Tricuspid Intervention

Treatment options of intervention

- **Edge-to-edge repair** (Coaptation devices)
  - TriClip
  - PASCAL
- **Direct ring-annuloplasty** (Repair)
  - Cardioband
- **Catheter-based valve replacement**

2020 AHA/ACC Guideline Indication of Tricuspid intervention

- **Severe TR (Stage C, D)**
  - undergoing left-sided valve surgery

    → TV surgery is recommended (**Class I**)
  - combined with signs and symptoms of right-sided HF

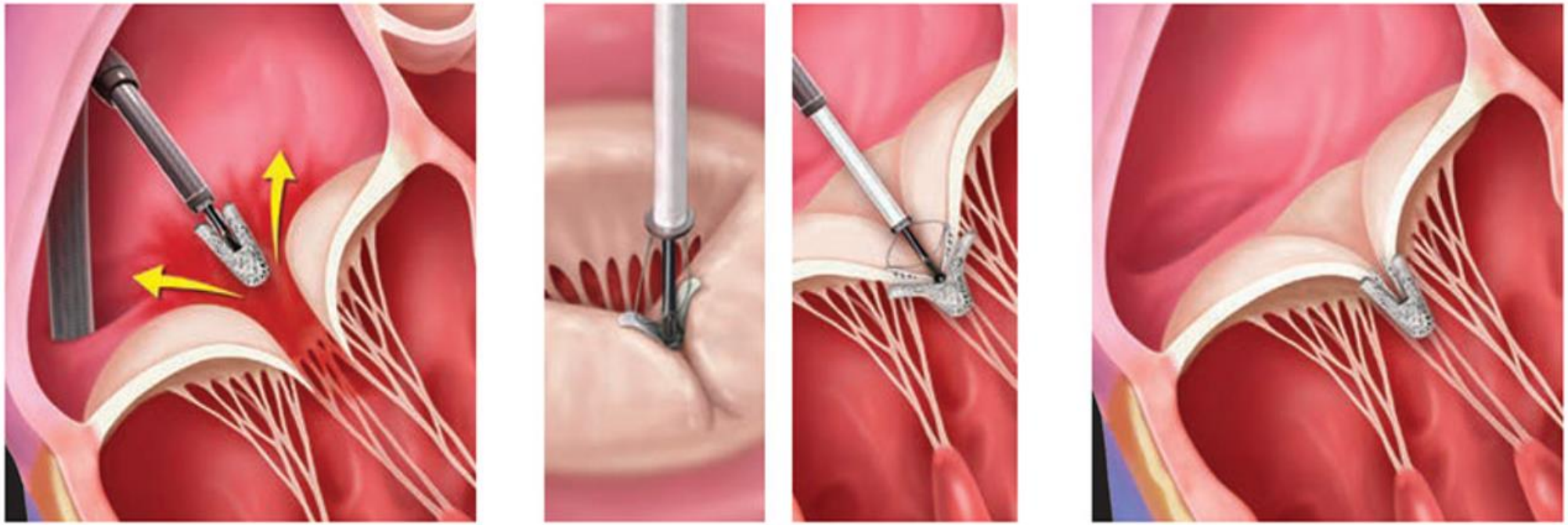
    → isolated tricuspid valve surgery (**Class IIa**)
  - asymptomatic and progressive RV dilation or systolic dysfunction

    → isolated tricuspid valve surgery (**Class IIb**)

2021 ESC/EACTS Guideline Indication of Transcatheter Tricuspid Valve Intervention

- TTVI are under clinical development
- Early registry and study → Coaptation devices, Direct annuloplasty, or Valve replacement can improve symptom and hemodynamics
- **Class IIb (LOE – C)**
  - Transcatheter treatment of symptomatic secondary severe TR may be considered in inoperable patients at a Heart Valve Center

Concept of TEER with TriClip

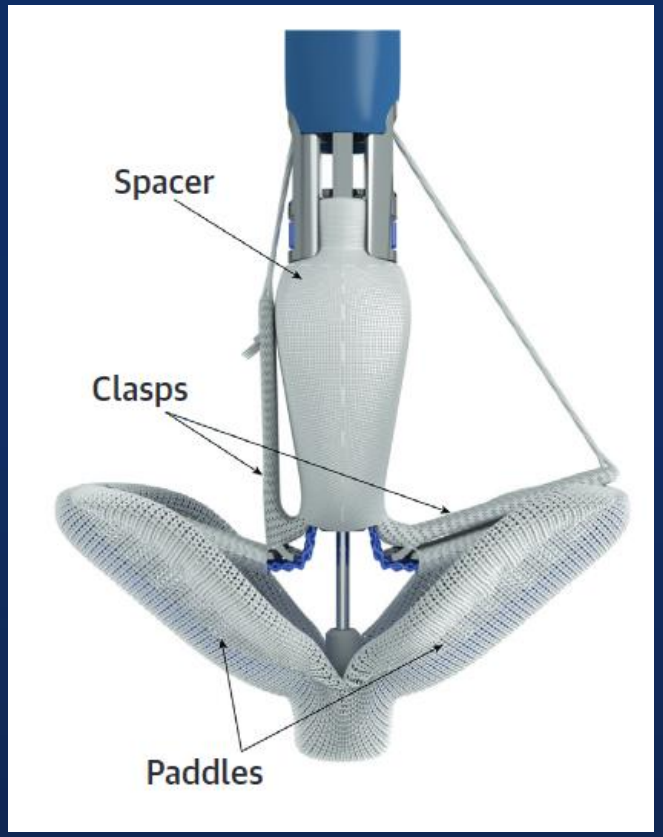


Repairing a tricuspid valve through a TriClip procedure (Image courtesy of Abbott)

Current Devices of TEER

TriClip (Abbott)

