Original Article

Immediate change following valve deployment in left ventricular systolic and diastolic functions in transcatheter aortic valve replacement: a retrospective cohort study

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Background: Transcatheter aortic valve replacement (TAVR) is an effective treatment for aortic valve disorder. Several studies have reported improvements in systolic and diastolic function following TAVR. However, few studies have addressed immediate post-deployment changes. Therefore, this study examines left ventricular (LV) systolic and diastolic function changes immediately after valve deployment in TAVR patients, distinguishing between those with normal and impaired LV ejection fraction (LVEF).

Methods: In this single-center retrospective cohort study, intraoperative changes in LV systolic and diastolic function were analyzed in patients undergoing TAVR from January 2012 to September 2014. Participants were categorized into two groups based on preprocedural LVEF: the low ejection fraction (EF) group (LVEF <50%) and the normal EF group (LVEF ≥50%). LVEF, as an indicator of LV systolic function, along with lateral e' and the E/e' ratio as indicators of LV diastolic function before and immediately after valve deployment were compared in the overall cohort and within each group.

Results: Forty-eight TAVR cases were included, comprising 15 in the low EF group and 33 in the normal EF group. Overall, there was a significant improvement in LVEF {51.7% [standard deviation (SD)] 15.0 *vs.* 58.0% (SD 11.6), P=0.007}, with no significant changes in e' or E/e'. In the low EF group, a significant increase was observed in LVEF [31.8% (SD 8.0) *vs.* 45.5% (SD 9.9), P=0.006], e' [5.0 cm/s (SD 1.4) *vs.* 6.2 cm/s (SD 1.0), P=0.004], and a significant decrease was observed in E/e' [22.3 (SD 7.6) *vs.* 16.1 (SD 3.4), P=0.01]. The normal EF group showed a significant decrease in e' [6.2 cm/s (SD 1.8) *vs.* 5.9 cm/s (SD 1.6), P=0.04] without significant changes in LVEF and E/e'.

Conclusions: This study revealed significant intraoperative improvements in systolic and diastolic functions immediately after valve deployment in TAVR patients with low preprocedural LVEF. These immediate improvements were not observed in patients with normal LVEF.

Keywords: Transcatheter aortic valve replacement (TAVR); left ventricular systolic function; left ventricular diastolic function; low ejection fraction

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Introduction

Transcatheter aortic valve replacement (TAVR) has emerged as an effective treatment for aortic valve disorder, benefiting an increasingly broad patient population in recent years (1,2). Several studies have reported improvements in left ventricular (LV) systolic and diastolic functions following TAVR in the postoperative period (3-5). Notably, patients with lower LV ejection fraction (LVEF) have demonstrated more pronounced cardiac function recovery post-TAVR (3,6). However, most studies evaluated the functional changes at least one week after valve deployment (3,7). Hence, it remains unclear at what point these improvements occur—whether they are immediately following valve deployment. To address this question, the current study aims to investigate the intraoperative changes in cardiac function immediately after valve deployment during TAVR. We hypothesize that significant intraoperative improvements in LV systolic and diastolic functions occur immediately after deployment in TAVR, especially in patients with lower LVEF. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-784/rc).

Highlight box

Key findings

- The study demonstrates significant improvements in left ventricular (LV) systolic and diastolic functions immediately after valve deployment in transcatheter aortic valve replacement (TAVR) patients with low preprocedural LV ejection fraction (LVEF <50%). However, no significant immediate improvements were observed in patients with normal preprocedural LVEF (LVEF ≥50%).

What is known and what is new?

- Previous research has shown improvements in LV functions following TAVR, typically observed postoperatively.
- This study highlights that immediate cardiac function improvements can occur intraoperatively, immediately after valve deployment, especially in patients with lower LVEF, filling a knowledge gap in the timing of functional improvements.

What is the implication, and what should change now?

- The findings suggest that intraoperative monitoring of LV functions could provide immediate feedback on TAVR effectiveness, especially in patients with low LVEF.
- Additional studies are necessary to understand the absence of immediate improvement in patients with normal LVEF. Moreover, the indicators used in this study for assessing diastolic and systolic LV functions were limited, suggesting a need for further research using a broader range of cardiac function metrics. Furthermore, larger patient cohort studies are warranted to validate and confirm the current study findings.

