Effect of Concomitant Tricuspid Valve Surgery With Left Ventricular Assist Device Implantation

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Background. **Tricuspid regurgitation (TR) is common in advanced heart failure (HF) patients. However, the effect of concomitant tricuspid valve repair or replacement (tricuspid valve intervention [TVI]) with left ventricular assist device (LVAD) implantation is controversial. The aim of this study was to investigate the longitudinal trend of TR after LVAD implantation and the effect of TVI on the TR trend and clinical outcomes.**

Methods. **We retrospectively reviewed patients at our institution who underwent LVAD implantation between April 2014 and August 2018. We evaluated the grade of TR by echocardiography before and after LVAD implantation. Moderate or greater TR was defined as significant.**

Results. **Among 199 consecutive patients, 194 had at least 2 echocardiographic TR assessments before and after LVAD implantation. Of these patients, 108 were included in the TVI-positive (TVI+) group and 86 in the TVI-negative (TVI–) group. In the TVI+ group, the prevalence of significant TR decreased from 52% to about 20% in the first 6 months after implantation ($P < .01$). Overall survival and HF readmission–free survival were comparable between the TVI+ and TVI– patients. In contrast, patients in both groups who had significant postoperative TR during early follow-up had worse 2-year HF readmission–free survival (36% in patients with significant postoperative TR vs 55% in those without significant postoperative TR; $P = .028$).**

Conclusions. **Concomitant TVI with LVAD implantation improved TR in most patients but did not have an impact on clinical outcomes. Significant postoperative TR after LVAD implantation, in patients with and without TVI, was associated with worse HF-free outcomes.**

(Ann Thorac Surg 2020;■:■-■)

Advanced heart failure (HF) patients frequently suffer from biventricular failure associated with dilation of both the left ventricle (LV) and right ventricle (RV). Dilation of the RV leads to tricuspid annular dilation, incomplete leaflet coaptation, and resultant tricuspid regurgitation (TR). Between 30% and 64% of patients with advanced HF have TR, which contributes to further RV failure caused by volume overload.[1,2]

Continuous-flow LV assist devices (LVADs) have become a mainstay of therapy for advanced HF patients, both as a bridge to transplantation and destination therapy.[3,4] The effect of LVADs on RV function and TR is complex. In some cases, LVADs improve RV function and TR through a reduction of LV filling pressures and RV afterload. However, the RV can be adversely affected by perioperative factors, such as volume resuscitation, hypoxia, and hypotension, leading to postoperative RV failure. Furthermore, leftward shifting of the interventricular septum because of suction may lead to tricuspid annular dilatation and reduced coaptation of the tricuspid valve (TV). RV failure

Dr Jeevanandam discloses a financial relationship with Abbott; Dr Burkhoff with Cardiac Implants LLC; and Dr Sayer with Medtronic.

The Supplemental Tables and Supplemental Figures can be viewed in the online version of this article [http://doi,org/10.1016/j.athoracsur.2019.12.047] on http://www.annalsthoracicsurgery.org.

Accepted for publication Dec 17, 2019.

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Published by Elsevier Inc.

0003-4975/$36.00
https://doi.org/10.1016/j.athoracsur.2019.12.047

can occur both early and late after implantation and is associated with worse clinical outcomes.[5-9]

Although previous studies have investigated the benefit of concomitant TV repair or replacement (TV intervention [TVI]) during LVAD implantation, the impact on outcomes remains controversial. Furthermore, the longitudinal trend of TR after LVAD implantation and the effect of TVI on that trend is unknown.[1,10-12] Additionally, there are scarce data regarding the impact of postoperative TR after LVAD implantation on clinical outcomes. The aim of this study was to investigate the longitudinal trend of TR after LVAD implantation and the effect of TVI on the TR development and progression, along with clinical outcomes.

Patients and Methods

Patient Selection

We retrospectively reviewed electronic medical records of patients who had undergone LVAD implantation at our institution between April 2014 and August 2018. Of these, we enrolled patients who had undergone TR grading by echocardiography before and after LVAD implantation. The study protocol was approved by the institutional review board at the University of Chicago.

