

ORIGINAL RESEARCH

STRUCTURAL

# Prognostic Implications of Residual Tricuspid Regurgitation Grading After Transcatheter Tricuspid Valve Repair



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## ABSTRACT

**BACKGROUND** The safety profile of transcatheter tricuspid valve (TTV) repair techniques is well established, but residual tricuspid regurgitation (TR) remains a concern.

**OBJECTIVES** The authors sought to assess the impact of residual TR severity post-TTV repair on survival.

**METHODS** We evaluated the survival rate at 2 years of 613 patients with severe isolated functional TR who underwent TTV repair in TRIGISTRY according to the severity of residual TR at discharge using a 3-grade (mild, moderate, and severe) or 4-grade scheme (mild, mild to moderate, moderate to severe, and severe).

**RESULTS** Residual TR was none/mild in 33%, moderate in 52%, and severe in 15%. The 2-year adjusted survival rates significantly differed between the 3 groups (85%, 70%, and 44%, respectively; restricted mean survival time [RMST]:  $P = 0.0001$ ). When the 319 patients with moderate residual TR were subdivided into mild to moderate ( $n = 201$ , 33%) and moderate to severe ( $n = 118$ , 19%), the adjusted survival rate was also significantly different between groups (85%, 80%, 55%, and 44%, respectively; RMST:  $P = 0.001$ ). Survival was significantly lower in patients with moderate to severe residual TR compared to patients with mild to moderate residual TR ( $P = 0.006$ ). No difference in survival rates was observed between patients with no/mild and mild to moderate residual TR ( $P = 0.67$ ) or between patients with moderate to severe and severe residual TR ( $P = 0.96$ ).

**CONCLUSIONS** The moderate residual TR group was heterogeneous and encompassed patients with markedly different clinical outcomes. Refining TR grade classification with a more granular 4-grade scheme improved outcome prediction. Our results highlight the importance of achieving a mild to moderate or lower residual TR grade during TTV repair, which could define a successful intervention. (J Am Coll Cardiol Intv 2024;17:1485-1495) © 2024 by the American College of Cardiology Foundation.

## ABBREVIATIONS AND ACRONYMS

**RMST** = restricted mean survival time

**RV** = right ventricular

**TR** = tricuspid regurgitation

**TTV** = transcatheter tricuspid valve

**TV** = tricuspid valve

**T**ricuspid regurgitation (TR) is 1 of the most common valvular heart diseases in Western countries. Its prevalence is estimated to be similar to that of aortic stenosis and is expected to further increase as the population ages.<sup>1</sup> TR is associated with excess mortality and morbidity that increase with the severity of the regurgitation.<sup>2-8</sup> The high mortality rates associated with isolated tricuspid valve (TV) surgery have led to the development of transcatheter tricuspid valve (TTV) interventions.<sup>9-12</sup> Although still under investigation, TTV interventions have emerged as a less invasive alternative to surgery and are nowadays the dominant treatment modality in several countries. The safety of TTV repair is well-documented, but significant residual TR observed in up to one-third of patients postprocedure remains an important issue.<sup>13-16</sup>

We and others have shown that significant residual TR post-TTV repair is associated with a poor outcome.<sup>13,16</sup> Interestingly, the current 3-grade scheme (mild, moderate, and severe) recommended for the assessment of TR severity before and after interventions by the European and North American Societies of Cardiology<sup>17,18</sup> contrasts with the 4-grade scheme routinely used for mitral regurgitation (mild,

mild to moderate, moderate to severe, and severe).<sup>17</sup> We hypothesized that a more granular grading classification, similar to that of mitral regurgitation, may better define the prognosis of patients undergoing TTV interventions and more specifically that the current moderate TR grade encompasses patients experiencing markedly different outcomes, shedding new light on the relatively neutral effect of TTV repair compared to guideline-directed medical therapy recently reported in the TRILUMINATE trial.<sup>15</sup>

In patients who underwent TTV repair in TRIGISTRY, a large international multicenter registry, we aimed to evaluate the impact of residual TR severity on all-cause mortality rates at 2 years and more specifically to compare mortality rates according to the degree of residual TR at discharge using the currently recommended 3-grade scheme<sup>17,18</sup> or a 4-grade scheme subdividing moderate TR into mild to moderate and moderate to severe residual TR.

## METHODS

**STUDY DESIGN.** TRIGISTRY is a retrospective international multicenter registry across 10 countries (Austria, Canada, France, Germany, Israel, Italy, the Netherlands, Spain, Switzerland, and the United States) and 33 centers including adult patients with

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severe isolated functional TR on a native valve who were conservatively/medically managed, underwent an isolated TV surgery, or underwent TTV repair (Supplemental Appendix). The inclusion and exclusion criteria have been previously reported.<sup>16</sup> Patients with moderate or greater concomitant left-sided valvular heart disease were excluded as well as patients who underwent an aortic or mitral valve intervention (either surgical or transcatheter) within 3 months before the TV intervention. In the present study, we identified all patients who underwent isolated TTV repair, with no concomitant interventions, who were discharged alive postintervention and had their degree of residual TR assessed at discharge. Clinical, laboratory, echocardiographic, and outcomes information were collected locally by each center and centralized in a unique depository anonymized database at the University of Ottawa Heart Institute (echocardiographic methodology is presented with more details elsewhere).<sup>16,19</sup> Data analyses were performed by the Cardiovascular Research Methods Center at the University of Ottawa Heart Institute. The study was conducted in accordance with local institutional policies and was approved by each local Institutional Review Board.

