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ORIGINAL RESEARCH

GLIDE Score

Scoring System for Prediction of Procedural Success in Tricuspid Valve Transcatheter Edge-to-Edge Repair

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ABSTRACT

BACKGROUND Tricuspid valve transcatheter edge-to-edge repair (T-TEER) is the most widely used transcatheter therapy to treat patients with tricuspid regurgitation (TR).

OBJECTIVES The aim of this study was to develop a simple anatomical score to predict procedural outcomes of T-TEER.

METHODS All patients (n = 168) who underwent T-TEER between January 2017 and November 2022 at 2 centers were included in the derivation cohort. Additionally, 126 patients from 2 separate institutions served as a validation cohort. T-TEER was performed using 2 commercially available technologies. Core laboratory assessment of procedural transesophageal echocardiograms was used to determine septolateral and anteroposterior coaptation gap, leaflet morphology, septal leaflet length and retraction, chordal structure density, tethering height, en face TR jet morphology and TR jet location, image quality, and the presence of intracardiac leads. A scoring system was derived using univariable and multivariable logistic regression. Endpoints assessed were immediate postprocedural TR reduction ≥2 grades and TR grade moderate or less.

RESULTS The median age was 82 years (Q1-Q3: 78-84 years); 48% of patients were women; and patients presented with severe (55%), massive (36%), and torrential (8%) TR. Five variables (septolateral coaptation gap, chordal structure density, en face TR jet morphology, TR jet location, and image quality) were identified as best predicting procedural outcome and were incorporated in the GLIDE (Gap, Location, Image quality, density, en-face TR morphology) score (range 0-5). TR reduction ≥2 grades and TR grade moderate or less were observed in >90% of patients with GLIDE scores of 0 and 1 and in only 5.6% and 16.7% of those with GLIDE scores ≥4. The GLIDE score was then externally validated in a separate cohort (area under the curve: 0.77; 95% CI: 0.69-0.86). TR reduction significantly correlated with functional improvement assessed by NYHA functional class and 6-minute walk distance at 3 months.

CONCLUSIONS The GLIDE score is a simple, 5-component score that is readily obtained during patient imaging and can predict successful T-TEER. (J Am Coll Cardiol Img 2024;17:729-742) © 2024 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

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ABBREVIATIONS AND ACRONYMS

TEE = transesophageal echocardiographic

TR = tricuspid regurgitation

T-TEER = tricuspid valve transcatheter edge-to-edge repair

TTVI = transcatheter tricuspid valve intervention

Severe tricuspid regurgitation (TR) is independently associated with adverse outcomes and increased mortality if it remains undertreated. Medical management of severe TR is often limited to diuretic agents and rhythm management, while surgical intervention typically poses high risk, as these patients often have multiple comorbidities.[1,2] With the advent of transcatheter tricuspid valve intervention (TTVI), there has been a notable increase in treatment options for patients with severe TR.[3-8]

The TriClip system (Abbott) and the PASCAL system (Edwards Lifesciences) are the 2 main tricuspid valve transcatheter edge-to-edge repair (T-TEER) technologies. Both systems are commercially available in Europe and have been shown to be safe and effective.[4,9] In early studies, T-TEER resulted in sustained TR reduction (≥2 grades) in 70% to 78% of patients as well as improved quality of life and functional status.[4,10,11]

Several prospective, randomized pivotal and registry trials are ongoing, evaluating outcomes of TTVI, the timing of intervention, optimal patient selection, and interventional techniques for those with significant TR.[12-15] A recent multicenter, prospective, randomized trial comparing T-TEER with optimal medical therapy demonstrated that T-TEER resulted in significant improvement in functional status that was most evident in those with final TR grades of moderate or less or those with a reduction of at least 2 grades in TR.[16] Also, registry data indicate that moderate or greater residual TR is associated with worsening heart failure symptoms and adverse events, including reduced survival.[17] Accordingly, it is important to identify anatomical characteristics of patients who are most likely to benefit from these technologies.

Despite increasing use of T-TEER, there is no anatomical algorithm to evaluate the procedural complexity and predict TR reduction. The aim of this study sought to develop a dedicated, simple, anatomical score to predict immediate postprocedural outcomes of T-TEER, with the goal of assisting patient selection for TTVI.

METHODS

STUDY POPULATION. All consecutive patients with TR who underwent T-TEER using the PASCAL or the TriClip device between January 2017 and November 2022 at 4 tertiary centers with dedicated transcatheter valve intervention programs were included in this study (Supplemental Methods, Supplemental Figures 1 to 11). Patients at 2 centers (the Heart and Diabetes Center NRW, Ruhr-Universität Bochum, Bad Oeynhausen, Germany, and the Department of Cardiology and Angiology, University Hospital Tübingen, Tübingen, Germany) were used as a derivation cohort (n = 168). Patients at 2 separate centers (the Department for Internal Medicine III, University of Cologne, Cologne, Germany, and the West German Heart and Vascular Center, University Hospital Essen, Essen, Germany) served as the validation cohort (n = 126).

Northwestern University served as the core laboratory for the assessment of echocardiographic images using guidelines and recommendations published by the American Society of Echocardiography and the European Society of Cardiovascular Imaging.[18,19]

Data collection was approved by the local Institutional Review Boards. Written informed consent was obtained from every patient.

OUTCOMES. T-TEER procedural success was defined by 2 methods using baseline and postprocedural transesophageal echocardiographic (TEE) imaging: TR reduction ≥2 grades or TR grade moderate or less. Intraprocedural success was defined according to the Tricuspid Valve Academic Research Consortium consensus: successful delivery, deployment, and positioning of the device; absence of procedural mortality; and freedom from emergency surgery related to the device (except for device performance).[20,21] Functional status was assessed by NYHA functional class and 6-minute walk distance at baseline and at 3 months.

STATISTICAL ANALYSIS AND GLIDE SCORE MODELING. Descriptive statistics were used to summarize baseline characteristics. Mean ± SD was used

The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

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for continuous and normally distributed variables, and median (Q1-Q3) was used for continuous and non-normally distributed variables. Normality of continuous variables were examined using skewness and kurtosis and by visual inspection of histograms. Frequencies and percentages were used for categorical variables. Postprocedural echocardiographic imaging parameters were compared with baseline parameters using paired Student's *t*-test and the McNemar test as appropriate. Baseline and echocardiographic characteristics were compared between the derivation and validation data sets using 2-sample Student's *t*-test, the Wilcoxon signed rank test, and the chi-square test as appropriate.

