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ORIGINAL ARTICLE

Preoperative left atrial volume index predicts postoperative atrial fibrillation in patients with severe aortic valve stenosis

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Abstract

Purpose Left atrial enlargement correlates with the severity of diastolic dysfunction and is a predictor of cardiovascular complications such as atrial fibrillation. Aortic valve stenosis (AS) causes left atrial enlargement and progression of diastolic dysfunction. The aim of this study was to investigate the efficacy of the preoperative left atrial volume index (LAVI) in predicting postoperative outcome in patients with severe AS.

Methods Forty-seven patients with severe AS who underwent aortic valve replacement were examined. Transthoracic echocardiography and LAVI measurement were performed on admission. Patients were divided into two groups according to optimal cut-off values of LAVI derived from receiver operating characteristic curves for postoperative atrial fibrillation (POAF) (group S: LAVI $<$52 ml/m^2, group L: LAVI $\geq$52 ml/m^2). The incidence of POAF, ventilation time, inotropic support time, duration of stay in intensive care, and overall duration of hospital stay were evaluated.

Results By univariate analysis, the incidence of POAF in group S was significantly lower than that in group L (25.9 and 65.0 %, respectively; $P < 0.01$). Values for other parameters were higher in group L, although the differences were insignificant.

Conclusion In patients with severe AS, a preoperative LAVI of $\geq$52 ml/m^2 may be a useful predictor of POAF, although the efficacy of this index for predicting other postoperative outcomes has yet to be determined.

Keywords Left atrial volume index · Aortic valve stenosis · Diastolic dysfunction · Postoperative atrial fibrillation

Introduction

Left atrial (LA) enlargement correlates with the severity of diastolic dysfunction and is a predictor of cardiovascular complications, such as atrial fibrillation (AF) and stroke [1, 2]. Aortic valve stenosis (AS) increases left ventricular (LV) afterload and decreases LV compliance, leading to an elevation of both LV end-diastolic pressure and LA filling pressure. Increased LA volume is most commonly related to increased wall tension as a result of increased LA filling pressure [3, 4]. Some studies indicate that increased LA volume predicts a poor prognosis in patients with heart failure [5] and is associated with adverse outcomes in patients with hypertrophic cardiomyopathy [6].

The American Society of Echocardiography Committee recommends that the left atrial volume index (LAVI; LA volume/body surface area) measurements should become a routine laboratory measure because they are a strong predictor of outcome [7]. Despite this recommendation, there are few reports describing the usefulness of LAVI in predicting the postoperative outcome of cardiac surgery.

The aim of this study was to investigate the efficacy of the preoperative LAVI in predicting postoperative outcome in patients with severe AS.

Materials and methods

This study was reviewed and approved by the Institutional Review Board of Kobe City Medical Center General

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Hospital, and the requirement for written informed consent was waived. Forty-seven patients with severe AS who underwent aortic valve replacement between February 2007 and October 2011 were retrospectively examined. Transthoracic echocardiography and LAVI measurement were performed before the operation. The LAVI was calculated using the area–length method or the disc method in a manner similar to its application for LV volume measurement (Fig. 1). According to the American Society of Echocardiography Committee, the reference range of LAVI is 22 ± 6 ml/m^2, and a LAVI of $\geq$40 ml/m^2 is severely abnormal. Other echocardiographic parameters (transmitral Doppler velocity, tissue Doppler early diastolic mitral annular velocity) were also measured.

Exclusion criteria were preoperative AF, moderate–severe mitral or tricuspid valve disease, moderate–severe aortic valve regurgitation, redo surgery, and preoperative inotropic or ventilatory support. We did not include patients who underwent aortic valve replacement combined with coronary artery bypass grafting.

