The value of preoperative risk scores prior to tricuspid valve interventions: The TRI-SCORE and beyond

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Tricuspid regurgitation (TR) is increasingly recognized as a condition associated with poor clinical outcomes, including reduced quality of life, progressive right-sided heart failure, and increased mortality. Its heterogeneous etiologies and systemic consequences, affecting both cardiac and extracardiac organs such as the kidneys and liver, make patient management particularly challenging. Accurate risk stratification and timely intervention are therefore essential. The 2025 European Society of Cardiology and European Association for Cardio-Thoracic Surgery Guidelines acknowledge the multifaceted nature of TR and emphasize the need for evaluation in expert centers through multidisciplinary Heart Team discussions. In this context, the TRI-SCORE, initially developed to predict in-hospital mortality after isolated tricuspid valve (TV) surgery, has been incorporated into the guideline decision-making algorithm as a key risk assessment tool to support therapeutic selection. This simple eight-variable model demonstrated excellent prognostic predictive performance and has been validated across several international cohorts of patients conservatively treated or who underwent a surgical or transcatheter intervention. Compared with other surgical scores such as EuroSCORE II, Model for End-Stage Liver Disease (MELD)/MELD-XI, or the Society of Thoracic Surgeons isolated TV surgery model, the TRI-SCORE is disease-specific, simple, and offers superior predictive value. It helps identify patients most likely to benefit from intervention, providing a practical framework for integrating disease stage, procedural risk, and expected benefit. Both surgical and transcatheter therapies may improve prognosis when performed early, whereas delayed referral at advanced stages offsets their potential benefit. The systematic use of TRI-SCORE within the Heart Team can therefore refine patient selection, guide the timing of intervention, and support personalized, lifetime management of TR.

Keywords: Tricuspid regurgitation (TR); surgery; transcatheter; risk stratification; Heart Team

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Introduction

Tricuspid regurgitation (TR) has long been overlooked. However, mounting evidence shows that untreated significant TR is associated with a dismal prognosis, reduced quality of life, progressive right-sided heart failure (HF), and increased mortality (1-3). Patients with TR represent a heterogeneous population, both in terms of phenotype, with diverse underlying etiologies and mechanisms (including atrial and ventricular functional TR, organic TR, as well as device-related TR) (4,5), and in terms of disease impact, which varies not only from one patient to another but also over time in the same individual, depending on the severity of regurgitation and its consequences on right ventricular (RV) function and other organs.

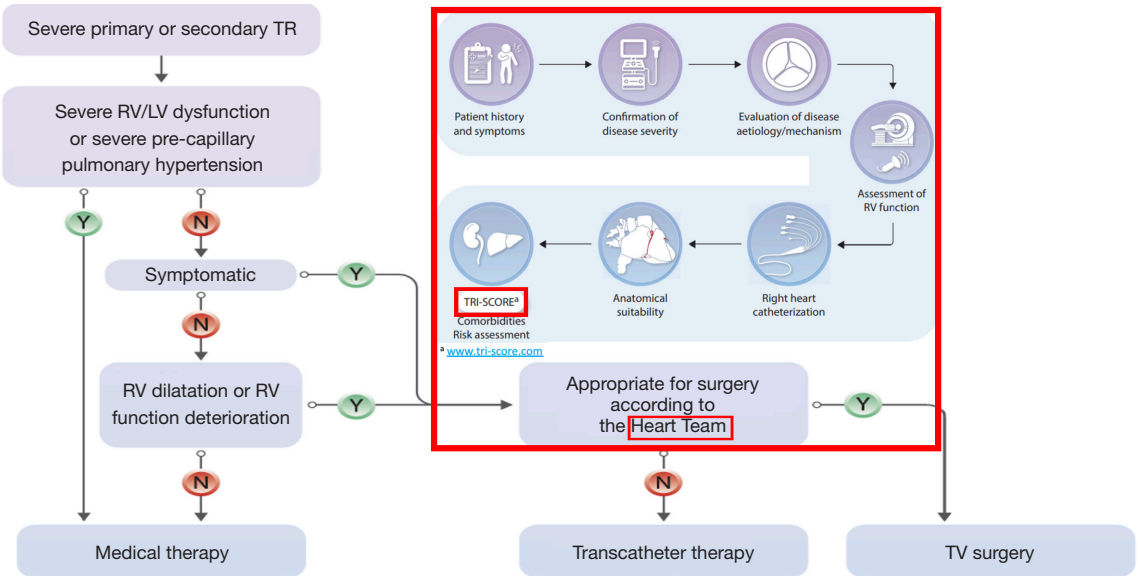

Figure 1 Algorithm for the management of patients with tricuspid regurgitation without left-sided valvular heart disease. Adapted from Praz *et al.* (6) with permission. LV, left ventricle; RV, right ventricle; TR, tricuspid regurgitation; TV, tricuspid valve.

