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ORIGINAL PAPER

Impact of age on outcomes after transcatheter tricuspid valve edge-to-edge repair: insights from EuroTR

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Abstract

Objective Age stratified data regarding symptomatic and survival outcome of patients undergoing transcatheter tricuspid valve edge-to-edge repair (T-TEER) for severe tricuspid regurgitation (TR) are scarce. Aim of this study was to evaluate TR reduction, symptomatic outcomes, and survival following T-TEER stratified by patient age at intervention.

Methods Using data from the large European Registry of Transcatheter Repair for Tricuspid Regurgitation (EuroTR registry, NCT06307262) we investigated the impact of patient age at intervention on procedural TR reduction, clinical outcome according to New York Heart Association (NYHA) class at latest available follow-up and two-year survival as well as two-year survival free from hospitalization for heart failure (HHF).

Results The study included 2340 patients divided into four groups according to quartiles of age at intervention (1st quartile: 668 patients [69.9 ± 7.2 years] up to 4th quartile: 561 patients [86.2 ± 2.2 years]). Most common TR etiology in all groups was secondary TR with 83.6%–90.1%. TR reduction from baseline to discharge was similar in all groups (TR ≤ 2+ 77.3% 1st quartile, 82% 2nd quartile, 79.5% 3rd quartile and 82.8% 4th quartile, p = 0.085). TR severity at follow-up was also comparable (TR ≤ 2+ 68.1% 1st quartile, 72.1% 2nd quartile, 76.7% 3rd quartile and 73.7% 4th quartile, p = 0.135). Regarding NYHA class patients in all groups benefited equally. Overall two-year survival and two-year survival free from HHF after intervention did not differ between age groups.

Conclusions T-TEER effectively reduces TR in elderly patients. Irrespective of age, patients showed symptomatic benefit and comparable two-year survival free from HHF.

Julia Novotny and Lukas Stolz contributed equally and shared first authorship.Shared first authorship.

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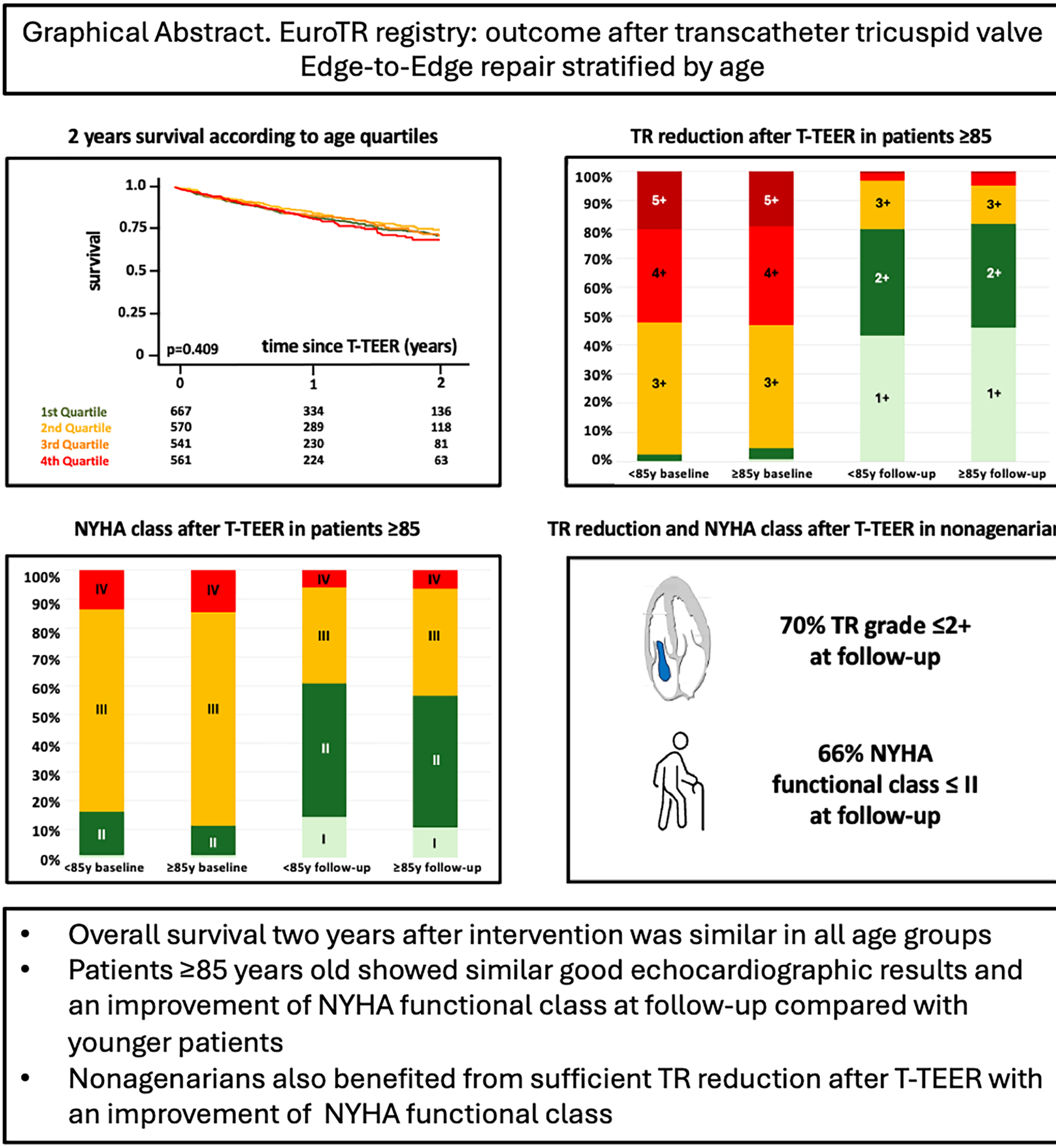
Graphical abstract

Impact of age on outcomes after T-TEER: T-TEER is associated with effective TR reduction and improvement in heart failure symptoms irrespective of patient age at intervention.