Methods

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the University of Iowa Institutional Review Board (No. 201408740) and individual consent for this retrospective analysis was waived. We reviewed all patients with aortic stenosis (AS) who underwent TAVR at the University of Iowa Hospital from January 2012 to September 2014. Inclusion criteria were limited to TAVR cases where intraoperative transesophageal echocardiography (TEE) was performed by a staff echocardiologist for analysis.

All patients underwent induction with general anesthesia by a staff cardiac anesthesiologist, followed by the oral insertion of a TEE probe. Intraoperative TEE assessments were consistently conducted by a staff echocardiologist. The intraoperative TEE measurements, including LVEF as an indicator of systolic function, and lateral e' and E/e' ratio as indicators of diastolic function (6,8) were recorded at the two observational points: before and immediately after valve deployment. The E-wave and lateral e' were measured using pulse-wave Doppler and pulse-wave tissue Doppler imaging techniques according to the American Society of Echocardiography recommendations (*Figure 1*) (9). These intraoperative TEE measurements were recorded under general anesthesia while vital signs were stable. Any cases with missing data from TEE reports by a staff echocardiologist, whether it be LVEF, lateral e', or E/e' ratio at either of the two observation points, were excluded from the analysis.

Based on LVEF before valve deployment, TAVR cases were categorized into the low ejection fraction (EF) group (LVEF <50%) and the normal EF group (LVEF ≥50%) (3). LV systolic function (LVEF), along with diastolic function (lateral e' and the E/e' ratio) before and immediately after valve deployment were compared in the overall cohort and within each group. Patient characteristics were reviewed, including age, gender, body mass index, history of coronary artery bypass grafting, coronary artery disease, and comorbidities such as atrial fibrillation, asthma, diabetes, chronic obstructive pulmonary disease, carotid artery disease, dyslipidemia, severity of aortic valve regurgitation (10), severity of mitral regurgitation (10), approach method (transfemoral *vs.* transapical), New York Heart Association

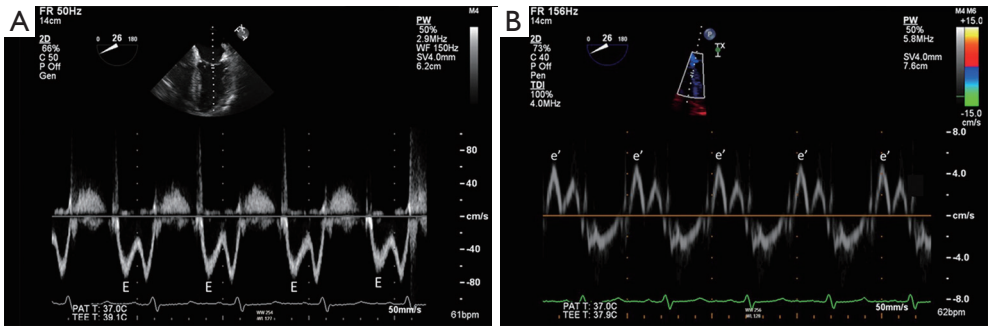

Figure 1 Intraoperative assessment of left ventricular diastolic function using mid-esophageal four-chamber view of transesophageal echocardiography. (A) Transmitral flow velocity measured by pulse-wave Doppler echocardiography. E indicates E-wave, representing the peak early transmitral velocity. (B) Mitral annular velocity measured by tissue Doppler imaging. e' represents the early diastolic velocity at the mitral annulus.

class, and the presence of LV hypertrophy (end-diastolic thickness ≥11 mm). Additionally, intraoperative complications, including the unplanned use of cardiopulmonary bypass (CPB), unplanned pacemaker insertion, cardiac arrest, and death, were also reviewed.

Statistical analysis

Continuous variables were expressed as mean ± standard deviation (SD), and nominal variables as counts and percentages [n (%)]. Paired *t*-tests were used for comparing changes in systolic and diastolic functions. A two-sided P-value of less than 0.05 was considered statistically significant. Statistical analyses were performed using Easy R software (EZR; Saitama Medical Center, Jichi Medical University, Saitama, Japan), a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria).

