Outcomes of isolated tricuspid replacement versus repair among older patients with tricuspid regurgitation in the United States

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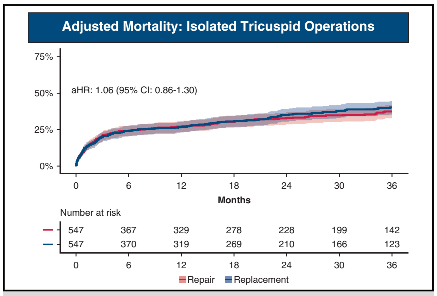
ABSTRACT

Objective: Evidence is limited regarding early-term outcomes after isolated tricuspid operations for tricuspid regurgitation (TR). We compared the early-term outcomes after isolated tricuspid valve replacement versus repair using the contemporary data.

Methods: We analyzed the national data on Medicare beneficiaries aged ≥65 years who underwent isolated tricuspid valve replacement or repair for TR between January 2016 and December 2020. The primary outcome was early-term (up to 3 years) all-cause mortality. The secondary outcomes included early-term major adverse cardiovascular events (MACE) and heart failure hospitalizations. MACE encompassed all-cause mortality, heart failure hospitalization, stroke, and tricuspid reoperations. A propensity score matching analysis was conducted to compare between replacement and repair.

Results: A total of 1501 patients were included (replacement: 610 patients, repair: 891 patients). In the matched cohort (n = 547 in each group), the overall mortality and MACE were 39% and 46% at 3 years, respectively. Tricuspid valve replacement was associated with similar all-cause mortality in comparison to repair (adjusted hazard ratio [HR], 1.06; 95% confidence interval [CI], 0.86-1.30; *P* = .600). Similarly, the rates of MACE and heart failure hospitalizations were similar (adjusted HR, 1.01; 95% CI, 0.84-1.22, *P* = .910; subdistribution HR, 1.04; 95% CI, 0.72-1.49, *P* = .850, respectively) between these 2 procedures.

Conclusions: Isolated surgical tricuspid valve replacement was associated with similar clinical outcomes compared to repair. Importantly, the high overall early-term mortality and morbidity with either treatment underscores the need for alternative intervention choices and further research to optimize the indication and timing of intervention. (JTCVS Open 2025;24:127-46)



Isolated tricuspid repair and replacement were associated with similar midterm mortality.

CENTRAL MESSAGE

This study presents a nationwide comparative analysis of early-term outcomes in patients undergoing isolated tricuspid valve replacement versus repair.

PERSPECTIVE

Currently, there are no available nationwide midterm data for isolated tricuspid valve repair and replacement. Our analysis of Medicare beneficiary data provides a comparative assessment of midterm mortality and morbidity between the 2 surgical techniques. Notably, our findings also underscore the elevated in-hospital and midterm mortality rates associated with both isolated tricuspid procedure.

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Abbreviations and Acronyms

aHR = adjusted hazard ratio
CI = confidence interval
MACE = major adverse cardiovascular events
TR = tricuspid regurgitation

Moderate-to-severe tricuspid regurgitation (TR) affects up to 1.6 million patients in the United States.[1] Despite its prevalence, TR has long been undertreated, with many considering it to be a "forgotten valve." However, recent studies have demonstrated untreated TR as an independent predictor of mortality.[2,3] Meanwhile, the benefit of tricuspid operation remains controversial with high rates of mortality and morbidity.[3-10] Data on isolated tricuspid operations, particularly regarding the choice between repair or replacement, remain limited, with conflicting outcomes.[4,6,7,11-13]

For severe symptomatic TR, isolated tricuspid operations are supported as a class IIa indication by the American College of Cardiology/American Heart Association and as a class I indication by the European Society of Cardiology and European Association of Cardio-Thoracic Surgery.[11,14] Although repair is preferred over replacement in both guidelines, evidence regarding direct comparisons between the 2 procedures is limited.[11,14] Previous studies with early-term results were conducted in tertiary care centers, limiting the generalizability on a nationwide scale,[4,5,13] and population-level data are limited to short-term follow-up.[6,7,15,16] With the emergence of transcatheter interventions for tricuspid valves, a comprehensive reappraisal of nationwide surgical outcomes, especially for the high-risk population, is important.[17]

In this context, we aimed to evaluate the early-term outcomes after isolated tricuspid replacement and repair and to compare these techniques using the contemporary Medicare Beneficiary database.

METHODS

The institutional review board at the University of California Los Angeles reviewed the study protocol and granted an exemption with a waiver for patient consent due to the nature of the secondary analysis of existing databases.

Data Source

We used Medicare fee-for-service 100% sample Inpatient File provided by the Centers for Medicare & Medicaid Services to identify the patient population. Demographic details, including age, sex, race, and ethnicity were extracted from the Master Beneficiary Summary File base segment and preoperative comorbidities (before the date of the index procedure) were extracted using 27 Chronic Conditions Warehouse Chronic Conditions and Other Chronic Conditions segments from the Master Beneficiary Summary File, from the year of the procedure.[18] The mortality data and death dates were obtained from the Master Beneficiary Summary File and verified by the Centers for Medicare & Medicaid Services.

Study Populations

We identified patients $\geq$65 years of age undergoing either isolated tricuspid replacement or repair in the United States between January 2016 and December 2020. Identifications of conditions and procedures were determined if the corresponding *International Classification of Diseases, Tenth Revision, Clinical Modification*, and Procedure Coding System codes were present in any position among 25 diagnostic and procedural codes (Table E1). Isolated tricuspid operations were defined as tricuspid operations without other major concomitant cardiovascular procedures, such as coronary artery bypass grafts, other valvular operations, aortic operations, and ventricular assist device implantations. Patients were excluded if concomitant cardiac operations were coded concurrently on the same day as the tricuspid operations. Patients with tricuspid stenosis, history of transplants, congenital cardiac disease, myxoma, pericardial malignancy, or carcinoid syndrome were excluded.[7,16,19,20] Additionally, patients were excluded if they were enrolled in a Medicare Advantage plan at the time of the procedure or had not been discharged by the end of the study period.

Primary and Secondary Outcomes

The primary outcome was early-term (up to 3 years) all-cause mortality. Secondary outcomes included early-term major adverse cardiovascular events (MACE), consisting of all-cause death, heart failure hospitalization, ischemic stroke, and tricuspid valve reoperations. The individual elements of MACE throughout the follow-up duration were considered as secondary outcomes of interest. Secondary outcomes also included in-hospital outcomes, including death, ischemic stroke, intracranial hemorrhage, acute kidney injury, cardiogenic shock, permanent pacemaker implantation in patients without baseline device leads, respiratory complications, postoperative hemorrhage, transfusion, pericardial effusion/tamponade, and length of stay in hospital.

Patients were followed from the day of the index procedure until censoring occurred. Censoring was defined as one of the following: the time of disenrollment from Medicare fee-for-service, at the event of an outcome occurrence, at the termination of the study duration, or 3 years after the index procedure, whichever occurred first. We defined occurrences of heart failure hospitalization, stroke, and infective endocarditis during the follow-up period by the corresponding *International Classification of Diseases, Tenth Revision, Clinical Modification* codes in the admitting diagnosis or principal diagnosis upon readmissions after the index procedures.[21] Tricuspid valve reoperation was defined if any surgical tricuspid valve intervention occurred at any point after the day of the index procedure.

Statistical Analysis

Continuous variables following a non-normal distribution were reported as median (interquartile range). Categorical variables were expressed as proportions. Comparison of baseline characteristics between groups were performed by calculating standardized mean difference with value <0.10 considered nonsignificant.

Outcomes were compared between the isolated tricuspid replacement and repair groups. A propensity score-matching approach with 1:1 ratio was used to create balanced treatment groups by accounting for confounders. The propensity score was calculated by using a multivariable logistic regression model and matched based on the following covariates: age, sex, race and ethnicity, Medicaid dual-eligible status, the 27 Chronic Condition comorbidities in the Chronic Conditions Warehouse, liver disease, peripheral vascular disease, obesity, procedure setting (elective, urgent, emergent), pulmonary hypertension, infective endocarditis, rheumatic heart disease, the presence of pacemaker/implantable cardioverter defibrillator leads, and the history of previous cardiac surgery. We performed nearest-neighbor matching with a caliper width equal to 0.2 times the SD of the propensity score.

Comparative early-term outcomes were presented with Kaplan-Meier survival curves after propensity score matching. A Cox proportional hazards regression model was applied to calculate the adjusted hazard ratio (aHR) and corresponding 95% confidence intervals (CIs). For the secondary early-term end points, death was considered as a competing risk to construct cumulative incidence curves.[22] A competing risk regression analysis using the Fine-Gray subdistribution hazard model was performed to provide the subdistribution hazard ratio with 95% CI. In-hospital outcomes were compared using either the Pearson χ^2 or Fisher exact test, depending on whether the expected count was 5 or greater.

Secondary Analyses

Sensitivity analyses were performed for comparing patients undergoing replacement with (1) bioprosthetic valves versus the repair group, (2) mechanical valves versus the repair group, and (3) replacement versus repair in patients without infective endocarditis. In addition, sensitivity analyses on the basis of the valve type (mechanical vs bioprosthetic) were performed among patients undergoing isolated tricuspid replacement. For each of the sensitivity analysis, a propensity score was separately calculated and matched.

In addition, we performed the following subgroup analyses from the matched cohort[23]: (1) patients aged 65 to younger than 75 years and those aged 75 years or older, (2) patients with and without preoperative device leads, and (3) patients with and without a previous history of cardiac surgery. For the subgroup analyses, *P*-interaction values were calculated for early-term mortality to assess the impact of different subgroups on the early-term outcome from the overall matched cohort.[23] No formal adjustments for multiple testing were performed.