Keywords Tricuspid regurgitation · Age · Demographics · T-TEER

Abbreviations

Afib	Atrial fibrillation
HHF	Hospitalization for heart failure
LV	Left ventricle
LVEF	Left ventricular ejection fraction
LVEDD	Left ventricular end-diastolic volume
NYHA	New York Heart Association functional class
RA	Right atrium
RV	Right ventricle
TAPSE	Tricuspid annular plane systolic excursion
TR	Tricuspid regurgitation
T-TEER	Transcatheter tricuspid valve edge-to-edge repair

Introduction

Despite its high prevalence and adverse clinical impact, severe tricuspid regurgitation (TR) has long been underestimated. Severe TR is associated with high rates of hospitalization for heart failure (HHF), morbidity, and mortality [1]. In about 4% of the general population severe TR is diagnosed, and its prevalence is expected to grow within an aging population [2].

Recently, diagnosis and treatment of severe TR gained importance and the rapid development of transcatheter repair techniques offers a low-risk therapeutic option even in patients with elevated surgical risk [3]. Retrospective data as well as a randomized controlled trial confirmed the safety and efficiency of transcatheter tricuspid valve edge-to-edge repair (T-TEER) and demonstrated high rates of procedural success with effective TR reduction and improvement of heart failure symptoms and quality of life beyond optimal medical therapy [4–7].

For mitral valve transcatheter edge-to-edge repair (M-TEER) data suggests that successful persistent mitral regurgitation reduction is key to survival improvement, particularly in patients 80 to 89 years of age [8]. Furthermore, patients after M-TEER benefited from a significant improvement in symptoms and quality of life regardless of age. The overall survival rate in these reports was similar in younger and elderly patients [9, 10].

Until today data on outcomes concerning symptoms and survival of elderly patients after T-TEER are scarce. The present study aims to evaluate the impact of age on outcomes after T-TEER using the large international EuroTR registry (European Registry of Transcatheter Repair for Tricuspid Regurgitation) with a dedicated focus on the very elderly patient population.

Methods

Study cohort, variables, and endpoints

The study used data from the EuroTR registry (European Registry of Transcatheter Repair for Tricuspid Regurgitation) which included TR patients who underwent T-TEER from 2016 until 2024 at twenty European study sites (NCT06307262). Patients who underwent concomitant M-TEER or ineligibility of information regarding age at intervention were excluded (Supplemental Fig. 1). Patient selection involved interdisciplinary consensus within local heart teams, considering factors such as comorbidities, symptoms, anatomy, and life expectancy, following the application of maximum tolerated medical treatment. The T-TEER procedure was performed using either the PASCAL device (Edwards Lifesciences, Irvine, California, USA) or the MitraClip/TriClip system (Abbott, Santa Clara, California, USA), as previously described [11]. A subanalysis was performed including only patients who underwent T-TEER after commercial introduction of the TriClip device (April 2020).

The study was performed in line with the principles outlined in the Declaration of Helsinki and received respective ethical oversight.

Experienced physicians performed echocardiographic analyses at each center according to recent recommendations [12, 13]. The primary study endpoint was two-year survival. Secondary outcomes included two-year survival free from HHF, changes in New York Heart Association functional class (NYHA), and changes in TR severity from baseline to the latest available follow-up.

Statistical analysis

Data were depicted using means and standard deviation or median with interquartile range (IQR), as appropriate. Patients were stratified into age quartiles. Differences between multiple independent samples were evaluated using the Kruskal Wallis Test. Two-year survival rates and two-year survival rates free from HHF were depicted using Kaplan Meier charts. Statistical significance of survival differences was assessed using the log-rank test. Sensitivity analyses (ROC charts and Youden's J) were used to identify the optimal age cut-off for prediction of two-year survival. Differences between two independent samples were evaluated using the Mann–Whitney-U-test. Dependent samples were compared by applying the Wilcoxon test. A two-sided p-value of < 0.05 yielded statistical significance. All analyses were performed using R (version 4.0.4) and SPSS (version 25, IBM, USA).