A scoring system was developed (the GLIDE score) on the basis of the current understanding of anatomical determinants of procedural success in T-TEER interventions for severe TR. Several readily available echocardiographic parameters obtained from the TEE examination prior to the intervention were assessed by the core laboratory, which was blinded to the procedural results. Parameters included: 1) septolateral coaptation gap, anteroposterior coaptation gap, and septal leaflet length (millimeters); 2) the number and morphology of leaflets;[15] 3) septal leaflet retraction (angle between the midsystolic septal leaflet position and the plane of the tricuspid annulus of ≤20°, 21°-40°, or >40°); 4) tethering height (millimeters); 5) chordal structure density (modest or high chordal density in a potential grasping zone); 6) en face tricuspid regurgitant jet morphology (circular or oval or star shaped) and jet location (anteroseptal or central, posteroseptal, or anteroposterior or diffuse); 7) image quality (good or limited because of, eg, shadowing from mechanical prostheses or calcifications, lack of clear leaflet identification, or imaging artifacts); and 8) intracardiac lead position and associated leaflet impingement.

Explanations of the selected parameters are provided in the Supplemental Methods.

To develop the score, we used univariable logistic regression to evaluate the association between immediate postprocedural TEE outcomes (TR reduction ≥2 grades and postprocedure TR moderate or less) and each baseline variable. Variables that were significant at $P < 0.10$ in univariable analysis were used to build multivariable logistic regression models. Variables were removed from the multivariable logistic regression model in a stepwise, backward approach at alpha <0.05 to choose a parsimonious model with balanced variable preservation and minimal collinearity, guaranteeing the highest predictive power of the GLIDE score (Supplemental Tables 1 and 2).

The continuous GLIDE score was generated using variables retained in the final multivariable logistic regression model. The categorical variables were allocated numerical values (0 points for

TABLE 1 Baseline and Procedural Characteristics of 168 Patients With TR Undergoing Edge-to-Edge Repair

Baseline and medical history	
Age, y	82 (78-84)
Female	81 (48.2)
Body mass index, kg/m^2	25.8 ± 4.7
EuroSCORE II, %	5.3 (3.1-8.8)
Atrial fibrillation	149 (88.7)
Diabetes mellitus	41 (24.4)
Chronic obstructive pulmonary disease	27 (16.1)
Coronary artery disease	86 (51.2)
History of cardiac surgery	57 (33.9)
Stroke	33 (19.8)
Dialysis	6 (3.6)
NT-proBNP, pg/mL[a] (n = 139)	2,750 (1,420-5,680)
Mean pulmonary artery pressure, mm Hg (n = 134)	30.0 ± 9.4
Pulmonary capillary wedge pressure, mm Hg (n = 129)	19.3 ± 6.8
Pulmonary vascular resistance, WU (n = 1,221)	3.2 (2.2-4.3)
TR etiology	
Atrial	71 (42.3)
Ventricular	88 (52.4)
Primary	9 (5.4)
TR grade	
Severe	93 (55.4)
Massive	61 (36.3)
Torrential	14 (8.3)
Procedure	
Implanted device type	
PASCAL	113 (67.3)
TriClip	55 (32.7)
Duration of procedure,[b] min	106.5 ± 51.8
Number of implanted devices	
0	3 (1.8)
1	37 (22.0)
2	107 (63.7)
3	19 (11.3)
4	2 (1.2)
Position of first device implanted	
Anteroseptal	141 (86.5)
Posteroseptal	21 (12.9)
Anteroposterior	1 (0.6)
Position of second device implanted (n = 128)	
Anteroseptal	38 (29.7)
Posteroseptal	87 (68.0)
Anteroposterior	3 (2.3)

Values are median (Q1-Q3), n (%), or mean ± SD. [a]Dialysis patients were excluded from the analysis. [b]From puncture to percutaneous suture.

EuroSCORE = European System for Cardiac Operative Risk Evaluation; NT-proBNP = aminoterminal pro-brain natriuretic peptide; TR = tricuspid regurgitation; TV = tricuspid valve.

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TABLE 2 Outcomes of 168 Patients With TR Undergoing Edge-to-Edge Repair

Intraprocedural success[a]	159 (94.6)
Postprocedural TR grade	
Trace	27 (16.1)
Mild	81 (48.2)
Moderate	30 (17.9)
Severe	16 (9.5)
Massive	11 (6.5)
Torrential	3 (1.8)
TR reduction ≥1 grade from baseline	154 (91.7)
TR reduction ≥2 grades from baseline	133 (79.2)
Postprocedural TR moderate or less	138 (82.1)
Cardiac-structural complications including device detachment	2 (1.2)
Bleeding requiring transfusion or intervention	6 (3.6)
Cerebrovascular events (n = 166)	1 (0.6)
Renal failure	5 (3.0)
Need for pacemaker therapy (n = 166)	1 (0.6)
Duration of hospitalization, d (n = 166)	5 (4-8)

Values are n (%) or median (Q1-Q3). [a]Intraprocedural success was defined according to the Tricuspid Valve Academic Research Consortium consensus: successful delivery, deployment, and positioning of the device; absence of procedural mortality; and freedom from emergency surgery related to the device (except for device performance).

Abbreviation as in Table 1.

straightforward and 1 point for complex) on the basis of the perceived complexity of the parameter in T-TEER. For simplicity, continuous variables were also converted into categorical variables using the same scale (0 or 1 point) before being included in the GLIDE score. The continuous GLIDE score for each patient was calculated. The association between continuous GLIDE score and each postprocedural outcome was evaluated using a univariable logistic regression model.

The model was calibrated using the derivation and validation data sets, comparing the predicted and observed procedural success rates and measuring against the area under the receiver-operating characteristics curve. The calibration curve was created by plotting the observed frequencies of procedural success on the y-axis and the predicted probabilities on the x-axis using locally weighted scatterplot smoothing. These analyses were performed using the standard procedures available in the GLM function and GGPLOT package in R (R Foundation for Statistical Computing).

TR reduction was compared with improvements in NYHA functional class and 6-minute walk distance.

Interobserver and intraobserver variability for each score component was assessed in blind-selected patients by a second investigator. Reproducibility data were reported using kappa statistics. Analyses were performed using SAS version 9.4 (SAS Institute) and R version 3.5.2, with values of $P < 0.05$ considered to indicate statistical significance.