TV Surgery

The decision to perform TVI at the time of LVAD implantation incorporated multiple pieces of data, including clinical presentation, hemodynamics, TR on preoperative transthoracic echocardiography, and TR on intraoperative transesophageal echocardiography. Therefore, TVI was performed in some patients who had less than moderate TR on their preoperative echocardiography. The choice of TVI (ring annuloplasty, DeVega annuloplasty, or TV replacement) was dependent on the individual surgeons' discretion. The ring size was determined depending on the length of the septal leaflet annulus and the size of the anterior leaflet.

Variables Evaluated

Preoperative demographic and echocardiographic data were collected. Additionally, we obtained perioperative data and all postoperative echocardiographic data. TR severity just after LVAD implantation was assessed by intraoperative transesophageal echocardiography. TR severity was assessed by color Doppler flow of the regurgitant jet within the right atrium and reviewed by independent experts who were blinded to the clinical outcomes. TR severity was graded as follows: 0 = none, 1 = mild, 2 = moderate, and 3 = severe, according to the American Society of Echocardiography guidelines.[13] We defined moderate or greater TR as significant TR. To describe the prevalence of TR, we divided the postimplant course into the following time periods: 0 to 1 month, 1 to 6 months, 6 to 12 months, 1 to 2 years, and greater than 2 years. If there were 2 or more tests in each period, we chose the most severe grade of TR. We defined the significant postoperative TR as the presence of moderate or greater TR on any echocardiography during the first 6 months postimplant. The dimensions of LV were measured in the standard manner.[14] Tricuspid annular plane systolic excursion was measured in an apical 4-channel view by placing the cursor at the tricuspid lateral annulus and measuring the vertical height between the peak and trough in a single cardiac cycle. The RV end-diastolic and end-systolic areas were measured by planimetry, tracing the endocardial outline of the RV and the plane of the TV. RV fractional area change was calculated as the following: (RV end-diastolic area – RV end-systolic area) / (RV end-diastolic area) × 100. Lateral tricuspid annular systolic motion velocity was measured by the peak systolic tissue Doppler velocity of the tricuspid annulus.

Clinical Outcomes

All patients were followed until November 2018. Follow-up was ceased at death, heart transplantation, pump exchange, or pump removal. Patients with heart transplantation, pump exchange, or pump removal were censored in the alive state. HF readmissions and all-cause death were recorded during the observational period.

Statistical Analyses

Continuous variables were presented as median (interquartile range [IQR]) and compared between the groups using the unpaired *t* test or Mann-Whitney *U* test, as appropriate. Categorical variables were compared between groups using the chi-square test or Fisher's exact test, as appropriate. The prevalence of significant TR in each period was compared using the McNemar's test. Clinical outcomes were assessed using Kaplan-Meier analysis and compared by the log-rank test. To investigate the significance of TVI and postoperative TR on HF readmission–free survival, we performed multivariate Cox proportional hazards regression analyses. Multivariate models were created to adjust demographic factors (age, sex, and race) and preoperative valvular regurgitation (mitral and tricuspid). Statistical analysis was performed using SPSS Statistics 23 (IBM Corporation, Armonk, NY). A 2-tailed *P* value less than .05 was considered significant.

Results

Among 199 consecutive LVAD patients in the study period, we enrolled 194 patients who had at least 1 echocardiographic TR grading after LVAD implantation. Of these, 108 (56%) patients underwent concomitant TVI with LVAD implantation (TVI positive [TVI+]) and 86 did not (TVI negative [TVI–]). Baseline characteristics of the 2 groups are shown in Table 1. Median age was 57 (IQR, 47-67) years in the TVI+ group and 61 (IQR, 52-68) years in the TVI– group ($P = .031$). Sex, race, ischemic etiology, indication for LVADs, and the presence of a transvenous implantable cardioverter-defibrillator (ICD) were comparable between the groups. LV end-diastolic diameter was larger ($P = .047$) and RV fractional area change was lower ($P = .035$) in the TVI+ group. The prevalence of significant mitral regurgitation and TR was significantly higher in the TVI+ group ($P < .001$). Concomitant mitral