The latest 2025 European Society of Cardiology (ESC)/European Association for Cardio-Thoracic Surgery (EACTS) Guidelines (6) acknowledge the complexity of TR and emphasize the need for evaluation in expert reference centers. A comprehensive assessment (Class I, Level C) should address the etiology and disease stage, including severity of regurgitation, RV and left ventricular (LV) function, and pulmonary pressures, as well as other relevant parameters. The guidelines also highlight the importance of assessing operative risk and the expected prognostic benefit within a multidisciplinary Heart Team discussion (*Figure 1*).

Given the complexity of TR, its management requires an experienced and diverse Heart Team including cardiac imaging specialists, HF and interventional cardiologists, electrophysiologists, cardiac surgeons, and when appropriate, anesthesiologists, geriatricians, hepatologists, or nephrologists, as patients are frequently elderly and comorbid. Notably, the TRI-SCORE has been integrated into the ESC/EACTS Guidelines as a key risk assessment tool to support individualized therapeutic decision-making in patients with TR (*Figure 1*) (6).

The aim of this article is to highlight the value of risk scores in this patient population, and particularly the TRI-SCORE, for predicting outcomes according to the management strategy, thereby guiding optimal patient selection and treatment planning. We will review the currently available risk prediction models in the context of the two main interventional approaches to TR: surgical and transcatheter therapies.

Surgical management and risk prediction

Guideline-based indications

According to the 2021 American Heart Association (AHA)/American College of Cardiology (ACC) guidelines (7), isolated TV surgery should be considered (Class IIa, Level B) for patients with severe, symptomatic TR despite optimal medical therapy and in the absence of severe pulmonary hypertension (PH), primarily aiming to reduce symptoms and recurrent hospitalizations.

The 2025 ESC/EACTS recommendations (6) go further, advocating isolated TV surgery in symptomatic patients or in those with RV dilation or early RV dysfunction, regardless of TR mechanism, provided there is no severe LV or RV dysfunction and no severe PH. Importantly, the decision must rely on comprehensive Heart Team evaluation (*Figure 1*).

Despite these recommendations, most patients with TR remain medically managed, receiving primarily diuretics to relieve congestion and improve symptoms, while isolated TV surgery is seldom performed. The perceived high operative mortality, historically reported at around 10% in national administrative databases (8,9), has further contributed to therapeutic inertia. However, such

aggregated data lack clinical granularity, thereby obscuring substantial inter-patient variability in risk and outcome.

Outcomes of isolated tricuspid surgery and the need for dedicated risk stratification

To fill this knowledge gap, a French multicenter registry across 12 tertiary centers included 466 consecutive patients who underwent isolated TV surgery on a native valve (no concomitant valvular [aortic or mitral], aortic, or coronary procedure) between 2007–2017. These cases represented 8% of all TV surgical procedures, and 92% (N=5,125) were performed in conjunction with other cardiac operations. Nearly half of the patients had functional TR (49%) and half had organic TR (51%), including cases related to infective endocarditis and carcinoid disease. Overall, operative mortality was 10.3%, but it varied markedly according to etiology, ranging from 4.9% in patients with infective endocarditis to 15.8% in those with functional TR following prior left-sided heart valve surgery. Interestingly, TR mechanism and etiology were not an independent predictor of postoperative mortality. Instead, outcomes were primarily driven by the severity of the clinical presentation (10). This major observation led to the development of a dedicated risk model, the TRI-SCORE (*Table 1*).

Development and validation of the TRI-SCORE

Development

The TRI-SCORE was designed to predict in-hospital mortality after isolated TV surgery on the native valve based on the French multicenter registry (11). It incorporates eight readily available variables:

- Clinical: age ≥70 years, New York Heart Association (NYHA) class III–IV, signs of right-sided HF, furosemide dose ≥125 mg/day;
- Biological: glomerular filtration rate <30 mL/min, elevated total bilirubin;
- Echocardiographic: LV ejection fraction <60%, moderate or severe RV dysfunction (assessed using a comprehensive multiparametric approach).

Each variable contributes 1 or 2 points, for a total score ranging from 0 to 12 (*Figure 2A*).

In-hospital mortality prediction after isolated TV surgery

Predicted mortality increases from 1% at 0 point to 65% at ≥9 points, with excellent discrimination [area under the curve (AUC) =0.81] and good calibration up to predicted risks of 50%. Importantly, three risk categories were defined: low (0–3 points), intermediate (4–5 points), and high (≥6 points) (*Figure 2B*).

Notably, mortality correlated with the TRI-SCORE regardless of TR mechanism, underscoring its robustness across TR etiologies.

Moreover, only 51% of operated patients had low TRI-SCOREs, while 18% had high scores ≥6, some even ≥9 points (predicting ≈65% mortality). This highlighted frequent late referral and the crucial need for objective preoperative risk assessment (12).

External validation

External validations in Spain, Italy, and Asia confirmed its accuracy (AUC consistently > 0.8) (13-15).