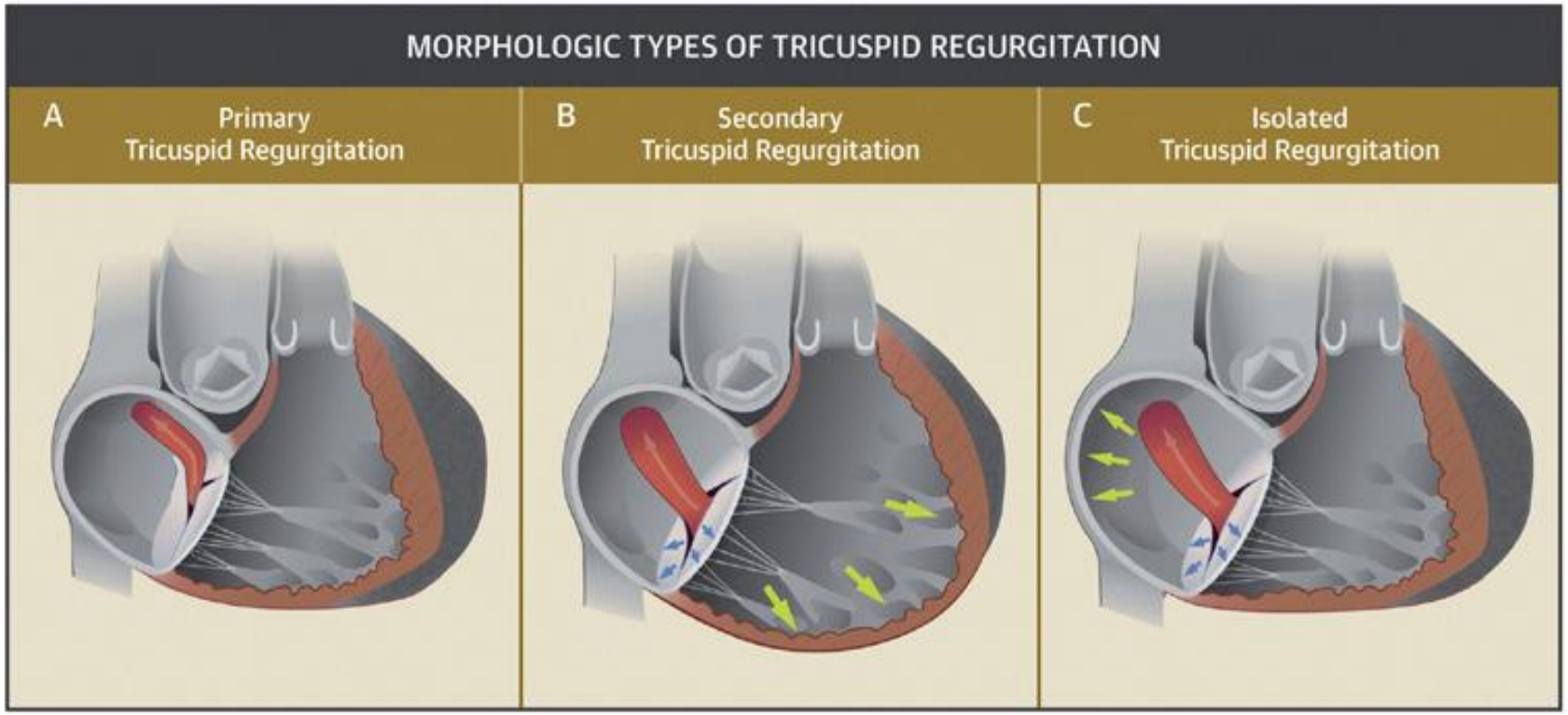
PASCAL (Edwards)



Status of Coaptation Device

Two Types of Tricuspid Regurgitation

CENTRAL ILLUSTRATION: Schematic Drawing of the Different Morphologic Types of Tricuspid Regurgitation



Prihadi, E.A. et al. J Am Coll Cardiol Img. 2019;12(3):491-9.

Evidence of TEER for Severe TR

TriClip
(Abbott Vascular)

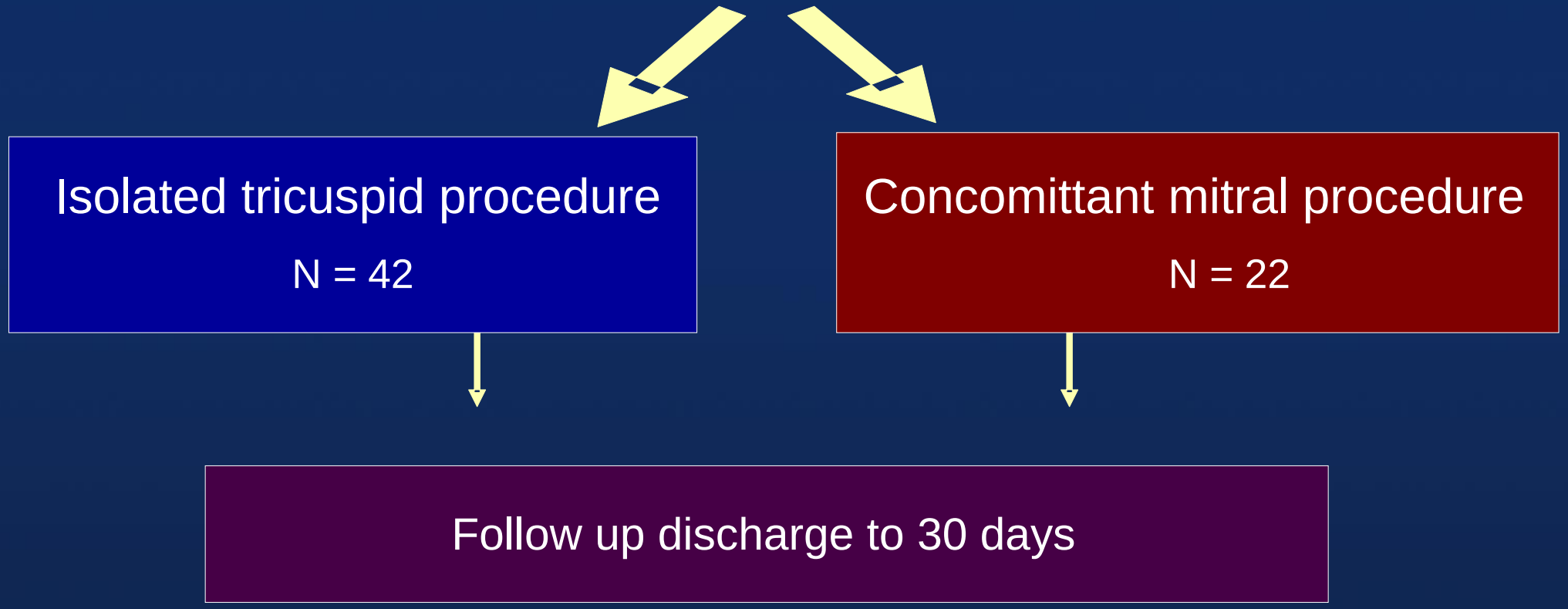
Mitraclip for Severe TR

64 patients enrolled at 10 sites

Severe TR (3+ or 4+)

Exclusion:

sPAP > 60mmHg, severe coaptation defect (>2cm)



Nickenig et al. Circulation 2017;135:1802-1814

MitraClip for Severe TR

64 patients, Single arm study

Baseline characteristics	N = 64
Age	76.6 ± 9.6
Male sex, %	29 (45%)
EuroSCORE, %	27.8 ± 16.7
STS mortality score, %	4.7 ± 4.6
GFR, mL/min	48.7 ± 19.7
AST, U/l	34.5 ± 15.6
ALT, U/l	26.3 ± 20.0
NT-proBNP, ng/l	5528.4±5938.8
NYHA III	47 (73%)
NYHA IV	13 (20%)
Atrial fibrillation / flutter, %	54 (84%)
COPD, %	18 (28%)

Nickenig et al. Circulation. 2017;135:1802-1814.

MitraClip for Severe TR

64 patients, Single arm study

Echo at baseline	N = 64
LV EF, %	46.9 ± 13.9
RA volume, %	117.5 ± 72.4
TAPSE, mm	16.9 ± 5.8
sPAP, mmHg	42.5 ± 15.0
IVC diameter, mm	25.8 ± 8.7
Functional TR, %	56 (88%)
Degenerative TR, %	5 (8%)
Mixed TR	3 (4%)
Moderate TR, %	8 (12%)
Severe TR, %	37 (58%)
Massive TR, %	19 (30%)
TR vena contracta, cm	1.0 ± 0.4
TR EROA, cm^2	0.9 ± 0.4
Septo-lateral diameter, mm	42.4 ± 10.4

Nickenig et al. Circulation. 2017;135:1802-1814.