Patients were divided into two groups (group S and group L) according to the optimal cut-off values of LAVI derived from receiver operating characteristic curves for postoperative atrial fibrillation (POAF): group S, LAVI of <52 ml/m^2; group L, LAVI of $\geq$52 ml/m^2 (Fig. 2). We decided on this cut-off value because POAF is associated with an increased risk of mortality and morbidity [8]. The groups were compared for incidence of POAF, ventilation time, inotropic support time, duration of stay in intensive care, and overall duration of hospital stay. We defined POAF as AF that develops within 2 weeks after the operation. Postoperative management, such as timing of extubation and weaning of inotropic support, was performed according to the judgement of the intensivist. The incidence of postoperative complications (pulmonary complication, myocardial infarction, cerebral infarction, renal

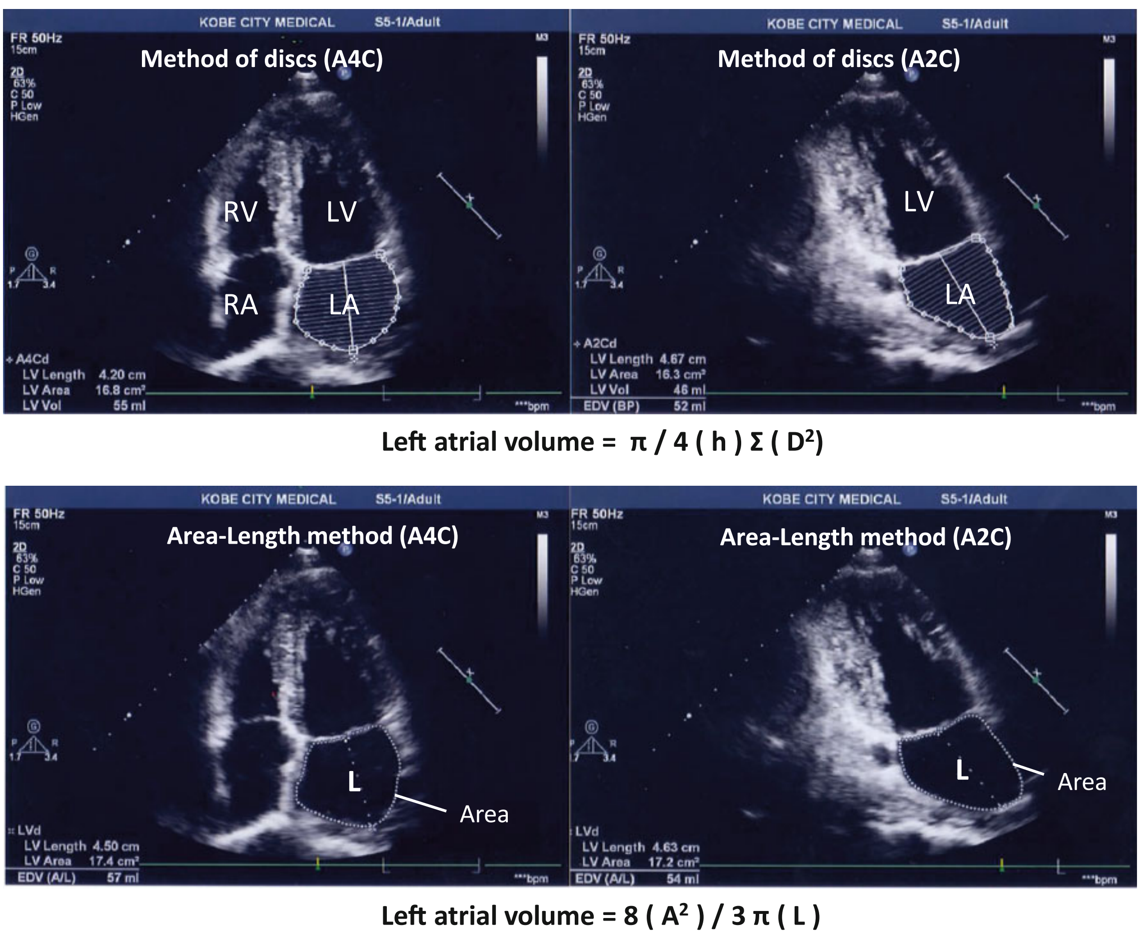

Fig. 1 Calculation of the left atrial volume index (LAVI). LA size is measured at end-ventricular systole. Two-dimensional measurements for volume calculations using the disc method [LAV = $\pi/4(h)\Sigma(D^2)$] (**a**) or biplane area–length method [LAV = $8(A^2)/3\pi(L)$] (**b**) in A4C and A2C are recommended. LAV = $(LAV_{4C} + LAV_{2C})/2$. *A* area, *A4C* apical-4-chamber view, *A2C* apical-2-chamber view, *D* orthogonal axes of stacked oval discs, *h* height of stacked oval discs, *L* long axis of atrium, *LV* left ventricle, *LAV* left atrial volume, *RA* right atrium, *RV* right ventricle

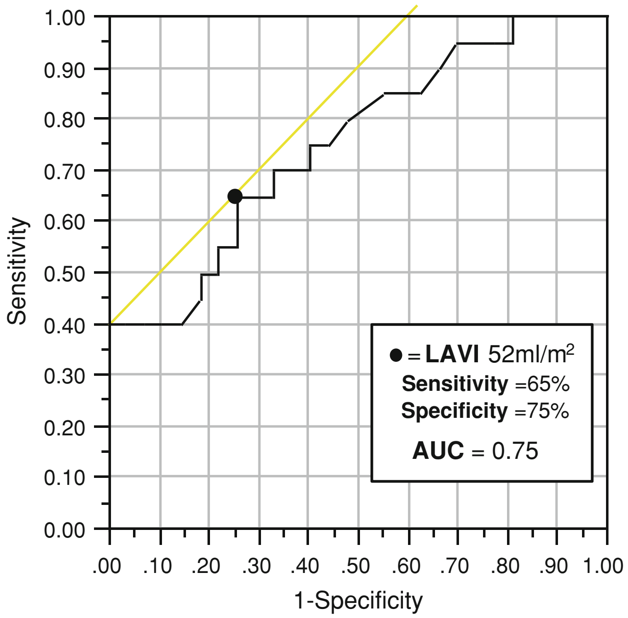

Fig. 2 Receiver operating characteristic (*ROC*) curves for the ability of LAVI to predict postoperative atrial fibrillation (*POAF*). Our cut-off value (LAVI = 52 ml/m^2) is that value which corresponds to a *point* on the ROC curve nearest to the *upper left corner* of the graph. *AUC* Area under the curve