In-hospital mortality prediction after redo isolated TV surgery

Beyond native TV surgery, the TRI-SCORE also demonstrated excellent predictive accuracy for in-hospital mortality in patients undergoing redo isolated TV surgery after a prior TV repair or replacement (AUC =0.83) (16).

Mid-term outcomes prediction

The concept of disease staging and the need for early intervention is not new. Several studies have consistently shown that mid-term mortality (at 5 years) is closely related to the timing of treatment, highlighting the detrimental effect of delayed referral and advanced disease (17,18).

These findings were reinforced by data from TRIGISTRY, an international multicenter registry including more than 2,400 patients with isolated (no associated significant left-sided heart valve disease) functional TR treated either medically, surgically (repair or replacement), or percutaneously (repair). Across all treatment strategies, the distribution of TRI-SCORE categories was similar, with roughly one-third of patients classified as low, intermediate, and high risk, respectively. Two-year mortality increased progressively across TRI-SCORE categories, with higher scores associated with higher mortality overall and within each treatment group. Notably, nearly 40% of patients with a high TRI-SCORE (≥6 points) had died at two years, highlighting the need for early and proactive management (*Figure 3*) (19).

Long-term outcomes prediction

Overall, no survival difference was observed at 10 years

Table 1 Surgical and transcatheter risk scores to assess outcomes in patients with tricuspid regurgitation (4)

Score	Number of patients	Design	Region	Inclusion period	Population	TR severity	Left-sided valve disease	Primary outcome	C-statistic	External validation	Strengths/limitations	Online calculator
TRI-SCORE	466	Multicenter (12 centers)	France	2007–2017	Isolated TV surgery (repair & replacement)	Severe	No	In-hospital mortality	0.81	Yes (AUC =0.82–0.87)	+: Validated, practical, TR-specific	Website & Apps
EuroSCORE II	22,381	Multicenter (154 centers)	Europe, North America, Asia, Oceania	May–July 2010	Major cardiac surgery (CABG, valve)	All grades	Yes	In-hospital mortality	–	Poor (AUC ~0.62)	–: Only 85 isolated TV surgeries, non-TR specific	Website
MELD/MELD-XI / MELD-Albumin	–	–	–	–	No TR (liver disease patients)	–	–	Mortality	–	Yes (MELD-Albumin: in-hospital mortality after isolated TV replacement, AUC =0.73)	–: Limited number of relevant parameters, INR confounded by anticoagulants	No
LaPar	2,050	Multicenter (50 centers)	USA (Virginia, Michigan)	2002–2014	Isolated TV surgery (repair & replacement)	All grades	No	Post-operative mortality	0.74	No	–: Complex, non-TR specific	No
STS-TV	13,587	Multicenter (842 centers)	USA and Canada	2017–2023	Isolated TV surgery (repair & replacement)	All grades (71% severe)	No	30-day mortality (+composite morbidity endpoint including stroke, renal failure, reoperation, prolonged ventilation, and length of hospital stay)	0.81 (and 0.76 for the composite endpoint)	No	–: Complex (>50 parameters), not integrating specifically TR consequences	Website
TRIVALVE	483	Multicenter (21 centers)	Europe, North America	2016–2022	Transcatheter TV repair	Severe	Yes	1-year mortality or rehospitalization	0.68	No	–: 1/3 with significant mitral regurgitation and concomitant mitral repair	No

Adapted from Hahn *et al.* (4) with permission. AUC, area under the curve; CABG, coronary artery bypass grafting; INR, international normalized ratio; MELD, Model for End-Stage Liver Disease; STS, Society of Thoracic Surgeons; TR, tricuspid regurgitation; TV, tricuspid valve.

A

Parameter	Points
Age ≥70 years	1
NYHA class III–IV	1
Right-sided heart failure signs	2
Daily furosemide ≥125 mg	2
GFR <30 mL/min	2
Elevated bilirubin	2
LVEF <60%	1
Moderate/severe RV dysfunction	1
TOTAL	12

B

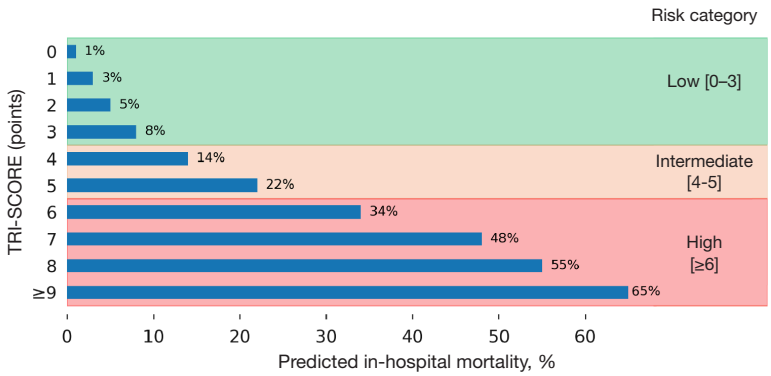

Figure 2 TRI-SCORE parameters and predicted in-hospital mortality. Adapted from Dreyfus *et al.* licensed under CC BY-NC 4.0 (11). (A) Parameters; (B) predicted in-hospital mortality. GFR, glomerular filtration rate; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; RV, right ventricle.