Table 1. Demographics of Patients With or Without TVI

Variable	TVI+ Group (n = 108)	TVI– Group (n = 86)	*P* Value
Age at implant, y	57 (47-67)	61 (52-68)	.031
Male	73 (68)	60 (70)	.746
Race/ethnicity			.660
African American	56 (52)	38 (44)	
White	42 (39)	41 (48)	
Hispanic	5 (5)	3 (3)	
Others	5 (5)	4 (5)	
Ischemic etiology	34 (31)	31 (36)	.503
Destination therapy	82 (76)	66 (77)	.894
Diabetes mellitus	39 (36)	37 (43)	.327
Atrial fibrillation	52 (48)	31 (36)	.091
History of stroke	16 (15)	16 (19)	.480
Transvenous ICD	86 (80)	72 (84)	.466
Body surface area, m^2	2.0 (1.8-2.1)	2.0 (1.8-2.2)	.281
LVEDD, mm	72 (64-77)	68 (62-76)	.047
LVEF, %	18 (15-24)	22 (16-26)	.048
TAPSE, mm	13 (10-16)	13 (10-16)	.908
RVFAC, %	23 (18-30)	26 (19-33)	.035
TV-S′, cm/s	9 (8-11)	10 (8-11)	.486
Significant MR	61 (56)	26 (30)	<.001
Significant TR	56 (52)	16 (19)	<.001
Type of TVI procedure			…
Annuloplasty (ring)	40 (37)	…	
Annuloplasty (DeVega)	67 (62)	…	
Replacement	1 (1)	…	
Other concomitant procedures			
Aortic valve surgery	13 (12)	15 (17)	.287
Mitral valve surgery	81 (75)	18 (21)	<.001
Coronary artery bypass grafting	4 (4)	6 (7)	.242

Values are median (interquartile range) or n (%).

ICD, implantable cardioverter-defibrillator; LVEDD, left ventricular end-diastolic diameter; LVEF, left ventricular ejection fraction; MR, mitral regurgitation; RVFAC, right ventricular fractional area change; TAPSE, tricuspid annular plane systolic excursion; TR, tricuspid regurgitation; TV-S′, lateral tricuspid annular systolic motion velocity; TVI, tricuspid valve intervention; TVI+, tricuspid valve intervention positive; TVI–, tricuspid valve intervention negative.

valve surgery was performed in 81 (75%) patients in the TVI+ group, compared with 18 (21%) in the TVI– group ($P < .001$). Among the TVI+ group, 40 (37%) patients underwent ring annuloplasty, 67 (62%) underwent DeVega annuloplasty, and 1 (1%) received a bioprosthetic TV. The follow-up period during LVAD therapy was 402 (IQR, 159-756) days in the TVI+ group and 415 (IQR, 205-876) days in the TVI– group ($P = .528$), and the number of TR assessments during the period was 5 (IQR, 3-8) in the TVI+ group and 6 (IQR, 3-9) in the TVI– group ($P = .489$).

Perioperative Effects of TVI

Table 2 shows the comparison of short-term effects of concomitant TVI with LVAD implantation. Cardiopulmonary bypass time was significantly longer in the TVI+ group (195 [IQR, 173-222] minutes vs 138 [IQR, 98-183] minutes; $P < .001$); however, the dose of red blood cell transfusion, the ratio of postoperative RV assist device use, and length of hospital stay were comparable between the groups.

Longitudinal Trend of TR

In the TVI+ group, TR grade decreased early after LVAD implantation from 2 (IQR, 1-2) to 1 (IQR, 1-1) ($P < .001$). In the TVI– group, preoperative TR grade was low and decreased slightly further with LVAD implantation from 1 (IQR, 1-1) to 1 (IQR, 1-1) ($P = .039$).