failure, infection, and other arrhythmia) were also compared between the two groups.

Patients' perioperative clinical, surgical, echocardiographic characteristics and postoperative complications were compared using the χ^2 test for categorical variables (expressed as percentages) and the Wilcoxon rank test for continuous variables (expressed in quartile ranges). A P value of 0.05 was selected for the threshold of statistical significance. All statistical analyses were performed using JMP statistical software (ver. 5.1.1; SAS Institute, Cary, NC).

Results

The median age of the 47 patients was 73 [interquartile range (IQR) 67–77] years, and 63.8 % patients were female. The median LAVI was 47 (IQR 37–62) ml/m^2, the median LV ejection fraction (LVEF) was 66 % (IQR 62–71 %), and 42.6 % of the patients developed POAF. The characteristics of patients did not show any significant intergroup difference (Table 1).

By univariate analysis, the incidence of POAF in group S was significantly lower than that in group L (25.9 and 65.0 %, respectively; $P < 0.01$). Ventilation time, inotropic support time, duration of stay in intensive care, and overall duration of hospital stay were higher in group L, although the differences were not significant (Table 2). Postoperative complications showed no significant differences between the two groups (Table 3). Additionally, one of group L patients with POAF developed cerebral infarction.

One of the echocardiographic parameters measured was the correlation between LAVI and E/E' (the ratio of transmitral Doppler early filling velocity to tissue Doppler early diastolic mitral annular velocity). There was a positive correlation between LAVI and E/E′ ($R = 0.46$, $P < 0.01$) (Fig. 3).