between surgically and medically treated patients (after adjustment). In-hospital mortality increased with TRI-SCORE category, from 2.7% in the low-risk group up to 16.9% in the high-risk group. At 10 years, surgical treatment was associated with better survival than medical therapy in low-risk patients, while no survival advantage was observed in the intermediate- and high-risk groups (20). Further subdivision by the type of surgery revealed that both TV repair and replacement were associated with improved survival compared with medical therapy in low-risk patients, with the best outcomes in those undergoing valve repair. Among intermediate-risk patients, a survival benefit was observed only in those who underwent TV repair, likely reflecting that the need for replacement identifies a more advanced stage of TR disease. Conversely, in high-risk patients, no survival benefit was observed with any surgical approach compared with medical management, likely reflecting a futile intervention at a late disease stage (*Figure 4*).

In practice

To facilitate its routine use, the TRI-SCORE is now freely accessible through an online calculator and mobile applications (iOS and Android), enabling quick and standardized risk assessment in daily clinical practice (https://www.tri-score.com).

Other surgical risk models

EuroSCORE II

EuroSCORE II (21) is a European risk model derived from 22,381 patients who underwent cardiac surgery, but it included only 85 patients with isolated TV surgery. As a result, the variables incorporated in the model are not specific to TR or isolated TV procedures, which translates into limited discriminative ability for both isolated TV surgery on native valve (AUC =0.63) and redo isolated TV surgery (AUC =0.61) (5,11). An online calculator is available (https://www.euroscore.org/) (*Table 1*).

