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Longitudinal echocardiographic changes in left ventricular diastolic function following bilateral total knee arthroplasty: A retrospective cohort study

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Abstract

This study aimed to investigate longitudinal changes in left ventricular diastolic function using echocardiography in patients undergoing bilateral total knee arthroplasty (TKA), based on preoperative and long-term follow-up assessments. This retrospective cohort study included patients who underwent bilateral TKA between 2019 and 2025. Of the 583 patients initially screened, only those who had transthoracic echocardiographic examinations both before surgery and 12–18 months postoperatively during routine clinical follow-up were included in the final analysis. Patients with reduced left ventricular ejection fraction, significant valvular heart disease, atrial fibrillation, chronic kidney disease, or clinically relevant rhythm abnormalities were excluded. Echocardiographic examinations were performed by experienced operators using a Philips EPIQ 7 system under standardized imaging conditions. Diastolic function was evaluated using the E/e′ ratio, transmitral E/A ratio, and septal e′ velocity. Longitudinal changes were assessed within the same individuals. For baseline comparison, a control group with similar demographic characteristics and available preoperative echocardiographic data was selected from the same screened population. At long-term follow-up, septal e′ velocity increased from 6.00 ± 1.19 to 6.71 ± 1.03 cm/s, while the E/e′ ratio decreased from 12.2 ± 2.9 to 11.1 ± 2.5 (both $p < 0.001$). The E/A ratio also increased significantly ($p < 0.001$), whereas left ventricular systolic function remained unchanged. Regression analysis showed that baseline E/e′ values independently predicted the magnitude of longitudinal changes in diastolic function ($p < 0.05$). Among patients with available long-term echocardiographic follow-up, bilateral TKA was associated with favorable changes in selected echocardiographic markers of left ventricular diastolic function. The observed decrease in the E/e′ ratio and increase in septal e′ velocity may indicate favorable hemodynamic adaptation during follow-up. Nevertheless, these findings should be interpreted with caution because of the retrospective study design and the potential for selection bias.

Keywords: Bilateral total knee arthroplasty, left ventricular diastolic function, echocardiography, diastolic function, hemodynamic adaptation

Introduction

Total knee arthroplasty (TKA) is a well-established treatment for advanced knee osteoarthritis, primarily aimed at relieving pain, restoring joint function, and improving quality of life. In patients with bilateral knee involvement, bilateral TKA—performed either simultaneously or within a short interval—may promote earlier functional recovery and enhance overall physical performance. However, because these patients are often older and have multiple comorbidities, careful perioperative evaluation is essential [1–3].

Selection of patients for bilateral TKA is based on clinical, functional, and perioperative considerations. Eligible patients typically have severe bilateral osteoarthritis that is refractory to conservative treatment, substantial limitations in daily activities, and an acceptable perioperative risk profile. Advanced cardiovascular instability or severe systemic disease may limit surgical eligibility and should be considered during preoperative assessment [4,5].

Patients undergoing bilateral TKA are generally older adults and frequently present with cardiovascular comorbidities such

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as hypertension, diabetes mellitus, and coronary artery disease [6,7]. Although the cardiovascular effects of major orthopedic surgery have received increasing attention, the long-term impact of improved mobility and reduced musculoskeletal burden on cardiac function remains poorly understood.

Echocardiography is a widely used imaging modality for assessing both systolic and diastolic cardiac function. Evaluation of left ventricular diastolic function is particularly relevant in older adults because diastolic dysfunction is associated with reduced exercise capacity, greater symptom burden, and worse cardiovascular outcomes despite preserved systolic function. Current recommendations advocate an integrated assessment incorporating the E/e′ ratio, transmitral inflow (E/A) ratio, tissue Doppler-derived e′ velocity, and left atrial size [8–11].

Most previous studies investigating cardiac changes after major orthopedic surgery have focused on perioperative complications or short-term cardiovascular outcomes. In contrast, evidence regarding long-term echocardiographic changes following bilateral TKA is limited, particularly beyond the first postoperative year. Improvements in mobility, relief of chronic pain, increased physical activity, and a reduction in systemic inflammatory burden after successful TKA may influence cardiac loading conditions and diastolic function over time. However, whether these potential physiological changes are reflected in echocardiographic markers of diastolic function remains uncertain [12–17].

Accordingly, the present study aimed to evaluate longitudinal changes in left ventricular diastolic function using preoperative and long-term follow-up echocardiographic assessments in patients undergoing bilateral TKA.