**FOLLOW-UP AND OUTCOME.** Post-TTV repair, the residual TR grade was semiquantitatively assessed at discharge locally at each center by experienced dedicated echocardiographers using transthoracic echocardiography and graded using a 4-grade scheme (no or mild, mild to moderate, moderate to severe, and severe), similar to mitral regurgitation, based on a multiparametric approach integrating jet extension into the right atrium, vena contracta, diameter of the flow convergence, residual gap width, and mechanism of the residual regurgitation. We then aggregated the mild to moderate and moderate to severe categories into a single moderate TR grade to obtain a 3-grade scheme (mild, moderate, and severe) as recommended by the current guidelines.<sup>17,18,20</sup> The study endpoint was all-cause death at 2 years.

**STATISTICAL ANALYSIS.** Variables were expressed as the mean  $\pm$  SD or median (25th-75th percentile) for continuous variables and the number of patients (percentage) for categorical variables. Comparisons of baseline characteristics between groups were performed using analysis of variance, the chi-square test, the Student's *t*-test, or the nonparametric Wilcoxon test as appropriate. The actuarial survival rates were calculated and presented using the Kaplan-Meier method. Because the proportional hazards assumption was violated, the restricted mean survival time (RMST) method was used to compare the survival

experience between groups and expressed using the RMST difference and 95% CI. We performed univariable and multivariable analyses adjusted for age (as a continuous variable), sex, atrial fibrillation, diabetes, chronic lung disease, coronary artery disease, prior left-sided heart valve intervention, and the TRI-SCORE (model 1).<sup>19</sup> Multivariable analyses were also repeated after adjustment for age, sex, atrial fibrillation, diabetes, chronic lung disease, coronary artery disease, prior left-sided heart valve intervention, and each of the individual components of the TRI-SCORE (age  $\geq$ 70 years, NYHA functional class III-IV, right-sided heart failure signs, daily dose of furosemide  $\geq$ 125 mg, glomerular filtration rate  $<$ 30 mL/min, elevated total bilirubin, left ventricular ejection fraction  $<$ 60%, and moderate/severe right ventricular [RV] dysfunction) (model 2); 2  $\times$  2 comparisons were also performed using the RMST method. Analyses were performed at the 2-tailed *P*  $<$  0.05 level using SAS statistical software version 9.4 (SAS Institute Inc).

## RESULTS

**POPULATION.** In TRIGISTRY, 645 adult patients underwent TTV repair for severe isolated functional TR on a native TV; 509 patients (79%) were treated with a tricuspid edge-to-edge repair system (MitraClip or TriClip system [Abbott Structural Heart] or PASCAL system [Edwards Lifesciences]), 125 patients (19%) with annuloplasty (CardioBand system [Edwards Lifesciences]), and 11 patients (1%) with other techniques (Trialign [Mitralign, Inc] or Trichinch [4Tech Cardio Ltd]). Our study population consisted of 613 patients after the exclusion of 16 patients who died after the intervention during the same hospitalization and 16 patients in whom TR residual severity was not documented at discharge. The baseline characteristics of the study population are presented in Table 1. Briefly, the mean age was  $78 \pm 8$  years, and 60% were women. A permanent pacemaker was present in 29%, and 33% had prior left-sided valvular heart disease interventions. Most patients were severely symptomatic (86% were in NYHA functional class III-IV, and 63% presented with overt heart failure), 86% had atrial fibrillation, and the mean TRI-SCORE was  $5 \pm 2$  (median = 5 [25th-75th percentile: 4-6]). TTV interventions consisted of edge-to-edge repair in 492 patients (80%) and annuloplasty in 115 (19%).

**SURVIVAL ACCORDING TO RESIDUAL TR USING THE 3-GRADE SCHEME.** Among the 613 patients considered in this study, 203 patients had no/mild residual TR (33%), 319 had moderate residual TR (52%), and 91 had severe residual TR (15%) at discharge.