Results

Characterization of the patient population

The study included a total of 2340 patients at a mean age of 78.7 ± 7.4 years (53.9% women). Patients were divided into four groups according to quartiles of age at intervention as described above (1st quartile 668 patients [69.8 ± 7.1 years], 2nd quartile 570 patients [78.6 ± 1.2 years], 3rd quartile 541 patients [82.0 ± 0.8 years], 4th quartile 561 patients [86.2 ± 2.2 years]). Younger patients presented with a higher BMI (1st quartile 27.4 ± 6.3 kg/m^2, 2nd quartile 26.1 ± 4.7 kg/m^2, 3rd quartile 26.0 ± 4.6 kg/m^2, and 4th quartile 25.3 ± 4.2 kg/m^2, $p < 0.001$) and a lower EuroScore II (1st quartile 5.6 ± 5.6%, 2nd quartile 5.9 ± 5.7%, 3rd quartile 5.9 ± 5.0%, 4th quartile 6.9 ± 5.9%, $p < 0.001$). The TRI-SCORE in all groups was the same with 5 points, $p = 0.305$. The percentage of female patients was significantly higher in the older patient groups (1st quartile 49.2%, 2nd quartile 55.3%, 3rd quartile 54.2%, 4th quartile 57.9%, $p = 0.019$). Older patients more often suffered from atrial fibrillation/flutter (1st quartile 85.2%, 2nd quartile 92.6%, 3rd quartile 91.5%, 4th quartile 94.2%, $p < 0.001$). Overall left ventricular (LV) dimension and function were preserved in all groups, but LVEF was significantly higher in older patients (1st quartile 50.8 ± 12.4%, 2nd quartile 53.3 ± 11.0%, 3rd quartile 54.2 ± 9.8%, 4th quartile 53.9 ± 10.7%, $p < 0.001$) and LV dimensions were smaller (LVEDD 1st quartile 50.2 ± 9.4 mm, 2nd quartile 48.0 ± 7.8 mm, 3rd quartile 47.9 ± 8.1 mm, 4th quartile 47.5 ± 7.4 mm, $p < 0.001$). RV dimensions and TV annulus diameter were significantly smaller in older patients. RV dysfunction according to tricuspid annular plane systolic excursion (TAPSE) was more prevalent in younger patients (TAPSE 1st quartile 16.7 ± 4.7 mm, 2nd quartile 17.4 ± 4.6 mm, 3rd quartile 17.7 ± 4.5 mm, 4th quartile 17.2 ± 4.3 mm, $p = 0.009$). The most common TR etiology in all groups was secondary TR (1st quartile 83.6%, 2nd quartile 87.9%, 3rd quartile 86.0%, 4th quartile 90.1%, $p = 0.394$). About 50% of patients in all groups showed massive to torrential TR. Table 1 shows detailed information concerning clinical and echocardiographic baseline characteristics within the four groups.

T-TEER outcomes stratified by age quartiles

TR reduction

At discharge, over 70% of patients in all groups showed TR reduction ≤ 2+ (1st quartile 77.3%, 2nd quartile 82%, 3rd quartile 79.5%, 4th quartile 82.8%) and under 20% of all patients had a residual TR 3+ at discharge (1st quartile 18.6%, 2nd quartile 14.6%, 3rd quartile 17.5%, 4th quartile 13.2%). At the latest follow-up, the percentage of residual TR 3+ mildly increased in all four groups (1st quartile 25.2%, 2nd quartile 22.0%, 3rd quartile 16.9%, 4th quartile 22.7%, $p = 0.135$) (Table 1 and Fig. 1).

Symptomatic benefit

Patients in all groups benefited after T-TEER with an improvement in NYHA functional class. While at least about 80% of all patients suffered from NYHA ≥ III at baseline (1st quartile 79.8%, 2nd quartile 83.2%, 3rd quartile 85.6%, 4th quartile 86.5%, $p = 0.211$), over 50% of all patients had a NYHA functional class ≤ II at follow-up with the highest percentage in the 2nd quartile group (1st quartile 57.9%, 2nd quartile 67.2%, 3rd quartile 58.7%, 4th quartile 56.1%, $p = 0.029$) (Table 1 and Fig. 2). Patients' 2-year survival rates did not differ between groups ($p = 0.409$) (Fig. 3) as well as survival free from HHF ($p = 0.185$) (Fig. 4).

Very elderly patients with ≥ 85 and ≥ 90 years of age experienced a sufficient TR reduction ≤ 2+ in 70–80% of patients (Supplemental Figs. 2 and 3) as well as a clinical benefit with an improvement in NYHA functional class. After T-TEER nearly 60% of patients older than 85 years and almost 70% of patients older than 90 years had a NYHA functional class ≤ II at follow-up (Supplemental Figs. 4 and 5). The overall survival of patients older than 85 and 90 years was comparable to all other patients in this study.

A subanalysis including only patients who underwent T-TEER after commercial introduction of the TriClip device (76% of the study cohort) confirmed the above-reported results. TR severity at baseline and discharge did not differ by age quartiles ($p = 0.899$ and $p = 0.294$, Supplementary Fig. 6). Same results were observed for NYHA functional class at baseline and follow-up ($p = 0.735$ and $p = 0.078$, Supplementary Fig. 7).

Discussion

This analysis presents data from over 2300 patients included in the EuroTR registry stratified by age at intervention. The registry contains the largest patient cohort treated by T-TEER for relevant TR in more than 25 European heart valve centers. The principal findings of our study are the following (Graphical Abstract):

1. Patients in all age groups showed an effective and comparable TR reduction at discharge and follow-up.
2. Regarding NYHA functional class improvement patients benefited from T-TEER irrespective of age at intervention.