Material and Methods

Population and Study Design

This retrospective cohort study included patients who underwent bilateral total knee arthroplasty (TKA) at a tertiary referral orthopedic center between 2019 and 2025. The study protocol was approved by the Antalya Training And Research Hospital Medical Research Scientific Ethics Committee (Approval No. 2026-119; Decision No. 5/14; March 5, 2026), and all procedures were conducted in accordance with the Declaration of Helsinki.

Because of the retrospective observational design, clinical trial registration was not required.

A total of 583 consecutive patients who underwent bilateral TKA were screened for eligibility. Since postoperative transthoracic echocardiography was not routinely performed as part of orthopedic follow-up, only patients with echocardiographic examinations available both before surgery and 12–18 months after surgery during routine clinical care were eligible for inclusion. These postoperative examinations were obtained for clinical indications during routine follow-up visits to various hospital departments rather than as part of a predefined prospective study protocol. After applying the eligibility criteria, 50 patients with both preoperative and long-term postoperative echocardiographic data were included in the final longitudinal analysis.

For baseline comparison, a control group of 35 patients was selected from the same screened cohort of individuals scheduled for bilateral TKA. Controls were selected based on comparable demographic characteristics, including age and sex, as well as the availability of preoperative echocardiographic examinations. Because postoperative follow-up echocardiographic data were unavailable for these individuals, the control group was used exclusively for baseline comparisons and was not included in the longitudinal analysis.

The study was designed and reported in accordance with accepted recommendations for observational research.

Exclusion Criteria

- Patients were excluded if they had any of the following:
- Clinically significant valvular heart disease
- Left ventricular systolic dysfunction (ejection fraction < 50%)
- Reduced renal function (estimated glomerular filtration rate (eGFR) < 60 mL/min/1.73 m²)
- Atrial fibrillation or persistent rhythm disturbances
- Previous major cardiac surgery
- Inadequate echocardiographic image quality

Patients without postoperative echocardiographic examinations performed 12–18 months after surgery were also excluded from the longitudinal analysis.

Echocardiographic Evaluation

All echocardiographic examinations were performed by experienced cardiologists using a Philips EPIQ 7 imaging system. Image acquisition was standardized and performed with patients in the left lateral decubitus position according to contemporary echocardiographic recommendations.

Standard two-dimensional, M-mode, and Doppler techniques were used for all echocardiographic measurements. The following parameters were assessed at baseline and follow-up:

- Left ventricular ejection fraction (LVEF), calculated using the biplane Simpson method
- Left ventricular end-diastolic and end-systolic dimensions
- Interventricular septal and posterior wall thickness
- Mitral inflow velocities (E and A)
- Septal early diastolic annular velocity (e′)
- E/e′ ratio
- Left atrial diameter

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Left ventricular diastolic function was evaluated using an integrated assessment of septal e′ velocity, the E/e′ ratio, transmitral E/A ratio, and left atrial size in accordance with current echocardiographic recommendations.

Because detailed postoperative transthoracic echocardiographic examinations were not routinely performed after bilateral TKA, follow-up studies were available only when clinically indicated during routine medical care.

Statistical Analysis

Statistical analyses were performed using R statistical software (R Foundation for Statistical Computing, Vienna, Austria).

Continuous variables are presented as mean ± standard deviation (SD) or median (interquartile range), depending on their distribution, whereas categorical variables are expressed as frequencies and percentages.

Normality was assessed using the Shapiro–Wilk test together with visual inspection of data distribution.

Within-patient comparisons between preoperative and follow-up echocardiographic measurements were performed using either the paired *t*-test or the Wilcoxon signed-rank test, as appropriate. Comparisons between the TKA and control groups were performed using the independent-samples *t*-test or the Mann–Whitney *U* test for continuous variables and the chi-square test for categorical variables, as appropriate.

To identify factors independently associated with changes in E/e′ (ΔE/e′), a multivariable linear regression model was constructed using clinically relevant demographic and echocardiographic variables. Multicollinearity was assessed by calculating variance inflation factors (VIFs).

Statistical significance was defined using a two-sided p-value <0.05.

Results

Patient Characteristics

Between 2019 and 2025, a total of 583 patients undergoing bilateral TKA were screened for eligibility. Following the application of predefined inclusion and exclusion criteria, 50 patients with both baseline and long-term postoperative transthoracic echocardiographic examinations were included in the final analysis. In all included patients, postoperative echocardiographic follow-up was performed between 12 and 18 months after surgery in accordance with the predefined study inclusion criteria.