Results

During the study period, 96 TAVR cases were performed. Out of the 96 cases, 48 cases were excluded from the analysis due to missing data in the intraoperative TEE report, leaving 48 cases for analysis. This missing data included one or more intraoperative measurements of LVEF, lateral e', or E/e' ratio at either or both observation points before or immediately after valve deployment. In the analyzed 48 cases, 15 were categorized in the low EF group and 33 in the normal EF group. Patient characteristics in each group are detailed in *Table 1*. Intraoperative complications occurred in 6 cases (12.5%) as follows: in the low EF group, one case (6.7%) required the unexpected use of CPB. In the normal EF group, complications occurred in 5 cases (15.2%), which included one case requiring pacemaker insertion, one case of cardiac arrest followed by return of spontaneous circulation and subsequent pacemaker insertion, one case of significant bleeding from the surgical site, and two cases of unexpected CPB use. There were no intraoperative deaths.

Table 2 presents the intraoperative changes in indicators for systolic and diastolic functions measured before and immediately after valve deployment. Among all patients, there was a significant increase in LVEF [51.7% (SD 15.0) *vs.* 58.0% (SD 11.6), P=0.007], and no significant changes were observed in lateral e' or the E/e' ratio. In the low EF group, both LVEF and lateral e' showed significant increases [31.8% (SD 8.0) *vs.* 45.5% (SD 9.9), P=0.006; 5.0 cm/s (SD 1.4) to 6.2 cm/s (SD 1.0), P=0.004, respectively]. The E/e' ratio significantly decreased [22.3 (SD 7.6) to 16.1 (SD 3.4), P=0.01]. In the normal EF group, lateral e' showed a significant decrease [6.2 cm/s (SD 1.8) to 5.9 cm/s (SD 1.6), P=0.04], and no significant changes were observed in LVEF and the E/e' ratio.

Discussion

The current study of TAVR revealed that during the operation, LVEF and e' significantly increased and E/e' significantly decreased immediately after valve deployment in patients with LVEF less than 50%, suggesting immediate improvement of both systolic and diastolic functions in this patient group.

Improvement in systolic and diastolic functions following

Table 1 Patient characteristics

Variables	Total (n=48)	Low EF group (n=15)	Normal EF group (n=33)
Age, years	84.7 [6.8]	83.2 [7.2]	85.4 [6.5]
Female	23 (47.9)	6 (40.0)	17 (51.5)
Body mass index, kg/m^2	28.7 [6.8]	29.7 [8.1]	28.3 [6.1]
Approach			
Trans-femoral	39 (81.3)	11 (73.3)	28 (84.8)
Trans-apical	9 (18.8)	4 (26.7)	5 (15.2)
Intra-op complications	6 (12.5)	1 (6.7)	5 (15.2)
Atrial fibrillation	21 (43.8)	5 (33.3)	16 (48.5)
Asthma	2 (4.2)	0 (0.0)	2 (6.1)
CABG	14 (29.2)	5 (33.3)	9 (27.3)
CAD	43 (89.6)	14 (93.3)	29 (87.9)
CKD	29 (60.4)	12 (80.0)	17 (51.5)
COPD	17 (35.4)	6 (40.0)	11 (33.3)
Carotid artery disease	9 (18.8)	3 (20.0)	6 (18.2)
Dyslipidemia	27 (56.3)	9 (60.0)	18 (54.5)
Diabetes	20 (41.7)	7 (46.7)	13 (39.4)
NYHA			
1–2	15 (31.2)	2 (13.3)	13 (39.4)
3–4	33 (68.8)	13 (86.7)	20 (60.6)
AR			
Non-mild	21 (43.8)	8 (53.3)	13 (39.4)
Moderate-severe	27 (56.2)	7 (46.7)	20 (60.6)
MR			
Non-mild	17 (35.4)	5 (33.3)	12 (36.4)
Moderate-severe	31 (64.6)	10 (66.7)	21 (63.6)
LVH	43 (89.6)	13 (86.7)	30 (90.9)

Data are presented as mean [standard deviation] or n (%). CABG, coronary artery bypass grafting; CAD, coronary artery disease; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; EF, ejection fraction; NYHA, New York Heart Association; AR, aortic valve regurgitation; MR, mitral valve regurgitation; LVH, left ventricular hypertrophy.

aortic valve replacement (AVR), encompassing both TAVR and surgical approaches, has been well documented in previous studies (3,4,6,11,12), with several reports indicating improvement as early as one week postoperatively (7, 11). These observations are consistent with the findings of the current study. However, while the focus of many studies lies in mid- or long-term postoperative recovery (5,6,13,14), data on immediate post-valve deployment functional changes are limited. Addressing this gap, the current study specifically explores the intraoperative changes in LV systolic and diastolic functions during TAVR, revealing significant improvement immediately after valve deployment, especially in patients with preprocedural low LVEF.