**TABLE 1** Baseline Characteristics Overall and According to Residual TR Grade at Discharge: 3-Grade Scheme

	Overall (N = 613)	No/Mild TR (n = 203)	Moderate TR (n = 319)	Severe TR (n = 91)	P Value
<b>Clinical</b>					
Age, y	78 ± 8	78 ± 7	77 ± 8	77 ± 7	0.11
Age ≥70 y <sup>a</sup>	542 (88)	188 (93)	277 (87)	77 (85)	0.05
Female	366 (60)	126 (62)	186 (58)	54 (59)	0.69
Body surface area, m <sup>2</sup>	1.86 ± 0.22	1.86 ± 0.22	1.86 ± 0.23	1.85 ± 0.19	0.88
Body mass index, kg/m <sup>2</sup>	26 ± 5	27 ± 5	26 ± 5	26 ± 5	0.39
Diabetes mellitus	155/610 (25)	51/201 (25)	85/318 (27)	19/91 (21)	0.53
Chronic lung disease	130 (21)	34 (17)	76 (24)	20 (22)	0.15
Coronary artery disease	246 (40)	74 (36)	126 (40)	46 (51)	0.07
Permanent pacemaker	178 (29)	47 (23)	102 (31)	29 (32)	0.08
Prior left-sided heart valve intervention	204 (33)	62 (31)	103 (32)	39 (43)	0.10
NYHA functional class III-IV <sup>a</sup>	528 (86)	175 (86)	273 (86)	80 (88)	0.85
Right-sided heart failure signs <sup>a</sup>	390 (63)	127 (63)	210 (66)	53 (58)	0.38
Daily dose of loop diuretic agents, mg	60 (40-120)	40 (20-80)	60 (40-120)	80 (40-120)	0.013
Daily dose of loop diuretic agents ≥125 mg <sup>a</sup>	116 (19)	21 (10)	74 (23)	21 (23)	<0.001
Atrial fibrillation	461/533 (86)	167/194 (86)	215/253 (85)	79/86 (92)	0.27
<b>Laboratory</b>					
Hemoglobin, g/dL	10.4 ± 2.6	10.7 ± 2.6	10.1 ± 2.7	11.1 ± 2	<0.001
Creatinine, μmol/L	125 ± 59	115 ± 46	128 ± 63	131 ± 61	0.03
Glomerular filtration rate, mL/min	52 ± 22	53 ± 20	52 ± 23	48 ± 19	0.19
Glomerular filtration rate <30 mL/min <sup>a</sup>	74 (12)	21 (10)	40 (13)	13 (14)	0.59
Elevated total bilirubin <sup>a</sup>	133 (22)	41 (20)	60 (19)	32 (35)	0.003
NT-proBNP, pg/mL	1,980 (1,135-3,783)	1,697 (1,052-3,673)	1,980 (1,133-3,539)	2,486 (1,630-4,988)	0.004
<b>Echocardiographic</b>					
Left ventricular ejection fraction, %	54 ± 11	54 ± 11	54 ± 11	53 ± 11	0.98
Left ventricular ejection fraction <60% <sup>a</sup>	446 (73)	145 (71)	235 (74)	66 (73)	0.85
Tricuspid annulus diameter in apical 4-chamber view, mm	45 ± 7	44 ± 6	46 ± 7	48 ± 9	0.0003
Moderate/severe right ventricular dilatation	420/541 (78)	119/181 (66)	229/282 (81)	72/78 (92)	<0.001
Moderate/severe right ventricular dysfunction <sup>a</sup>	160 (26)	47 (23)	83 (26)	30 (33)	0.21
Systolic pulmonary artery pressure, mm Hg	44 ± 16	45 ± 15	45 ± 16	39 ± 16	0.02
<b>TRI-SCORE</b>					
TRI-SCORE	5 (4-6)	5 (3-6)	5 (4-6)	5 (4-7)	0.05
≤3	144 (23)	56 (28)	69 (22)	19 (21)	–
4-5	245 (40)	84 (41)	128 (40)	33 (36)	–
≥6	224 (37)	63 (31)	122 (38)	39 (43)	–

Values are mean ± SD, n (%), n/N (%), or median (Q1-Q3). <sup>a</sup>The 8 parameters included in the TRI-SCORE.  
NT-proBNP = N-terminal pro-B-type natriuretic peptide; TR = tricuspid regurgitation.

Comparisons of the baseline characteristics according to residual TR severity using the 3-grade scheme are presented in **Table 1**. Groups differed with regard to age, daily dose of loop diuretics, creatinine, hemoglobin and total bilirubin level, presence of moderate/severe RV dilatation, systolic pulmonary pressure, and TRI-SCORE categories (**Table 1**). Differences in terms of a prior history of coronary artery disease, prior left-sided heart valve intervention, and permanent pacemaker were of borderline statistical difference.

Overall, the median follow-up was 0.74 years (25th-75th percentile: 0.27-1.77 years), and the survival rate, available in 98% of the population, was 71% at 2 years. As shown in **Figure 1**, survival was markedly different between patients with no/mild,

moderate, and severe residual TR (85%, 70%, and 44%, respectively;  $P = 0.0001$ ). After adjustment for age, sex, atrial fibrillation, diabetes, chronic lung disease, coronary artery disease, prior left-sided heart valve intervention, and the TRI-SCORE (model 1), the residual TR grade remained significantly associated with survival ( $P = 0.01$ ). The survival rates of patients with no/mild residual and moderate TR were both significantly better than the survival of patients with severe TR (RMST difference = 0.27; 95% CI: 0.09-0.46;  $P = 0.004$  and RMST difference = 0.10; 95% CI: 0.01-0.38;  $P = 0.04$ , respectively). Importantly, the survival of patients with moderate residual TR was not significantly different than the survival of patients with no/mild residual TR (RMST difference = -0.08; 95% CI: -0.21 to 0.06;  $P = 0.25$ ). Adjusting

for each of the components of the TRI-SCORE instead of the TRI-SCORE (model 2) only marginally changed our results with a persistent significant difference in survival between the groups overall ( $P = 0.02$ ), a lack of difference in survival between patients with no/mild and moderate residual TR ( $P = 0.27$ ), a significant difference between patients with no/mild and severe residual TR ( $P = 0.006$ ), and a difference in survival between patients with moderate and severe residual TR of borderline statistical significance ( $P = 0.06$ ).