A control cohort of 35 individuals selected from the same screened population and matched for age and sex distribution was included for baseline comparison. Baseline demographic and echocardiographic characteristics are summarized in Table 1. No statistically significant differences were observed between the groups with respect to age or sex distribution (67.35 ± 5.86 vs. 67.83 ± 5.40 years, p = 0.789).

Table 1. Baseline demographic and echocardiographic characteristics of the TKA and control groups

Variable	TKA group (n=50)	Control group (n=35)	p-value
Female sex, n (%)	27 (54.0)	15 (42.9)	0.310
Male sex, n (%)	23 (46.0)	20 (57.1)	0.310
Age (years)	67.35 ± 5.86	67.83 ± 5.40	0.789
E/A ratio	0.81 ± 0.23	0.71 ± 0.13	0.036
E/e′ ratio	12.2 ± 2.9	12.7 ± 2.3	0.058
Ejection fraction (%)	63.00 ± 2.65	62.38 ± 2.53	0.201
Interventricular septum (mm)	11.64 ± 1.14	11.43 ± 1.11	0.478
LVIDd (mm)	45.24 ± 3.59	44.90 ± 2.62	0.599
LVIDs (mm)	28.22 ± 3.69	25.88 ± 1.92	0.001
Left atrial diameter (mm)	36.38 ± 3.91	35.52 ± 2.84	0.219
Posterior wall thickness (mm)	11.13 ± 1.07	11.18 ± 0.90	0.690
Septal e′ (cm/s)	6.00 ± 1.19	5.90 ± 0.81	0.772

Values are presented as mean ± standard deviation or number (%); Continuous variables were compared using the independent samples t-test, and categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate; A p value < 0.05 was considered statistically significant; E: early diastolic transmitral flow velocity, A: late diastolic transmitral flow velocity, e′: early diastolic mitral annular velocity, E/e′: ratio of transmitral early filling velocity to mitral annular early diastolic velocity, LVIDd: left ventricular internal diameter in diastole, LVIDs: left ventricular internal diameter in systole

Preoperative Comparison

At baseline, the control group had numerically higher E/e′ values; however, the difference did not reach statistical significance (12.7 ± 2.3 vs. 12.2 ± 2.9, p = 0.058).

Left ventricular internal diameter in systole (LVIDs) was greater in the patient group compared with controls (28.22 ± 3.69 mm vs. 25.88 ± 1.92 mm, p = 0.001).

Although septal e′ velocity was numerically higher in the patient

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group, the difference was not statistically significant (6.00 ± 1.19 vs. 5.90 ± 0.81 cm/s, p = 0.772).

The E/A ratio was modestly higher in the patient group (0.81 ± 0.23 vs. 0.71 ± 0.13, p = 0.036). However, the clinical relevance of this difference should be interpreted cautiously.

There was no statistically significant difference in left ventricular ejection fraction between the two groups (63.00 ± 2.65% vs. 62.38 ± 2.53%, p = 0.201).

Longitudinal Echocardiographic Changes

During follow-up, E/e′ values decreased significantly (12.2 ± 2.9 to 11.1 ± 2.5; p < 0.001).

At the same time, septal e′ velocity increased (6.00 ± 1.19 cm/s to 6.71 ± 1.03 cm/s; p < 0.001).

The E/A ratio also increased during follow-up (0.81 ± 0.23 to 0.88 ± 0.18; p < 0.001), indicating a shift in diastolic filling indices over time.

LVIDs measurements decreased from 28.22 ± 3.69 mm to 27.31 ± 2.66 mm (p < 0.001).

No statistically significant change was observed in left ventricular ejection fraction over time (63.00 ± 2.65% vs. 63.16 ± 2.51%, p = 0.181). These longitudinal echocardiographic changes are summarized in Table 2.

Table 2. Within-patient changes in echocardiographic parameters from preoperative assessment to 12–18-month follow-up in the TKA group (n = 50)

Parameter	Preoperative	Follow-up	p-value
E/e′ ratio	12.2 ± 2.9	11.1 ± 2.5	< 0.001
Septal e′ (cm/s)	6.00 ± 1.19	6.71 ± 1.03	< 0.001
E/A ratio	0.81 ± 0.23	0.88 ± 0.18	< 0.001
LVIDs (mm)	28.22 ± 3.69	27.31 ± 2.66	< 0.001
Interventricular septum (mm)	11.64 ± 1.14	11.45 ± 1.02	0.005
Ejection fraction (%)	63.00 ± 2.65	63.16 ± 2.51	0.181

Values are presented as mean ± standard deviation; Preoperative and follow-up measurements were compared using paired samples t-tests; A p value < 0.05 was considered statistically significant; E: early diastolic transmitral flow velocity, A: late diastolic transmitral flow velocity, e′: early diastolic mitral annular velocity, LVIDs: left ventricular internal diameter in systole

Figure 1 illustrates individual longitudinal trajectories in E/e′ values, demonstrating variability across patients while showing an overall directional change at the group level.