RESULTS

BASELINE AND ECHOCARDIOGRAPHIC CHARACTERISTICS. In total, 168 patients at 2 centers constituted the derivation cohort. The median age of the derivation cohort was 82 years (Q1-Q3: 78-84 years), and 48% were women (Table 1). The majority had atrial fibrillation (n = 149 [89%]). Most patients (n = 124 [74%]) had normal left ventricular ejection fractions. The mean pulmonary artery pressure was mildly elevated (30.0 ± 9.4 mm Hg), as were pulmonary wedge pressure (19.3 ± 6.8 mm Hg) and median pulmonary vascular resistance (3.2 WU; Q1-Q3: 2.2-4.3 WU). The mean right ventricular basal diameter was 46.4 ± 8.5 mm, and the mean tricuspid annular plane systolic excursion was 17.2 ± 4.7 mm (Supplemental Table 3). The mean right atrial area was 34.2 ± 12.3 cm^2, and the mean inferior vena cava diameter was 24.2 ± 5.7 mm. The anticipated risk for mortality during the first 30 days after surgery was elevated (median European System for Cardiac Operative Risk Evaluation II score 5.3%; Q1-Q3: 3.1%-8.8%).

PROCEDURAL CHARACTERISTICS AND OUTCOMES. Fifty-five patients (32.7%) were treated with T-TEER using the TriClip system, and 113 patients (67.3%) were treated using the PASCAL system (Table 1, Supplemental Table 4). Mean procedure time (from puncture to percutaneous suture) was 106 ± 52 minutes, and the median number of devices implanted was 2 (Q1-Q3: 1-2). The first device was implanted anteroseptally in 141 cases (87%) and posteroseptally in 21 of cases (13%). The second device was implanted anteroseptally in 38 cases (30%), posteroseptally in 87 cases (68%), and anteroposteriorly in 3 cases (2%).

Intraprocedural success was achieved in 159 patients (95%) (Table 2). Postprocedural TR reduction ≥1 grade was achieved in 154 patients (92%) and TR reduction ≥2 grades was observed in 133 patients (79%). Postprocedural TR grade moderate or less was achieved in 138 patients (82%). Few patients (n = 15 [9%]) experienced adverse complications: device detachment and cardiac structural complications including leaflet damage or perforation (n = 2), bleeding requiring transfusion or intervention (n = 6), cerebrovascular events (n = 1), renal failure (n = 5), or the need for pacemaker therapy (n = 1). The postprocedural mean tricuspid pressure gradient was 2.4 ± 1.3 mm Hg. The median duration of hospitalization was 5 days (Q1-Q3: 4-8 days). Importantly, there were no significant differences in baseline structural or functional parameters or procedural results between the PASCAL and the TriClip groups at discharge (Supplemental Table 5).

TABLE 3 Univariable Association Between Anatomic Determinants and Postprocedural Outcomes Among 168 Patients With TR Undergoing Edge-to-Edge Repair

		Model 1: TR Reduction ≥2 Grades		Model 2: TR Grade Moderate or Less	
	Baseline	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Septolateral coaptation gap, mm[a]	3 (2-5)	0.57 (0.47-0.70)	<0.01	0.54 (0.43-0.67)	<0.01
Septolateral coaptation gap, mm			<0.01		<0.01
0-5	141 (83.9)	14.59 (5.66-37.62)		16.74 (6.36-44.03)	
≥6	27 (16.1)	Ref.		Ref.	
Anterior posterior coaptation gap, mm	2 (0-4)	0.74 (0.64-0.84)	<0.01	0.77 (0.68-0.88)	<0.01
Septal leaflet length, mm[a]	2 (1-15)	0.92 (0.88-0.97)	<0.01	0.91 (0.87-0.97)	<0.01
Septal leaflet length, mm			<0.01		<0.01
≤6	98 (58.3)	3.51 (1.60-7.68)		4.24 (1.80-9.97)	
≥7	70 (41.7)	Ref.		Ref.	
Leaflet number/morphology			<0.01		<0.01
Type I or II	98 (58.3)	11.07 (2.99-40.93)		17.60 (4.49-69.04)	
Type III	58 (34.5)	3.38 (0.94-12.13)		7.67 (1.97-29.81)	
Type IV	12 (7.1)	Ref.		Ref.	
Septal leaflet retraction			<0.01		<0.01
≤20°	144 (85.7)	10.33 (3.99-26.77)		8.83 (3.42-22.80)	
>20°	24 (14.3)	Ref.		Ref.	
Chordal structure density			<0.01		<0.01
Minimal	132 (78.6)	11.80 (4.97-27.99)		10.00 (4.14-24.17)	
Moderate/high	24 (14.3)	Ref.		Ref.	
En face TR jet morphology			<0.01		<0.01
Linear to oval	116 (69.0)	23.12 (8.61-62.04)		27.99 (8.99-87.15)	
Star shaped	52 (31.0)	Ref.		Ref.	
Jet location			<0.01		
Anteroseptal/central	119 (70.8)	17.47 (6.28-48.63)		17.10 (5.60-52.26)	
Posteroseptal/anteroposterior	49 (29.2)	Ref.		Ref.	
Image quality			<0.01		<0.01
Good	119 (70.8)	4.08 (1.87-8.89)		3.64 (1.61-8.23)	
Limited	49 (29.2)	Ref.		Ref.	
Pacing leads[b]			0.25		0.42
None	151 (89.9)	4.21 (0.57-31.13)		1.68 (0.17-16.82)	
Near the grasping zone	13 (7.7)	2.25 (0.23-22.14)		0.75 (0.06-9.62)	
Leaflet impingement/attachment	4 (2.4)	Ref.		Ref.	
Tethering height, mm (n = 155)	6 (4-8)	0.89 (0.80-0.99)	0.032	0.86 (0.77-0.97)	0.013

Values are median (Q1-Q3) or n (%), unless otherwise indicated. [a]Septolateral coaptation gap and septal leaflet length were dichotomized according to Praz et al.[9] [b]Pacing leads was the only anatomic variable that was not associated with either outcome and was therefore not included in the candidate pool for multivariable modeling.

Ref. = Reference; other abbreviation as in Table 1.