MitraClip for Severe TR

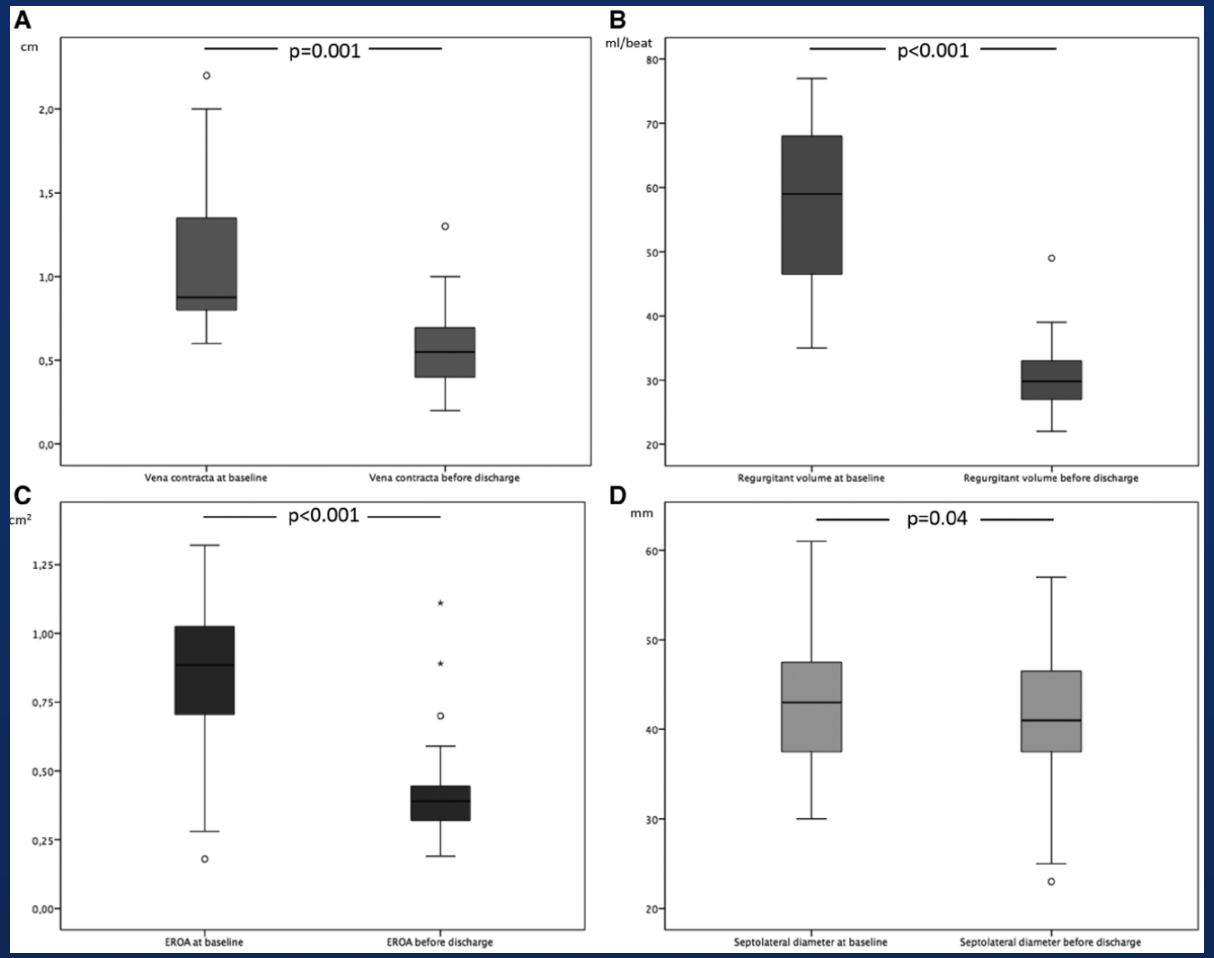
64 patients, Single arm study

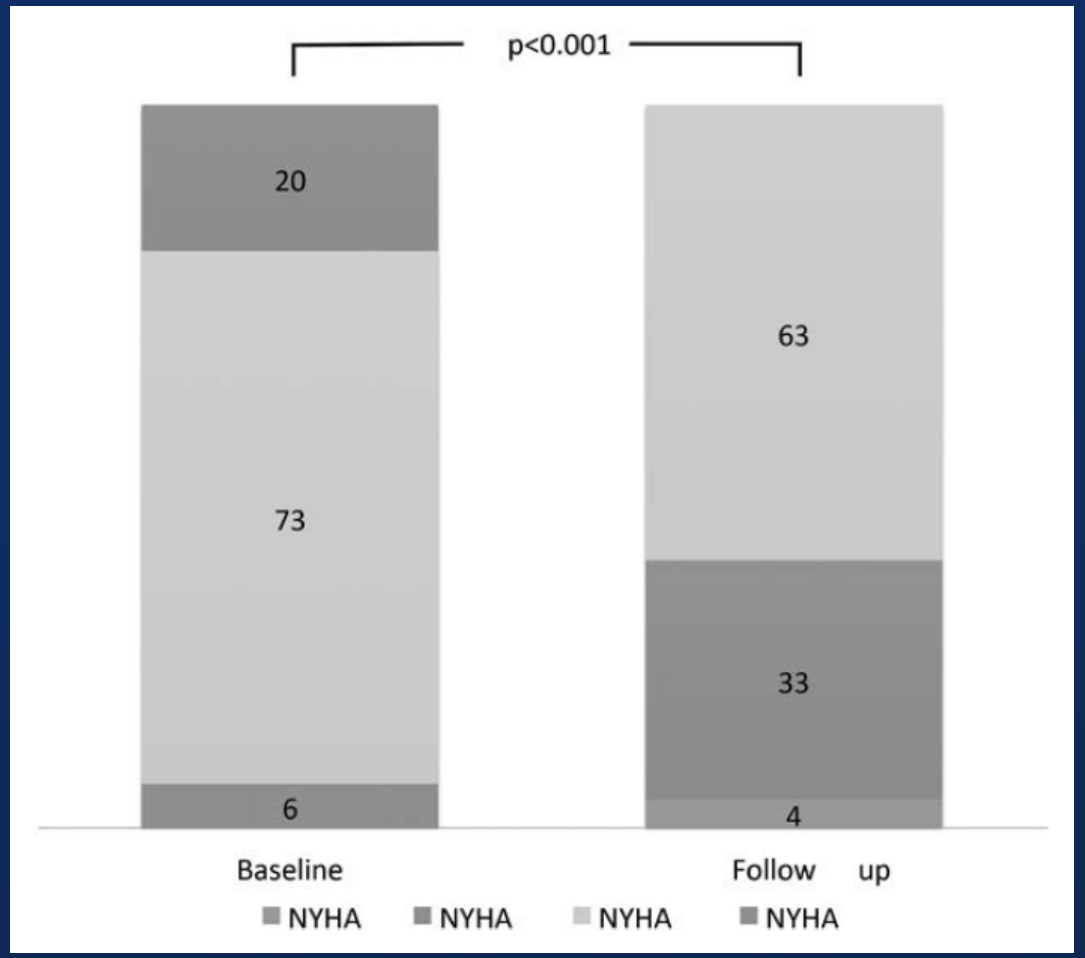
Changes in variables	N	Baseline	Discharge	P value
6MWT, m	21/64	177.4 ± 103.0	193.5 ± 115.9	0.007
GFR, mL/min	64/64	48.7 ± 19.7	49.7 ± 5.4	0.4
NT-proBNP, ng/L	28/64	5528.4 ± 5938.8	5396.8 ± 8191.3	0.9
LV EF, %	50/64	46.6 ± 13.7	48.3 ± 14.1	0.03
RA volume, %	29/64	107.5 ± 61.6	98.1 ± 51.5	0.3
TAPSE, mm	50/64	16.8 ± 5.8	17.1 ± 5.8	0.8
sPAP, mmHg	46/64	44.1 ± 15.4	40.4 ± 12.7	0.02
IVC diameter, mm	23/64	26.1 ± 10.1	24.3 ± 6.9	0.3
TR vena contracta, cm	26/64	1.1 ± 0.5	0.6 ± 0.3	0.001
TR EROA, cm^2	32/64	0.9 ± 0.3	0.4 ± 0.2	< 0.001
Septo-lateral diameter, mm	31/64	41.2 ± 10.6	35.7 ± 16.2	0.04