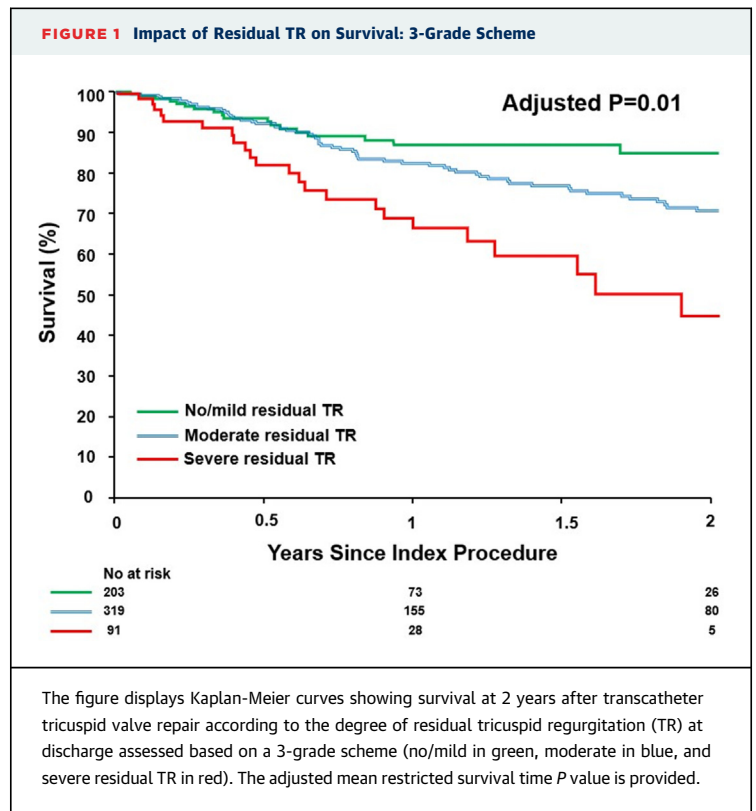
**SURVIVAL ACCORDING TO RESIDUAL TR USING THE 4-GRADE SCHEME.** Among the 319 patients with moderate TR at discharge, 201 had mild to moderate residual TR (33% of the overall study population), and 118 had moderate to severe residual TR (19%). Comparisons between residual TR groups using the 4-grade scheme are presented in [Table 2](#). There were several differences between groups regarding the daily dose of diuretics, hemoglobin and bilirubin levels, the presence of RV dilatation, and the TRI-SCORE.

The 2-year survival rate was markedly different between the 4 groups (85%, 80%, 55%, and 44% in patients with no/mild, mild to moderate, moderate to severe, and severe residual TR, respectively) in univariate and multivariate analyses ( $P = 0.001$ ; [Figure 2](#)). Adjusted survival was also significantly better in patients with mild to moderate residual TR than in patients with moderate to severe residual TR (RMST difference = 0.27; 95% CI: 0.07-0.47;  $P = 0.006$ ). Adjusted survival of patients with mild to moderate residual TR and no/mild TR was not different (RMST difference = 0.03; 95% CI: -0.12 to 0.17;  $P = 0.67$ ) nor was adjusted survival of patients with moderate to severe residual TR and severe residual TR (RMST difference = 0.01; 95% CI: -0.24 to 0.25;  $P = 0.96$ ). Adjusting for each component of the TRI-SCORE provided very similar results for the overall and  $2 \times 2$  comparisons.

The results remained grossly unchanged when analyses were repeated in the transcatheter edge-to-edge repair ( $P < 0.0001$ ) and transcatheter non-edge-to-edge repair subsets, although they did not reach statistical significance in the latter ( $P = 0.10$ ), likely because of the limited number of patients in each TR grade category in this subset ([Supplemental Figures 1A and 1B](#)).

**DISCUSSION**

In this large multicenter international registry of patients with severe isolated functional TR who



underwent TTV repair, we assessed the impact of residual TR severity evaluated at discharge on mortality and observed that the 2-year survival rate decreased with increasing residual TR grade ([Central Illustration](#)). More importantly, we observed important heterogeneity in the outcome of patients with moderate residual TR, which accounted for approximately one-half of the population. The survival rates of patients with mild to moderate and moderate to severe TR were markedly different, showing that a more granular 4-grade scheme further refines the prognosis of these patients. Conversely, the survival of patients with no/mild and mild to moderate residual TR was not different, whereas patients with moderate to severe residual TR experienced a survival akin to those with severe residual TR.

Transcatheter treatment of severe mostly functional TR has gained a substantial momentum, with repair techniques being widely adopted globally nowadays. Despite the excellent safety profile of these interventions, residual TR post-TTV repair is common and represents an important limitation. TRIGISTRY encompassed 613 patients who underwent TTV repair; 33% presented with no/mild residual TR, whereas 52% and 15% exhibited moderate or