Discussion

Our study shows that the incidence of POAF was significantly different between the two groups. POAF is a frequent complication occurring in 30–50 % of patients following cardiac surgery [8]. Many risk factors for the development of POAF, such as aging, obesity, male gender, a history of AF, decreased LVEF, chronic obstructive pulmonary disease, chronic renal failure, and diabetes mellitus, have been identified. With respect to these risk factors, there were no significant differences between the two groups. Although LA enlargement is known to be one of the risk factors for the development of POAF, few reports have demonstrated this statistically. Martin et al. [9] found a LAVI of >32 ml/m^2 to be a strong predictor of POAF, with an almost fivefold increase in the risk independent of age and other clinical and surgical parameters. Their cut-off value was lower than that in our study, likely because many of the patients in their study were undergoing coronary artery bypass grafting, and not only LAVI but also atrial ischemia may be related to the development of POAF. We found that a LAVI of ≥52 ml/m^2 to be a predictor of POAF in patients with severe AS without coronary artery disease.

Although values for the other parameters measured in our study (ventilation time, inotropic support time, duration of stay in intensive care, and overall duration of hospital stay) were higher in group L patients than in group S patients, the differences were not significant. The reason for this is because LVEF was comparatively well maintained in both groups and both exhibited normal sinus rhythm. If we had included patients already diagnosed with AF, a significant intergroup difference might have been noted.

LA enlargement is a marker of both the severity and chronicity of diastolic dysfunction and the magnitude of LA pressure elevation [1, 2, 10]. As opposed to the Doppler-derived parameters (the mitral E/A ratio, mitral deceleration time, and pulmonary venous flow velocity profile), LAVI provides a long-term indication as to whether a patient has diastolic dysfunction, regardless of the loading conditions present at the time of examination [11].

Table 1 Perioperative clinical, surgical, and echocardiographic characteristics of patients

Patient characteristics	Group S[a] ($n = 27$)	Group L[a] ($n = 20$)	P value
Age (years)	70 (65–76)	74 (69.5–81)	0.07
Male gender (%)	40.7	30	0.45
Body mass index (kg/m^2)	21.9 (20.6–24.7)	23.6 (20.8–26.8)	0.29
Hypertension (%)	60.3	75	0.26
Diabetes mellitus (%)	22.2	20	0.85
Hyperlipidemia (%)	51.8	40	0.42
Coronary artery disease (%)	0	0	NA
Preoperative values			
Hemoglobin (g/dl)	11.4 (11–12.4)	11.7 (10.6–12.5)	0.53
eGFR (ml/min)	59 (54–70.3)	61 (47.9–69)	0.55
LVEF (%)	68 (63–72)	64.5 (58.5–68.8)	0.09
Beta-blockers (%)	11.1	20	0.4
ACE-I, ARB (%)	48.2	60	0.42
Ca-blockers (%)	25.9	40	0.31
Statin (%)	37	45	0.58
Anesthesia time (min)	420 (395–475)	387 (326–470)	0.22
Operation time (min)	344 (297–387)	305 (241–390)	0.32
Cardiopulmonary bypass time (min)	144 (133–190)	134 (112–191)	0.2
Aortic clamping time (min)	104 (92–138)	89 (71–152)	0.27
Transfusion volume (ml)	1,520 (800–2,440)	1,320 (1,010–2,460)	0.64

Patients' characteristics and postoperative complications were compared using the χ^2 test for categorical variables, with the data expressed as a percentage, and the Wilcoxon rank test was used for continuous variables, with the interquartile range (IQR) given in parenthesis. The characteristics of patients did not show any significant intergroup difference

ACE-I Angiotensin converting enzyme inhibitor, *ARB* angiotensin receptor antagonist, *eGFR* estimated glomerular filtration rate, *LVEF* left ventricular ejection fraction, *NA* not applicable

[a] Group S, Patients with a left atrial volume index (LAVI) of <52 ml/m^2; Group L, patients with a LAVI of ≥52 ml/m^2