Additionally, multivariable Cox regression analyses were conducted in the unmatched cohort to assess early-term all-cause mortality and MACE, incorporating the same variables used for propensity score calculation.

Statistical significance was determined by using 2-tailed tests. All analyses were performed with SAS 9.4 (SAS Institute, Inc) and R 4.2.2 (R Foundation for Statistical Computing) programming language.

RESULTS

Patient Population

A total of 1501 patients (replacement: 610 patients, repair: 891 patients) underwent isolated tricuspid valve replacement or repair between January 2016 and December 2020 (Figure E1). The annual procedural volume of isolated tricuspid operations during the study period is summarized in Figure E2. The median follow-up period was 18.7 months (IQR, 3.9-36.0 months).

Patients who underwent replacement were more likely to have a history of hypertension, heart failure, atrial fibrillation, chronic kidney disease, asthma, liver disease, anemia, cancer, and rheumatic tricuspid valve conditions and less likely to have a history of myocardial infarction (Table E2). In addition, the replacement group was more likely to have device leads, including permanent pacemakers and implantable cardioverter defibrillators. The replacement group was less likely to have previous history of cardiac surgery. The replacement group more frequently underwent operations in elective settings. Among those receiving replacements, mechanical valves were used in 9.7%. After propensity score matching, there were 547 matched pairs, and groups were overall well-balanced on baseline characteristics, except for race, rheumatic disease, and device leads (Figure E3).

Early-Term Outcomes

In the matched cohort, the Kaplan-Meier estimate of overall 3 years all-cause mortality was 38.8%. The occurrences of all-cause mortality, MACE, heart failure hospitalization, strokes, infective endocarditis, and tricuspid reoperations are summarized in Table 1.

Early-term comparative outcomes are summarized in Table 1. In the matched cohort, we found no evidence that replacement was associated with greater mortality in comparison with repair (aHR, 1.06; 95% CI, 0.86-1.30; $P = .600$) (Figure 1). Similarly, no significant between-group differences were observed for MACE (aHR, 1.01; 95% CI, 0.84-1.22; $P = .910$), heart failure hospitalization (subdistribution HR, 1.04; 95% CI, 0.72-1.49; $P = .850$), strokes, infective endocarditis, and tricuspid reoperations (Figure 2).

In-Hospital Outcomes

In the matched cohorts, there were no differences in in-hospital deaths (13.2% vs 12.8%, $P = .930$) and strokes (Table 2). Patients undergoing replacement required permanent pacemaker implantations (26.3% vs 13.3%; $P < .001$) more frequently. The pericardial effusion/tamponade occurred more frequently in the repair group. The median length of stay was comparable at 12 (IQR, 7-20) and 11 (IQR, 6-20) days, respectively. In both groups, discharge location was home in approximately 50% of patients.

Secondary Analyses

A series of sensitivity analyses were performed, and the early-term results are summarized in Figure E4. In a sensitivity analysis comparing patients treated by replacement using bioprosthetic valve and repair, the findings were overall consistent with the main analyses. Notable differences included a greater incidence of infective endocarditis in the bioprosthetic valve replacement group, while rates of pericardial effusion/tamponade were similar between the 2 groups (Tables E3 and E4). Similarly, a sensitivity analysis comparing mechanical valve replacement and repair showed no differences in early-term outcomes. In addition, the sensitivity analysis restricted to patients without infective endocarditis demonstrated trends consistent with the main analysis, except for greater rates of infective endocarditis with the replacement group during follow-up.

Furthermore, the comparison between patients receiving mechanical and bioprosthetic valves demonstrated comparable in-hospital and early-term outcomes (Figure E4).

A series of subgroup analyses were conducted for (1) patients aged 65 to younger than 75 years versus those aged

TABLE 1. Comparative early-term outcomes in the matched cohort

Outcomes	Event number (%)		aHR (95% CI)	*P* value
	Replacement (n = 547)	Repair (n = 547)		
All-cause mortality	187 (40.2%)	179 (37.5%)	1.06 (0.86-1.30)	.600
MACE	219 (46.3%)	218 (45.1%)	1.01 (0.84-1.22)	.910
Heart failure hospitalization	59 (15.5%)	57 (14.5%)	1.04 (0.72-1.49)	.850
Stroke	≤10	≤10	0.60 (0.22-1.66)	.330
Endocarditis	≤10	≤10	7.18 (0.88-58.4)	.070
Tricuspid valve reoperations	≤10	≤10	0.68 (0.11-4.06)	.670

Percentages displayed are Kaplan-Meier estimates. Cells with ≤10 patients are suppressed to protect the privacy of beneficiaries in accordance with the Centers for Medicare & Medicaid Services guidance. *aHR*, Adjusted/subdistribution hazard ratio; *CI*, confidence interval; *MACE*, major adverse cardiovascular events.

75 years or older, (2) patients with device leads versus those without, and (3) patients with a previous history of cardiac surgery versus those without. The early-term mortality for each subgroup is summarized in Figure E5. There were 740 patients aged between 65 to less than 75, and 761 patients aged 75 years old or older. Comparable early-term mortality was observed between both surgical techniques in the younger and older age subgroups with no statistically significant interaction (aHR, 1.10; 95% CI, 0.82-1.48, aHR, 1.02; 95% CI, 0.77-1.36, respectively). There were 260 patients with preoperative device leads (replacement = 144 patients, repair = 116 patients) (Table E5). In patients with and without preoperative device leads, both replacement and repair groups were associated with similar in-hospital (Table E6) results. The early-term mortality between the surgical techniques was comparable in both subgroups with no interaction (aHR, 1.12; 95% CI, 0.63-1.98, aHR, 1.07; 95% CI, 0.86-1.34, respectively). For subgroups with and without a previous history of cardiac surgery, comparable early-term outcomes were observed for both subgroups with no significant interaction (aHR, 1.26; 95% CI, 0.78-2.02; aHR, 1.02; 95% CI, 0.81-1.28, respectively).

Multivariable Cox regression analyses for early-term all-cause mortality and MACE were performed for the unmatched cohort. These findings were largely consistent with the propensity score-matched cohorts, with no between-group differences for death (aHR, 1.17; 95% CI, 0.96-1.44, *P* = .130) and MACE (aHR, 1.10; 95% CI, 0.91-1.32, *P* = .330).

DISCUSSION

In this nationally representative contemporary study investigating isolated tricuspid valve replacement and repair, there were several important findings. First, the all-cause mortality was notably high in our cohort, with an

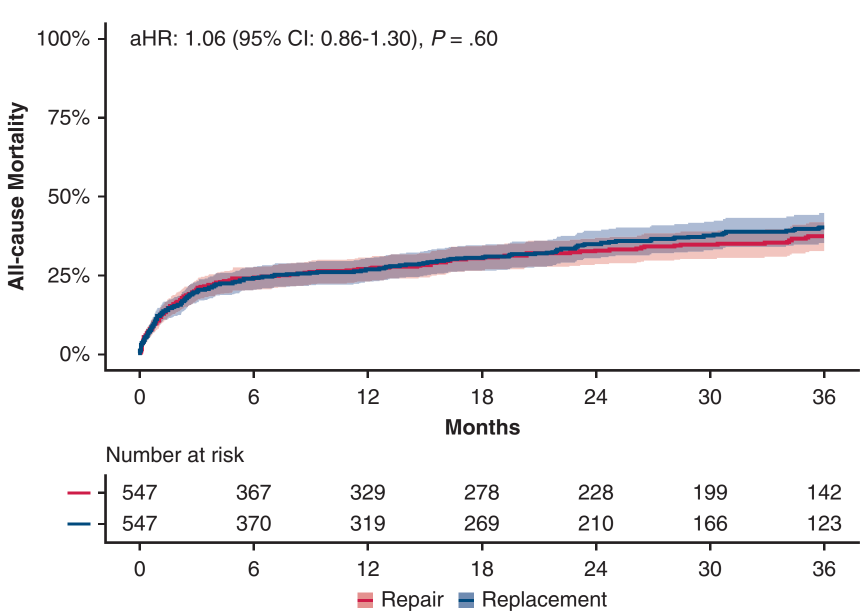

FIGURE 1. All-cause mortality after propensity score matching Kaplan-Meier analysis of all-cause mortality. *Solid lines* represent the estimates, and the *surrounding bands* represent the 95% CIs. *aHR*, Adjusted/subdistribution hazard ratio; *CI*, confidence interval.

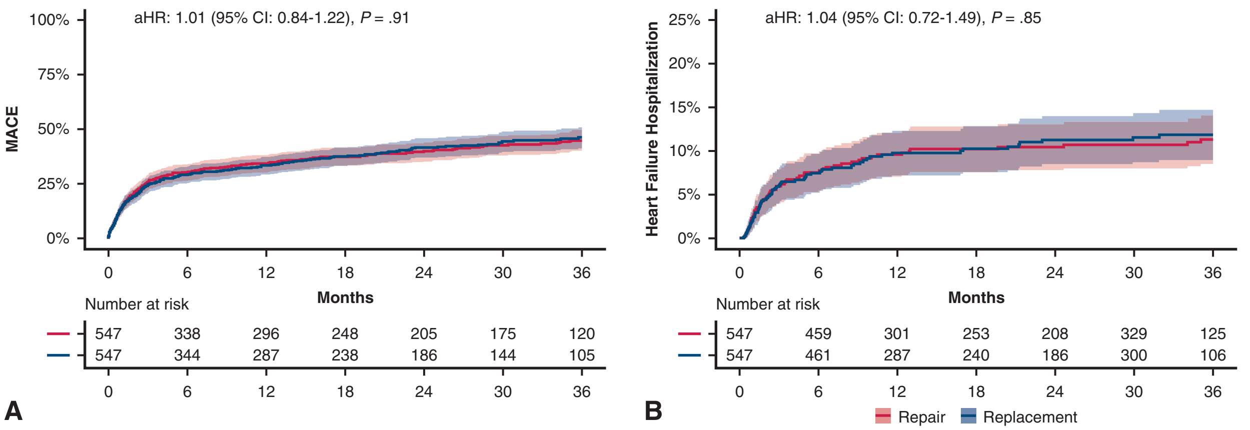

FIGURE 2. MACE and heart failure hospitalization rate after propensity score matching Kaplan-Meier analysis of (A) MACE and (B) heart failure hospitalization rate. *Solid lines* represent the estimates, and the *surrounding bands* represent the 95% CI. *aHR*, Adjusted/subdistribution hazard ratio; *CI*, confidence interval; *MACE*, major adverse cardiovascular events.

in-hospital mortality of 13% and 3-year mortality of 39%. Second, there were no differences in the early-term mortality, MACE, and heart failure hospitalizations between the replacement and repair groups (Figure 3). Taken together, future studies to clarify the selection criteria between replacement and repair techniques are mandated to optimize long-term outcomes of these high-risk TR patients.