Table 1 Study baseline characteristics stratified by age quartiles

	All patients (n = 2340)	1st quartile (n = 668)	2nd quartile (n = 570)	3rd quartile (n = 541)	4th quartile (n = 561)	p-value
Female sex, n (%)	1254 (53.9)	326 (49.2)	313 (55.3)	292 (54.2)	323 (57.9)	**0.019**
Age, years	78.7 ± 7.4	69.9 ± 7.2	78.6 ± 1.2	82.0 ± 0.8	86.2 ± 2.2	**< 0.001**
BMI, kg/cm^2	26.2 ± 5.1	27.4 ± 6.3	26.1 ± 4.7	26.0 ± 4.6	25.3 ± 4.2	**< 0.001**
EuroScore II, n (%)	6.1 ± 5.6	5.6 ± 5.6	5.9 ± 5.7	5.9 ± 5.0	6.9 ± 5.9	**< 0.001**
TRI-SCORE, pts	4 [5–7]	5 [3–7]	5 [4–6]	5 [3–7]	5 [4–7]	0.305
AHT, n (%)	1736 (80.8)	501 (80.2)	405 (77.9)	409 (83.0)	421 (82.4)	0.150
Dyslipidemia, n (%)	1080 (50.4)	331 (53.2)	269 (51.7)	236 (48.0)	244 (47.8)	0.184
Prior MI, n (%)	215 (10.6)	73 (12.3)	44 (8.6)	47 (10.0)	51 (11.2)	0.227
COPD, n (%)	376 (17.0)	115 (18.0)	77 (14.4)	105 (20.6)	79 (15.0)	**0.027**
DM, n (%)	533 (24.8)	172 (27.5)	148 (28.5)	115 (23.4)	98 (19.1)	**0.001**
Prior Stroke, n (%)	185 (11.8)	54 (12.1)	41 (11.5)	49 (14.0)	41 (10.0)	0.392
TV Lead, n (%)	602 (25.8)	177 (26.6)	149 (26.2)	139 (25.7)	137 (24.5)	0.849
Afib/flutter, n (%)	2077 (90.7)	559 (85.2)	514 (92.6)	483 (91.5)	521 (94.2)	**< 0.001**
CAD, n (%)	976 (42.5)	258 (39.9)	233 (41.8)	233 (43.8)	252 (45.9)	0.124
LVEF, n (%)	52.9 ± 11.2	50.8 ± 12.4	53.3 ± 11.0	54.2 ± 9.8	53.9 ± 10.7	**< 0.001**
LVEDD, mm	48.5 ± 8.4	50.2 ± 9.4	48.0 ± 7.8	47.9 ± 8.1	47.5 ± 7.4	**< 0.001**
TR EROA, cm^2	0.71 ± 0.58	0.73 ± 0.68	0.76 ± 0.69	0.65 ± 0.40	0.67 ± 0.43	0.538
TR RegVol, ml	57.0 ± 38.7	56.5 ± 41.5	58.3 ± 44.6	55.4 ± 30.6	58.0 ± 35.8	0.709
TR VC, mm	12.7 ± 3.6	13.2 ± 36.8	11.5 ± 4.5	12.0 ± 7.8	11.6 ± 5.7	0.780
RV FAC, %	39.7 ± 21.0	37.6 ± 11.5	39.8 ± 10.3	39.6 ± 10.8	26.1 ± 13.0	**0.006**
RV EDA, cm^2	27.3 ± 12.1	29.4 ± 13.4	28.0 ± 11.9	25.6 ± 8.9	26.1 ± 13.0	**< 0.001**
RV ESA, cm^2	17.0 ± 7.9	18.7 ± 8.8	17.2 ± 7.5	16.0 ± 6.0	15.7 ± 8.2	**< 0.001**
RVmid, mm	40.0 ± 9.2	41.2 ± 9.3	41.3 ± 9.1	39.3 ± 8.7	37.9 ± 9.2	**< 0.001**
RVbase, mm	48.5 ± 9.3	49.4 ± 9.5	49.5 ± 9.3	47.3 ± 9.0	47.9 ± 9.2	**0.018**
RV length, mm	71.0 ± 12.6	73.7 ± 13.5	71.7 ± 11.6	69.4 ± 11.8	68.9 ± 12.7	**< 0.001**
TV annulus diameter, mm	44.0 ± 8.0	44.1 ± 8.3	45.1 ± 8.0	43.4 ± 7.9	43.2 ± 7.8	**< 0.001**
RAA, cm^2	36.0 ± 13.2	34.9 ± 12.0	37.2 ± 16.4	35.8 ± 11.4	36.3 ± 12.5	0.190
TAPSE, mm	17.2 ± 4.5	16.7 ± 4.7	17.4 ± 4.6	17.7 ± 4.5	17.2 ± 4.3	**0.009**
Echo-sPAP, mmHg	43.5 ± 14.8	41.7 ± 15.0	43.7 ± 15.0	44.2 ± 14.7	44.6 ± 14.5	**0.006**
Coaptation gap, mm	5.9 ± 3.4	6.0 ± 3.4	6.2 ± 3.4	5.7 ± 3.3	5.7 ± 3.6	0.304
Tenting height, mm	7.3 ± 3.4	7.7 ± 3.6	7.7 ± 3.5	7.0 ± 3.4	6.7 ± 3.3	**0.005**
Tenting area, cm^2	1.8 ± 1.1	1.9 ± 1.2	1.8 ± 1.0	1.7 ± 1.0	1.8 ± 1.2	0.083
eGFR, ml/min	47.8 ± 21.6	51.2 ± 24.2	48.2 ± 21.4	46.4 ± 19.6	44.7 ± 19.6	**< 0.001**
NTproBNP, pg/ml	4607 ± 8389	5671 ± 11,512	3793 ± 6412	4038 ± 6553	4680 ± 7016	**< 0.001**
MRA, n (%)	912 (42.2)	287 (45.9)	236 (44.9)	190 (38.3)	199 (61.1)	**0.016**
Loop diuretic, n (%)	1986 (92.0)	565 (90.4)	480 (91.1)	456 (91.9)	426 (83.0)	**0.034**
Thiazide diuretic, n (%)	352 (2201)	114 (24.5)	75 (20.9)	86 (23.8)	77 (18.7)	0.155
Beta blocker, n (%)	1811 (83.3)	511 (81.5)	452 (85.9)	422 (85.3)	426 (83.0)	0.158
RASI, n (%)	1058 (58.3)	293 (56.0)	244 (58.0)	253 (61.3)	268 (58.6)	0.450
NYHA functional class Baseline, n (%)						
I	28 (1.2)	7 (1.1)	4 (0.7)	10 (1.9)	7 (1.3)	0.211
II	353 (15.2)	127 (19.2)	91 (16.1)	67 (12.5)	68 (12.2)	
III	1640 (70.1)	438 (66.1)	402 (71.0)	392 (73.1)	408 (73.4)	
IV	300 (12.9)	91 (13.7)	69 (12.2)	67 (12.5)	73 (13.1)	
NYHA functional class follow-up, n (%)						
I	166 (13.8)	57 (15.7)	47 (15.4)	35 (13.2)	27 (10.0)	**0.029**
II	557 (46.3)	154 (42.2)	158 (51.8)	121 (45.5)	124 (46.1)	