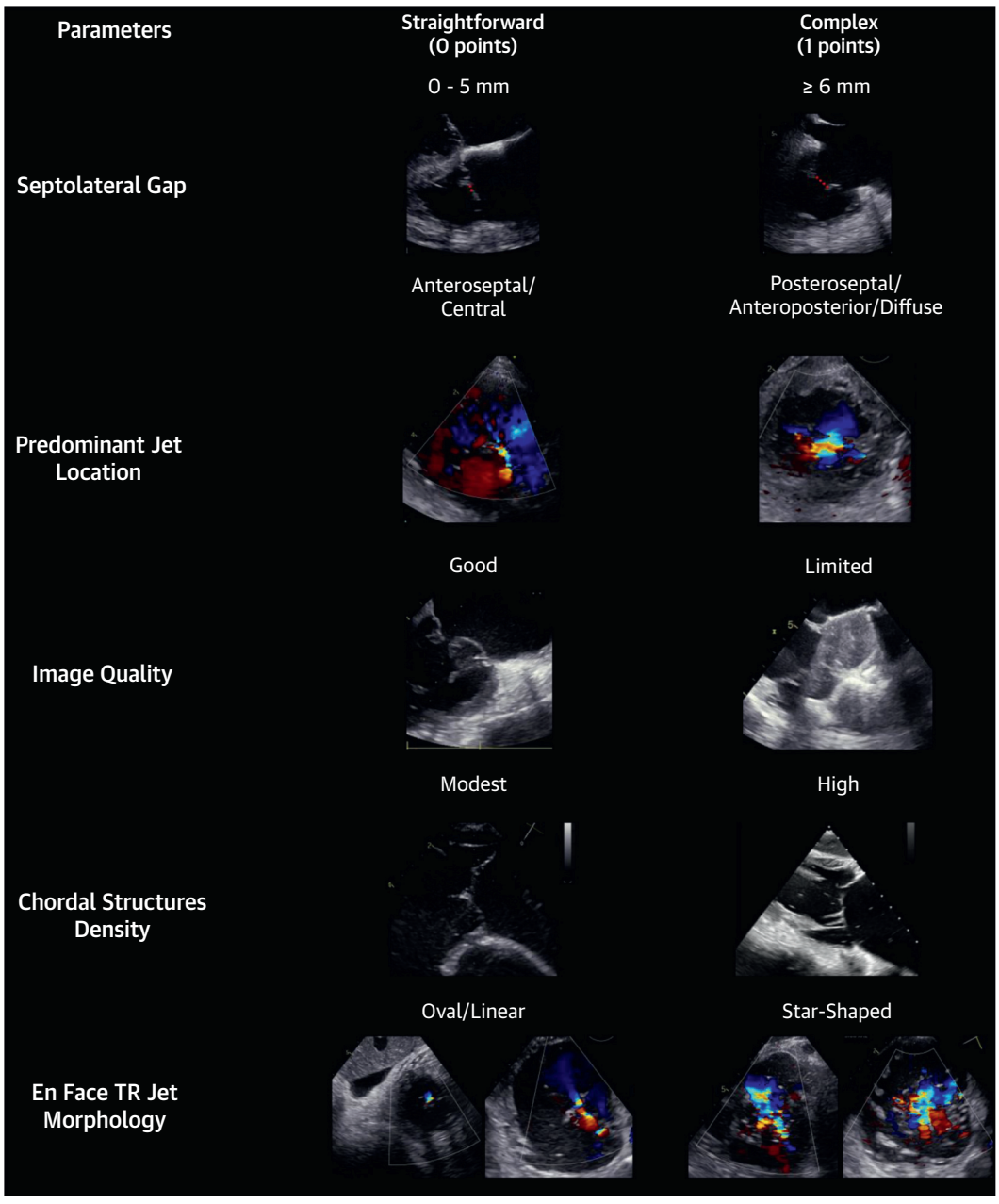
Additionally, in the univariable analysis, baseline left-sided echocardiographic parameters were not associated with procedural success in T-TEER interventions. However, procedural failure was associated with enlarged inferior vena cava and systolic pulmonary artery pressure (Supplemental Table 3).

DEVELOPMENT OF THE GLIDE SCORE. To establish a scoring system for clinical decision making and to offer future clinical guidance, a stepwise backward regression analysis was conducted. A backward selection based on likelihood ratio tests in multivariable modeling was applied.

Univariable analysis showed that the endpoints TR reduction ≥2 grades and TR grade moderate or less were significantly associated with septolateral coaptation gap, anterior posterior coaptation gap, septal leaflet length, leaflet morphology, septal leaflet retraction, chordal structure density, jet location, en face TR jet morphology, image quality, TR jet location, and tethering height (Table 3). Nonsignificant variables were removed from the full model in a stepwise approach.

Five variables remained significant with the likelihood ratio test and stepwise backward selection at