Figure 1 shows the prevalence of significant TR in each time period. The prevalence of significant TR decreased immediately in the TVI+ group; however, 17% and 18% of them had significant postoperative TR in 0 to 1 month and 1 to 6 months after LVAD implantation, respectively. The prevalence of significant TR remained less than 30% during the entire follow-up period. The prevalence of significant TR in the TVI– group was about 20% throughout the course. The rate of freedom from significant TR after LVAD implantation was similar between the groups ($P = .545$) (Figure 2). Freedom from significant TR was slightly lower in patients with DeVega annuloplasty compared with ring annuloplasty, which was not statistically significant ($P = .300$) (Supplemental Figure 1).

Comparison of Clinical Outcomes

Two-year survival was the same between the groups (71% in the TVI+ group vs 75% in the TVI– group; $P = .566$) (Figure 3A). There was also no difference in 2-year HF readmission–free survival between the groups (55% vs 43%; $P = .537$) (Figure 3B). We also compared clinical outcomes of patients with and without significant preoperative TR. Baseline characteristics of these groups are shown in Supplemental Table 1. Frequency of significant preoperative mitral regurgitation, mitral valve surgery, and TVI were significantly higher in patients with significant preoperative TR. Cardiopulmonary bypass time was also significantly longer in these patients. Two-year overall survival and HF readmission–free survival were statistically comparable between the groups (Supplemental Figure 2).

Postoperative TR After LVAD Implantation

Among 194 patients in our cohort, we excluded 2 patients who did not have echocardiographic TR grading in the first 6 months postimplant. Of 192 patients, 46 (24%) had significant TR in the first 6 months postimplant. Baseline characteristics, perioperative data, and echocardiographic parameters for patients with and without significant postoperative TR are shown in Table 3. Among patients with significant postoperative TR, 25 (54%) had received a concomitant TVI while 19 (46%) had not. In patients who had undergone ring annuloplasty, the size of the annuloplasty ring was 28 (IQR, 28-30) mm in patients with significant postoperative TR and 28 (IQR, 28-30) mm in patients

Table 2. Short-Term Effect of TVI

Variable	TVI+ Group (n = 108)	TVI– Group (n = 86)	*P* Value
CPB time, min	195 (173-222)	138 (98-183)	<.001
PRBCs transfusion, units	0 (0-3)	0 (0-2)	.984
Postoperative RVAD use	11 (10)	9 (10)	.949
Length of hospital stay, d	22 (17-28)	19 (15-29)	.162

Values are median (interquartile range) or n (%).

CPB, cardiopulmonary bypass; PRBCs, packed red blood cells; RVAD, right ventricular assist device; TVI, tricuspid valve intervention; TVI+, tricuspid valve intervention positive; TVI–, tricuspid valve intervention negative.

without significant postoperative TR ($P = .883$). Only 50% of patients with significant postoperative TR were men as compared with 74% of patients without significant postoperative TR ($P = .002$). In patients with significant postoperative TR, there was a numerical increase in the number of African Americans that did not reach statistical significance ($P = .067$). The frequency of a transvenous ICD was significantly higher in patients with significant postoperative TR. Other demographic characteristics and perioperative data were similar between the 2 groups. Patients with significant postoperative TR were more likely to have had significant preoperative TR than were those without significant postoperative TR (61% vs 29%; $P < .001$). Other echocardiographic characteristics were similar between the groups.

Postoperative TR and Clinical Outcomes

Survival at 2 years was similar between the patients with and without significant postoperative TR (65% vs 76%; $P = .363$) (Figure 4A). However, patients with significant postoperative TR had worse HF readmission–free survival at 2 years (36% vs 55%; $P = .028$) (Figure 4B). Moreover, among the 106 patients in the TVI+ group (Supplemental Table 2), those with significant postoperative TR had a numerically worse 2-year survival (49% vs 78%; $P = .068$) (Supplemental Figure 3A) and significantly worse 2-year survival free of HF readmissions (28% vs 64%; $P = .009$) (Supplemental Figure 3B). Multivariate analysis showed that significant postoperative TR was associated with worse HF readmission–free survival after adjustment with demographic factors (preoperative valvular regurgitation [hazard ratio, 1.74; 95% confidence interval, 1.03-2.95; $P = .040$]) (Table 4). Concomitant TVI was not a significant predictor of HF readmission–free survival.