Nickenig et al. Circulation. 2017;135:1802-1814.

MitraClip for Severe TR

64 patients, Single arm study





Nickenig et al. Circulation. 2017;135:1802-1814.

Univariate and Multivariate analysis of procedural failure TriValve Registry

249 patients, from 14 centers in Europe and North America

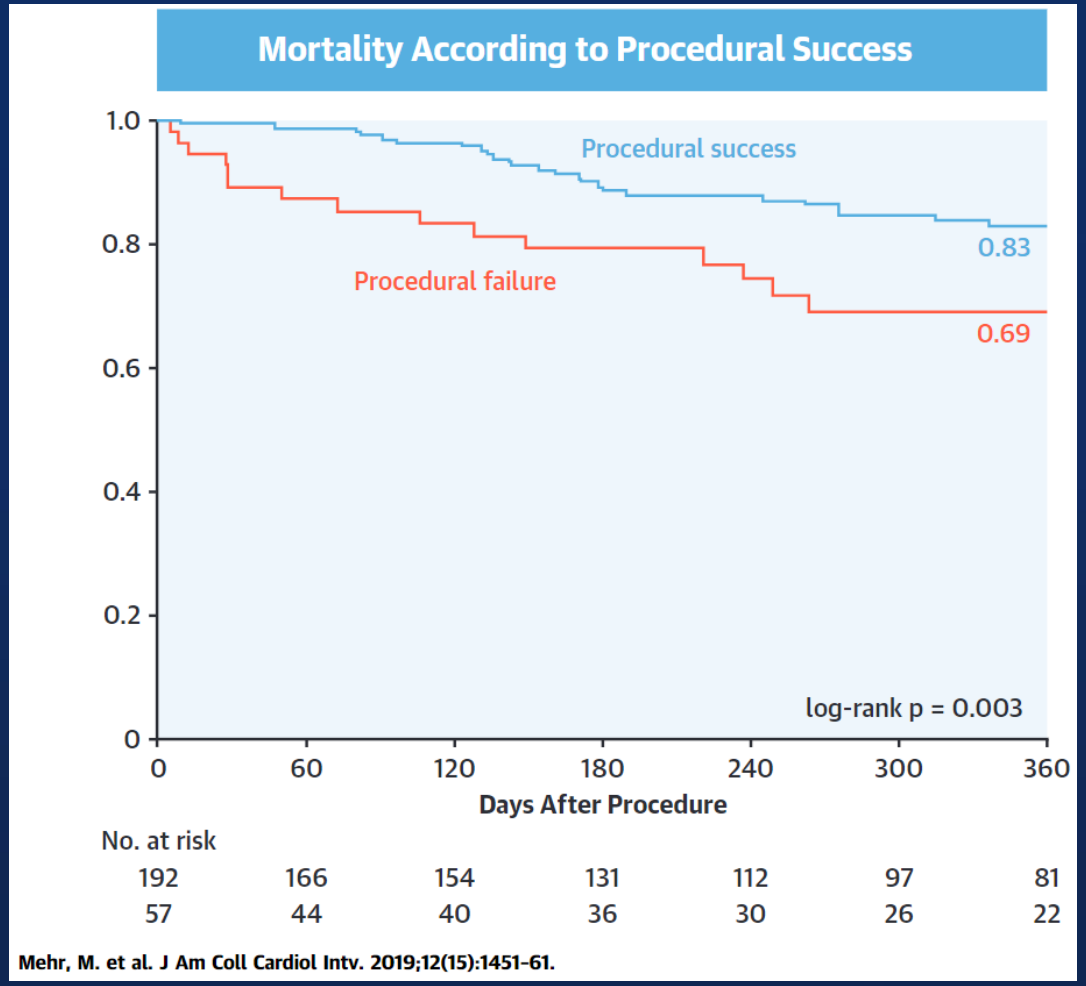
Variables	Univariate		Multivariate	
	OR (95% CI)	P value	OR (95% CI)	P value
Pacemaker or ICD lead	1.53 (0.81-2.84	0.18		
LVEF	1.00 (0.98-1.02)	0.95		
TAPSE	1.02 (0.95-1.10)	0.55		
MR grade	1.10 (0.84-1.44)	0.48		
TR vena contracta	1.76 (0.87-3.53)	0.11		
TR coaptation gap > 6.5 mm	6.16 (3.19-12.18)	<0.001	1.23 (1.10-1.38)	<0.001
TR EROA > 0.695 cm^2	4.79 (2.52-9.33)	<0.001	1.21 (1.09-1.35)	<0.001
TR coaptation depth > 9.75 mm	3.17 (1.71-6.04)	<0.001	1.01 (0.90-1.44)	0.83
TR tenting area > 3.15 cm^2	4.78 (2.49-9.30)	<0.001	1.18 (1.01-1.37)	0.035
Noncentral or nonanteroseptal TR jet location	2.38 (0.98-5.52)	0.047	1.21 (1.04-1.41)	0.013
Tricuspid annular diameter	1.03 (0.99-1.08	0.098	1.00 (0.99-1.00)	0.60
Concomitant mitral valve TEER	0.66 (0.36-1.20)	0.17		
Number of clips	0.81 (0.57-1.12)	0.20		