FIGURE 1 Components of the GLIDE Score

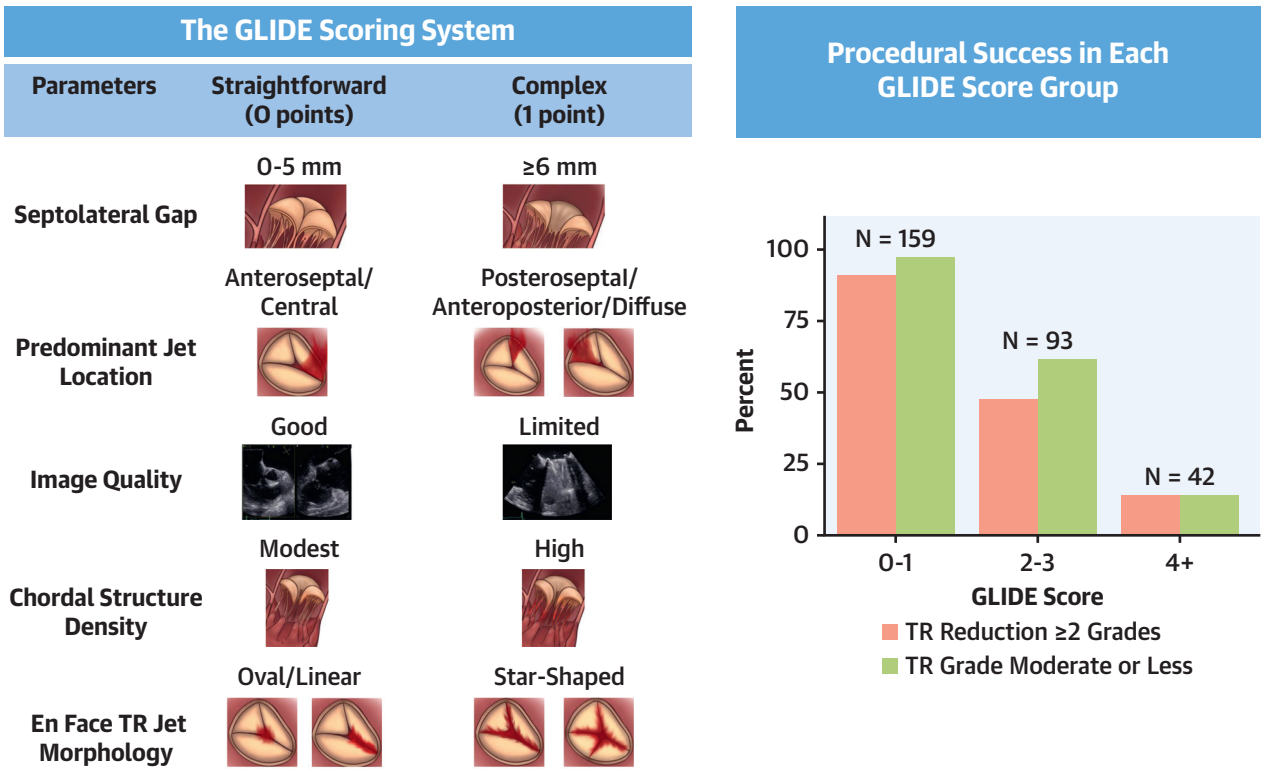


Echocardiographic illustration of the GLIDE (Gap, Location, Image quality, density, en-face TR morphology) score parameters: septolateral coaptation gap, chordal structure density, tricuspid regurgitation (TR) jet location, en face TR jet morphology, and image quality.

alpha <0.05 (Supplemental Tables 2 and 5). The final model included septolateral coaptation gap, chordal structure density, en face tricuspid regurgitant jet morphology, TR jet location, and image quality (**Figure 1**, Supplemental Tables 2 and 3). All variables were modeled in binary form to simplify the scoring algorithm. A 5-point GLIDE score was generated from these 5 variables (**Central Illustration**, **Table 4**).

The total GLIDE score, with the 5 defined variables and a total score of 5 points (reference), was associated with intraprocedural success (OR: 0.37 [95% CI: 0.22-0.63]; $P < 0.01$) and the procedural success

CENTRAL ILLUSTRATION The GLIDE Score



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The GLIDE (Gap, Location, Image quality, density, en-face TR morphology) score is a simple, 5-component score that is readily obtained during patient imaging and can predict successful T-TEER. T-TEER = tricuspid valve transcatheter edge-to-edge repair; TR = tricuspid regurgitation.

endpoints TR reduction ≥2 grades (OR: 0.14 [95% CI: 0.07-0.27]; $P < 0.01$) and TR grade moderate or less (OR: 0.17 [95% CI: 0.10-0.31]; $P < 0.01$). The median GLIDE score was 1 (Q1-Q3: 0-3), with the distribution shown in **Table 5**. Procedural success defined by TR reduction ≥2 grades was observed in 91% of patients with scores of 0 or 1 point, 47% of those with scores of 2 or 3 points, and 14% of those with scores of ≥4 points. Procedural success, defined as post-procedural TR grade moderate or less, was observed in 97% of patients with scores of 0 or 1 point, 61% of those with scores of 2 or 3 points, and 14% of those with scores ≥4 points (**Central Illustration**). Intraobserver and interobserver reliability were high, proving a robust validity of the GLIDE score (Supplemental Table 6). Importantly, our data demonstrated no significant difference in GLIDE score prediction and procedural outcome between the PASCAL and TriClip systems (Supplemental Table 7).

TR reduction defined as moderate or less or ≥2 grades was significantly correlated with NYHA functional class improvement ($P = 0.006$ and $P = 0.019$, respectively) and increase in 6-minute walk distance ($P = 0.043$ and $P = 0.010$, respectively) (**Figures 2 and 3**, Supplemental Figure 12 for TR changes in NYHA functional class according to TR reduction ≥2 grades).

EXTERNAL VALIDATION CONFIRMS THE PREDICTIVE VALUE OF THE GLIDE SCORE. The 5-component GLIDE score was then tested on 126 patients who underwent T-TEER interventions for severe TR at 2 centers. Demographic, clinical, and echocardiographic characteristics of the validation cohort are listed in Supplemental Tables 8 and 9 and were generally similar to those of the validation cohort, with the following exceptions: the validation cohort had more women (69%), less frequent history of prior stroke (8.7%), and lower pulmonary vascular resistance (3.2 WU [Q1-Q3: 2.2-4.3 WU] vs 2.4 WU [Q1-Q3: 1.5-3.5 WU]). With regard to TR grading, patients from the

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TABLE 4 Scoring and Association of GLIDE Score Components With Outcomes With Multivariable Regression

		Model 1[a]: TR Reduction ≥2 Grades		Model 2[a]: TR Grade Moderate or Less	
	Scored Points	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Septolateral coaptation gap, mm			0.013		<0.01
0-5	0	7.55 (1.54-37.14)		7.01 (1.63-30.16)	
≥6	1	Ref.		Ref.	
Chordal structure density			<0.01		0.024
Minimal	0	7.49 (2.03-27.64)		4.25 (1.21-14.88)	
Moderate/high	1	Ref.		Ref.	
Predominant jet location			<0.01		<0.01
Anteroseptal/central	0	8.10 (2.10-31.21)		6.51 (1.57-26.90)	
Posteroseptal/anteroposterior/diffuse	1	Ref.		Ref.	
En face TR jet morphology			0.010		0.014
Linear to oval	0	5.91 (1.53-22.84)		5.96 (1.43-24.91)	
Star shaped	1	Ref.		Ref.	
Image quality			<0.01		<0.01
Good	0	11.00 (2.65-45.61)		6.23 (1.66-23.36)	
Limited	1	Ref.		Ref.	
Total GLIDE score[b]		0.14 (0.07-0.27)	<0.01	0.17 (0.10-0.31)	<0.01

[a]Multivariable logistic regression model with TR reduction ≥2 grades or "TR grade moderate or less including covariates with values of $P < 0.10$ in the univariable regression.
[b]The OR represents the increase in odds of each respective outcome for each unit increase in the overall GLIDE score. The GLIDE score is the summative total score based on the "scored points" column.

GLIDE = Gap, Location, Image quality, density, en face TR morphology; other abbreviation as in Table 1.

validation cohort had a higher rate of torrential TR (21.4%) at baseline.

However, the applied GLIDE score was also predictive regarding procedural success in the validation cohort, with an area under the curve of 0.77 (95% CI: 0.69-0.86) (Figures 4 and 5).

Additionally, there was no association of the device type used (TriClip or PASCAL) with procedural success in the training, validation, or combined data set (Supplemental Table 10).