**TABLE 2** Baseline Characteristics According to Residual TR Grade at Discharge: 4-Grade Scheme

	No/Mild TR (n = 203)	Mild to Moderate TR (n = 201)	Moderate to Severe TR (n = 118)	Severe TR (n = 91)	P Value
<b>Clinical</b>					
Age, y	78 ± 7	76.8 ± 8	77.5 ± 9	77 ± 7	0.17
Age ≥70 y <sup>a</sup>	188 (93)	174 (87)	103 (87)	77 (85)	0.13
Female	126 (62)	123 (61)	63 (53)	54 (59)	0.45
Body surface area	1.86 ± 0.22	1.85 ± 0.22	1.89 ± 0.23	1.85 ± 0.19	0.42
Body mass index	27 ± 5	26 ± 5	26 ± 5	26 ± 5	0.53
Diabetes mellitus	51/201 (25)	53 (26)	32/117 (27)	19/91 (21)	0.75
Chronic lung disease	34 (17)	51 (25)	25 (21)	20 (22)	0.21
Coronary artery disease	74 (36)	73 (36)	53 (45)	46 (51)	0.06
Permanent pacemaker	47 (23)	63 (31)	39 (33)	29 (32)	0.16
Prior left-sided heart valve intervention	62 (31)	66 (33)	37 (31)	39 (43)	0.20
NYHA functional class III-IV <sup>a</sup>	175 (86)	174 (87)	99 (84)	80 (88)	0.86
Right-sided heart failure signs <sup>a</sup>	127 (63)	134 (67)	76 (64)	53 (58)	0.56
Daily dose of loop diuretic agents, mg	40 (20-80)	60 (30-120)	70 (40-160)	80 (40-120)	0.02
Daily dose of loop diuretic agents ≥125 mg <sup>a</sup>	21 (10)	42 (21)	32 (27)	21 (23)	<0.001
Atrial fibrillation	167/194 (86)	138/163 (85)	77/90 (86)	79/86 (92)	0.44
<b>Laboratory</b>					
Hemoglobin, g/dL	10.7 ± 2.6	10 ± 2.7	10.2 ± 2.8	11.1 ± 2	0.002
Creatinine, μmol/L	115 ± 46	127 ± 66	130 ± 59	131 ± 61	0.08
Glomerular filtration rate, mL/min	53 ± 20	54 ± 22	51 ± 24	48 ± 19	0.30
Glomerular filtration rate <30 mL/min <sup>a</sup>	21 (10)	21 (10)	19 (16)	13 (14)	0.35
Elevated total bilirubin <sup>a</sup>	41 (20)	34 (17)	26 (22)	32 (35)	0.005
NT-proBNP, pg/mL	1,697 (1,052-3,673)	1,930 (1,100-3,050)	2,156 (1,172-4,214)	2,486 (1,630-4,988)	0.006
<b>Echocardiographic</b>					
Left ventricular ejection fraction, %	54 ± 11	53.85 ± 10.4	53.2 ± 11.1	53 ± 11	0.96
Left ventricular ejection fraction <60% <sup>a</sup>	145 (71)	149 (74)	86 (73)	66 (73)	0.95
Moderate/severe right ventricular dilatation	119/181 (66)	137/165 (83)	92/117 (79)	72/78 (92)	0.0001
Tricuspid annulus diameter in apical 4-chamber view	44 ± 6	46 ± 6	47 ± 7	48 ± 9	0.006
Moderate/severe right ventricular dysfunction <sup>a</sup>	47 (23)	57 (28)	26 (22)	30 (33)	0.20
Systolic pulmonary artery pressure, mm Hg	45 ± 15	47 ± 16	42 ± 16 <sup>b</sup>	39 ± 16	0.003
<b>TRI-SCORE</b>					
≤3	5 (3-6)	5 (4-6)	5 (4-6)	5 (4-7)	0.03
4-5	56 (28)	44 (22)	25 (21)	19 (21)	–
4-5	84 (41)	84 (42)	44 (37)	33 (36)	–
≥6	63 (31)	73 (36)	49 (42)	39 (43)	–

Values are mean ± SD, n (%), n/N (%), or median (Q1-Q3). <sup>a</sup>The 8 parameters included in the TRI-SCORE. <sup>b</sup>P < 0.05 between moderate to severe and mild to moderate TR. Abbreviations as in [Table 1](#).

severe residual TR at discharge, respectively. These proportions mirror those reported in the TRILUMINATE randomized trial in which 175 patients underwent TTV edge-to-edge repair.<sup>15</sup> The multiparametric and centralized evaluation of TR severity in TRILUMINATE revealed that 38% had moderate residual TR, and 13% had severe residual TR at 30 days. Additionally, findings from the BRIGHT prospective multicenter registry, featuring 511 patients who underwent TTV edge-to-edge repair, demonstrated that 23% and 20% of patients had moderate residual TR and severe residual TR at 30 days, respectively.<sup>14</sup> The alignment between TRIGISTRY and other studies, which included a centralized echocardiographic

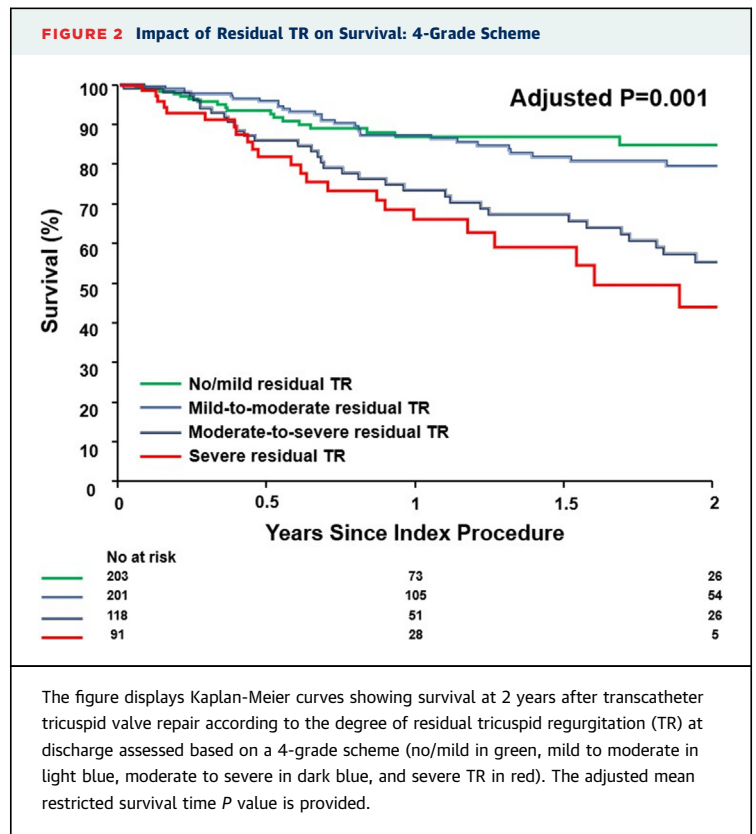
evaluation regarding residual TR rates, emphasizes the magnitude of the problem and the relevance of our findings.