Mehr, M et al. JACC. 2019;12(15):1451-61

1-Year Outcomes after TEER with MitraClip

TriValve Registry

249 patients, from 14 centers in Europe and North America

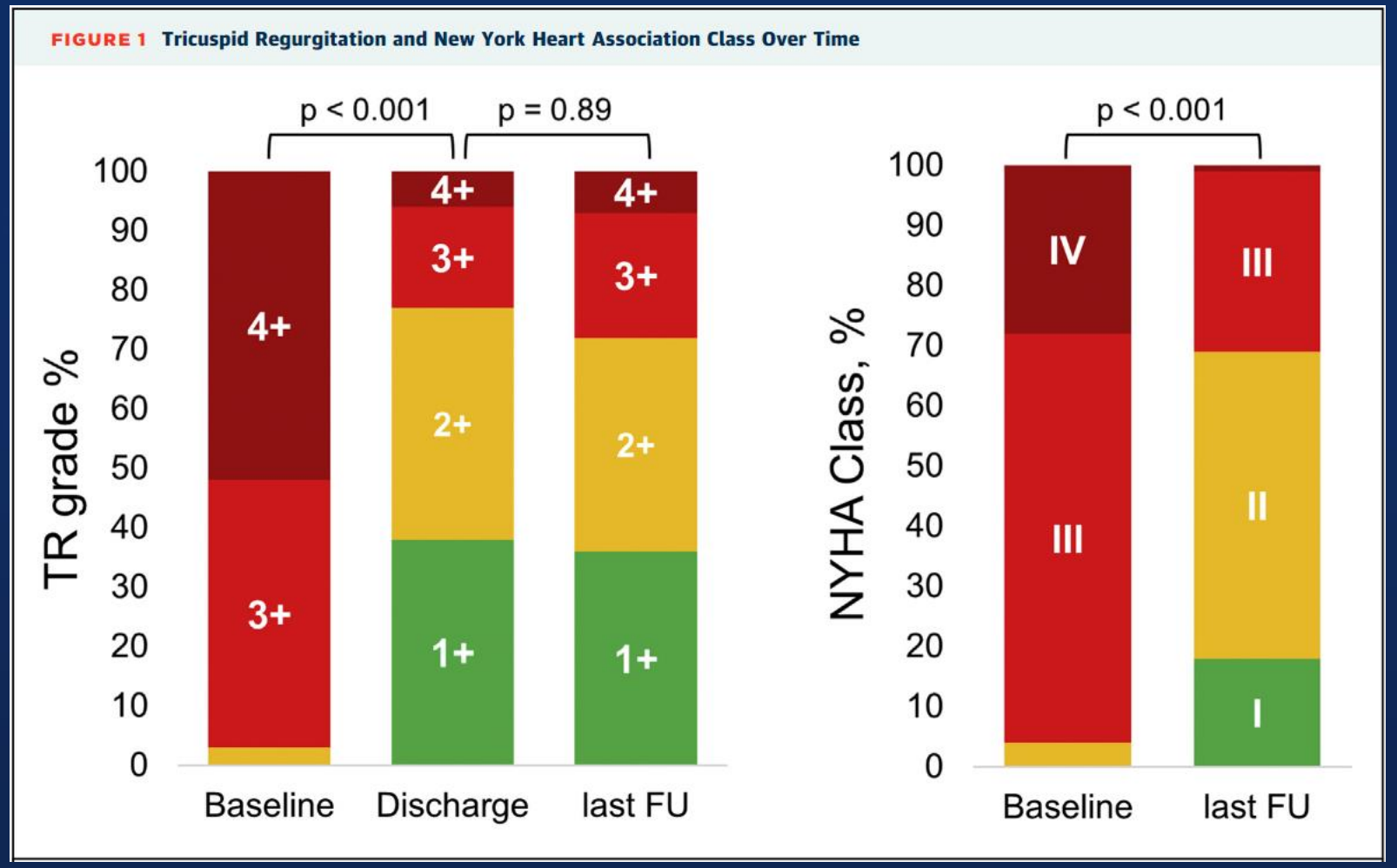


Mehr, M et al. JACC. 2019;12(15):1451-61

1-Year Outcomes after TEER with MitraClip

TriValve Registry

249 patients, from 14 centers in Europe and North America



Mehr, M et al. JACC. 2019;12(15):1451-61

1-Year Outcomes after TEER with MitraClip

TriValve Registry

249 patients, from 14 centers in Europe and North America

Outcomes at Last F/U	N = 249
Estimated mortality at 1 yr	20.3 (14.6-25.8)
Estimated combined mortality and unplanned rehospitalization for HF at 1 yr	34.7 (27.3-41.0)
Tricuspid surgery	7 (2.8)
Decreased of ≥ 1 NYHA functional class (n=175/212)	130 (72.0)
Peripheral edema (n=169/212)	45 (26.6)
Ascites (n=179/212)	37 (20.7)
TAPSE, cm (n=140/212)	15.9 ± 4.3
LVEF, % (n=157/212)	49.6 ± 14.1
sPAP, mmHg (n=141/212)	39.3 ± 14.8
TR severity grade (n=167/212)	
1+, mild	61 (36.5)
2+, moderate	60 (35.9)
3+, severe	35 (21.0)
4+, massive	11 (6.6)

Mehr, M et al. JACC. 2019;12(15):1451-61

Univariate and Multivariate analysis of 1-year Mortality TriValve Registry

249 patients, from 14 centers in Europe and North America

Variables	Univariate		Multivariate	
	OR (95% CI)	P value	OR (95% CI)	P value
Age	1.02 (0.98-1.06)	0.31		
EuroSCORE II	0.99 (0.97-1.02)	0.57		
COPD	0.49 (0.21-1.16)	0.103		
Pacemaker / ICD	1.52 (0.83-2.79)	0.18		
Absence of sinus rhythm	3.85 (1.19-12.43)	0.024	4.40 (1.34-14.49)	0.015
Decrease of 10 ml/min in eGFR	1.29 (1.07-1.55)	0.007	1.25 (1.02-1.51)	0.018
NYHA functional class	2.08 (1.20-3.62)	0.009	1.73 (0.96-3.13)	0.069
Decrease of 10% in LVEF	1.25 (1.02-1.52)	0.028	1.20 (0.98-1.47)	0.084
TAPSE	0.97 (0.90-1.04)	0.42		
TR grade	1.16 (0.67-2.00)	0.59		
MR grade	1.13 (0.86-1.50)	0.39		
Concomitant MV TEER	1.07 (0.59-1.94)	0.83		
Procedure failure	2.43 (1.33-4.46)	0.004	2.12 (1.12-4.02)	0.014