Comment

In the current study, we investigated the effect of TVI on the TR trend and clinical outcomes. The main findings of the study are as follows: (1) concomitant TVI decreased the severity of TR significantly after LVAD implantation, but TR also decreased significantly in the group without TVI; (2) approximately 20% of patients who underwent TVI continued to have significant TR after LVAD implantation; (3) TVI had no impact on clinical outcomes; and (4) significant postoperative TR was associated with decreased survival free of HF readmissions, regardless of whether patients had received concomitant TVI.

Longitudinal Trend of TR After LVAD Implantation

The prevalence of TR at baseline in our study is similar to reported rates in the advanced HF population.[1,2] The effect of TVI on long-term rates of TR in LVAD patients has previously been reported for a cohort predominantly implanted with extracorporeal pulsatile LVADs.[15] Our study included only patients with continuous-flow LVADs and showed that the overall degree of TR decreased with TVI, but moderate or greater TR persisted in a significant minority of the population. Similarly, the TR-free rate rapidly decreased to 70% within the first 6 months even in the TVI+ group.

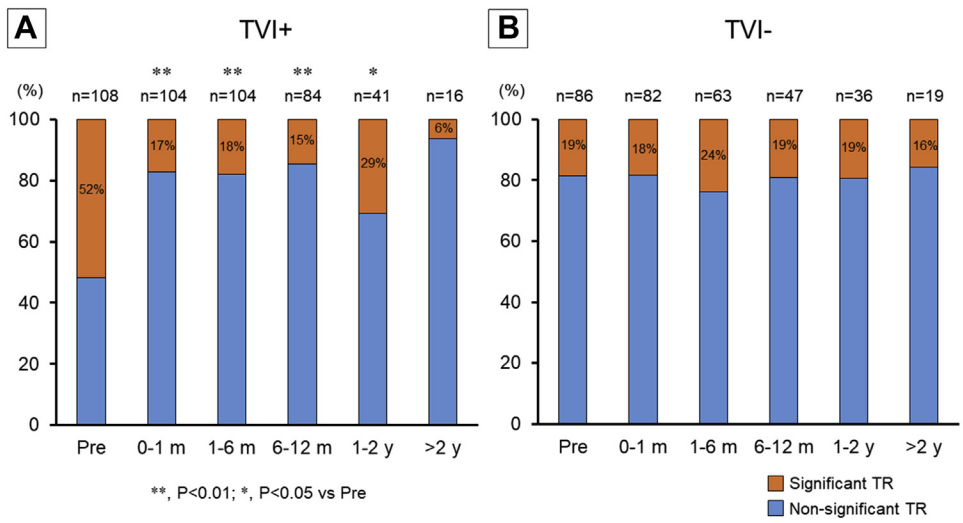

*Figure 1. The prevalence of significant tricuspid regurgitation (TR) in each period. The prevalence of significant TR patients in the tricuspid valve intervention–positive (TVI+) and TVI-negative (TVI–) groups is shown. *P < .05 vs Pre; **P < .01 vs Pre.*

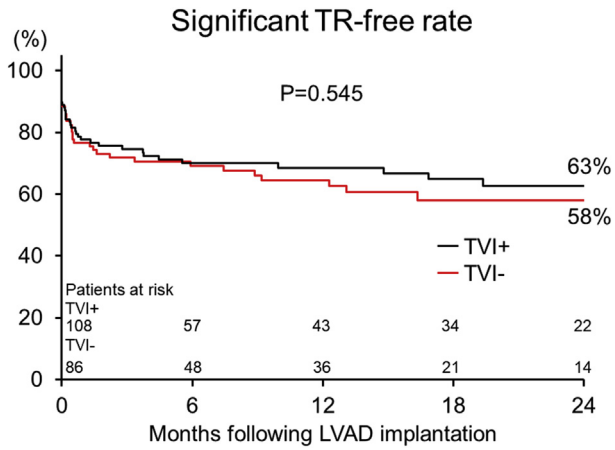

Figure 2. Significant tricuspid regurgitation (TR)–free rate after left ventricular assist device (LVAD) implantation. A significant TR-free rate in the tricuspid valve intervention–positive (TVI+) and TVI-negative (TVI–) groups is shown.