The physiological mechanism in AS for functional improvement after AVR follows: Increased wall stress

Table 2 Intraoperative transesophageal echocardiographic measurements for systolic and diastolic function before and immediately after valve deployment

Variables	Before deployment	Immediately after deployment	P value
Total (n=48)			
LVEF, %	51.7 (15.0)	58.0 (11.6)	0.007
e', cm/s	5.8 (1.8)	6.0 (1.5)	0.92
E/e'	18.7 (7.5)	18.0 (6.1)	0.28
Low EF group (n=15)			
LVEF, %	31.8 (8.0)	45.5 (9.9)	0.006
e', cm/s	5.0 (1.4)	6.2 (1.0)	0.004
E/e'	22.3 (7.6)	16.1 (3.4)	0.01
Normal group (n=33)			
LVEF, %	60.7 (5.8)	62.4 (8.5)	0.27
e', cm/s	6.2 (1.8)	5.9 (1.6)	0.04
E/e'	17.0 (7.0)	18.9 (6.9)	0.26

Continuous variables were expressed as mean ± standard deviation (SD). LVEF, left ventricular ejection fraction; SD, standard deviation.

and oxygen demand due to pressure overload lead to LV remodeling and compensatory hypertrophy, impairing diastolic function (4). AVR alleviates this strain, reducing wall stress and promoting beneficial remodeling (11), with these changes reportedly occurring within several weeks (11,15). Additionally, improvements in hemodynamic afterload, diastolic myocardial perfusion, the systolic component of coronary flow, and sub-endocardial perfusion immediately after AVR positively influence LVEF during the procedure (16). Typically, the myocardium undergoes reverse remodeling over several months, improving both systolic and diastolic functions (5,6,17).

In the normal EF group, although there was a statistically significant decrease in e' [from 6.2 cm/s (SD 1.8) to 5.9 cm/s (SD 1.6), P=0.04], this change was clinically negligible, and there was no improvement of either systolic and diastolic function. These findings of the current study are in line with previous studies, which also reported no improvement in diastolic function post-TAVR in patients with preserved EF (4,6). The exact mechanism for this lack of immediate improvement in the respective group remains unclear, requiring further investigation.

This study has several limitations. Firstly, being a retrospective study, inherent limitations associated with retrospective data collection and analysis such as potential biases and incomplete records, should be acknowledged. Secondly, the data are not recent, which affects the relevance of the types of valves used, the frequency of intraoperative complications, and the rate of the transapical approach in comparison to current TAVR procedures (18,19). However, the study period was chosen because it offered access to more accurate echocardiographic measurements. During this time, echocardiologist-led TEE under general anesthesia was routine for all TAVR procedures, likely providing more precise data than recent TAVR procedures. Recently, TAVR has mainly used transthoracic echocardiography under local anesthesia, often without an echocardiologist present. Thirdly, while various indicators for assessing LV systolic and diastolic functions exist, this study used LVEF, lateral e', and lateral E/e' as indicators. Although these indicators are well-supported by past reports (9,14,20), the results of the current study could be affected if different indicators were used for LV systolic and diastolic functions. Fourthly, the fact that all intraoperative TEE measurements were performed under general anesthesia could have influenced the results. Fifthly, the current study aimed to ensure that the analysis of TEE data was based on complete and reliable measurements performed by staff cardiologists. This led to the exclusion of half of the cases during the study period from the analysis due to incomplete data availability for LVEF, e', and E/e', which could have affected the study results. Lastly, the number of cases analyzed is relatively small. However, the current trend of performing TAVR procedures under local

anesthesia without TEE assessments presents challenges in data accumulation. Therefore, data collection from multi-institutional studies would be beneficial to enhance the generalizability of the analysis.

Conclusions

The current retrospective cohort study demonstrated that in patients with AS, an immediate intraoperative improvement in LVEF was observed during TAVR. Among patients with reduced preprocedural LVEF less than 50%, a significant improvement in LV diastolic function was also observed immediately after valve deployment. In contrast, patients with normal preprocedural LVEF showed no improvements in either systolic or diastolic functions.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-784/rc

Data Sharing Statement: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-784/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-784/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the University of Iowa Institutional Review Board (No. 201408740) and individual consent for this retrospective analysis was waived.

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