Table 1 (continued)

	All patients (n = 2340)	1st quartile (n = 668)	2nd quartile (n = 570)	3rd quartile (n = 541)	4th quartile (n = 561)	p-value
III	407 (33.8)	122 (33.6)	87 (28.5)	97 (36.5)	101 (37.5)	
IV	73 (6.1)	30 (8.3)	13 (4.3)	13 (4.9)	18 (6.3)	
TR severity, n (%)						
2+	59 (2.6)	12 (1.9)	15 (2.7)	15 (2.9)	17 (3.1)	0.625
3+	1017 (44.9)	300 (46.2)	238 (43.3)	238 (45.3)	241 (44.5)	
4+	736 (32.5)	192 (29.5)	182 (33.1)	180 (34.3)	182 (33.6)	
5+	454 (20.0)	146 (22.5)	115 (20.9)	92 (17.5	101 (18.7)	
TR severity discharge, n (%)						
1+	912 (43.8)	247 (41.0)	223 (42.8)	219 (45.0)	223 (47.4)	0.085
2+	759 (36.5)	219 (36.3)	204 (39.2)	168 (34.5)	168 (35.4)	
3+	335 (16.1)	112 (18.6)	76 (14.6)	85 (17.5)	62 (13.2)	
4+	57 (2.7)	17 (2.8)	15 (2.9)	11 (2.3)	14 (3.0)	
5+	18 (0.9)	8 (1.3)	3 (0.6)	4 (0.8)	3 (0.6)	
TR severity follow-up, n (%)						
1+	443 (32.0)	126 (29.7)	119 (32.2)	95 (30.4)	103 (37.2)	0.135
2+	557 (40.3)	163 (38.4)	148 (40.1)	145 (46.3)	101 (36.5)	
3+	304 (22.0)	107 (25.2)	81 (22.0)	53 (16.9)	63 (22.7)	
4+	56 (4.0)	20 (4.7)	14 (3.8)	14 (4.5)	8 (2.9)	
5+	23 (1.7)	8 (1.9)	7 (1.9)	6 (1.9)	2 (0.7)	
TR etiology, n (%)						
Primary	120 (5.6)	40 (6.5)	24 (4.5)	34 (6.8)	22 (4.5)	0.394
Secondary	1855 (86.7)	514 (83.6)	474 (87.9)	431 (86.0)	436 (90.1)	
Mixed	164 (7.7)	61 (9.9)	41 (7.6)	36 (7.2)	26 (5.4)	

Afib atrial fibrillation, *AHT* arterial hypertension, *BMI* body mass index, *CAD* coronary artery disease, *COPD* chronic obstructive pulmonary disease, *DM* diabetes mellitus, *Echo-sPAP* echocardiographically estimated systolic pulmonary artery pressure, *EDA* end diastolic area, *eGFR* estimated glomerular filtration rate, *ESA* end systolic area, *EROA* effective regurgitant orifice area, *FAC* fractional area change, *LVEDD* left ventricular end diastolic diameter, *LVEF* left ventricular ejection fraction, *MI* myocardial infarction, *MR* mitral regurgitation, *MRA* mineralocorticoid receptor antagonist, *NTproBNP* N-terminal prohormone of brain natriuretic peptide, *RAA* right atrial area, *RASI* Renin angiotensin aldosterone system inhibitor, *RegVol* regurgitant volume, *RV* right ventricle, *RV base* right ventricular basal diameter, *RV mid* right ventricular midventricular diameter, *TAPSE* tricuspid annular plane systolic excursion, *TrMaxPG* tricuspid regurgitation maximum pressure gradient, *TR* tricuspid regurgitation, *TV* tricuspid valve, *VC* vena contrac

3. Overall survival and survival free from hospitalization for heart failure two years after intervention were similar in all age groups.
4. Even nonagenarians demonstrated a relevant and comparable symptomatic improvement after T-TEER.

The interventional TEER of severe atrioventricular valve regurgitation was developed for the treatment of patients with high perioperative risk and/or advanced age. So far, the impact of age on periprocedural success and patients' outcomes after T-TEER has not been examined in a larger contemporary real-world cohort. Our data show an effective and comparable TR reduction in all patients regardless of age at intervention. Consequently, survival and survival free from hospitalization were comparable in all four analyzed age strata. Even in nonagenarian patients, T-TEER was associated with effective procedural results and symptomatic improvement. This underlines the fact that age alone is an insufficient parameter when evaluating patient eligibility for interventional TR treatment.