The reason why TVI failed in such a high rate still needs to be investigated. A similar pattern has also been seen in the non-LVAD population who underwent TV surgery. One study reported that among patients who underwent concomitant TVI during left-sided valve surgery, 34% had moderate or greater TR at 3 months after surgery.[16] The authors speculated that the high rate of residual TR was partly due to the inability to address underlying anatomic factors contributing to TR.[16] In other words, repairing the TV does not arrest or reverse the underlying process driving residual TR in many patients. This limitation of TVI may be greater in LVAD patients because of the severity of underlying myocardial disease and additional stresses applied to TV morphology as a result of septal shifting. Furthermore, most of the patients with advanced HF have a transvenous ICD, which can impinge upon TV leaflets, and may represent another factor that leads to postoperative TR. These additional factors must be considered when deciding whether to proceed with TVI at the time of LVAD implantation. Further investigation should focus on the use of imaging techniques, such as 3-dimensional echocardiography, to identify the etiology of TR and features of both RV and TV anatomy that may predispose patients to having persistent TR despite TVI.[9] In addition, a better understanding of underlying RV contractility, and its potential response to different loading conditions, could provide more data to identify which patients will benefit from concomitant TVI.

Clinical Outcomes

Despite the fact that many studies have investigated the benefit of concomitant TVI at the time of LVAD implantation, the topic remains controversial.[1,10-12] A recent meta-analysis concluded that both short-term and long-term clinical outcomes were comparable between the LVAD+TVI patients and the isolated LVAD patients.[17] All studies in this field have been observational, and so it has been difficult to compare the outcomes. In the absence of randomized data, it is unknown if the equivalence of outcomes is actually reflecting a benefit of TVI. Confirming the previous data, TVI did not improve clinical outcomes in our study, despite reducing the prevalence and severity of TR postoperatively.

A previous study found that residual TR 1 year after LVAD implantation was associated with worse survival.[18] However, this report only included patients without concomitant TVI. In our study, we demonstrated that significant postoperative TR was not associated with overall survival but was related to worse HF readmission–free survival. This finding applied to patients in the TVI+ group as well. As discussed previously, the persistence of TR in the LVAD population may reflect an increased severity of underlying myocardial disease, which explains its association with adverse clinical outcomes.[8,9] Our data suggest the importance of future studies in predicting the patients who will have significant postoperative TR. Furthermore, it may be also important to decrease postoperative TR with several postoperative interventions,

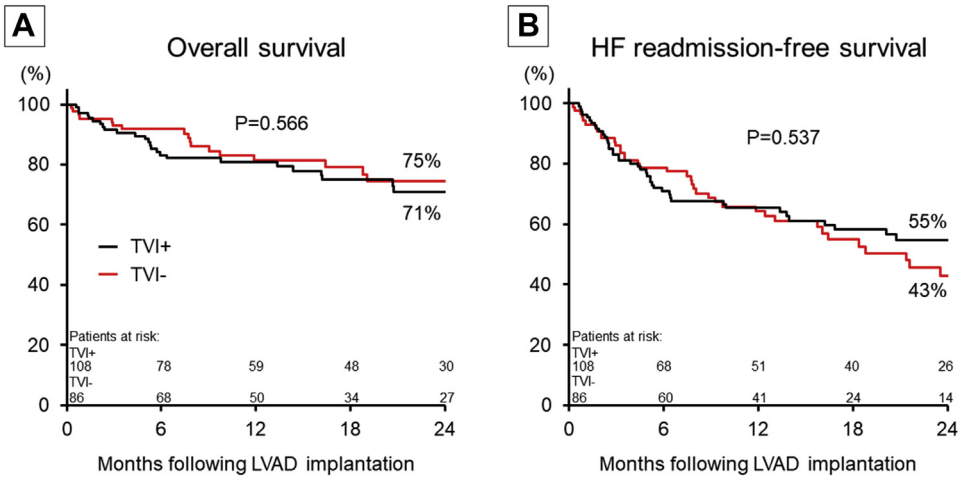

Figure 3. Comparison of clinical outcomes in the tricuspid valve intervention–positive (TVI+) and TVI-negative (TVI–) groups. (A) Overall survival and (B) heart failure (HF) readmission–free survival of the TVI+ and TVI– groups. (LVAD, left ventricular assist device.)