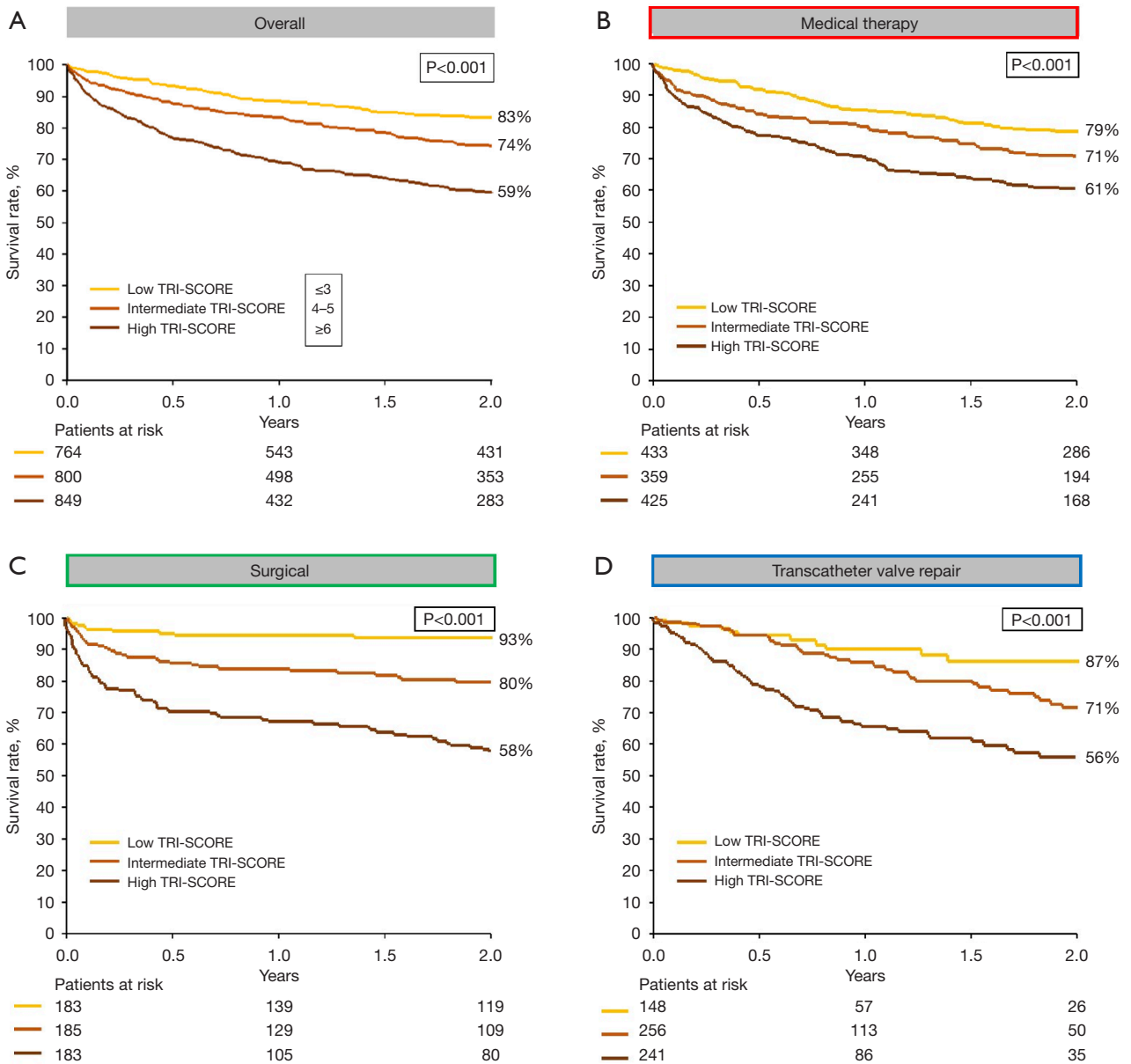

Figure 3 Two-year survival according to TRI-SCORE category and treatment strategy in TRIGISTRY. Adapted from Dreyfus *et al.* (19) with permission. (A) Overall population; (B) medical group; (C) surgical group; (D) transcatheter repair group.

Model for End-Stage Liver Disease (MELD)

The MELD score has also been proposed as a potential predictor of outcomes after isolated TV surgery in patients with TR (22-24). Originally developed to stratify prognosis in patients with end-stage liver disease (25), MELD incorporates three laboratory parameters (the international normalized ratio (INR), total bilirubin, and creatinine), reflecting hepatic and renal function {MELD = 3.78 × ln[Bilirubin (mg/dL)] + 11.2 × ln(INR) + 9.57 × ln[Creatinine (mg/dL)] + 6.43}. However, its applicability in TR is limited, as most patients are anticoagulated, either with vitamin K antagonists or non-vitamin K oral anticoagulants, for atrial fibrillation (AF), making the INR unreliable. To address this limitation, the MELD-XI score (26) was introduced, excluding the INR component and relying solely on bilirubin and creatinine, while the MELD-Albumin (27) variant additionally includes serum albumin. In practice, however, the clinical relevance of these

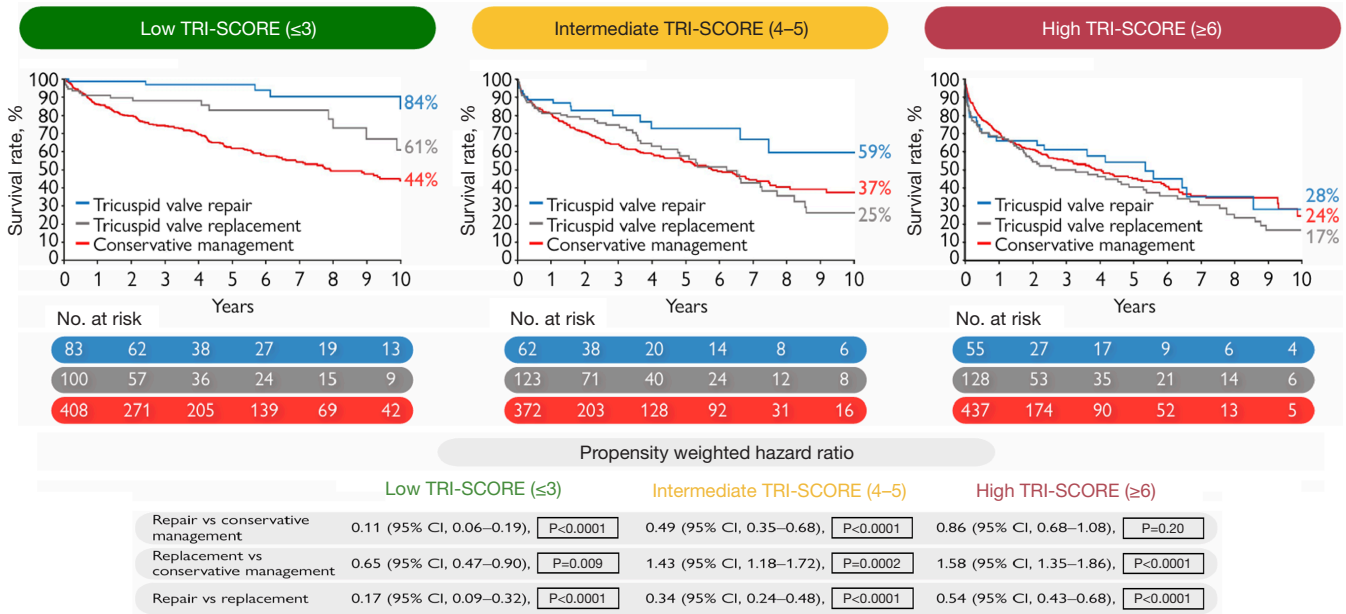

Figure 4 Ten-year survival by treatment strategy (surgical repair or replacement *vs.* medical therapy) and TRI-SCORE category in TRIGISTRY. Adapted from Dreyfus *et al.* with permission (20). CI, confidence interval.

scores in TR remains limited beyond reflecting end-organ dysfunction involving the liver and kidneys (*Table 1*).

