automated GLS; (3) Approximately 35% of cases required manual correction, leading to measurable differences among automated, semi automated, and manual GLS values; (4) Both automated and semi automated GLS could predict cardiovascular adverse events in CKD patients, though the predictive performance of fully automated GLS was lower than that of semi automated GLS.

Cardiovascular complications can occur at any stage of CKD. Clinically, some patients may die from cardiovascular events even before progressing to end stage renal disease. Therefore, early detection and intervention of cardiovascular impairment are critically important in CKD patients. GLS has emerged as a sensitive marker of subclinical left ventricular dysfunction, detecting subtle changes in LV function earlier than LVEF. It provides important prognostic information for adverse cardiovascular events in CKD patients and outperforms LVEF in risk stratification[10]. However, conventional GLS measurement is time consuming and operator dependent, limiting its routine use in busy clinical workflows. Therefore, automated GLS measurement presents a promising solution to this clinical need. Previous studies, such as that by Tetsuji Kitano et al.[11], demonstrated that automated GLS offers valuable prognostic information in patients with asymptomatic aortic valve disease. Similarly, Gonzalez Manzanares et al. reported that automated GLS outperformed conventional echocardiography in early detection of cardiotoxicity and could serve as an effective tool for long term cardiac monitoring in childhood leukemia survivors. Nevertheless, the feasibility, reproducibility, and prognostic utility of fully automated GLS in the CKD population remain underexplored.

The reproducibility of GLS is essential for its clinical application across various cardiac conditions. Kitano et al.[12] used automatic 2D strain software to evaluate the prognostic value of GLS in asymptomatic aortic stenosis and reported a test retest ICC of 0.95 (0.90–0.98). Kawakami et al.[13] studied 558 patients with asymptomatic heart failure and found that intra observer ICCs were 1.00 (95% CI, 1.00–1.00) for fully automated GLS, 0.97 (95% CI, 0.95–0.98) for semi automated GLS, and 0.94 (95% CI, 0.90–0.97) for manual GLS. Corresponding inter observer ICCs were 1.00 (1.00–1.00), 0.90 (0.84–0.95), and 0.92 (0.87–0.96), respectively. These findings align with our results, which confirm high reproducibility and consistency across automated, semi automated, and manual methods. When the same images are analyzed, fully automated algorithms yield identical results due to consistent machine learning processing—a key advantage for longitudinal follow up in CKD patients, enabling reliable detection of true changes in LV systolic function.

Our study highlights distinct practical and prognostic differences between fully automated and semi automated approaches. While fully automated measurement is rapid (15.23 ± 0.75 s) and perfectly reproducible, it may overlook suboptimal tracking in cases with poor acoustic windows or atypical anatomy. In contrast, semi automated analysis (75.06 ± 19.01 s) allows for targeted manual adjustment when automatic tracking deviates from the true endocardial border, thereby improving accuracy while retaining much of the efficiency gain over manual measurement (236.81 ± 45.41 s). Clinically, this balance makes semi automated GLS particularly suitable for routine practice: it reduces operator time and variability compared with manual analysis, yet maintains higher prognostic accuracy than the fully automated approach. In settings where image quality is often suboptimal—common in CKD patients due to comorbidities and body habitus—the semi automated method provides a safeguard against erroneous fully automated readings, enhancing diagnostic reliability without substantially increasing workflow burden.

In our cohort, 35% of cases required manual correction after initial automated tracking, a proportion comparable to the ≈40% reported by Kawakami et al.[13]. Suboptimal image quality remains an inherent limitation in echocardiography and affects both manual and automated measurements[14,15]. This explains the observed differences among the three methods and underscores why semi automated GLS—which integrates automated speed with selective human oversight—exhibited stronger predictive value for adverse cardiovascular events than the fully automated technique.

Potential limitations

Several limitations should be acknowledged. First, this was a single center retrospective study, and the results may be influenced by selection bias. Second, only CKD patients in sinus rhythm were included; the applicability of automated GLS in patients with arrhythmias requires further investigation. Third, subgroup analyses based on different CKD configurations were not performed, and whether etiology or stage of kidney disease affects automated measurement performance remains unknown. Fourth, image quality variability—a common challenge in echocardiography—directly impacts tracking accuracy and represents a persistent constraint for both automated and semi automated methods. Although we followed standardized acquisition protocols, differences in sonographer experience and patient related factors (e.g., body habitus, lung interference) could affect generalizability. Fifth, while semi automated analysis reduced operator dependence compared with fully manual measurement, it did not eliminate variability entirely, as the threshold for manual correction and the extent of adjustment remained at the operator's discretion. Finally, the fact that semi automated GLS outperformed the fully automated approach indicates that current AI based algorithms still have room for refinement, particularly in handling challenging image sets.

Conclusion

Automated GLS assessment of LV systolic function in CKD patients is feasible and reproducible. However, given that a substantial proportion of images still require manual correction at this stage, the semi automated mode of this AI based software offers a preferable balance between efficiency and clinical accuracy. It enables faster, more standardized GLS evaluation than manual methods while preserving prognostic performance that is superior to fully automated measurement. For routine implementation in CKD populations, semi automated GLS represents a pragmatic and reliable tool for early risk stratification and monitoring of cardiovascular impairment.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Hainan General Hospital. Written informed consent was obtained from all participants.