Building on our previous findings that procedural success, defined based on the degree of residual TR at discharge, correlated with 2-year mortality rates,<sup>16</sup> we aimed in the present study to delve deeper into the association between residual TR severity and survival rates. Using first the recommended 3-grade scheme, we observed a decrease in survival rates as the residual TR grade increased. This association was observed in univariate analysis as well as using multiple adjustments and modeling, reinforcing the strength of the association between the degree of

residual TR and mortality. Importantly, we adjusted for the TRI-SCORE, which has been specifically developed to predict in-hospital mortality after isolated TV surgery.<sup>19</sup> The TRI-SCORE is dedicated to TV interventions and specifically captures the clinical presentation and sequelae of TR on the right ventricle, kidney, and liver. It is noteworthy that in TRIGISTRY, the survival of patients with significant residual TR after TTV repair was comparable to the survival of patients conservatively managed (medical therapy), whereas a successful procedure demonstrated a benefit compared to conservative management in the subsets of patients with low ( $\leq 3$ ) and, to a lesser extent, intermediate TRI-SCORE categories.<sup>4,5</sup>

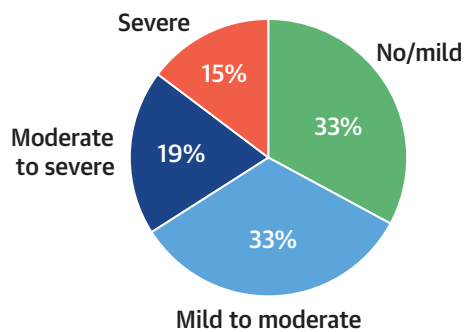
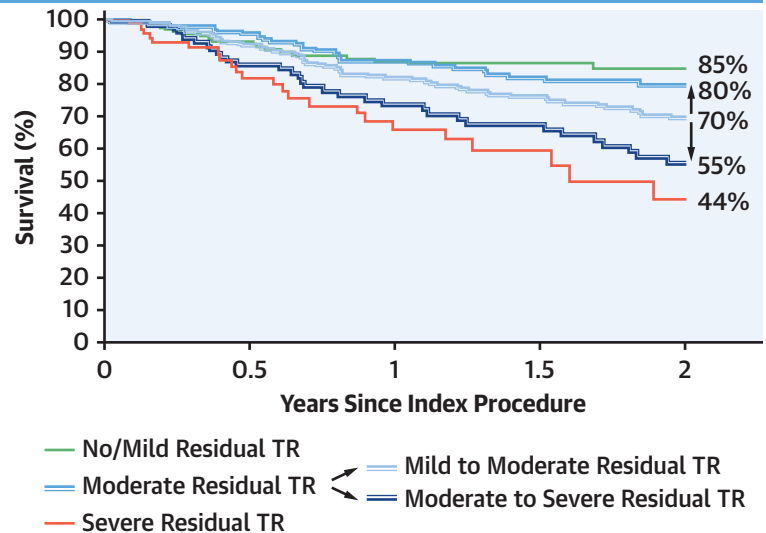
A major result of the present study is to highlight the limitations of the current 3-grade scheme for the assessment of TR severity. TR severity is a continuum, and it has been suggested to add at the right hand of the spectrum 2 additional grades: massive and torrential (5-grade scheme).<sup>21,22</sup> We show that the left hand of the spectrum also deserves a more precise assessment of the severity of the regurgitation as routinely performed for mitral regurgitation. Indeed, moderate TR encompasses a wide range of TR severity with patients experiencing different outcomes, and subdividing the moderate grade into mild to moderate and moderate to severe as for mitral regurgitation further refined the prognosis of these patients (4- or 6-grade scheme when also considering massive and torrential). Thus, patients with mild to moderate residual TR experienced a significantly better 2-year survival rate than patients with moderate to severe residual TR (80% and 55%, respectively;  $P = 0.006$ ). Although others are still ongoing, TRILUMINATE is the only randomized controlled study reported so far with a TTV repair arm.<sup>15</sup> TRILUMINATE showed an improvement in the quality of life of patients in the transcatheter edge-to-edge TV repair arm compared to the conservative management arm but no benefit on mortality or admission for heart failure at 1 year. As mentioned previously, 38% of patients presented a moderate residual TR and 13% a severe residual TR at 30 days. Assuming a similar subdivision of patients with moderate residual TR as in TRIGISTRY (two-thirds mild to moderate and one-third moderate to severe), 25% of the patients exhibited an unsuccessful intervention in TRILUMINATE, which might explain, at least partially, the absence of benefit of the intervention on hard endpoints.

**CLINICAL IMPLICATIONS AND PERSPECTIVES.** Our results advocate for a shift toward a more nuanced 4-grade scheme for the assessment of TR severity,



subdividing the moderate TR category into mild to moderate and moderate to severe. Notably, patients with mild to moderate TR exhibited survival rates comparable to those with no/mild TR, emphasizing the importance of achieving a mild to moderate or less residual TR grade and not considering moderate residual TR uniformly as a conclusive measure of successful TTV interventions. As transcatheter techniques continue to evolve and more technology becomes available, the choice between repair and replacement strategies will be crucial. Balancing safety, efficacy, durability, and predictability of procedural results will be imperative. Our results underscore the need for directing effort toward technological advancements and operator expertise to optimize the procedural results of TTV repair.