The in-hospital mortality rate of 13% in this study was significantly higher than previous studies with incidences of less than 10%.[4,5,7-9,13,16] The high mortality trend was consistently observed up to 3 years. The median age in our cohort was 75 years, greater than previous studies with ages ranging from 30 to 60,[4,5,13,16,24] highlighting the increased susceptibility of the Medicare beneficiaries

TABLE 2. In-hospital outcomes

Characteristics	Unmatched cohort Replacement	Unmatched cohort Repair	Unmatched cohort *P* value	Matched cohort Replacement	Matched cohort Repair	Matched cohort *P* value
Patients	610	891		547	547	
In-hospital death	82 (13.4)	100 (11.2)	.225	72 (13.2)	70 (12.8)	.928
Ischemic stroke	≤10	20 (2.2)	.056	≤10	≤10	1
Intracerebral hemorrhage	≤10	≤10	1	≤10	≤10	1
Acute kidney injury	213 (34.9)	274 (30.8)	.102	189 (34.6)	164 (30.0)	.121
Cardiogenic shock	97 (15.9)	136 (15.3)	.793	87 (15.9)	77 (14.1)	.446
Permanent pacemaker	122 (26.2)	117 (15.1)	<.001	113 (26.3)	60 (13.3)	<.001
Respiratory complications	61 (10.0)	103 (11.6)	.386	50 (9.1)	68 (12.4)	.098
Postoperative hemorrhage	33 (5.4)	38 (4.3)	.367	29 (5.3)	20 (3.7)	.242
Transfusions	161 (26.4)	196 (22.0)	.057	138 (25.2)	118 (21.6)	.175
Pericardial effusion/tamponade	16 (2.6)	49 (5.5)	.010	13 (2.4)	29 (5.3)	.018
Heart failure	66 (10.8)	81 (9.1)	.308	58 (10.6)	52 (9.5)	.615
Length of stay, d	12.00 [7.00, 20.00]	13.00 [7.00, 21.00]	.625	12.00 [7.00, 20.00]	11.00 [6.00, 20.00]	.190
Discharge location			.100			.318
Home	320 (52.5)	444 (49.8)		289 (52.8)	278 (50.8)	
Hospice	≤10	≤10		≤10	≤10	
Long-term care	31 (5.1)	67 (7.5)		29 (5.3)	36 (6.6)	
Skilled nursing facility	170 (27.9)	270 (30.3)		150 (27.4)	156 (28.5)	

Baseline characteristics of patients undergoing isolated tricuspid valve repair and replacement before and after propensity score matching. Values are median [Q1, Q3] or n (%). Cells with ≤10 patients are suppressed to protect the privacy of beneficiaries in accordance with the Centers for Medicare & Medicaid Services guidance. *Q1*, Quartile 1; *Q3*, quartile 3.

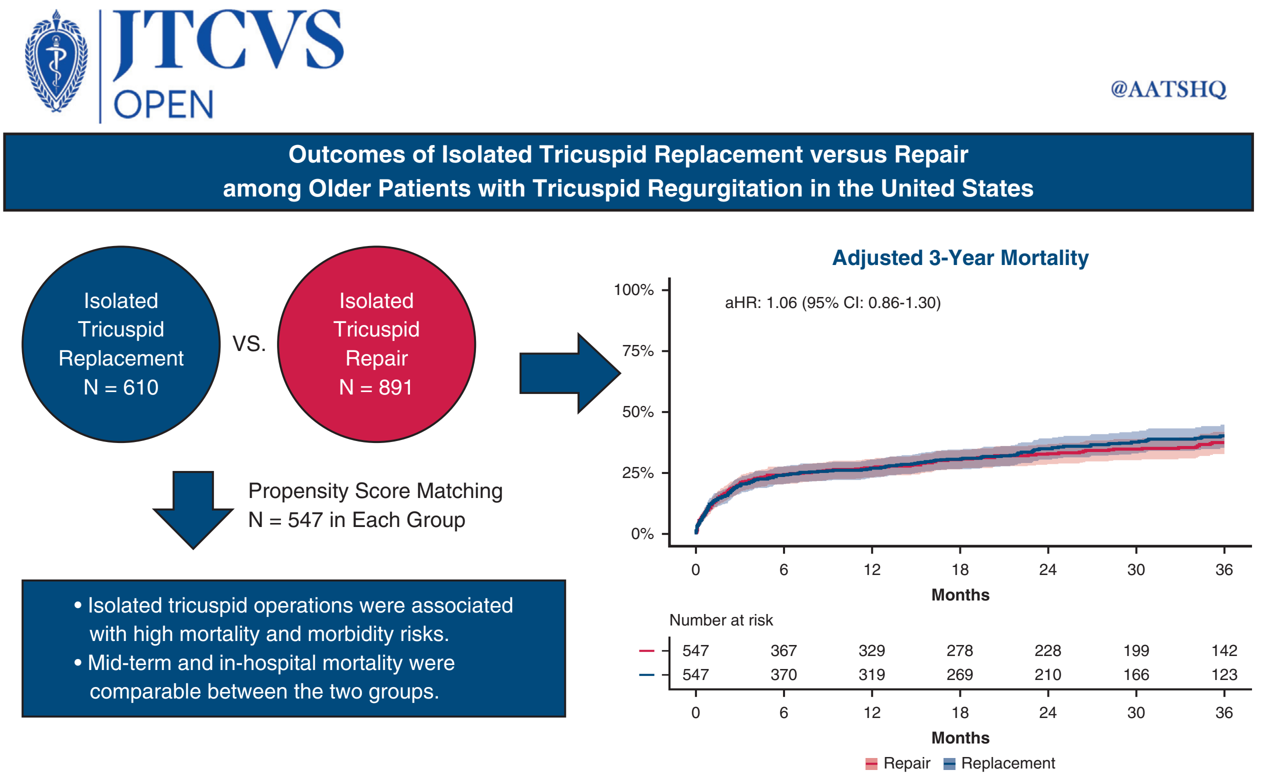

FIGURE 3. In Medicare beneficiaries, isolated tricuspid operations were associated with high mortality. Both techniques were associated with comparable early-term mortality. *aHR*, Adjusted/subdistribution hazard ratio; *CI*, confidence interval.

to adverse outcomes. Notably, survival curves in both our investigation and the previous Medicare study[15] (encompassing the period from 2003 to 2014) evidenced an abrupt escalation in mortality in the perioperative period, followed by a gradual increase, highlighting the strikingly elevated risk associated with isolated tricuspid surgery. This further emphasizes the substantial comorbidity burden and perioperative risks associated with patients requiring isolated tricuspid valve surgery. Interestingly, studies involving younger patients have shown a more gradual increase in mortality during the perioperative period.[4,5]

According to the American and European guidelines, tricuspid valve repair is preferred over replacement.[11,13,14] Merits of the repair technique include better preservation of subvalvular apparatus and ventricular morphology.[11,14] Conversely, rigid prostheses could distort the right ventricle, worsening right ventricular function.[25] Meanwhile, the replacement may be preferable for cases with pronounced annular dilatation[5,8] or severely damaged, fibrosed valve leaflets.[26-28] In our unmatched cohort, the replacement group included higher proportions of heart failure, liver disease, rheumatic heart disease, and device leads, suggesting a generally more complex population. The recent development of the Society of Thoracic Surgeons risk model for isolated tricuspid operation may better aid the optimal treatment selection.[16]

The literature have demonstrated conflicting results; some studies reported inferior prognosis with replacement,[5,7,15,29] whereas others found no such differences.[4,9,13] Some hypothesized earlier intervention, with better-preserved leaflets and ventricular function, as the drivers for superior outcomes with the repair.[7] Meanwhile, other studies argued that age and timing, rather than the techniques, may be more responsible for the outcomes.[9,24,25]

The possible mechanisms of our findings can be multifactorial. First, our analysis included a considerably older population compared with previous studies.[4,5,13,16,24,25,29] Such demographic differences may reduce the benefits of repair as a per se protective factor, considering the heightened risks in the population with older age. Furthermore, aggressive pursuit of repair in advanced cases with severely damaged leaflets may expose patients to residual and recurrent TR.[4] In high-risk populations with appropriate anatomy, a less-hesitant selection of replacement may be preferable to aggressive repair.[7] However, we lack granular data on key factors such as right ventricular function, size, pulmonary arterial pressure, and the severity of TR, which limits our ability to fully understand the rationale behind the decision to repair or replace the valve.