LaPar model

A risk model was proposed by LaPar *et al.* (28), based on data from the Society of Thoracic Surgeons (STS) database covering the states of Virginia and Michigan. The model included nine preoperative parameters: age (50–59, 60–69, or ≥70 years), female sex, history of stroke, hemodialysis, chronic lung disease (moderate or severe), LV ejection fraction <55%, NYHA class III or IV, reoperation, and emergent surgical status. However, this model had important limitations. Although the STS database is extensive, it was not specifically designed for TV surgery, and therefore lacks variables specific to TR, such as RV function or hepatic involvement. In addition, model calibration was suboptimal in high-risk patients, with a maximum predicted mortality of only 34%, leading to an underestimation of operative risk in the most advanced stages of disease (*Table 1*).

STS isolated TV surgery

More recently, a dedicated STS risk model for isolated TV surgery has been proposed (29). This score was developed from a large cohort of 13,587 patients across 842 centers in the United States and Canada between 2017 and 2023, encompassing all mechanisms and etiologies of TR. It predicts both 30-day mortality and a composite morbidity endpoint that includes stroke, renal failure, reoperation, prolonged ventilation, and length of hospital stay. Separate risk estimates are provided according to the type of surgery, distinguishing between TV repair and TV replacement procedures. The model demonstrated good discrimination, with an AUC of 0.81 for in-hospital mortality and 0.76 for the composite mortality-morbidity endpoint, and an online calculator is available for use. However, the score has not yet undergone internal or external validation. Its main limitations are its complexity, requiring the collection of more than 50 variables, and the fact that the dataset was not specifically designed for TR, meaning that most of the included parameters are not disease-specific for TR or TV surgery. An online calculator is available (https://www.sts.org/resources/isolated-tricuspid-valve-surgery-risk-calculator) (*Table 1*).

Transcatheter management and risk stratification

Rationale and clinical context

The recent advent of transcatheter tricuspid valve interventions (TTVI) has expanded the therapeutic

armamentarium, providing a less invasive option for high-risk patients traditionally considered inoperable, with a wide range of devices for TV repair or replacement (30,31).

Supported by accumulating evidence from both randomized trials and large registries, the 2025 ESC/EACTS guidelines (6) recommend performing such interventions after Heart Team discussion, with the goal of improving quality of life and promoting RV reverse remodeling in appropriately selected patients (*Figure 1*).

TRI-SCORE applicability to transcatheter TR therapy

Transcatheter approaches across valvular diseases are less invasive and carry lower procedural risk than open-heart surgery. Accordingly, surgical risk scores tend to overestimate mortality after transcatheter procedures, a pattern also observed with the TRI-SCORE, which was originally developed in a surgical population. Nevertheless, the TRI-SCORE retains a discriminative value in patients undergoing TTVI, with an in-hospital mortality rising from 0.7% in patients with a low TRI-SCORE to 4.3% in those with a high TRI-SCORE. Notably, the in-hospital mortality of patients with high TRI-SCOREs undergoing transcatheter repair is higher than that of surgically treated patients with low TRI-SCOREs (2.7%) (5). More critically, several other registries have extended the excellent predictive performance of the TRI-SCORE for both mortality and HF hospitalization at 1 year (32-34). Importantly, the performance of TRI-SCORE in transcatheter populations, as in surgical populations, may be influenced by patient selection (35); it should therefore be used only within its intended clinical setting, namely in patients with isolated severe tricuspid regurgitation, without concomitant significant left-sided valvular disease or the need for combined left-sided valve intervention.

Insights from randomized trials and real-world data

To date, three randomized trials have compared TTVI (edge-to-edge repair or valve replacement) with medical therapy: TRILUMINATE (36), TRI-FR (37), and TRISCEND II (38). One-year mortality in the medical arms of these studies varied considerably (5.4%, 10.6%, and 15.2%, respectively) (36-38), compared to 20% in TRIGISTRY (19). This heterogeneity reflects the diverse disease stages and risk profiles of enrolled patients (*Figure 3*).

In TRIGISTRY, overall two-year survival did not differ between transcatheter and medically treated patients. Two key determinants of survival emerged: the TRI-SCORE category and the degree of residual TR, when assessed using a 4-grade rather than a 3-grade classification, by dividing "moderate" TR into "mild-to-moderate" and "moderate-to-severe" TR, with residual TR ≤ mild-to-moderate considered a successful result. A survival benefit with TTVI was observed only in low-to-intermediate-risk patients with "mild-to-moderate" or lesser residual TR. In contrast, no survival advantage was seen in high-risk patients, even after successful procedures (19,39). Patients with ≥ "moderate-to-severe" residual TR had significantly worse survival, with no survival benefit compared with medically managed patients, irrespective of the TRI-SCORE category (*Figure 5*) (19). These findings prompted a refined classification of TR severity (40,41). Roughly 25–33% of patients still fail to achieve optimal procedural results (42,43). Thus, combining risk stratification with procedural success prediction is essential for personalized treatment strategies.