Especially elderly patients should be considered within a broader clinically context taking into consideration all relevant comorbidities which might impact quality of life and survival prognosis. Moreover, in nonagenarian patients, improvement of heart failure symptoms and quality of life seems to be the most important aim. In conclusion, T-TEER should not be withheld from nonagenarian patients in a good general state without relevant comorbidities which might dilute the beneficial effect of tricuspid valve treatment.

For mitral regurgitation, several studies investigated at the impact of age on patients' outcomes after treatment. An observational study showed fourfold higher mortality in patients ≥ 80 years of age after surgical mitral valve repair/replacement compared to patients undergoing M-TEER [14]. Mortality in young and elderly patients was consistently reduced after M-TEER compared to optimal medical

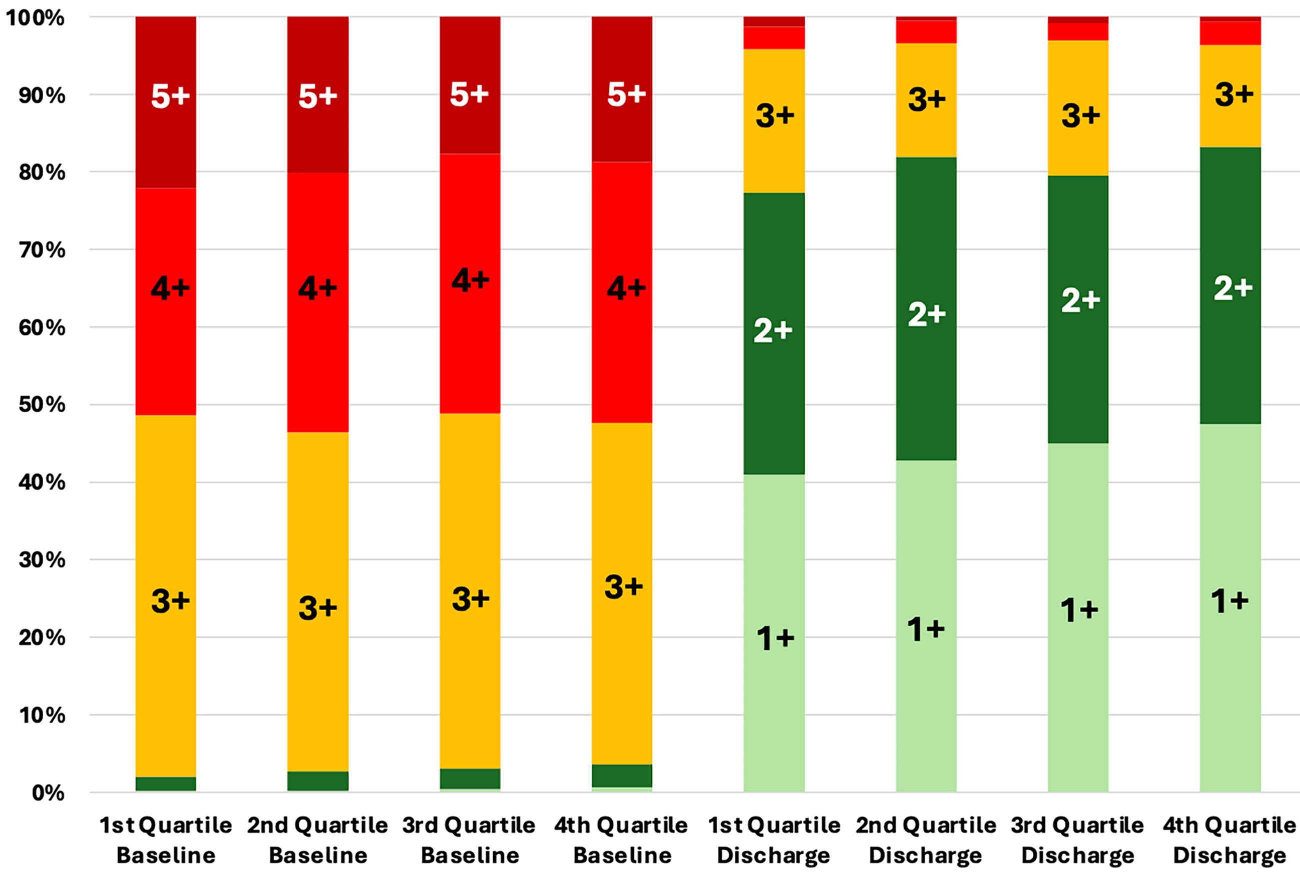


Fig. 1 TR reduction stratified by age quartiles. This figure shows changes in TR severity functional class by age quartiles