The replacement group necessitated permanent pacemakers more than the repair group, as previously reported.[5,7,29] The annuloplasty rings employed in tricuspid repair are often incomplete to avoid sutures in the septal area. Postoperative conduction abnormalities may be more common after replacement due to suture placement near an atrioventricular node, as well as the radial force from prostheses. The replacement group is also more clinically predisposed to requiring pacemaker implantation, including markedly dilated annulus, atrial and ventricular damage, and longer operative periods.[4,7,30] Avoidance of postoperative lead placement is pertinent since it is an independent predictor of RV remodeling and heart failure readmissions.[30] A few techniques are often adopted to reduce post-procedural pacemaker implantations, including the beating heart technique and superficial sutures near the septal leaflet.[30,31] Additionally, alternative pacing measures including prophylactic epicardial pacemakers, leadless pacemakers, and coronary sinus pacing need to be further investigated.

Our sensitivity analysis comparing mechanical and bioprosthetic valves demonstrated no statistically significant differences in mortality up to 3 years. However, a recent meta-analysis comprising 7166 patients demonstrated superior survival and freedom from reoperation in those receiving mechanical valves, though the analysis was not confined to isolated tricuspid valve surgery.[32] Notably, freedom from reintervention in the bioprosthetic valve cohort significantly declined after 7 years,[32] potentially due to the longevity of the bioprosthetic valve. Given our limited follow-up period of 3 years, our data may not capture the long-term trends related to bioprosthetic valve durability. In high-risk older patients, the trade-off between the need for lifelong anticoagulation with mechanical valves and the limited long-term durability of the bioprosthetic valve despite the potential for valve-in-valve therapy[33] remains unclear. Currently, the choice of valve type often depends on the preferences of the surgeon or the practices of the institution. Our data suggest that, in high-risk older patients undergoing isolated tricuspid valve replacement, both types of valves perform similarly up to 3 years.

A few RCTs are investigating transcatheter tricuspid valve edge-to-edge repair and replacement.[17] Transcatheter edge-to-edge repair reduced TR severity and patient symptoms, although no advantage in mortality was observed.[17] Transcatheter replacement can eliminate TR in 95% of patients, albeit with high permanent pacemaker implantation rates.[34] Future comparative studies are warranted to seek if transcatheter modalities could mitigate the elevated early-term surgical mortality.

Limitations

Our study has several limitations. First, because of the nature of administrative data analysis, we were unable to obtain detailed information on symptoms, echocardiography results such as left ventricular ejection fraction, degree of TR, pulmonary hypertension, indications for operation and causes of death, and the Tri-score and the Society of Thoracic Surgeons risk scores. Second, despite efforts to adjust for confounders using propensity score matching, there is still a possibility of unmeasured confounders affecting our results. Third, the specific types of tricuspid valve repair and replacement techniques were not available in the current analysis. Finally, our study focused specifically on Medicare beneficiary population with an age of 65 or older. Therefore, the results may not be generalizable to a younger population.

CONCLUSIONS

In conclusion, isolated tricuspid valve replacement and repair were associated with similar in-hospital and early-term outcomes. Importantly, both procedures were associated with high mortality, with approximately 39% mortality at 3 years. These findings underscore the critical need for improved modalities for tricuspid intervention, as well as a reassessment of the indication and timing of these procedures.

Conflict of Interest Statement

Dr Elmariah has received research grants and consulting fees from Edwards Lifesciences and Medtronic. Dr Fukuhara has received consulting fees from Terumo Aortic, Medtronic, Edwards Lifesciences, and Artivion. Dr Kaneko has received consulting fees from Edwards Lifesciences, Medtronic, 4C Medical, CardioMech, and Cook Medical; and has been a speaker for Abbott and Baylis. Dr Tsugawa serves on the board of directors of M3. Study sponsors were not involved in study design, data interpretation, writing, or the decision to submit the article for publication. All other authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: tricuspid valve repair, tricuspid valve replacement, tricuspid regurgitation, medicare beneficiaries

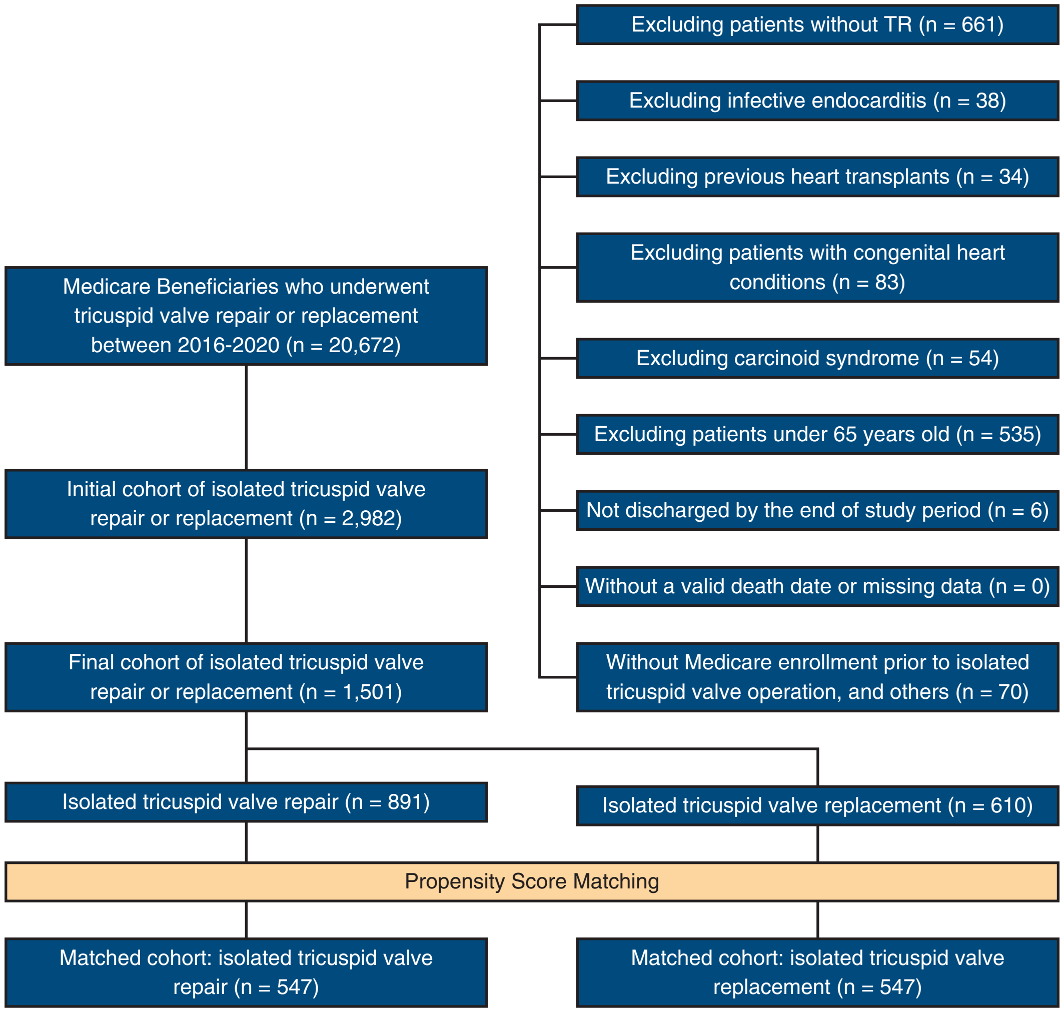

FIGURE E1. Study flowchart of included cohort. *TR*, Tricuspid regurgitation.

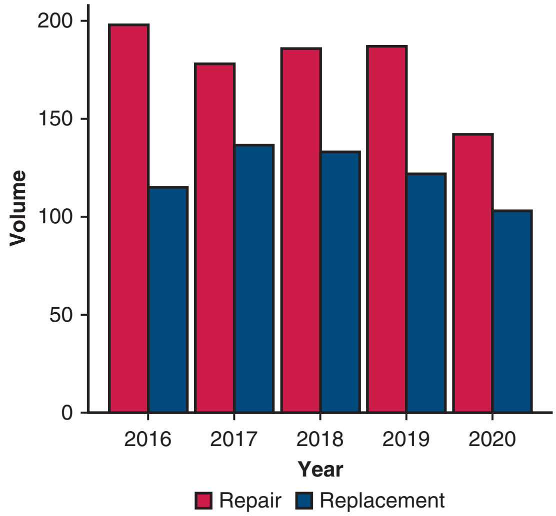

FIGURE E2. Annual procedural volumes of isolated tricuspid operations. The number of procedural volumes of isolated tricuspid valve repair and replacement from 2016 to 2020 in Medicare beneficiaries older than the age of 65 years.