Mehr, M et al. JACC. 2019;12(15):1451-61

TriClip for Severe TR

1-year outcomes of the TRILUMINATE study

84 patients, Single arm study

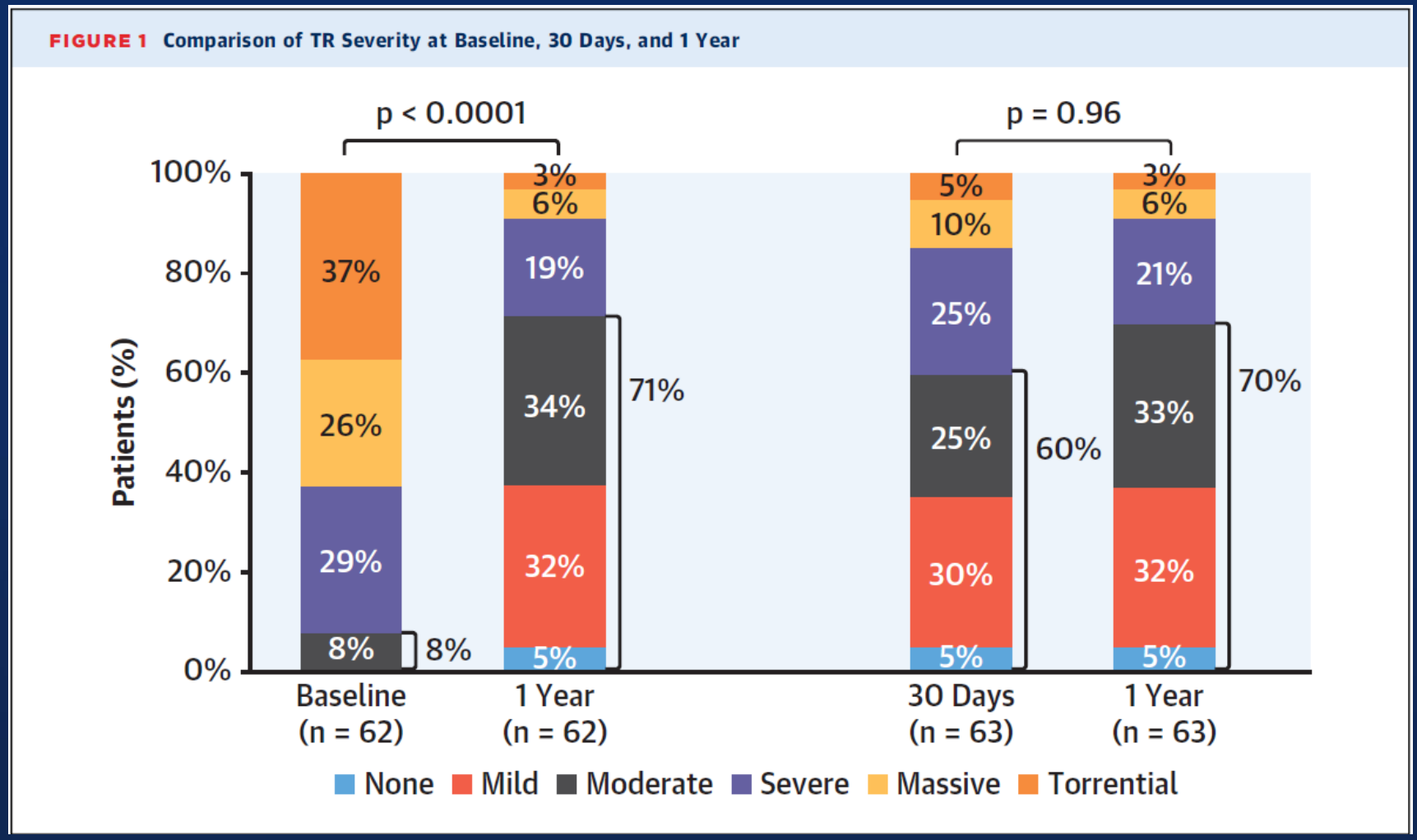
Variables	Baseline (n=85)	30 Days (n=83)	1 Year (n=70)		
			Result	P value (base vs 1 year)	P value (30 days vs 1 year)
EROA, cm² (SE)	0.65 (0.03)	0.40 (0.03)	0.32 (0.05)	<0.0001	0.1053
Regurgitant volume, mL/beat (SE)	52.20 (2.35)	34.83 (2.92)	27.68 (3.08	<0.0001	0.0607
TR jet area, cm² (SE)	14.28 (0.69)	9.18 (0.64	7.55 (0.56)	<0.0001	0.0007
TR vena contracta width, cm (SE)	1.73 (0.07)	1.00 (0.06)	0.78 (0.05)	<0.0001	<0.0001
PISA radius, cm (SE)	0.91 (0.03)	0.68 (0.03)	0.63 (0.04)	<0.0001	0.2092
IVC diameter, cm (SE)	2.29 (0.06)	2.20 (0.06)	2.06 (0.06)	0.0014	0.0216
RV end diastolic dimension, cm (SE)	5.28 (0.07)	4.93 (0.08)	4.79 (0.08)	<0.0001	0.0319
RA volume, mL (SE)	129 (5.84)	117 (6.03)	116 (6.55)	0.0166	0.8536
RV systolic pressure, mmHg (SE)	42.7 (1.08)	42.0 (1.49)	43.9 (2.30)	0.5727	0.4525
TAPSE, cm (SE)	1.44 (0.03)	1.49 (0.03)	1.59 (0.04)	0.0002	0.0069

Lurz et al. JACC. 2021;77:229-39

TriClip for Severe TR

1-year outcomes of the TRILUMINATE study

84 patients, Single arm study



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TriClip for Severe TR

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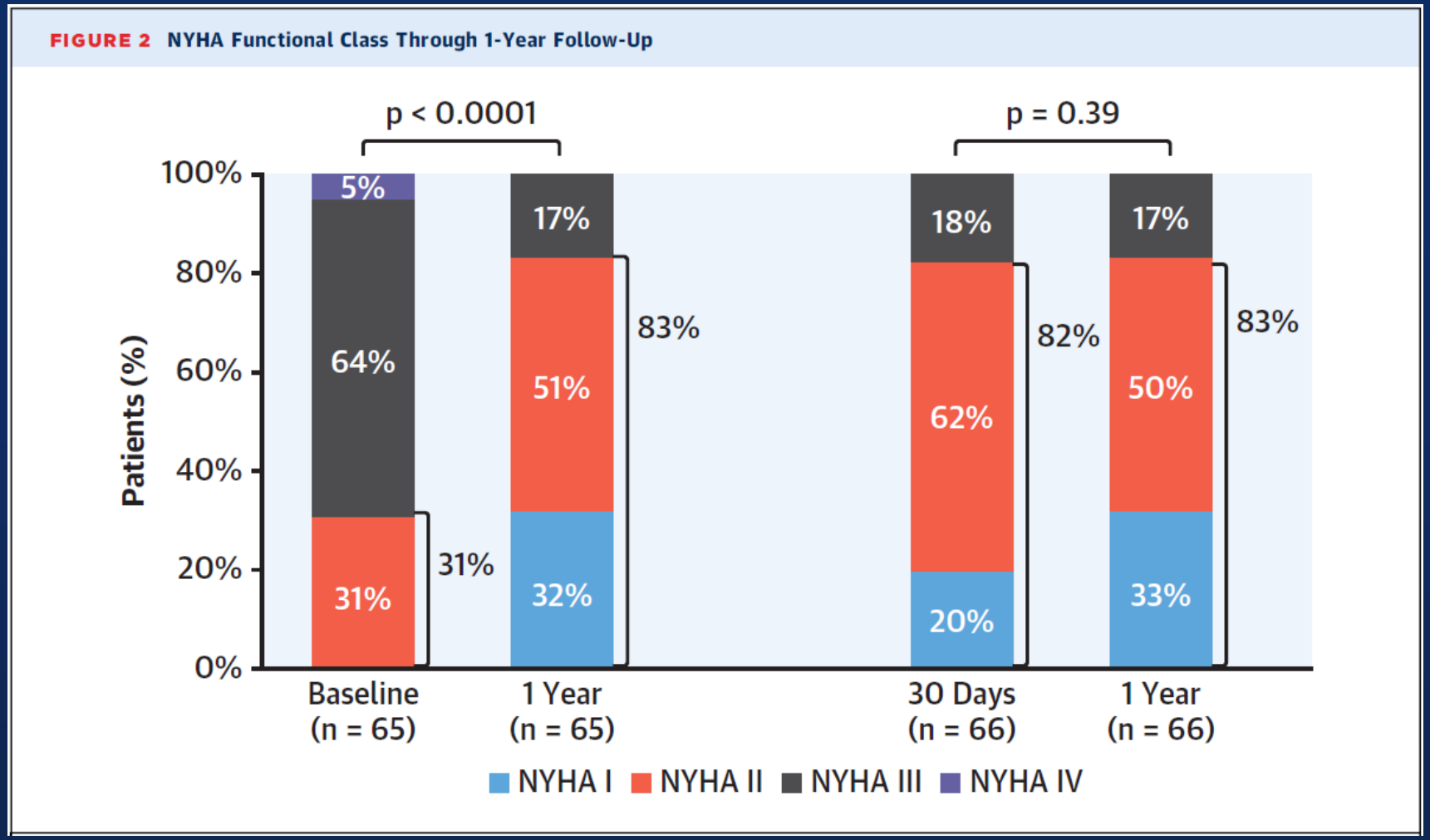