DISCUSSION

In this study, a simple 5-component, readily obtainable anatomical GLIDE score was developed to predict procedural success in patients with TR undergoing T-TEER. The components WERE septolateral coaptation gap, chordal structure density, TR jet location, en face TR jet morphology, and image quality. The GLIDE score predicted procedural success defined by TR reduction ≥2 grades and postprocedure TR grade moderate or less, regardless of T-TEER technology.

Topilsky et al[22] noted that 4% of the population aged ≥75 years have significant TR.[22] TR is associated with poor outcomes, increased hospitalization for cardiac decompensation, and impaired quality of life. However, surgical intervention is often not pursued, because of significant operative risk. As such, the large number of patients with untreated symptomatic severe TR may benefit from T-TEER. The procedure has evolved and has been quickly accepted commercially in Europe because of clinician experience and transferrable technologies derived from mitral valve T-TEER. Yet anatomical and imaging challenges for device efficacy in the tricuspid valve space remain. The tricuspid valve consists of 3 leaflets in only about 50% of patients, with a substantial proportion having 4 or more leaflets.[15] Among other characteristics, thinner leaflets of the tricuspid valve represent an additional challenge in T-TEER interventions.

To date, known predictors for procedural results are scarce. Besler et al[23] described a coaptation gap size of >7.2 mm as unfavorable for MitraClip NTR T-TEER interventions, as it is difficult to achieve TR reduction ≥1 grade. Ruf et al[24] reported that the XTR device's longer grasping arms enable safe treatment and TR reduction ≥1 grade for coaptation gaps up to 8.4 mm.

We demonstrated that the extent of TR reduction as predicted by the GLIDE score is significantly correlated with functional improvement. Patients with final TR reduction to moderate or less or ≥2-grade reduction experienced greater improvements in functional status at 3 months. This lends to further validation of the GLIDE score as a clinically useful tool to determine whether this therapy should be offered.

TABLE 5 Score Distribution in Overall, Derivation, and Validation Cohorts and Procedural Success Among Each GLIDE Score Point

	Overall Cohort					Derivation Cohort		
GLIDE Score	All (N = 294)	With TR Reduction ≥2 Grades (n = 195)	Sensitivity[a]	Specificity[a]	Accuracy[a] (%)	All (N = 168)	With TR Reduction ≥2 Grades (n = 133)	Sensitivity[a]
0	79	77 (97.5)	0.39	0.98	97.5	59	59 (100)	0.44
1	80	68 (85)	0.74	0.86	85	47	44 (93.6)	0.77
2	47	30 (63.8)	0.90	0.69	63.8	28	24 (85.7)	0.95
3	46	14 (30.4)	0.97	0.36	69.6	16	5 (31.2)	0.99
4	32	4 (12.5)	0.99	0.08	87.5	13	1 (7.7)	1.00
5	10	2 (20)	NA	NA	80	5	0 (0)	NA

The total GLIDE score ranges from 0 to 5 (median 1; Q1-Q3: 0-3). [a]Sensitivity and specificity were evaluated using a 2 × 2 table with each GLIDE integer score as a cutoff. Accuracy was computed by fitting the predictive model to each data set using each GLIDE integer score point as a cutoff.

NA = not applicable; other abbreviations as in Table 4.

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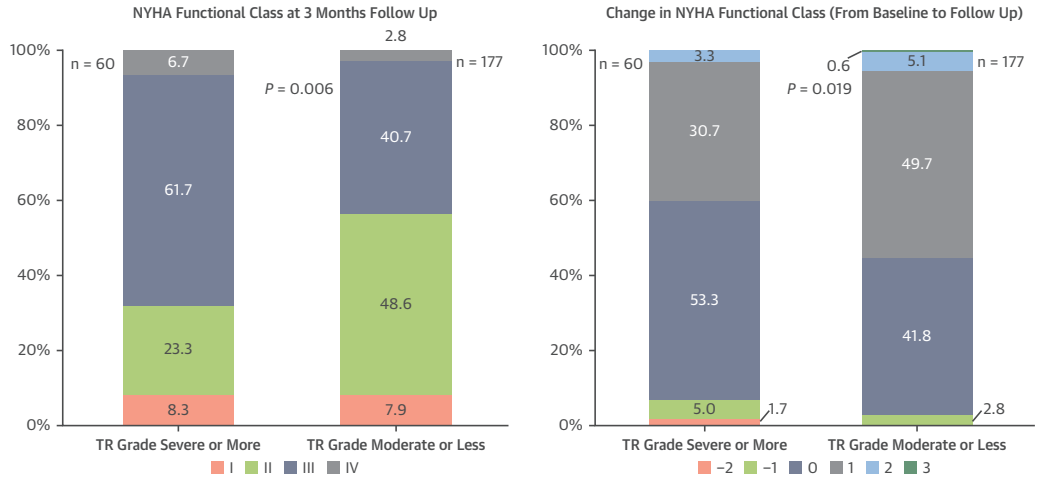
The TRILUMINATE (Trial to Evaluate Cardiovascular Outcomes in Patients Treated with the Tricuspid Valve Repair System) pivotal study was the first multicenter, prospective, randomized trial to demonstrate that TR reduction with T-TEER was associated with improvements in quality of life. Kansas City Cardiomyopathy Questionnaire score improvement was correlated with reduction in TR as measured by similar parameters in the present study.[16] Specifically, those with TR reduction of at least 2 grades or residual TR moderate or less had the most clinical benefit. Given this strong association between more severe residual TR and suboptimal outcome, GLIDE score-predicted procedural results (TR reduction ≥2 grades and TR grade moderate or less at the end of the procedure) are desired. Although the TRILUMINATE trial did not demonstrate an reduction in mortality or heart failure hospitalizations, Sugiura et al[25] demonstrated that residual TR after TTVI is associated with increased mortality and heart failure hospitalizations.

Echocardiographic scoring for transcatheter interventions began with the Wilkins score for mitral valvuloplasty more than 30 years ago.[26] Yet a simple scoring system was lacking to assist in case selection for T-TEER interventions.

Initially we evaluated multiple anatomical parameters, but through statistical analysis we focused the

FIGURE 2 Relationship of NYHA Functional Class at 3 Months to Immediate Postprocedural TR Grade



Abbreviation as in Figure 1.