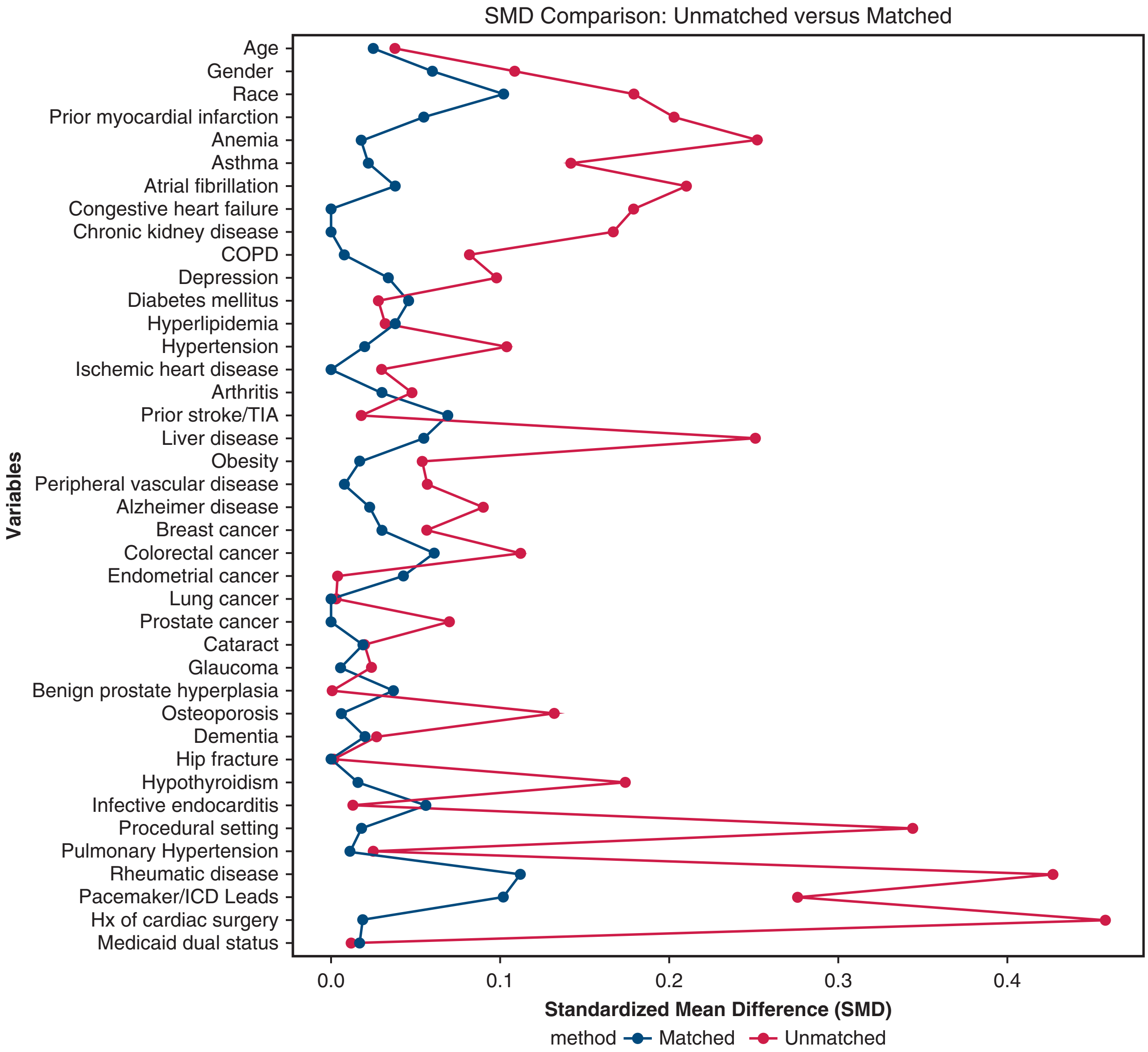

FIGURE E3. Standard mean difference of unmatched and matched population. *SMD*, Standard mean difference; *COPD*, chronic obstructive pulmonary disease; *TIA*, transient ischemic attack; *ICD*, implantable cardioverter-defibrillator; *Hx*, history.

Sensitivity Analysis	Outcome	Adjusted HR (95% CI)
Bioprosthetic valve replacement vs. repair	All-cause mortality	1.05 (0.85 to 1.30)
	MACE	1.05 (0.86 to 1.27)
	Heart failure hospitalization	1.30 (0.89 to 1.91)
Mechanical valve replacement vs. repair	All-cause mortality	1.19 (0.63 to 2.23)
	MACE	0.98 (0.54 to 1.76)
	Heart failure hospitalization	0.94 (0.19 to 4.68)
Replacement vs. repair in patients without IE	All-cause mortality	1.16 (0.94 to 1.44)
	MACE	1.11 (0.92 to 1.35)
	Heart failure hospitalization	1.20 (0.83 to 1.75)
Mechanical valve vs. Bioprosthetic valve	All-cause mortality	1.09 (0.6 to 1.98)
	MACE	0.82 (0.47 to 1.44)
	Heart failure hospitalization	0.28 (0.08 to 1.03)

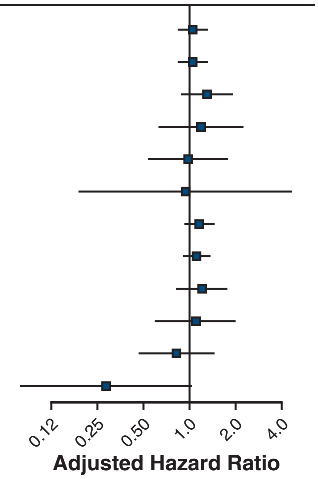

FIGURE E4. Sensitivity analyses. Sensitivity analyses of early-term mortality on the basis of (1) bioprosthetic valve replacement versus repair, (2) mechanical valve replacement versus repair, and (3) patients without infective endocarditis. *HR*, Hazard ratio; *CI*, confidence interval; *MACE*, major cardiovascular adverse events; *IE*, infective endocarditis.

Subgroups	Replacement	Repair	Adjusted HR (95% CI)	*P*-interaction
Overall	547	547	1.06 (0.86 to 1.30)	
Age				.74
65<year<75	279	270	1.10 (0.82 to 1.48)	
75≤year	268	277	1.02 (0.77 to 1.36)	
Device Leads				.94
Present	118	96	1.12 (0.63 to 1.98)	
Not present	429	451	1.07 (0.86 to 1.34)	
Prior History of Cardiac Surgery				.42
Present	91	95	1.26 (0.78 to 2.02)	
Not present	456	452	1.02 (0.81 to 1.28)	

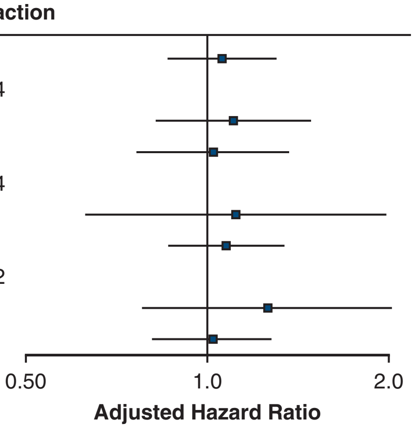

FIGURE E5. Subgroup analyses. Subgroup analysis of early-term mortality on the basis of (1) patients aged 65 to younger than 75 years and those aged 75 years or older, (2) patients with and without preoperative device leads, and (3) patients with and without a previous history of cardiac surgery. P-interaction value demonstrates the interaction between subgroups for mortality. *HR*, Hazard ratio; *CI*, confidence interval.

TABLE E1. *International Classification of Diseases Tenth Revision*, *Clinical Modification* (ICD-10-CM), and Procedure Coding System (PCS) codes used to identify procedures and outcomes