**STUDY LIMITATIONS.** First, TRIGISTRY is a retrospective, observational registry with inherent bias related to its design. However, TRIGISTRY is a large, homogenous, multicenter international registry with patients consecutively enrolled at each center. In addition, only patients with isolated functional severe TR were enrolled. Second, the assessment of residual TR degree, which may be difficult, particularly after edge-to-edge repair, was semiquantitative

**CENTRAL ILLUSTRATION** Impact on Mortality of Residual Tricuspid Regurgitation Grade After Transcatheter Tricuspid Valve Repair**TRIGISTRY: Transcatheter Tricuspid Valve Repair in Severe Isolated Functional Tricuspid Regurgitation, N = 613****A** Residual TR at Discharge**B** Survival According to Residual TR Severity

- Survival at 2 years following TTVR was worse in patients with moderate to severe compared to mild to moderate residual TR ( $P = 0.006$ ) but not different between no/mild and mild to moderate ( $P = 0.67$ ) and between moderate to severe and residual TR ( $P = 0.96$ )
- Prediction of survival is improved using a more granular 4-grade TR classification (ie, dividing moderate residual TR into 2 subgroups)
- These results highlight the importance of achieving mild to moderate or less residual TR during transcatheter tricuspid valve repair

Dreyfus J, et al. *J Am Coll Cardiol Intv.* 2024;17(12):1485-1495.

We evaluated the survival rates up to 2 years of 613 TRIGISTRY patients who underwent transcatheter tricuspid valve repair (TTVR) according to the degree of residual tricuspid regurgitation (TR) at discharge (A) using either a 3-grade scheme (no/mild, moderate, and severe) or a 4-grade scheme subdividing moderate TR into mild to moderate and moderate to severe. The residual TR grade was semiquantitatively assessed using transthoracic echocardiography based on a multiparametric approach. There was a significant difference between groups using both the 3- and 4-grade classifications (adjusted  $P = 0.01$  and  $P = 0.001$ , respectively), but it is noteworthy that survival was significantly different between patients with mild to moderate and moderate to severe residual TR (B), suggesting that a more granular grading scheme improves outcome prediction.

and conducted locally by each center without a centralized assessment and no precise quantitative thresholds. However, the echocardiographic assessment was performed by experienced dedicated echocardiographers, and the large number of participating centers mitigates the risk of systematic underestimation or overestimation of TR severity. The similar distribution of TR grades between TRIGISTRY and other studies is also very reassuring. Nevertheless, we show that real-life assessment of residual TR severity by centers and more granular

grading predict survival. Providing definition for mild to moderate and moderate to severe TR is outside the scope of the present study but should definitively be part of future objectives under the guidance of scientific societies. Third, TR grade was only assessed at discharge, and we were unable to evaluate the prognostic impact of changes in TR severity over time. Similarly, changes in diuretic doses were not captured. Fourth, the survival rates of patients with mild to moderate and no/mild residual TR were not statically different although numerically lower (80%

vs 85%, respectively) as survival rates between patients with moderate to severe and severe residual TR (55% vs 44%, respectively). These results deserve validation in future studies, but we cannot exclude that the lack of difference observed in the present study was not because of a lack of statistical power. Fifth, although TTV interventions are relatively recent and a learning curve is expected, 80% of the transcatheter interventions were performed after 2018. In addition, different devices were used in TRIGISTRY. Transcatheter edge-to-edge repair was performed in 80% of the population, but the impact of residual TR was consistent across the types of interventions (transcatheter edge-to-edge repair vs transcatheter non-edge-to-edge repair) (Supplemental Figures 1A and 1B). Although the rate of moderate to severe or severe residual TR might decrease with experience and advances in technology, it does not affect our main finding (ie, the impact of residual TR on survival and the need for a more granular evaluation of TR severity). Sixth, the determinants of residual TR are likely complex, involving a combination of factors such as patients' characteristics, tricuspid valve anatomy including gap width, and the experience of the operators. The lack of precise anatomical evaluation in our registry precluded performing relevant analysis regarding the determinants of residual TR. Seventh, we defined isolated TR as TR occurring in the absence of other concomitant significant valvular disease but did not exclude patients with prior left-sided interventions (which accounted to one-third of our population). In addition, we were not able to differentiate between atrial and ventricular functional TR. Also, echocardiographic evaluation of the RV systolic pulmonary pressure in patients with severe TR is often inaccurate, especially when TR is laminar, explaining why it was not an independent determinant of outcome and not part of the TRI-SCORE. Hemodynamic assessment of the RV systolic pulmonary pressure would have been of interest but was not collected in TRIGISTRY. Eighth, the cause of death was not collected, and we only reported all-cause death. Finally, our findings deserve further validation in other observational studies and in subgroup analyses of randomized controlled studies showing a potential benefit of TTV intervention only in patients with mild to moderate or lower residual TR.

## CONCLUSIONS

We have evaluated the impact of the degree of residual TR after TTV repair in TRIGISTRY and showed that survival rates decreased with the grade of

residual TR. We also showed that the outcome of patients with moderate residual TR grade was heterogeneous and that subdividing the moderate TR grade into mild to moderate and moderate to severe TR grades refined the prognosis of these patients. Our results support the use of a more granular 4-grade scheme and highlight the importance of achieving optimal procedural results defined as a mild to moderate or lower residual TR grade instead of a moderate or lower residual TR grade. These findings deserve further confirmation in other studies and critically in randomized controlled studies.

**ACKNOWLEDGMENTS** The authors thank Dr George Wells and Jordan Bernick for their help with the statistical analysis. They also thank all the investigators of TRIGISTRY for their active participation and support.