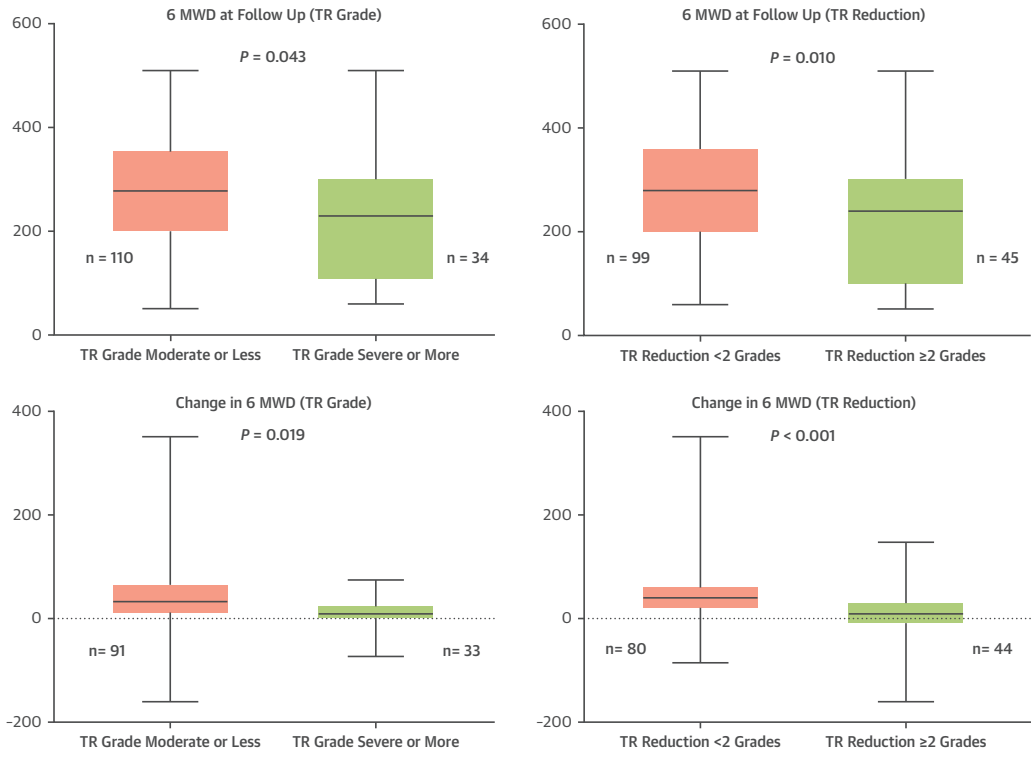
TABLE 5 Continued

Derivation Cohort		Validation Cohort				
Specificity[a]	Accuracy[a] (%)	All (N = 126)	With TR Reduction ≥2 Grades (n = 62)	Sensitivity[a]	Specificity[a]	Accuracy[a] (%)
1.00	100	20	18 (90)	0.29	0.97	90
0.91	93.6	33	24 (72.7)	0.67	0.83	72.7
0.80	85.7	19	6 (31.6)	0.77	0.63	31.6
0.48	68.7	30	9 (30)	0.92	0.30	70
0.14	92.3	19	3 (15.8)	0.97	0.05	84.2
NA	100	5	2 (40)	NA	NA	60

scope to 5 easily assessable TEE parameters. Of these, the strongest predictive parameter alongside image quality was TR jet location. This parameter is intuitive, as it might determine device positioning and the number of devices necessary to sufficiently treat patients with TR.

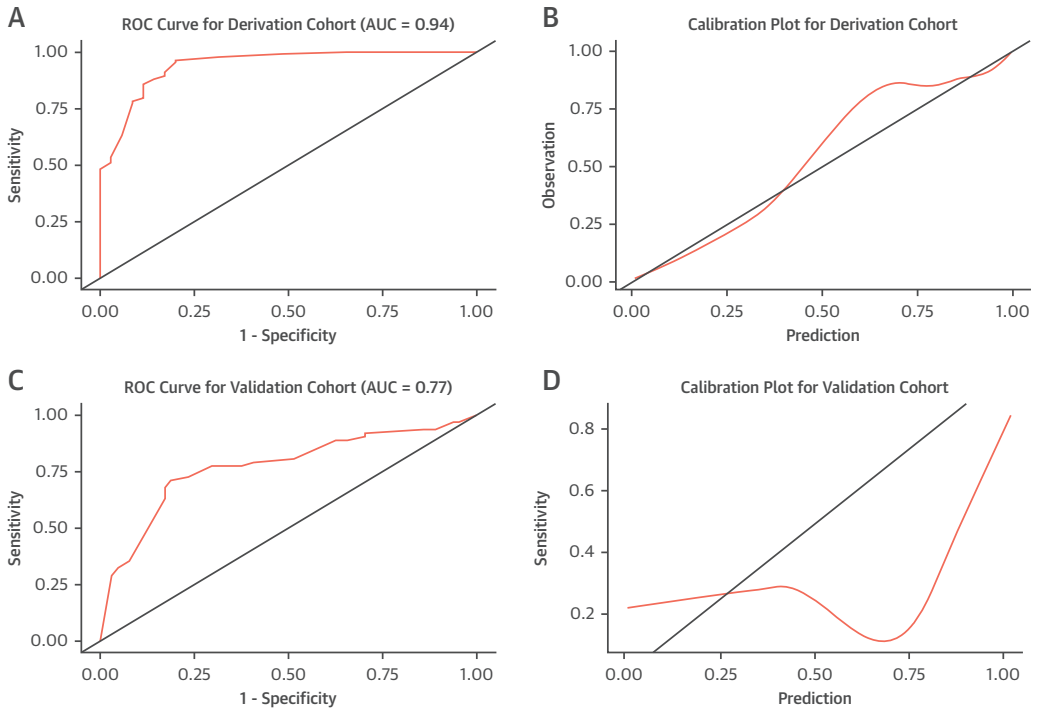
In almost all cases, the first device was implanted to the septal and lateral leaflets, which is consistent with the current practice and is why increased attention should be paid to septal leaflet morphology.[23,24] Also, septolateral coaptation gap and chordal structure density are intuitive parameters for secure leaflet grasping, where approximation might be challenging if the gap is large or if chordal structures hamper proper device positioning. Accordingly, the GLIDE score showed a remarkable discernment in case complexity. From a practical standpoint, the GLIDE score adds knowledge

FIGURE 3 Relationship of Absolute and Relative Changes in 6MWD at 3 Months to Immediate Postprocedural TR Grade and Reduction



6MWD = 6-minute walk distance; other abbreviation as in Figure 1.

FIGURE 4 Receiver-Operating Characteristic Curve and Calibration Plot of the Derivation and Validation Cohorts of the GLIDE Score



(A, B) Derivation cohort. (C, D) Validation cohort.

permitting better case selection for T-TEER and is a novel easily applied clinical tool to accurately predict acute procedural outcome.