Conditions/procedures	ICD-10 CM/PCS codes
Operations	
Tricuspid valve repair	027J04Z, 027J0DZ, 027J0ZZ, 02NJ0ZZ, 02QJ0ZZ, 02UJ07Z, 02UJ08Z, 02UJ0JZ, 02UJ0KZ, 027J44Z, 027J4DZ, 027J4ZZ, 02NJ4ZZ, 02QJ4ZZ, 02UJ47Z, 02UJ48Z, 02UJ4JZ, 02UJ4KZ
Tricuspid valve replacement	02RJ07Z, 02RJ08Z, 02RJ0JZ, 02RJ0KZ, 02RJ47Z, 02RJ48Z, 02RJ4JZ, 02RJ4KZ
Aortic valve repair	024F07J, 024F08J, 024F0JJ, 024F0KJ, 025F0ZZ, 025F4ZZ, 027F04Z, 027F0DZ, 027F0ZZ, 027F44Z, 027F4DZ, 027F4ZZ, 02BF0ZX, 02BF0ZZ, 02BF4ZX, 02BF4ZZ, 02CF0ZZ, 02CF4ZZ, 02NF0ZZ, 02NF4ZZ, 02QF0ZJ, 02QF0ZZ, 02QF4ZJ, 02QF4ZZ, 02UF07J, 02UF07Z, 02UF08J, 02UF08Z, 02UF0JJ, 02UF0JZ, 02UF0KJ, 02UF0KZ, 02UF47J, 02UF47Z, 02UF48J, 02UF48Z, 02UF4JJ, 02UF4JZ, 02UF4KJ, 02UF4KZ, 02WF07Z, 02WF08Z, 02WF0JZ, 02WF0KZ, 02WF47Z, 02WF48Z, 02WF4JZ, 02WF4KZ
Aortic valve replacement	02RF07Z, 02RF08Z, 02RF0JZ, 02RF0KZ, 02RF47Z, 02RF48Z, 02RF4JZ, 02RF4KZ
Mitral valve repair	024G072, 024G082, 024G0J2, 024G0K2, 025G0ZZ, 025G4ZZ, 027G04Z, 027G0DZ, 027G0ZZ, 027G44Z, 027G4DZ, 027G4ZZ, 02890ZZ, 028D0ZZ, 02BG0ZX, 02BG0ZZ, 02BG4ZX, 02BG4ZZ, 02CG0ZZ, 02CG4ZZ, 02NG0ZZ, 02NG4ZZ, 02Q90ZZ, 02QD0ZZ, 02QG0ZE, 02QG0ZZ, 02QG4ZE, 02QG4ZZ, 02UG07E, 02UG07Z, 02UG08E, 02UG08Z, 02UG0JE, 02UG0JZ, 02UG0KE, 02UG0KZ, 02UG47E, 02UG47Z, 02UG48E, 02UG48Z, 02UG4JE, 02UG4JZ, 02UG4KE, 02UG4KZ, 02VG0ZZ, 02VG4ZZ, 02WG07Z, 02WG08Z, 02WG0JZ, 02WG0KZ, 02WG47Z, 02WG48Z, 02WG4JZ, 02WG4KZ
Mitral valve replacement	02RG07Z, 02RG08Z, 02RG0JZ, 02RG0KZ 02RG47Z, 02RG48Z, 02RG4JZ, 02RG4KZ
Pulmonary valve repair	025H0ZZ, 025H4ZZ, 027H04Z, 027H0DZ, 027H0ZZ, 027H44Z, 027H4DZ, 027H4ZZ, 02BH0ZX, 02BH0ZZ, 02BH4ZX, 02BH4ZZ, 02CH0ZZ, 02CH4ZZ, 02LH0CZ, 02LH0DZ, 02LH0ZZ, 02LH4CZ, 02LH4DZ, 02LH4ZZ, 02NH0ZZ, 02NH4ZZ, 02QH0ZZ, 02QH4ZZ, 02RP07Z, 02RP08Z, 02RP0JZ, 02RP0KZ, 02RP47Z, 02RP48Z, 02RP4JZ, 02RP4KZ, 02RQ07Z, 02RQ08Z, 02RQ0JZ, 02RQ0KZ, 02RQ47Z, 02RQ48Z, 02RQ4JZ, 02RQ4KZ, 02RR07Z, 02RR08Z, 02RR0JZ, 02RR0KZ, 02RR47Z, 02RR48Z, 02RR4JZ, 02RR4KZ, 02TH0ZZ, 02TH4ZZ, 02UH07Z, 02UH08Z, 02UH0JZ, 02UH0KZ, 02UH47Z, 02UH48Z, 02UH4JZ, 02UH4KZ, 02WH07Z, 02WH08Z, 02WH0JZ, 02WH0KZ, 02WH47Z, 02WH48Z, 02WH4JZ, 02WH4KZ
Pulmonary valve replacement	02RH07Z, 02RH08Z, 02RH0JZ, 02RH0KZ 02RH47Z, 02RH48Z, 02RH4JZ, 02RH4KZ
Tricuspid valve operations (extirpations, etc)	024J072, 024J082, 024J0J2, 024J0K2, 02CJ0ZZ, 02QJ0ZG, 02UJ07G, 02UJ08G, 02UJ0JG, 02UJ0KG, 02WJ07Z, 02CJ4ZZ, 02QJ4ZG, 02UJ47G, 02UJ48G, 02UJ4JG, 02UJ4KG, 02WJ47Z, 02BJ0ZZ, 02BJ4ZZ, 025J0ZZ, 025J4ZZ, 02BJ0ZX, 02BJ4ZX, 02WJ08Z, 02WJ0JZ, 02WJ0KZ, 02WJ48Z, 02WJ4JZ, 02WJ4KZ
Ventricular assist device implantations	02HA0QZ, 02HA4QZ
Coronary artery bypass graft	0210083, 0210088, 0210089, 0210093, 0210098, 0210099, 0210483, 0210488, 0210489, 0210493, 0210498, 0210499, 0211083, 0211088, 0211089, 0211093, 0211098, 0211099, 0211483, 0211488, 0211489, 0211493, 0211498, 0211499, 0212083, 0212088, 0212089, 0212093, 0212098, 0212099, 0212483, 0212488, 0212489, 0212493, 0212498, 0212499, 0213083, 0213088, 0213089, 0213093, 0213098, 0213099, 0213483, 0213488, 0213489, 0213493, 0213498, 0213499, 021008C, 021008F, 021008W, 021009C, 021009F, 021009W, 02100A3, 02100A3, 02100A8, 02100A9, 02100AC, 02100AF, 02100AW, 02100J3, 02100J8, 02100J9, 02100JC, 02100JF, 02100JW, 02100K3, 02100K8, 02100K9, 02100KC, 02100KF, 02100KW, 02100Z3, 02100Z8, 02100Z9, 02100ZC, 02100ZF, 021048C, 021048F, 021048W, 021049C, 021049F, 021049W, 02104A3, 02104A8, 02104A9, 02104AC, 02104AF, 02104AW, 02104J3, 02104J8, 02104J9, 02104JC, 02104JF, 02104JW, 02104K3, 02104K8, 02104K9, 02104KC, 02104KF, 02104KW, 02104Z3, 02104Z8, 02104Z9, 02104ZC, 02104ZF, 021108C, 021108F, 021108W, 021109C, 021109F, 021109W, 02110A3, 02110A8, 02110A9, 02110AC, 02110AF, 02110AW, 02110J3, 02110J8, 02110J9, 02110JC, 02110JF, 02110JW, 02110K3, 02110K8, 02110K9,

(Continued)

TABLE E1. Continued

Conditions/procedures	ICD-10 CM/PCS codes
	02110KC, 02110KF, 02110KW, 02110Z3, 02110Z8, 02110Z9, 02110ZC, 02110ZF, 021148C, 021148F, 021148W, 021149C, 021149F, 021149W, 02114A3, 02114A8, 02114A9, 02114AC, 02114AF, 02114AW, 02114J3, 02114J8, 02114J9, 02114JC, 02114JF, 02114JW, 02114K3, 02114K8, 02114K9, 02114KC, 02114KF, 02114KW, 02114Z3, 02114Z8, 02114Z9, 02114ZC, 02114ZF, 021208C, 021208F, 021208W, 021209C, 021209F, 021209W, 02120A3, 02120A8, 02120A9, 02120AC, 02120AF, 02120AW, 02120J3, 02120J8, 02120J9, 02120JC, 02120JF, 02120JW, 02120K3, 02120K8, 02120K9, 02120KC, 02120KF, 02120KW, 02120Z3, 02120Z8, 02120Z9, 02120ZC, 02120ZF, 021248C, 021248F, 021248W, 021249C, 021249F, 021249W, 02124A3, 02124A8, 02124A9, 02124AC, 02124AF, 02124AW, 02124J3, 02124J8, 02124J9, 02124JC, 02124JF, 02124JW, 02124K3, 02124K8, 02124K9, 02124KC, 02124KF, 02124KW, 02124Z3, 02124Z8, 02124Z9, 02124ZC, 02124ZF, 021308C, 021308F, 021308W, 021309C, 021309F, 021309W, 02130A3, 02130A8, 02130A9, 02130AC, 02130AF, 02130AW, 02130J3, 02130J8, 02130J9, 02130JC, 02130JF, 02130JW, 02130K3, 02130K8, 02130K9, 02130KC, 02130KF, 02130KW, 02130Z3, 02130Z8, 02130Z9, 02130ZC, 02130ZF, 021348C, 021348F, 021348W, 021349C, 021349F, 021349W, 02134A3, 02134A8, 02134A9, 02134AC, 02134AF, 02134AW, 02134J3, 02134J8, 02134J9, 02134JC, 02134JF, 02134JW, 02134K3, 02134K8, 02134K9, 02134KC, 02134KF, 02134KW, 02134Z3, 02134Z8, 02134Z9, 02134ZC, 02134ZF
Other cardiac operations (left atrial appendage closure, superior vena cava procedures, etc)	02570ZK, 02570ZZ, 02574ZK, 02574ZZ, 02B70ZK, 02B70ZZ, 02B74ZK, 02B74ZZ, 02L70CK, 02L70DK, 02L70ZK, 02BW0ZZ, 02BX0ZZ, 02QX0ZZ, 02RW07Z, 02RW08Z, 02RW0JZ, 02RW0KZ, 02RW47Z, 02RW48Z, 02RW4JZ, 02RW4KZ, 02RX07Z, 02RX08Z, 02RX0JZ, 02RX0KZ, 02RX47Z, 02RX48Z, 02RX4JZ, 02RX4KZ, 02UW4JZ, 02UX4JZ, 02VW0DZ, 02VW0EZ, 02VW0FZ, 02VW4DZ, 02VW4EZ, 02VW4FZ, 02VX0DZ, 02VX0EZ, 02VX0FZ, 02VX4DZ, 02VX4EZ, 02VX4FZ, 04B00ZZ, 02RS07Z, 02RS08Z, 02RS0JZ, 02RS0KZ, 02RS47Z, 02RS48Z, 02RS4JZ, 02RS4KZ, 02RT07Z, 02RT08Z, 02RT0JZ, 02RT0KZ, 02RT47Z, 02RT48Z, 02RT4JZ, 02RT4KZ, 02RV07Z, 02RV08Z, 02RV0JZ, 02RV0KZ, 02RV47Z, 02RV48Z, 02RV4JZ, 02RV4KZ
Conditions	
Tricuspid regurgitation	I071, I072, I078, I079, I361, I362, I368, I369
Isolated rheumatic tricuspid conditions (excluding TS)	I071, I072, I078, I079
Rheumatic conditions with left-sided valve involvement	I050, I051, I052, I058, I059, I060, I061, I062, I068, I069, I080, I083
Carcinoid disease	D3A00, E340, C7A
Tricuspid stenosis	I070, I360
Myxoma	D151
Malignancy of pericardium	C452
Congenital*	Q20, Q21, Q22, Q23, Q24, Q25
Infective endocarditis	I330, I38, I339, I39, B376, A3951, A5483, T826, T826XX, T826XXA, T826XXD, T826XXS, A3282, A5203, B3321, I398, I423
Device leads	Z950, Z95810
Pulmonary hypertension	I270, I272
Outcomes	
Ischemic stroke	I63, I6300, I63011, I63012, I63013, I63019, I6302, I63031, I63032, I63033, I63039, I6309, I6310, I63111, I63112, I63113, I63119, I6312, I63131, I63132, I63133, I63139, I6320, I63211, I63212, I63213, I63219, I6322, I63231, I63232, I63239, I6329, I6330, I63311, I63312, I63313, I63319, I63321, I63322, I63323, I63329, I63331, I63332, I63333, I63339, I6340, I63411, I63412, I63413, I63419, I63421, I63422, I63423, I63429, I63431, I63432, I63433, I63439, I63441, I63442, I63443, I63449, I6349, I6350, I63511, I63512, I63513, I63519, I63521, I63522, I63523, I63529, I63531, I63532, I63533, I63539, I63541, I63542, I63543, I63549, I6359, I636, I6381, I6389, I639, I65, I6501, I6502, I6503, I6509, I651, I658, I659, I6521, I6522, I6523, I6529, I66, I663, I668, I669, I6601, I6602, I6603, I6609, I6611, I6781, I6782, I6789, I679

(Continued)