Table 3. Demographics of Patients With or Without Significant Postoperative TR

Variable	TR+ Group (n = 46)	TR– Group (n = 146)	*P* Value
Age at implant, y	61 (48-69)	58 (49-66)	.690
Male	23 (50)	108 (74)	.002
Race/ethnicity			.067
African American	29 (63)	65 (45)	
White	12 (26)	70 (48)	
Hispanic	2 (4)	6 (4)	
Others	3 (7)	5 (3)	
Ischemic etiology	12 (26)	51 (35)	.265
Destination therapy	35 (76)	112 (77)	.930
Diabetes mellitus	14 (30)	62 (42)	.146
Atrial fibrillation	22 (48)	61 (42)	.470
History of stroke	11 (24)	21 (14)	.130
Transvenous ICD	44 (96)	112 (77)	.005
Body surface area, m^2	1.9 (1.7-2.1)	2.0 (1.9-2.2)	.039
LVEDD, mm	70 (63-74)	71 (63-77)	.374
LVEF, %	21 (16-26)	20 (15-25)	.329
TAPSE, mm	14 (11-17)	13 (10-16)	.107
RVFAC, %	24 (18-32)	24 (18-31)	.370
TV-S′, cm/s	9.4 (8.3-11.3)	9.5 (8.2-11.1)	.815
Significant preoperative MR	25 (54)	61 (42)	.135
Significant preoperative TR	28 (61)	43 (29)	<.001
Concomitant procedures			
TVI	25 (54)	81 (55)	.893
Aortic valve surgery	9 (20)	19 (13)	.272
Mitral valve surgery	25 (54)	74 (51)	.665
Coronary artery bypass grafting	2 (4)	8 (5)	.556
CPB time, min	178 (137-208)	178 (135-209)	.801

Values are median (interquartile range) or n (%).

CPB, cardiopulmonary bypass; ICD, implantable cardioverter-defibrillator; LVEDD, left ventricular end-diastolic diameter; LVEF, left ventricular ejection fraction; MR, mitral regurgitation; RVFAC, right ventricular fractional area change; TAPSE, tricuspid annular plane systolic excursion; TR, tricuspid regurgitation; TR+, tricuspid regurgitation positive; TR–, tricuspid regurgitation negative; TV-S′, lateral tricuspid annular systolic motion velocity; TVI, tricuspid valve intervention.

such as pump speed optimization and aggressive medical therapy to augment diuresis and enhance myocardial recovery, and in the future, percutaneous TVI in the catheterization laboratory.

Study Limitations

First, as a retrospective, nonrandomized study, background characteristics are significantly different between the groups. In particular, the TVI+ group had more TR (as expected) and more mitral regurgitation, and therefore was likely to contain patients with a more advanced disease process. These differences restrict our ability to compare outcomes between the 2 groups and the findings regarding TVI should be viewed as hypothesis-generating. Owing to the limited number of patients, it was not possible to perform propensity score–matching analyses to reduce the bias. However, multivariate analyses revealed that significant postoperative TR, but not TVI, was a significant predictor of HF outcome, after adjustment with baseline characteristics. Second, we had very few patients with significant preoperative TR who did not undergo concomitant TVI; therefore, we are unable to make direct conclusions about the benefit of TVI. Our results demonstrate that concomitant TVI effectively decreased the frequency of significant postoperative TR, which was related to worse HF outcome; therefore, concomitant TVI for patients with significant preoperative TR is a reasonable strategy. However, we should emphasize that about 20% of patients had postoperative TR even after TVI, indicating the importance of future studies to investigate the etiology of postoperative TR and identify specific patients who will benefit from TVI. Third, the decision to proceed with TVI was impacted by multiple factors and was ultimately at the discretion of individual surgeons, which may have impacted the results. The main reason that patients without significant preoperative TR underwent TVI was the presence of moderate or greater TR on intraoperative transesophageal echocardiography. Fourth, follow-up duration was short in this study, and further studies with longer follow-up duration are warranted. Last, the timing of echocardiographic TR grading after LVAD implantation was