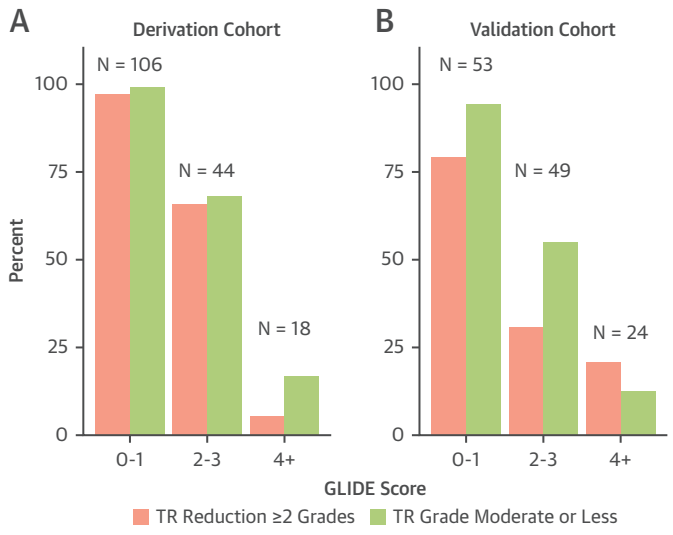
The immediate and long-term outcomes of patients undergoing transcatheter intervention for valvular regurgitation are likely multifactorial, but the use of echocardiographic data in conjunction with clinical predictors should sufficiently identify patients likely to have better long-term clinical outcomes from transcatheter therapy. We analyzed acute procedural results of T-TEER interventions and early outcomes. However, our findings could lead to other studies on long-term outcome predictability in patients undergoing T-TEER. These studies could also assess the extent to which the GLIDE score will predict right ventricular remodeling and improvement in cardiac output and the impact these will have on symptoms and prognosis.

Considering the expected increase in the use of tricuspid valve interventions in the future, the GLIDE score could also validate a patient's candidacy for interventions, offering comparison of predicted procedural outcomes with other interventions or combination therapies.

In our cohort, 54% of patients had low GLIDE scores (0 or 1 point) and also showed the greatest benefit in TR reduction from T-TEER. Patients with high GLIDE scores (≥4 points) may not be reliably treated using T-TEER, resulting in significant residual TR. Alternative interventional strategies could be considered, such as direct annuloplasty, valve replacement, or heterotopic caval valve implantation.[3,7,27]

STUDY LIMITATIONS. Although our study represents one of the largest patient cohorts in the field of TTVI, and our statistical analysis revealed strong predictive value of these 5 variables, the sample size was modest. Second, primary (degenerative) TR was present in only 5% of patients, which may cause an underrepresentation of degenerative TR. Therefore the GLIDE score should be used cautiously in these patients, and further echocardiographic parameters should be considered during procedural planning in degenerative TR.

FIGURE 5 The Applied GLIDE Score Was Predictive Regarding Procedural Success in the Derivation and Validation Cohorts



Abbreviations as in Figure 1.

Third, although the images were independently reviewed, the data were analyzed in the Northwestern University core laboratory retrospectively, and the GLIDE score was developed on the basis of patients who had already undergone T-TEER. Thus, a selection bias favoring T-TEER interventions cannot be fully excluded, as shown with the calibration plot (Figure 4D). However, there was an excellent separation in outcomes within the 3 scoring ranges (straightforward, moderately complex, and complex cases), with decent receiver-operating characteristic curves. Additionally, cases involving leaflet impingement or attachment or short septal leaflets that were the primary mechanism of TR were excluded from T-TEER during the screening process and were not part of our study cohort. Nevertheless, we recognize that leads may still interact or interfere with accurate device positioning, which may affect the acute procedural outcome. Consequently, we have chosen to incorporate intracardiac leads and septal leaflet lengths in our initial analyses, but we did not observe statistically significant effects guiding our decision making. Additionally, follow-up data were available for 81% of the patients, so a certain survivorship bias cannot be ruled out.

The validation cohort had less massive but more torrential TR, and the percentage of overall procedural success was less in the derivation cohort (79% vs 49%). There were intrinsic differences between the validation and derivation cohorts in their baseline clinical characteristics, and tricuspid interventions for torrential TR can be much more complex than for "only" severe TR. On one hand, we cannot completely rule out differences between centers in their expertise in tricuspid interventions; however, the derivation cohort was drawn from centers that also offer transcatheter tricuspid valve annuloplasty, so patients with large gaps may have been considered for transcatheter tricuspid valve annuloplasty rather than T-TEER, while the other centers could perform only T-TEER procedures even in complex cases. Indeed, gap sizes in patients with torrential TR were larger in the validation cohort than in the derivation cohort (median 6.0 mm [Q1-Q3: 4.0-8.0 mm] vs 11.0 mm [Q1-Q3: 8.0-15.0 mm]; $P < 0.001$). This again shows that adequate patient selection is crucial for successful tricuspid interventions.

Furthermore, the GLIDE score performed more accurately with low and high scores and less accurately with moderate scores (2 or 3 points), as demonstrated in Table 5 and the calibration curves. From a clinical perspective, this is useful because T-TEER should be considered the preferred therapy with a low score, while valve replacement or other technologies should be strongly considered for patients with high scores. Intermediate scores require both anatomical and clinical assessment to select the optimal mechanical or medical therapies. This should also include factors such as bleeding risk, right ventricular function, and durability.

CONCLUSIONS

We developed a novel GLIDE score using 5 readily assessable, preinterventional TEE parameters that predict patient procedural and clinical outcomes. The GLIDE score should reliably guide the decision-making process in selecting the best candidates for T-TEER interventions.

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PERSPECTIVES

COMPETENCY IN PATIENT CARE AND PROCEDURAL SKILLS: T-TEER interventions are the most widely used transcatheter therapy to treat patients with severe TR. The GLIDE score, calculated using 5 easily assessable TEE parameters, can assist in selecting appropriate patients who are likely to obtain optimal anatomical results with T-TEER.

TRANSLATIONAL OUTLOOK: The novel 5-component GLIDE score can guide the selection of patients with severe TR. In patients with high GLIDE scores, alternative strategies, including transcatheter valve replacement, should be considered to achieve optimal procedural results. Additional studies are needed to further validate the GLIDE score in for prediction of long-term prognosis.

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KEY WORDS transcatheter therapy, tricuspid edge-to-edge valve repair, tricuspid regurgitation

APPENDIX For an expanded Methods section as well as supplemental figures, tables, and a reference, please see the online version of this paper.