TABLE E1. Continued

Conditions/procedures	ICD-10 CM/PCS codes
Intracranial hemorrhage	I60, I602, I604, I606, I607, I608, I609, I6000, I6001, I6002, I6010, I6011, I6012, I6030, I6031, I6032, I6050, I6051, I6052, I61, I610, I611, I612, I613, I614, I615, I616, I618, I619, I62, I6200, I6201, I6202, I6203, I621, I629
Acute kidney injury	N17, N170, N171, N172, N178, N179, N19, N990, R34, R944, S370
Cardiogenic shock	R570
Respiratory complications	J9561, J9562, J9571, J9572, J95811, J95821, J95822, J95830, J95831, J95860, J95861, J95862, J95863, J9588, J9589
Hemorrhage	I97411, I97418, I9742, I97611, I97618, I97620, T85838, T85838A, T85838D, T85838S, T82837, T82837A, T82837D, T82837S, T82838, T82838A, T82838D, T82838S
Cardiac tamponade	I312, I313, I314, I318
Heart failure	I502, I5020, I5021, I5022, I5023, I503, I5030, I5031, I5032, I5033, I504, I5040, I5041, I5042, I5043
New permanent pacemaker	0JH604Z, 0JH605Z, 0JH606Z, 0JH607Z, 0JH609Z, 0JH634Z, 0JH635Z, 0JH636Z, 0JH637Z, 0JH639Z, 0JH804Z, 0JH805Z, 0JH806Z, 0JH807Z, 0JH809Z, 0JH834Z, 0JH835Z, 0JH836Z, 0JH837Z, 0JH839Z, 02HK3JZ, 02HK3MZ, 02H63JZ
Transfusions	30230H0, 30230H1, 30230N0, 30230N1, 30230P0, 30230P1, 30233N0, 30233N1, 30233P0, 30233P1, 30240H0, 30240H1, 30240N0, 30240N1, 30243N0, 30243N1, 30243P0, 30243P1, 30243H0, 30243H1, 30240P0, 30240P1

TS, Tricuspid stenosis. *Congenital cardiac conditions.

TABLE E2. Baseline characteristics of the unmatched and matched cohort

Characteristics	Unmatched cohort			Matched cohort		
	Replacement	Repair	SMD	Replacement	Repair	SMD
Patients	610	891		547	547	
Age, y	75.00 [70.00, 79.00]	74.00 [69.50, 78.00]	0.038	74.00 [70.00, 78.00]	75.00 [70.00, 79.00]	0.025
Female	379 (62.1)	506 (56.8)	0.109	335 (61.2)	319 (58.3)	0.06
Race			0.179			0.102
White	496 (81.3)	750 (84.2)		448 (81.9)	458 (83.7)	
Black	40 (6.6)	60 (6.7)		38 (6.9)	34 (6.2)	
Asian	31 (5.1)	20 (2.2)		22 (4.0)	17 (3.1)	
Hispanic	27 (4.4)	37 (4.2)		24 (4.4)	23 (4.2)	
Hypertension	565 (92.6)	799 (89.7)	0.104	503 (92.0)	506 (92.5)	0.02
Hyperlipidemia	463 (75.9)	664 (74.5)	0.032	410 (75.0)	419 (76.6)	0.038
Diabetes mellitus	219 (35.9)	308 (34.6)	0.028	187 (34.2)	199 (36.4)	0.046
Previous myocardial infarction	≤10	40 (4.5)	0.203	≤10	≤10	0.055
Ischemic heart disease	524 (85.9)	756 (84.8)	0.03	464 (84.8)	464 (84.8)	<0.001
Congestive heart failure	561 (92.0)	770 (86.4)	0.179	499 (91.2)	499 (91.2)	<0.001
Atrial fibrillation	476 (78.0)	613 (68.8)	0.21	418 (76.4)	409 (74.8)	0.038
Chronic kidney disease	370 (60.7)	467 (52.4)	0.167	324 (59.2)	324 (59.2)	<0.001
Previous stroke/TIA	37 (6.1)	58 (6.5)	0.018	30 (5.5)	22 (4.0)	0.069
COPD	179 (29.3)	229 (25.7)	0.082	156 (28.5)	154 (28.2)	0.008
Asthma	86 (14.1)	85 (9.5)	0.142	70 (12.8)	66 (12.1)	0.022
Liver disease	173 (28.4)	159 (17.8)	0.251	143 (26.1)	130 (23.8)	0.055
Anemia	491 (80.5)	621 (69.7)	0.252	430 (78.6)	426 (77.9)	0.018
Peripheral vascular disease	175 (28.7)	233 (26.2)	0.057	150 (27.4)	148 (27.1)	0.008
Dementia	56 (9.2)	75 (8.4)	0.027	46 (8.4)	43 (7.9)	0.02
Depression	156 (25.6)	191 (21.4)	0.098	136 (24.9)	128 (23.4)	0.034
Cancer	99 (16.2)	108 (12.1)	0.118	86 (15.7)	76 (13.9)	0.051
Arthritis	245 (40.2)	379 (42.5)	0.048	219 (40.0)	227 (41.5)	0.03
Obesity	156 (25.6)	249 (27.9)	0.054	146 (26.7)	142 (26.0)	0.017
Infective endocarditis	22 (3.6)	30 (3.4)	0.013	19 (3.5)	25 (4.6)	0.056
Procedural setting			0.344			0.018
Elective	447 (73.3)	543 (60.9)		398 (72.8)	399 (72.9)	
Emergency	61 (10.0)	196 (22.0)		59 (10.8)	61 (11.2)	
Urgent	102 (16.7)	151 (16.9)		90 (16.5)	87 (15.9)	
Pulmonary hypertension	239 (39.2)	360 (40.4)	0.025	211 (38.6)	214 (39.1)	0.011
Rheumatic disease	285 (46.7)	237 (26.6)	0.427	234 (42.8)	204 (37.3)	0.112
Pacemaker/ICD leads	144 (23.6)	116 (13.0)	0.276	118 (21.6)	96 (17.6)	0.102
Hx of cardiac surgery	93 (15.2)	308 (34.6)	0.458	91 (16.6)	95 (17.4)	0.019

Baseline characteristics of patients undergoing isolated tricuspid valve repair and replacement before and after propensity score matching. Values are median [Q1, Q3] or n (%). Cells with ≤10 patients are suppressed to protect the privacy of beneficiaries in accordance with the Centers for Medicare & Medicaid Services guidance. *SMD*, Standard mean difference; *TIA*, transient ischemic attack; *COPD*, chronic obstructive pulmonary disease; *ICD*, implantable cardioverter defibrillator; *Hx*, history; *Q1*, quartile 1; *Q3*, quartile 3.

TABLE E3. Baseline characteristics: replacement with bioprosthetic valves versus repair

Characteristics	Unmatched cohort			Matched cohort		
	Replacement	Repair	SMD	Replacement	Repair	SMD
Patients	551	891		504	504	
Age, y	75.00 [70.00, 79.00]	74.00 [69.50, 78.00]	0.071	75.00 [70.00, 79.00]	75.00 [70.00, 79.00]	0.008
Female	348 (63.2)	506 (56.8)	0.13	316 (62.7)	313 (62.1)	0.012
Race			0.171			0.123
White	445 (80.8)	750 (84.2)		412 (81.7)	419 (83.1)	
Black	39 (7.1)	60 (6.7)		37 (7.3)	35 (6.9)	
Asian	26 (4.7)	20 (2.2)		19 (3.8)	14 (2.8)	
Hispanic	25 (4.5)	37 (4.2)		20 (4.0)	24 (4.8)	
Hypertension	509 (92.4)	799 (89.7)	0.095	465 (92.3)	461 (91.5)	0.029
Hyperlipidemia	413 (75.0)	664 (74.5)	0.01	382 (75.8)	380 (75.4)	0.009
Diabetes mellitus	192 (34.8)	308 (34.6)	0.006	173 (34.3)	180 (35.7)	0.029
Previous myocardial infarction	≤10	40 (4.5)	0.208	≤10	≤10	0.019
Ischemic heart disease	470 (85.3)	756 (84.8)	0.013	432 (85.7)	430 (85.3)	0.011
Congestive heart failure	509 (92.4)	770 (86.4)	0.194	463 (91.9)	453 (89.9)	0.069
Atrial fibrillation	429 (77.9)	613 (68.8)	0.206	387 (76.8)	382 (75.8)	0.023
Chronic kidney disease	329 (59.7)	467 (52.4)	0.147	299 (59.3)	293 (58.1)	0.024
Previous stroke/TIA	34 (6.2)	58 (6.5)	0.014	26 (5.2)	25 (5.0)	0.009
COPD	159 (28.9)	229 (25.7)	0.071	139 (27.6)	140 (27.8)	0.004
Asthma	76 (13.8)	85 (9.5)	0.133	62 (12.3)	61 (12.1)	0.006
Liver disease	156 (28.3)	159 (17.8)	0.25	128 (25.4)	127 (25.2)	0.005
Anemia	443 (80.4)	621 (69.7)	0.249	399 (79.2)	394 (78.2)	0.024
Peripheral vascular disease	152 (27.6)	233 (26.2)	0.032	142 (28.2)	133 (26.4)	0.04
Dementia	50 (9.1)	75 (8.4)	0.023	41 (8.1)	38 (7.5)	0.022
Depression	137 (24.9)	191 (21.4)	0.081	126 (25.0)	119 (23.6)	0.032
Cancer	96 (17.4)	108 (12.1)	0.15	83 (16.5)	68 (13.5)	0.083
Arthritis	217 (39.4)	379 (42.5)	0.064	198 (39.3)	209 (41.5)	0.044
Obesity	136 (24.7)	249 (27.9)	0.074	133 (26.4)	124 (24.6)	0.041
Infective Endocarditis	20 (3.6)	30 (3.4)	0.014	17 (3.4)	23 (4.6)	0.061
Procedural setting			0.321			0.04
Elective	400 (72.6)	543 (60.9)		365 (72.4)	373 (74.0)	
Emergency	59 (10.7)	196 (22.0)		56 (11.1)	55 (10.9)	
Urgent	92 (16.7)	151 (16.9)		83 (16.5)	76 (15.1)	
Pulmonary hypertension	216 (39.2)	360 (40.4)	0.025	198 (39.3)	191 (37.9)	0.029
Rheumatic disease	259 (47.0)	237 (26.6)	0.433	220 (43.7)	197 (39.1)	0.093
Pacemaker/ICD Leads	129 (23.4)	116 (13.0)	0.272	112 (22.2)	93 (18.5)	0.094
Hx of cardiac surgery	84 (15.2)	308 (34.6)	0.458	84 (16.7)	82 (16.3)	0.011

Baseline characteristics of patients undergoing isolated tricuspid valve repair and replacement before and after propensity score matching. Values are median [Q1, Q3] or n (%). Cells with ≤10 patients are suppressed to protect the privacy of beneficiaries in accordance with the Centers for Medicare & Medicaid Services guidance. *SMD*, Standard mean difference; *TIA*, transient ischemic attack; *COPD*, chronic obstructive pulmonary disease; *ICD*, implantable cardioverter defibrillator; *Hx*, history; *Q1*, quartile 1; *Q3*, quartile 3.