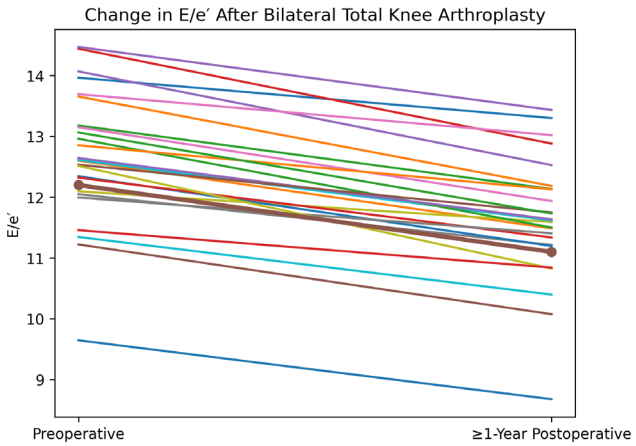

Figure 1. Longitudinal changes in E/e′ following bilateral total knee arthroplasty; For visualization purposes, a representative subgroup of 25 patients is presented; Preoperative and 12–18-month follow-up E/e′ values are shown; Within-subject changes are illustrated by connecting lines, whereas mean values with corresponding 95% confidence intervals are displayed as overlay markers

Baseline E/e′ and Longitudinal Change

Baseline E/e′ values were significantly associated with the magnitude of change observed during follow-up. Higher baseline values corresponded to greater reductions over time ($R^2 = 0.525$, p < 0.001) as illustrated in Figure 2 before the period.

After adjustment for clinically relevant demographic and echocardiographic covariates, baseline E/e′ remained independently associated with longitudinal changes in diastolic indices (p < 0.05).

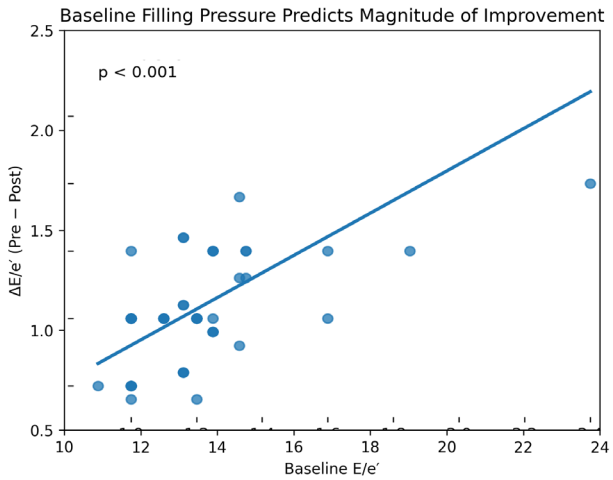

Figure 2. Association between baseline E/e′ values and longitudinal change following bilateral total knee arthroplasty; Graphical representation of the relationship between baseline E/e′ values and subsequent change (ΔE/e′) during follow-up; The fitted regression line and corresponding 95% confidence interval are shown

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Discussion

In the present study, favorable longitudinal changes were observed in selected echocardiographic markers of left ventricular diastolic function among patients with available long-term follow-up after bilateral TKA. Specifically, the E/e′ ratio decreased while septal e′ velocity increased during follow-up, whereas left ventricular systolic function remained unchanged.

Because E/e′ is closely associated with invasive measures of left ventricular filling pressure, it is widely used as a non-invasive marker of diastolic function [11,18]. In our cohort, the observed reduction in E/e′ may indicate lower left ventricular filling pressures over time. However, given the retrospective design and the absence of serial echocardiographic follow-up in the control group, these findings should be interpreted cautiously and should not be considered evidence of a causal relationship.

Left ventricular diastolic function is influenced by multiple systemic factors, including inflammatory activity, neurohumoral regulation, functional capacity, and hemodynamic status. Previous research has demonstrated improvements in functional capacity accompanied by favorable changes in echocardiographic indices of diastolic function following TKA [19]. Previous studies have shown that systemic inflammation may adversely affect diastolic function, leading to higher E/e′ values and lower e′ velocities [20]. Therefore, the longitudinal changes observed in our cohort may reflect improved mobility, reduced chronic pain, attenuation of systemic inflammation, and favorable circulatory adaptation following successful orthopedic intervention. Nevertheless, these mechanisms remain speculative because they were not directly evaluated in the present study.