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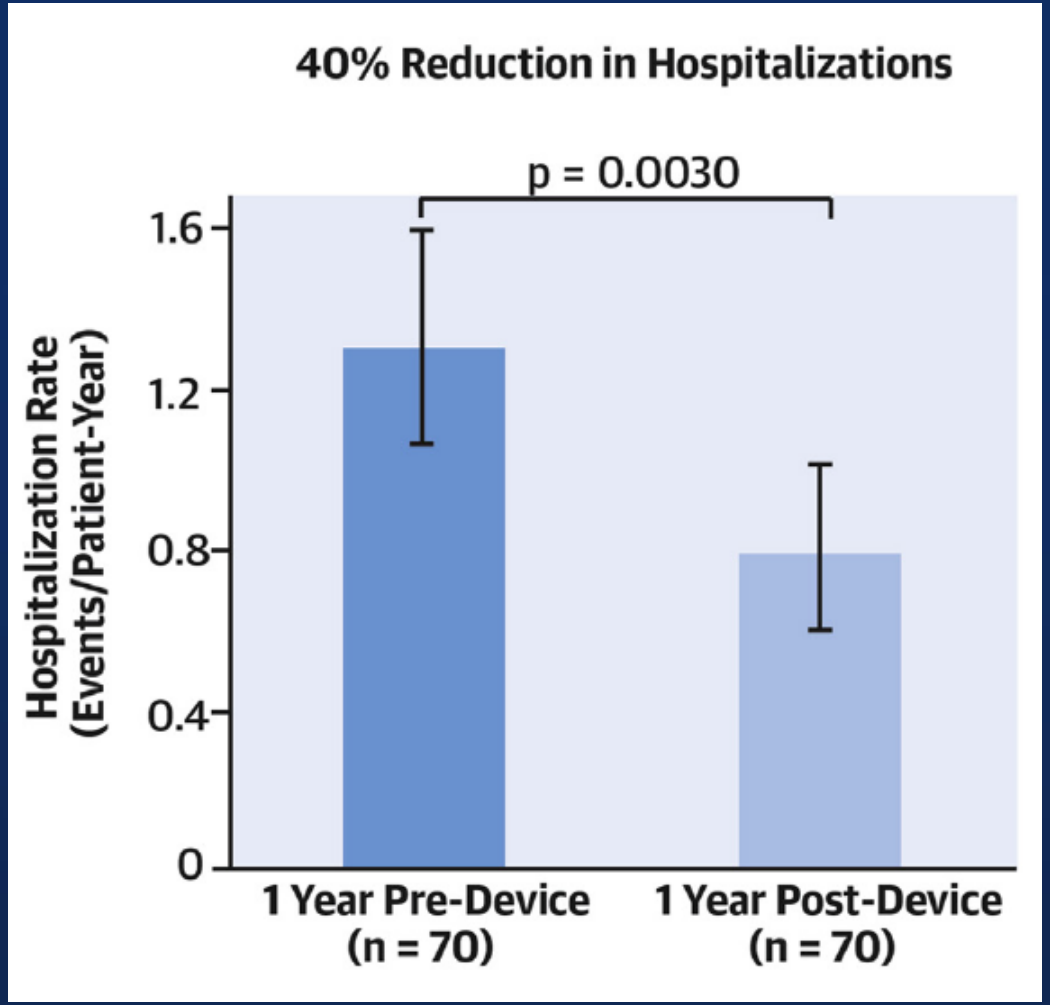
TriClip for Severe TR

1-year outcomes of the TRILUMINATE study

84 patients, Single arm study



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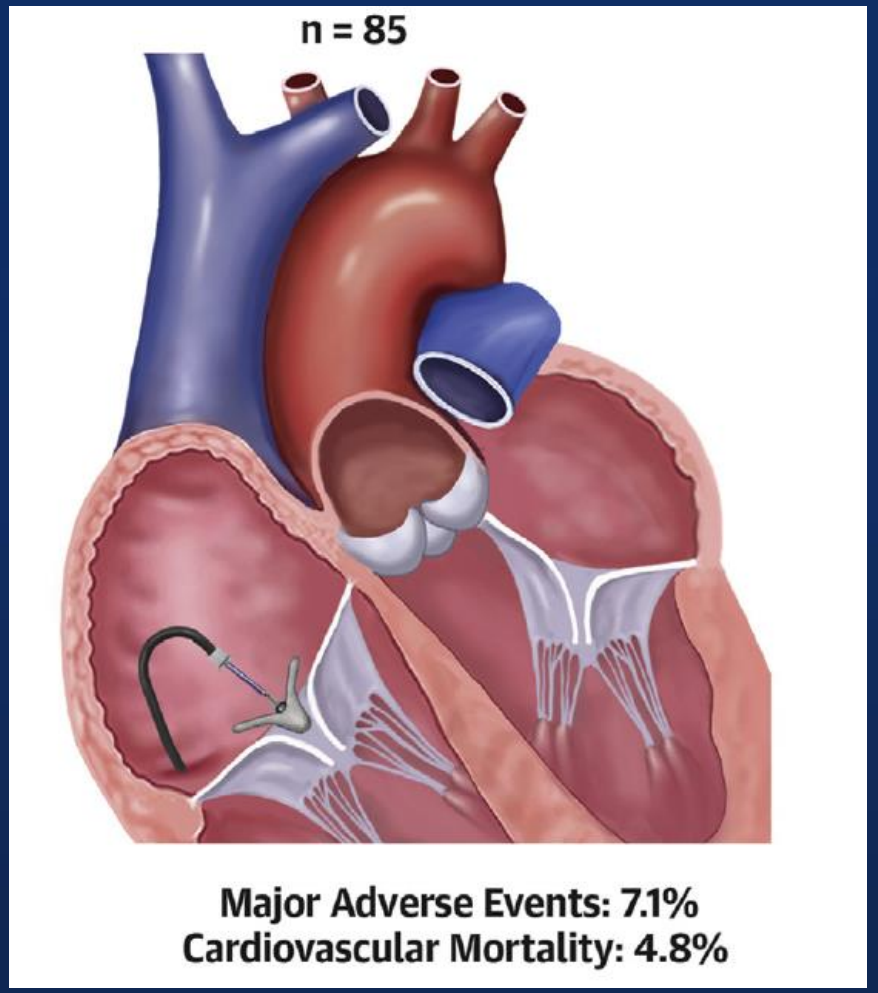
TriClip for Severe TR