Table 2 Postoperative outcomes

	Group S ($n = 27$)	Group L ($n = 20$)	P value
Postoperative atrial fibrillation (%)	25.9	65	<0.01*
Ventilation support time (h)	4 (2.5–14)	8 (4–15)	0.11
Inotropic support time (h)	11 (4–18)	17.5 (5–38)	0.09
Intensive care unit stay (h)	23 (21–45)	44 (22–97)	0.13
Hospital stay (day)	18 (14–23)	18.5 (15.5–27)	0.6

For postoperative outcome, the χ^2 test was used for categorical variables, with the data expressed as a percentage, and the Wilcoxon rank test was used for continuous variables, with the IQR in parenthesis

* $p < 0.05$: the incidence of POAF in group S was significantly lower than that in group L

In our study, we did not evaluate the Doppler-derived parameters to predict postoperative outcome because they can be affected by loading conditions. On the basis of reports that E/E′ has a better correlation with diastolic dysfunction [12], we studied the correlation between LAVI and E/E′, and found it to be positive ($R = 0.46$, $P < 0.01$) (Fig. 2). This positive value might indicate that LAVI is a useful indicator of diastolic function.

Functional assessment of LA has recently been shown to be a predictor of cardiovascular complications [13]. The relative contribution of LA phasic function to LV filling is dependent upon the LV diastolic properties [14]. The LA ejection fraction [(maximal LAV − minimal LAV)/maximal LAV] is one of LA phasic functions and is associated with LA diastolic dysfunction [15]. Considering these facts, further studies are needed to evaluate LA phasic

Table 3 Postoperative complications

	Group S ($n = 27$)	Group L ($n = 20$)	P value
Pulmonary complication (%)	7.4	5	0.74
Myocardial infarction (%)	0	0	NA
Cerebral infarction (%)	0	5	0.24
Renal failure (%)	0	0	NA
Infection (%)	11.5	5	0.43
Other arrhythmia (%)	7.4	10	0.75

Postoperative complications were compared using the χ^2 test. There were no significant differences between the two groups. One of the group L patients with POAF developed cerebral infarction

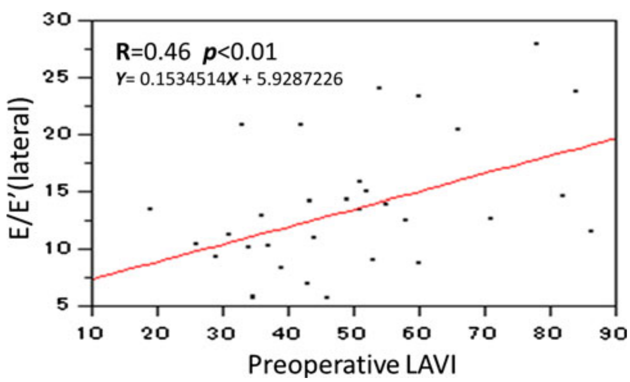

Fig. 3 Relationship between LAVI and E/E′. There was a positive correlation between LAVI and E/E′ ($R = 0.46$, $P < 0.01$). E/E′ = 0.1534514 × LAVI + 5.9287226. *E/E′* Ratio of transmitral Doppler early filling velocity to tissue Doppler early diastolic mitral annular velocity

function as well as LAVI to determine their efficacy to predict postoperative outcomes.

Our study is limited by its design in that it was a retrospective, nonrandomized, and relatively small study. However, the main advantage of our study is that we enrolled only patients with severe AS; as such, the pathophysiology of LA enlargement was standardized, and our results might be applicable to clinical practice.

In conclusion, based on our results, a preoperative LAVI of ≥52 ml/m^2 is a useful predictor for POAF in patients with severe AS, although effects on other postoperative outcomes have yet to be determined. A larger study should be performed to confirm these results. On the basis of our findings, prophylactic treatment for POAF should be administered to patients with a LAVI of ≥52 ml/m^2.

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