Other risk models

The TRIVALVE score (44), derived from 483 patients undergoing transcatheter TV repair at 21 centers in Europe and North America, aimed to predict one-year mortality or hospitalization. It includes six variables: AF, glomerular filtration rate <30 mL/min, elevated γ-glutamyl transferase, elevated bilirubin, clinical signs of right-sided HF, and LV ejection fraction <50%. Its discrimination was modest (AUC =0.68), about one-third had concomitant grade III–IV mitral regurgitation, and many underwent combined mitral and tricuspid interventions. Moreover, four of the five TRIVALVE parameters overlap with the TRI-SCORE, while the fifth, AF, has limited discriminative value in TTVI cohorts, since ≈90% of such patients are in AF across published studies (*Table 1*).

In addition to intervention-focused risk scores, other models have been developed to predict outcomes in patients with TR managed medically, such as the score proposed by Wang *et al.* (45) and the TRIO score (46).

Integrating risk stratification into lifetime management

TR should be viewed as a progressive, systemic disease affecting multiple organs. Optimal outcomes require a lifetime management strategy (47,48) spanning early diagnosis to long-term follow-up:

- ❖ Early identification and referral before irreversible

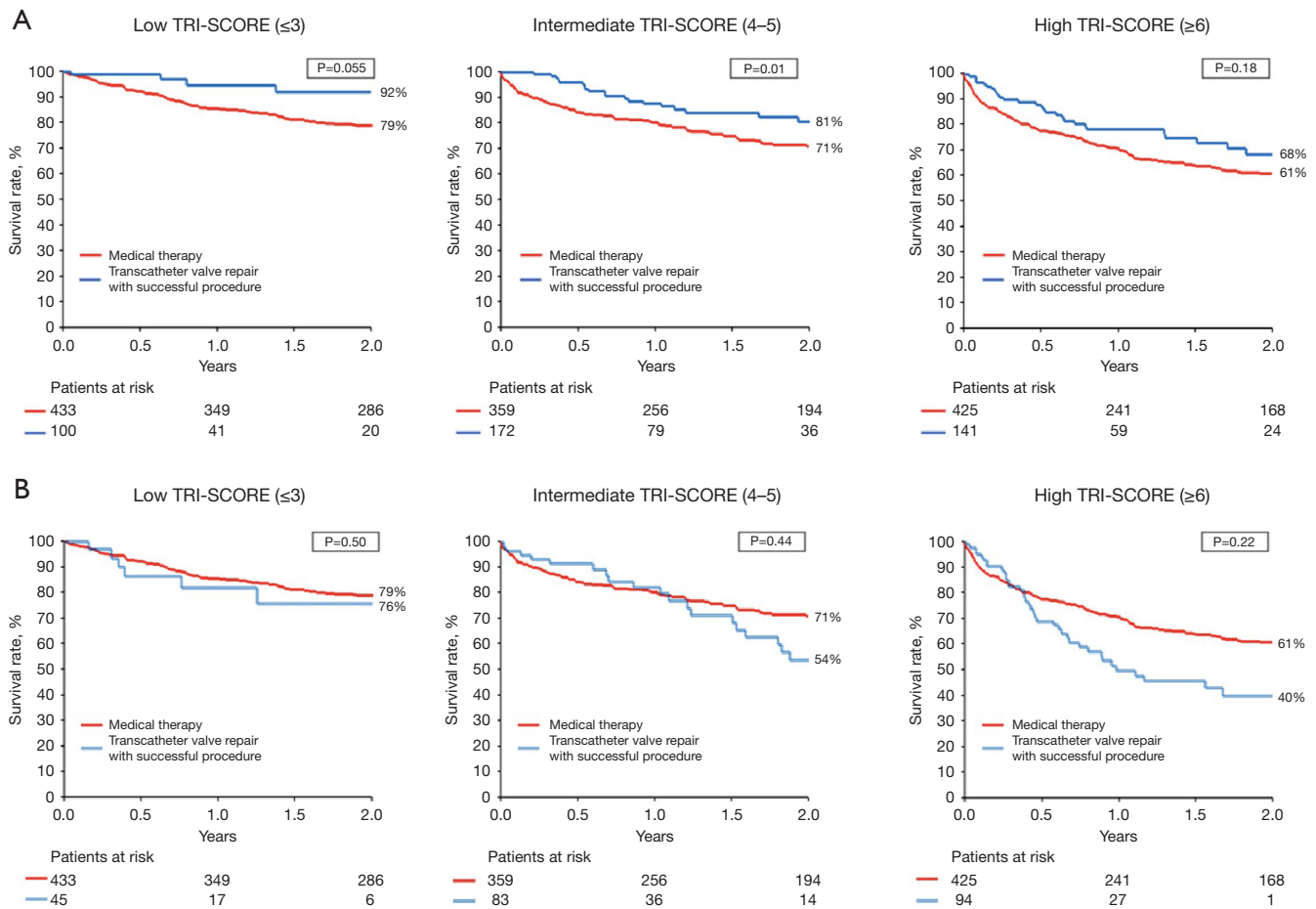

Figure 5 Two-year survival by treatment strategy (transcatheter repair *vs.* medical therapy) and TRI-SCORE category according to procedural success in TRIGISTRY. Adapted from Dreyfus *et al.* with permission (19). (A) Patients achieving procedural success (residual tricuspid regurgitation ≤ mild-to-moderate at discharge); (B) patients with unsuccessful procedure (residual tricuspid regurgitation ≥ moderate-to-severe at discharge).

RV dysfunction or end-organ damage.

- ❖ Comprehensive Heart Team assessment integrating frailty, clinical presentation and organ damages, anatomical features and likelihood of procedural success.

Objective risk stratification using dedicated tools such as the TRI-SCORE. Digital tools now facilitate rapid clinical implementation and global harmonization (49).

Tailored selection of intervention (surgical or transcatheter) based on risk-benefit balance and procedural feasibility.

Structured follow-up to monitor residual TR, RV recovery, and systemic improvement.