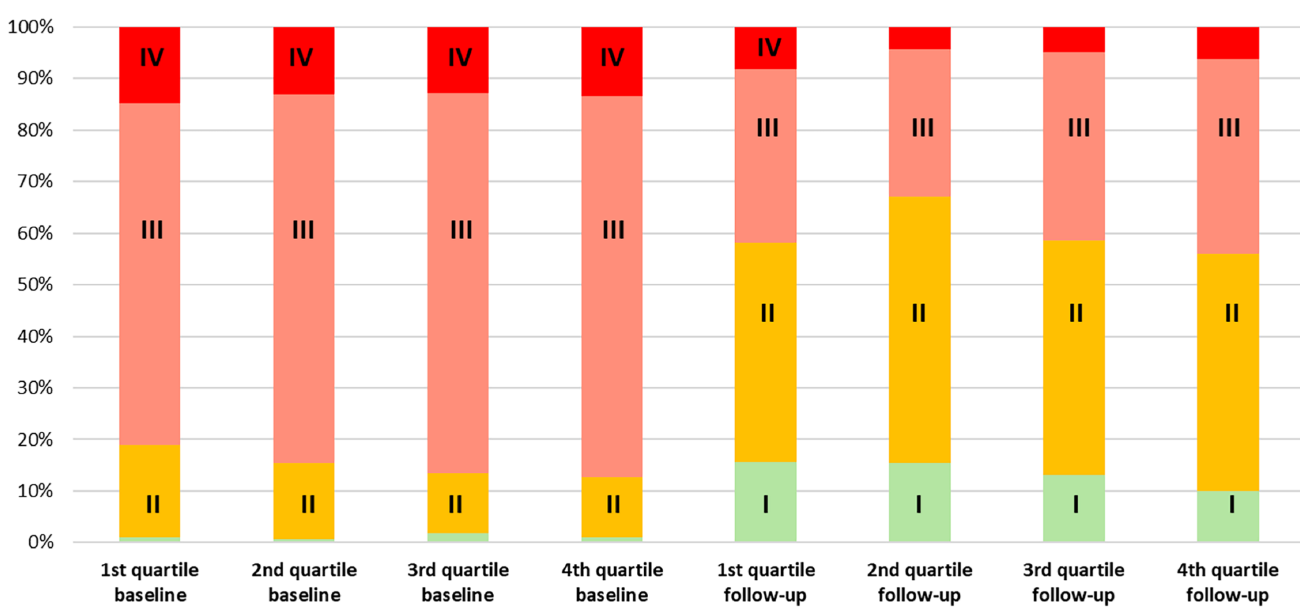


Fig. 2 NYHA functional class stratified by age quartiles. This figure shows changes in NYHA functional class by age quartiles

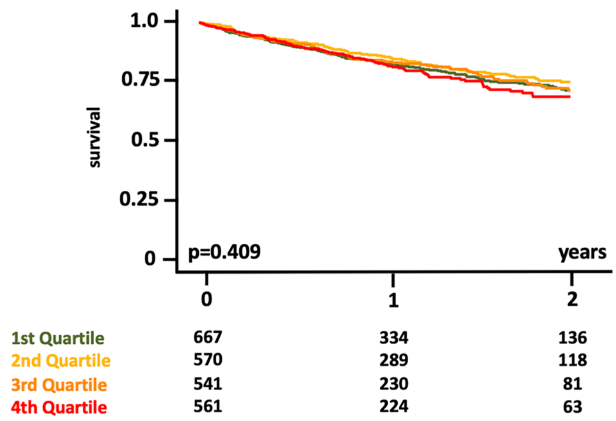


Fig. 3 Survival stratified by age. It shows two years survival stratified by patient age at intervention

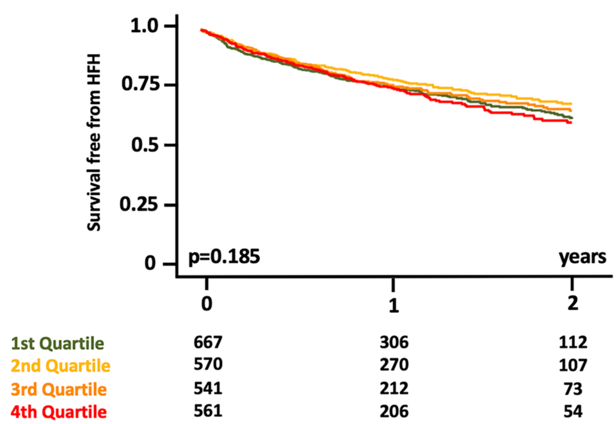


Fig. 4 Survival free from HHF stratified by age. It shows two years survival stratified by patient age at intervention

treatment alone [10], and other data showed M-TEER to be a safe intervention with a positive clinical impact in patients with advanced age [9]. As stated above, our analysis shows similar results for patients after T-TEER. TR reduction at discharge and at follow up were effective in all analyzed groups regardless of patients' age. Furthermore, a comparable 2-year survival was observed although patients in the 4th age quartile were approximately 16 years older than patients in the 1st age quartile, which might be explained by a better LV and RV function in older patients.

In younger patients a more pronounced valve tenting before intervention was found while tenting area was comparable in all groups. Former studies identified high valve tenting as a predictor of residual TR after T-TEER as well as after tricuspid annuloplasty [15, 16]. In our study, TR reduction at latest available follow-up was comparable in all groups. This might be explained through the interaction of multiple factors (echocardiographic parameters and comorbidities). Older patients more often suffered from atrial fibrillation while LV and RV function were preserved in older patients, and RV diameter and TV annulus diameter were significantly smaller in these patients [17].

To date, studies focused on the impact of other patients' characteristics on outcomes after T-TEER. Former studies showed sustained TR reduction, improvement of patients' symptoms, and better 1-year outcomes after successful intervention even in the presence of baseline massive or torrential TR in patients with an average age of 75–78 years [5, 18, 19]. About half of the patients included in our recent analysis presented with massive or torrential TR at baseline and also benefited from sufficient TR reduction concerning NYHA class and survival free from HHF independent from age at intervention. Older patients in our cohort had a higher EuroScore II but the same TRI-SCORE compared to younger patients with similar 2-year survival in all groups. The TRI-SCORE was formerly developed to predict outcome after isolated tricuspid valve surgery for severe TR. In contrast to the EuroScore II the TRI-SCORE also includes echocardiographic and clinical signs of right heart failure as well as age itself [20]. Our data might give a hint that the TRI-SCORE might be more suitable for outcome prediction after T-TEER than the EuroScore II. However, recent data show limited long-term prognostic value of all currently available TR risk scores in a T-TEER cohort [21].