TABLE E4. In-hospital outcomes: replacement with bioprosthetic valves versus repair groups

Characteristics	Unmatched cohort			Matched cohort		
	Replacement	Repair	*P* value	Replacement	Repair	*P* value
Patients	551	891		504	504	
In-hospital death	74 (13.4)	100 (11.2)	.243	69 (13.7)	67 (13.3)	.927
Ischemic stroke	≤10	20 (2.2)	.092	≤10	≤10	.772
Intracerebral hemorrhage	≤10	≤10	1	≤10	≤10	1
Acute kidney injury	195 (35.4)	274 (30.8)	.077	175 (34.7)	155 (30.8)	.202
Cardiogenic shock	86 (15.6)	136 (15.3)	.920	74 (14.7)	74 (14.7)	1
Permanent pacemaker	114 (27.0)	117 (15.1)	<.001	104 (26.5)	52 (12.7)	<.001
Respiratory complications	55 (10.0)	103 (11.6)	.398	49 (9.7)	60 (11.9)	.310
Postoperative hemorrhage	29 (5.3)	38 (4.3)	.455	25 (5.0)	17 (3.4)	.270
Transfusions	148 (26.9)	196 (22.0)	.041	134 (26.6)	111 (22.0)	.106
Pericardial effusion/tamponade	16 (2.9)	49 (5.5)	.029	14 (2.8)	27 (5.4)	.056
Heart failure	58 (10.5)	81 (9.1)	.420	50 (9.9)	40 (7.9)	.320
Length of stay, d	12.00 [7.00, 20.00]	13.00 [7.00, 21.00]	.716	12.00 [7.00, 20.00]	11.00 [6.00, 20.00]	.111
Discharge location			.086			.401
Home	291 (52.8)	444 (49.8)		267 (53.0)	262 (52.0)	
Hospice	≤10	≤10		≤10	≤10	
Long-term care	28 (5.1)	67 (7.5)		23 (4.6)	33 (6.5)	
Skilled nursing facility	74 (13.4)	107 (12.0)		68 (13.5)	72 (14.3)	

Baseline characteristics of patients undergoing isolated tricuspid valve repair and replacement before and after propensity score matching. Values are median [Q1, Q3] or n (%). Cells with ≤10 patients are suppressed to protect the privacy of beneficiaries in accordance with the Centers for Medicare & Medicaid Services guidance. *Q1*, Quartile 1; *Q3*, quartile 3.

TABLE E5. Baseline characteristics: replacement versus repair in patients with device leads at baseline

Characteristics	Unmatched cohort			Matched cohort		
	Replacement	Repair	SMD	Replacement	Repair	SMD
Patients	144	116		118	96	
Age, y	75.00 [69.75, 79.25]	76.00 [71.00, 80.00]	0.134	75.00 [69.00, 79.00]	76.00 [71.00, 80.00]	0.191
Female	92 (63.9)	69 (59.5)	0.091	74 (62.7)	59 (61.5)	0.026
Race			0.445			0.434
White	128 (88.9)	100 (86.2)		105 (89.0)	83 (86.5)	
Black	≤10	≤10		≤10	≤10	
Asian	≤10	≤10		≤10	≤10	
Hispanic	≤10	≤10		≤10	≤10	
Hypertension	133 (92.4)	111 (95.7)	0.141	108 (91.5)	92 (95.8)	0.178
Hyperlipidemia	114 (79.2)	91 (78.4)	0.018	95 (80.5)	78 (81.2)	0.019
Diabetes mellitus	42 (29.2)	38 (32.8)	0.078	33 (28.0)	32 (33.3)	0.117
Previous myocardial infarction	≤10	≤10	0.027	≤10	≤10	0.056
Ischemic heart disease	127 (88.2)	103 (88.8)	0.019	102 (86.4)	87 (90.6)	0.132
Congestive heart failure	137 (95.1)	104 (89.7)	0.208	111 (94.1)	87 (90.6)	0.13
Atrial fibrillation	123 (85.4)	99 (85.3)	0.002	99 (83.9)	85 (88.5)	0.135
Chronic kidney disease	82 (56.9)	67 (57.8)	0.016	65 (55.1)	59 (61.5)	0.13
Previous stroke/TIA	13 (9.0)	≤10	0.079	≤10	≤10	0.13
COPD	32 (22.2)	30 (25.9)	0.085	23 (19.5)	29 (30.2)	0.25
Asthma	17 (11.8)	19 (16.4)	0.132	11 (9.3)	18 (18.8)	0.274
Liver disease	37 (25.7)	17 (14.7)	0.278	25 (21.2)	17 (17.7)	0.088
Anemia	120 (83.3)	83 (71.6)	0.285	94 (79.7)	73 (76.0)	0.087
Peripheral vascular disease	43 (29.9)	25 (21.6)	0.191	36 (30.5)	23 (24.0)	0.148
Dementia	14 (9.7)	≤10	0.137	≤10	≤10	0.044
Depression	38 (26.4)	30 (25.9)	0.012	34 (28.8)	25 (26.0)	0.062
Cancer	22 (15.3)	14 (12.1)	0.093	19 (16.1)	13 (13.5)	0.072
Arthritis	57 (39.6)	59 (50.9)	0.228	48 (40.7)	48 (50.0)	0.188
Obesity	30 (20.8)	31 (26.7)	0.139	28 (23.7)	24 (25.0)	0.03
Infective Endocarditis	≤10	≤10	0.149	≤10	≤10	0.206
Procedural setting			0.274			0.088
Elective	113 (78.5)	80 (69.0)		94 (79.7)	73 (76.0)	
Emergency	≤10	15 (12.9)		≤10	≤10	
Urgent	23 (16.0)	21 (18.1)		17 (14.4)	16 (16.7)	
Pulmonary Hypertension	62 (43.1)	46 (39.7)	0.069	50 (42.4)	38 (39.6)	0.057
Rheumatic Disease	69 (47.9)	39 (33.6)	0.294	46 (39.0)	38 (39.6)	0.012
Hx of cardiac surgery	19 (13.2)	35 (30.2)	0.421	19 (16.1)	19 (19.8)	0.096

Cells with ≤10 patients are suppressed to protect the privacy of beneficiaries in accordance with the Centers for Medicare & Medicaid Services guidance. *SMD*, Standard mean difference; *TIA*, transient ischemic attack; *COPD*, chronic obstructive pulmonary disease; *Hx*, history; *Q1*, quartile 1; *Q3*, quartile 3.

TABLE E6. In-hospital outcomes: replacement versus repair groups in patients with device leads at baseline

Characteristics	Unmatched cohort			Matched cohort		
	Replacement	Repair	*P* value	Replacement	Repair	*P* value
Patients	144	116		118	96	
In-hospital death	≤10	≤10	1	≤10	≤10	.725
Ischemic stroke	≤10	≤10	1	≤10	≤10	1
Intracerebral hemorrhage	≤10	≤10	.914	≤10	≤10	.917
Acute kidney injury	36 (25.0)	26 (22.4)	.734	31 (26.3)	22 (22.9)	.685
Cardiogenic shock	17 (11.8)	14 (12.1)	1	14 (11.9)	≤10	.908
Respiratory complications	16 (11.1)	≤10	.647	12 (10.2)	≤10	.435
Postoperative hemorrhage	≤10	≤10	.807	≤10	≤10	1
Transfusions	41 (28.5)	16 (13.8)	.007	32 (27.1)	12 (12.5)	.014
Pericardial effusion/tamponade	≤10	≤10	.494	≤10	≤10	1
Heart failure	16 (11.1)	≤10	.341	14 (11.9)	≤10	.144
Length of stay (d)	10.00 [6.00, 14.00]	9.00 [6.00, 16.00]	.901	10.00 [6.00, 14.00]	9.00 [6.00, 14.00]	.528
Discharge location			.691			.509
Home	89 (61.8)	67 (57.8)		74 (62.7)	56 (58.3)	
Long-term care	≤10	≤10		≤10	≤10	
Skilled nursing facility	44 (30.6)	39 (33.6)		36 (30.5)	31 (32.3)	

Baseline characteristics of patients undergoing isolated tricuspid valve repair and replacement before and after propensity score matching. Values are median [Q1, Q3] or n (%). Cells with ≤10 patients are suppressed to protect the privacy of beneficiaries in accordance with the Centers for Medicare & Medicaid Services guidance. *Q1*, Quartile 1; *Q3*, quartile 3.