Incorporating TRI-SCORE into decision algorithms will enhance patient selection, optimize timing, and improve outcomes.

Beyond individual prediction, TRI-SCORE categories offer a common framework for clinical trials and registries, enabling consistent comparison across treatment modalities and disease stages (50).

Perspectives for future risk stratification

Artificial intelligence

Machine learning will augment traditional models by combining imaging biomarkers, hemodynamics, and longitudinal data, providing dynamic, individualized prediction.

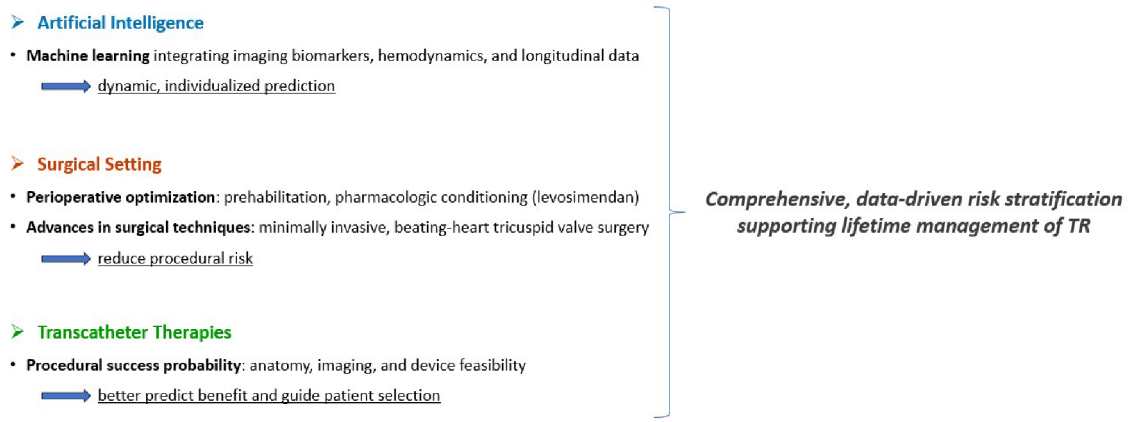

Figure 6 Perspectives for future risk stratification. TR, tricuspid regurgitation.

Surgical setting

Future models should account for perioperative optimization, including prehabilitation and pharmacologic conditioning (e.g., levosimendan), as well as advances in surgical techniques such as minimally invasive and beating-heart TV surgery, which may reduce procedural risk.

Transcatheter therapies

Next-generation models should integrate procedural success probability, incorporating anatomy, imaging, and device feasibility, to better predict benefit and guide patient selection. In addition, further data are required to better define the respective roles of transcatheter repair and replacement strategies and to assess the performance of risk scores in patients undergoing valve replacement procedures. Integrating these elements will pave the way toward comprehensive, data-driven risk stratification supporting lifetime management of TR (*Figure 6*).

Conclusions

TR represents one of the most challenging valvular heart diseases. While both surgical and transcatheter approaches can improve outcomes when performed early and in a timely manner, late referral remains too frequent. The TRI-SCORE has transformed clinical practice by offering a simple, disease-specific, and validated method for risk stratification. It enhances Heart Team decision-making, identifies patients most likely to benefit from intervention, and facilitates personalized, lifetime management. Future perspectives may include its integration into dynamic risk models incorporating imaging biomarkers and artificial intelligence–based prediction to further tailor therapy.

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Footnote

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