The increase in septal e′ velocity during follow-up may suggest an improvement in myocardial relaxation. However, although statistically significant, the magnitude and clinical relevance of this change should be interpreted with caution, particularly in view of potential measurement variability and the absence of direct functional outcome assessment [21,22].

Similarly, the increase in the E/A ratio may reflect changes in diastolic filling characteristics over time. Because this parameter is influenced by both age and loading conditions, interpretation of the E/A ratio in isolation may be misleading. Accordingly, E/A should be interpreted together with the E/e′ ratio and septal e′ velocity rather than as an independent indicator of diastolic function [11].

Left ventricular systolic function remained stable throughout follow-up. The lack of significant changes in left ventricular ejection fraction suggests that the observed echocardiographic alterations were confined primarily to diastolic rather than systolic function [23,24].

Baseline E/e′ emerged as an independent predictor of longitudinal change. Patients with higher baseline E/e′ values experienced greater reductions during follow-up, suggesting that the initial degree of diastolic dysfunction may influence the magnitude of subsequent improvement. Similar findings have been reported in studies of exercise-based interventions and cardiovascular rehabilitation, where baseline physiological status has been associated with the extent of treatment response [25,26].

Overall, our findings suggest an association between bilateral TKA and favorable longitudinal changes in selected echocardiographic markers of diastolic function among patients with available long-term follow-up. However, because of the retrospective observational design, the selected study population, and the lack of longitudinal control data, these results should be regarded as hypothesis-generating rather than as definitive evidence of cardiovascular benefit. Prospective studies with standardized echocardiographic follow-up are needed to confirm these findings and further clarify their clinical significance.

Limitations

Several limitations should be considered when interpreting the findings of this study. First, because of the retrospective observational design, causal relationships cannot be established. Although the availability of both baseline and long-term postoperative echocardiographic examinations enabled longitudinal within-patient assessment, the observed associations should not be interpreted as definitive evidence of a treatment effect.

Second, postoperative echocardiographic examinations were not performed according to a predefined prospective protocol and were available only for a subset of patients who returned for routine clinical care after surgery. Consequently, selection bias cannot be excluded, and the study population may not be fully representative of all patients undergoing bilateral TKA.

The single-center design may also limit the generalizability of our findings. However, it may have contributed to greater consistency in surgical technique, perioperative management, and echocardiographic assessment.

Diastolic function was evaluated exclusively using non-invasive echocardiographic parameters. Although indices such as the E/e′ ratio and septal e′ velocity correlate well with left ventricular filling pressures, direct invasive hemodynamic measurements were not available.

In addition, the control group was included solely for baseline comparison because longitudinal postoperative echocardiographic follow-up was unavailable. As a result, it remains uncertain to what extent the observed echocardiographic changes were related to surgery rather than to aging, natural temporal variation, or changes in medical management.

Potential confounding factors that may influence cardiac function—including physical activity, adherence to rehabilitation, pain relief, changes in body weight, and modifications in medical therapy—were not quantitatively evaluated and may have affected the observed findings.

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Finally, although the sample size was adequate for longitudinal within-patient analyses, it may have limited the ability to perform more detailed subgroup analyses. Larger prospective multicenter studies with standardized echocardiographic follow-up are warranted to validate these findings and better define their clinical implications.

Conclusion

Among patients with available long-term echocardiographic follow-up after bilateral TKA, favorable longitudinal changes were observed in selected echocardiographic markers of left ventricular diastolic function. Specifically, the E/e′ ratio decreased and septal e′ velocity increased during follow-up, while left ventricular systolic function remained unchanged.

These changes may indicate favorable adaptations in left ventricular diastolic filling during long-term follow-up. However, given the retrospective observational design, the selected study population, and the absence of longitudinal control data, the findings should be interpreted with caution and should not be considered definitive evidence of a causal cardiovascular benefit of bilateral TKA.

Further prospective multicenter studies with standardized postoperative echocardiographic follow-up are needed to confirm these findings, elucidate the underlying mechanisms, and determine their clinical significance.

Ethical Approval

The study protocol was approved by the Antalya Training And Research Hospital Medical Research Scientific Ethics Committee (Approval No: 2026-119, Decision No: 5/14, dated 05 March 2026). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent

The requirement for informed consent was waived by the Ethics Committee due to the retrospective nature of the study.

Conflict of Interest

The authors confirm the absence of any conflicts associated with this work.

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