Physical activity improved after T-TEER, especially in frail patients with very low baseline activity measured by one-week actigraphy at different time points after T-TEER in patients at a median age of 79 years [22]. Furthermore, cognitive function of octogenarians improved significantly in the executive function and memory most likely due to improved cardiac output 3 months after T-TEER [23]. The data from both studies combined with our current findings indicate that particularly elderly patients with symptomatic TR might exhibit a larger than expected improvement in quality of life and that these patients should not be excluded from this therapy.

Limitations

The key limitations of this analysis are due to its retrospective nature. All echocardiographic analyses were evaluated by highly experienced specialists at each center but were not subject to core laboratory supervision.

Conclusions

T-TEER is effective and results in a durable reduction of TR also in elderly and very elderly patients. These patient groups demonstrate a similar improvement in functional

NYHA class and present with a comparable 2-year survival compared to younger patients. Thus, T-TEER should not be withheld from patients due to advanced age as long as the expected improvement in quality of life outweighs the low procedural complication rates.

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Data availability In general, we highly appreciate further collaborations to extend the results of this study and optimize treatment of TR. Due to multiple registries and centers being included in this study, each site will need to agree with potential data sharing for further projects. Therefore, we request contacting the author with appropriate requests.

Declarations

Conflict of interest Lukas Stolz received speaker honoraria from Edwards Lifesciences. Karl-Patrik Kresoja reports travel expenses from Edwards Lifesciences. Jennifer von Stein received Lecture honoraria from Edwards Lifesciences. Wolfgang Rottbauer received speaker honoraria Edwards and Abbott. Paolo Denti served as Consultant for InnovHeart, Picardia, HVR, Approxima and received Speaker Honoraria from Abbott and Edwards. Tienush Rassaf received speaker honoraria and consulting fees from Astra Zeneca, Bayer, Pfizer, Daiichi Sankyo. Manuel Barreiro-Perez received speaker fees from Abbott Vascular, Edwards Lifesciences and Venus Medtech. Marianna Adamo received consulting fees in the last three years from Abbott Structural Heart and Edwards LifeSciences. Stefan Toggweiler has received personal honoraria from Medtronic, Boston Scientific, Biosensors, Abbott Vascular, Medira, Shockwave, Teleflex, atHeart Medical, Cardiac Dimensions, Polares Medical, Amarin, Sanofi, AstraZeneca, ReCor Medical, Daiichi Sankyo, has received institutional research grants from Edwards Lifesciences, Boston Scientific, Fumedica, Novartis, Boehringer Ingelheim, and holds equity in Hi-D Imaging. Marco Metra received consulting fees in the last three years from Abbott Structural Heart, Astra-Zeneca, Bayer, Boheringer Ingelheim, Edwards LifeSciences, Roche Diagnostics. Tobias Geisler received speaker honoraria/research grants from Astra Zeneca, Bayer, Bristol Myers Squibb/Pfizer, Ferrer/Chiesi, Medtronic and Edwards Lifesciences. None of them was related to this study. Rodrigo Estévez-Loureiro received speaker fees from Abbott Vascular, Edwards Lifesciences, Boston Scientific and Venus Medtech. Peter Lüdike received speaker honoraria and consulting fees from Astra Zeneca, Bayer, Pfizer, Edwards Lifesciences, and research honoraria from Edwards Lifesciences. Francesco Maisano received Grant and/or Research Institutional Support from Abbott, Medtronic, Edwards Lifesciences, Biotronik, Boston Scientific Corporation, NVT, Terumo, Venus and Consulting fees, Honoraria personal and Institutional from Abbott, Medtronic, Edwards Lifesciences, Xeltis, Cardiovalve, Occlufit, Simulands, Mtex, Venus, Squadra, Valgen Royalty Income/IP Rights Edwards Lifesciences and is shareholder (including share options) of Magenta, Transseptalsolutions, 4Tech. Fabien Praz received Travel expenses from Edwards Lifesciences, Abbott Vascular, Polares Medical, Medira, and Siemens Healthineers. Mirjam Kessler received speaker honoraria Edwards and Abbott. Daniel Kalbacher has received personal fees from Abbott Medical, Edwards Lifesciences, Pi-Cardia Ltd and Medtronic Inc. Volker Rudolph received Research grants from Abbott Medical, Boston Scientific, and Edwards Lifesciences. Christos Iliadis received consultant fees and travel expenses from Abbott Medical and Edwards LifeSciences. Philipp Lurz received institutional grants from Edwards Lifesciences and honoraria from Innoventrics. Jörg Hausleiter reports research grant support and speaker honoraria from Edwards Lifesciences. All other authors have no relevant conflicts of interest to declare. Giuseppe Tarantini received speaker fee for Abbott Vascular and Edwards Lifesciences. Amir Mahabadi received peaker fees and/or advisory boards: Amgen, Berlin Chemie, Daiichi Sankyo, Edwards, Novartis, Sanofi. Research funding: Daiichi Sankyo, Edwards, all outside the submitted work.

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