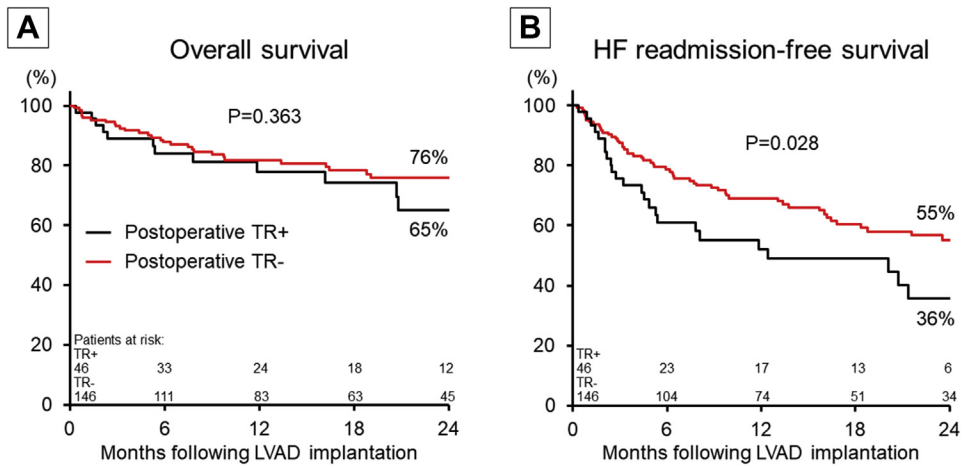

Figure 4. Comparison of clinical outcomes in patients with and without significant postoperative tricuspid regurgitation (TR). (A) Overall survival and (B) heart failure (HF) readmission–free survival in patients with and without significant postoperative TR. (LVAD, left ventricular assist device; TR+, tricuspid regurgitation positive; TR–, tricuspid regurgitation negative.)

Table 4. Multivariate Cox Proportional Hazards Regression Analyses for HF Outcome

	Model 1 (Postoperative TR)		Model 2 (TVI)	
Variable	HR (95% CI)	*P* Value	HR (95% CI)	*P* Value
Median age >58 y	1.329 (0.827-2.133)	.240	1.277 (0.801-2.036)	.304
Male	1.166 (0.696-1.952)	.559	1.082 (0.655-1.785)	.759
African American	0.876 (0.538-1.425)	.593	0.911 (0.566-1.464)	.699
Significant preoperative MR	1.211 (0.758-1.936)	.423	1.334 (0.832-2.139)	.231
Significant preoperative TR	1.209 (0.745-1.961)	.442	1.469 (0.898-2.405)	.126
Concomitant TVI	…	…	0.714 (0.438-1.165)	.177
Significant postoperative TR	1.739 (1.026-2.949)	.040	…	…

CI, confidence interval; HF, heart failure; HR, hazard ratio; MR, mitral regurgitation; TR, tricuspid regurgitation; TVI, tricuspid valve intervention.

variable. Therefore, the clinical course of each patient might affect the timing and number of tests.

Conclusion

Concomitant TVI during LVAD implantation decreased the prevalence of significant TR but did not improve clinical outcomes. The presence of significant postoperative TR after LVAD implantation was associated with decreased HF-free survival, but significant preoperative TR did not impact HF-free survival.

Dr Fujino receives financial support from MSD Life Support Foundation, Public Interest Incorporated Foundation, and The Mochida Memorial Foundation for Medical and Pharmaceutical Research. Dr Uriel receives grant support from Abbott and Medtronic.

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