Conflict of interest

The authors declare no conflict of interest.

Funding

This work was supported by the Research Project of Health Industry in Hainan Province (No. 21A200235).

Authors' contributions

FT conceived and designed the study; ZW and LZ collected data; JQ analysed the data; HT supervised the study and revised the manuscript. All authors approved the final version.

Acknowledgements

The authors thank the staff of the Department of Ultrasonography, Hainan General Hospital, for technical support.

References

1.Joachim J, Jürgen F, Danilo F, Michael B, Nikolaus M. Cardiovascular Disease in Chronic Kidney Disease: Pathophysiological Insights and Therapeutic Options. 2021;143(11):1157-72.

2.Hensen LCR, Goossens K, Podlesnikar T, Rotmans JI, Jukema JW, Delgado V, et al. Left Ventricular Mechanical Dispersion and Global Longitudinal Strain and Ventricular Arrhythmias in Predialysis and Dialysis Patients. Journal of the American Society of Echocardiography. 2018;31(7):777-83.

3.Hensen LCR, Goossens K, Delgado V, Abou R, Rotmans JI, Jukema JW, et al. Prevalence of left ventricular systolic dysfunction in pre-dialysis and dialysis patients with preserved left ventricular ejection fraction. . European journal of heart failure. 2018;20(3):560-8.

4.Hensen LCR, Goossens K, Delgado V, Rotmans JI, Jukema JW, Bax JJ. Prognostic Implications of Left Ventricular Global Longitudinal Strain in Predialysis and Dialysis Patients. . The American journal of cardiology. 2017;120(3):500-4.

5.Valocikova I, Vachalcova M, Valocik G, Kurecko M, Dvoroznakova M, Mitro P, et al. Incremental value of global longitudinal strain in prediction of all-cause mortality in predialysis and dialysis chronic kidney disease patients. . Wiener klinische Wochenschrift. 2016;128(13-14):495-503.

6.Sveric KM, Botan R, Winkler A, Dindane Z, Alothman G, Cansiz B, et al. The role of artificial intelligence in standardizing global longitudinal strain measurements in echocardiography. Eur Heart J Imaging Methods Pract. 2024;2(4):qyae130.

7.Cotella JI, Slivnick JA, Sanderson E, Singulane C, O'Driscoll J, Asch FM, et al. Artificial intelligence based left ventricular ejection fraction and global longitudinal strain in cardiac amyloidosis. Echocardiography. 2023;40(3):188-95.

8.Mitchell C, Rahko PS, Blauwet LA, Canaday B, Finstuen JA, Foster MC, et al. Guidelines for Performing a Comprehensive Transthoracic Echocardiographic Examination in Adults: Recommendations from the American Society of Echocardiography. J Am Soc Echocardiogr. 2019;32(1):1-64.

9.Badano LP, Kolias TJ, Muraru D, Abraham TP, Aurigemma G, Edvardsen T, et al. Standardization of left atrial, right ventricular, and right atrial deformation imaging using two-dimensional speckle tracking echocardiography: a consensus document of the EACVI/ASE/Industry Task Force to Standardize Deformation Imaging. . Eur Heart J Cardiovasc Imaging. 2018;19(6):591-600.

10.Hemmelgarn BR, Clement F, Manns BJ, Klarenbach S, James MT, Ravani P, et al. Overview of the Alberta Kidney Disease Network. BMC Nephrol. 2009;10(1):30.

11.Kitano T, Nabeshima Y, Negishi K, Takeuchi M. Prognostic value of automated longitudinal strain measurements in asymptomatic aortic stenosis. . Heart 2020.

12.Gonzalez-Manzanares R, Castillo JC, Molina JR, Ruiz-Ortiz M, Mesa D, Ojeda S, et al. Automated Global Longitudinal Strain Assessment in Long-Term Survivors of Childhood Acute Lymphoblastic Leukemia. . Cancers (Basel). 2022;14(6):1513.

13.Kawakami H, Wright L, Nolan M, Potter EL, Yang H, Marwick TH. Feasibility, Reproducibility, and Clinical Implications of the Novel Fully Automated Assessment for Global Longitudinal Strain. J Am Soc Echocardiogr. 2021;34(2):136-45.

14.Salte IM, Østvik A, Smistad E, Melichova D, Nguyen TM, Karlsen S, et al. Artificial Intelligence for Automatic Measurement of Left Ventricular Strain in Echocardiography. JACC Cardiovasc Imaging. 2021;14(10):1918-28.

15.Knackstedt C, Bekkers SC, Schummers G, Schreckenberg M, Muraru D, Badano LP, et al. Fully automated versus standard tracking of left ventricular ejection fraction and longitudinal strain: the FAST-EFs multicenter study. J Am Coll Cardiol. 2015;66(13):1456-66.