## FUNDING SUPPORT AND AUTHOR DISCLOSURES

Dr Dreyfus has received speaker or proctoring fees from Abbott. Dr Kresoja has received consulting fees from Edwards Lifesciences. Dr Taramasso has received consulting or speaker fees from Abbott Vascular, Edwards Lifesciences, Medtronic, Boston Scientific, Shenqi Medical, PiCardia, CoreMedic, VentriMend, MEDIRA, CoreQuest, and HiD Imaging. Dr Iliadis has received consulting fees from Abbott Vascular and Edwards Lifesciences. Dr Nombela-Franco has received consulting or speaker fees from Abbott Vascular, Edwards Lifesciences, and Products and Features. Dr Estevez-Loureiro has received speaker fees from Abbott Vascular, Edwards Lifesciences, Boston Scientific, and Venus Medtech. Dr Hausleiter has received grants and consulting fees from Edwards Lifesciences. Dr Stolz has received consulting or speaker fees from Edwards Lifesciences. Dr Windecker has received research, travel, or educational grants to the institution without personal remuneration from Abbott, Abiomed, Amgen, AstraZeneca, Bayer, Braun, Biotronik, Boehringer Ingelheim, Boston Scientific, Bristol Myers Squibb, Cardinal Health, CardioValve, Cordis Medical, Corflow Therapeutics, CSL Behring, Daiichi-Sankyo, Edwards Lifesciences, Farapulse Inc Fumedica, Guerbet, Idorsia, Inari Medical, InfraRedx, Janssen-Cilag, Johnson & Johnson, Medalliance, Medtronic, Merck Sharp & Dohme, Miracor Medical, MonarQ, Novartis, Novo Nordisk, Organon, OrPha Suisse, Pharming Tech Pfizer, Polares, Regeneron, Sanofi, Servier, Sinomed, Terumo, Vifor, and V-Wave; has served as an Advisory Board member and/or member of the Steering/Executive Group of trials funded by Abbott, Abiomed, Amgen, AstraZeneca, Bayer, Boston Scientific, Biotronik, Bristol Myers Squibb, Edwards Lifesciences, MedAlliance, Medtronic, Novartis, Polares, Recardio, Sinomed, Terumo, and V-Wave with payments to the institution but no personal payments; and has served as a member of the Steering/Executive Committee Group of several investigator-initiated trials that receive funding by industry without impact on his personal remuneration. Dr Zamorano has received consulting or speaker fees from Novartis, Bayer, and Pfizer. Dr von Bardeleben has received consulting or speaker fees from Abbott Vascular, Edwards Lifesciences, Medtronic, Philips, and Siemens. Dr Tang has received speaker honoraria and has served as a physician proctor, consultant, Advisory Board member, TAVR Publications Committee Member, APOLLO Trial Screening Committee Member, and IMPACT MR Steering Committee member for Medtronic; has received speaker honoraria and has served as a physician proctor, consultant, Advisory Board member, and TRILUMINATE Trial Anatomic Eligibility and Publications Committee member for Abbott Structural Heart; has served as an Advisory Board member for Boston

Scientific and JenaValve; has served as a consultant and Physician Screening Committee Member for Shockwave Medical; has served as a consultant for NeoChord, Peija Medical, and Shenqi Medical Technology; and has received speaker honoraria from Siemens Healthineers. Dr Hahn has received speaker fees from Boston Scientific, Edwards Lifesciences, and Philips Healthcare. Dr Webb has received consulting fees from Edwards Lifesciences; and has received research funding from Medtronic, Abbott, Boston Scientific, and Edwards Lifesciences. Dr Lauten has received speaker fees from Boehringer Ingelheim, Medtronic, Amgen, Bayer, Novartis, Sanofi, Chiesi, and AstraZeneca; and is a shareholder of the Devie Medical Drug Eluting Valve for Endocarditis Treatment. Dr Rodés-Cabau has received consulting or speaker fees from Abbott Vascular, Edwards Lifesciences, and Medtronic. Dr Nejjari has received consulting or speaker fees from Abbott Vascular, Medtronic, Edwards Lifesciences, Boston Scientific, and Robocath. Dr Badano has received consulting or speaker fees from Edwards Lifesciences, GE Healthcare, and Philips Medical Systems. Dr Himbert has received proctoring fees from Edwards Lifesciences and Abbott Vascular. Dr Modine has received speaker or consulting fees from Abbott, Edwards Lifesciences, Medtronic, Microport, and GE. Dr Rudolph has received consulting or speaker fees from Abbott Vascular and Edwards Lifesciences. Dr Bax has received lecture fees from Abbott and Edwards Lifesciences. Dr Lurz has received consulting fees from Abbott Medical, Innoventric, and Edwards Lifesciences. Dr Maisano has received grant and/or research institutional support from Abbott, Medtronic, Edwards Lifesciences, Biotronik, Boston Scientific Corporation, NVT, Terumo, Venus, and 3mensio; has received consulting fees and personal and institutional honoraria from Abbott, Medtronic, Edwards Lifesciences, Xeltis, Cardiovalve, Occlufit, Simulands, Mtex, Venus, and Squadra; has received royalty income/IP rights from Edwards Lifesciences; and is a shareholder (including share options) in Cardiogard, Cardiovalve, Magenta, SwissVortex, Transseptalsolutions, and 4Tech. Dr Messika-Zeitoun has received research grants from Edwards Lifesciences. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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## PERSPECTIVES

**WHAT IS KNOWN?** Significant residual TR is common after TTV repair.

**WHAT IS NEW?** Residual TR grade after TTV repair significantly impacts survival. Procedural success should be defined as a mild to moderate or lower TR grade at discharge.

**WHAT IS NEXT?** Future recommendations should aim to refine TR grade assessment by adopting a 4-grade scheme that subdivides moderate TR into mild to moderate and moderate to severe TR, and efforts should be directed toward achieving mild to moderate or lower residual TR grade after TTV repair.

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**KEY WORDS** survival, transcatheter intervention, tricuspid regurgitation

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**APPENDIX** For the supplemental appendix and figures, please see the online version of this paper.