1-year outcomes of the TRILUMINATE study

84 patients, Single arm study



Lurz et al. JACC. 2021;77:229-39

TriClip for Severe TR

1-year outcomes of the TRILUMINATE study

84 patients, Single arm study

Safety outcomes	N = 84
MACE through 1 year	6 (7.1%)
CV mortality	4 (4.8%)
Myocardial infarction	1 (1.2%)
Stroke	1 (1.2%)
New onset renal failure	1 (1.2%)
Non-elective CV surgery or Tricuspid valve repair system	0 (0%)
Device-related adverse event	0 (0%)
Other safety endpoints	
All-cause mortality	6 (7.1%)
Major bleeding (BARC type 3a)	10 (11.9%)
New onset AF	1 (1.2%)
Pulmonary thromboembolism	0 (0.0%)
Single leaflet device attachment	5/65 (7.7%)
Mean tricuspid gradient ≥ 5 mmHg	4/64 (6.3%)

Lurz et al. JACC. 2021;77:229-39

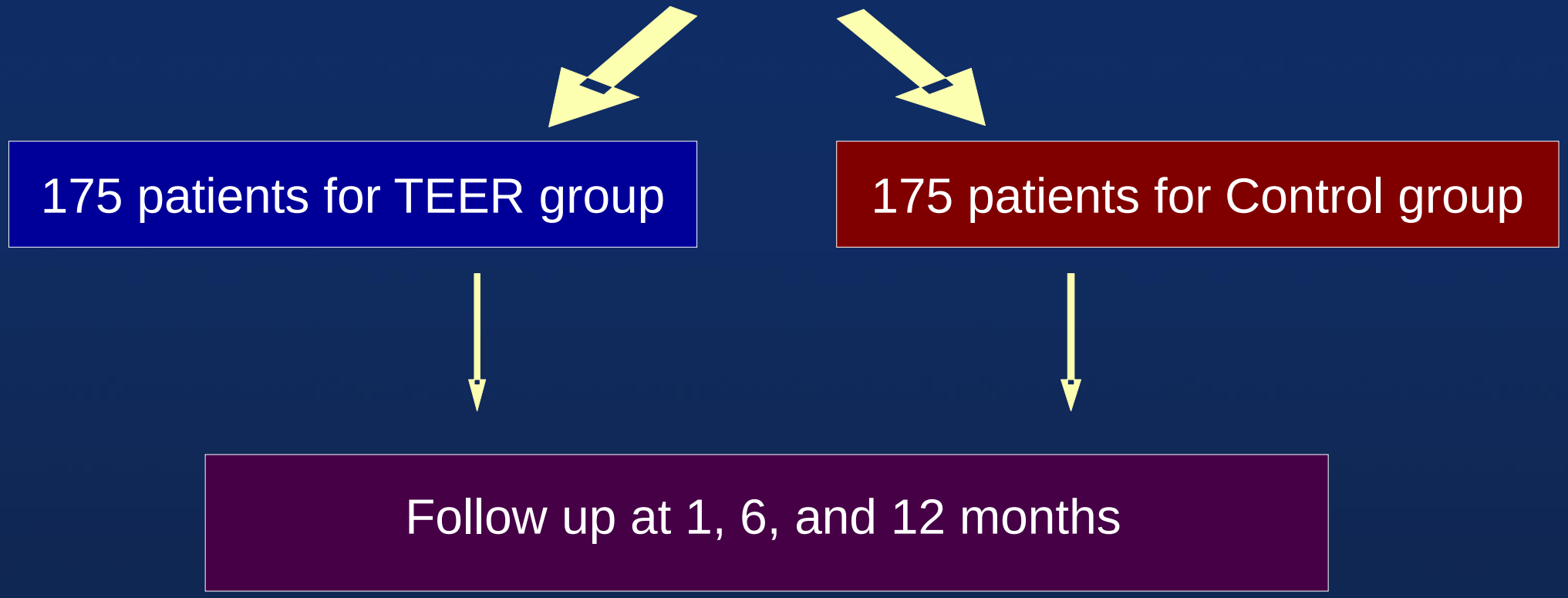
TriClip for Severe TR

TRILUMINATE Pivotal trial (TEER vs Medical Therapy)

84 patients, RCT

Symptomatic Severe TR

sPAP < 70 mmHg, ≥ 30 days GDMT, ≥ intermediate Op risk,
no other CV diseases in need of intervention or surgery



Sorajja et al. NEJM. 2023

TriClip for Severe TR

TRILUMINATE Pivotal trial (TEER vs Medical Therapy)

84 patients, RCT

Baseline Characteristics	TEER Group (N=175)	Control Group (N=175)
Age	78.0 ± 7.4	77.85 ± 7.2
Female sex	98 (56.0%)	94 (53.7%)
NYHA III or IV	104 (59.4%)	97 (55.4%)
Atrial fibrillation	153 (87.4%)	162 (92.6%)
Hypertension	142 (81.1%)	141 (80.6%)
Stroke	11 (6.3%)	19 (10.9%)
Diabetes mellitus	28 (16.0%)	27 (15.4%)
Peripheral vascular disease	16 (9.1%)	18 (10.3%)
Renal disease	62 (35.4%)	62 (35.4%)
Liver disease	11 (6.3%)	16 (9.1%)
Cardiac implantable device	28 (16.0%)	24 (13.7%)
Hospitalization for HF within 1 year	44 (25.1%)	44 (25.1%)
NT-proBNP	382.0 ± 347.5	355.4 ± 283.4

Sorajja et al. NEJM. 2023

TriClip for Severe TR

TRILUMINATE Pivotal trial (TEER vs Medical Therapy)

84 patients, RCT

Primary and Secondary End Points	TEER Group (N=175)	Control Group (N=175)	Difference (95% CI)	P value
Primary				
Hierarchical composite of death from any cause or TV surgery; hospitalization for HF; and improvement of ≥ 15 points in KCCQ score at 1 yr – no. of wins	11,348	7643	1.48 (1.06 – 2.13)	0.02
Secondary, listed in hierarchical order				
KM estimate of percentage of patients with freedom from major adverse events through 30 days after the procedure (Lower 95% confidence limit)	98.3 (96.3)	—	—	<0.001
Change in KCCQ score	12.3 ±1.8	0.6 ±1.8	11.7 (6.8 – 16.6)	<0.001
TR of no greater than moderate severity at 30-day f/u	140/161 (87.0%)	7/146 (4.8%)	—	<0.001
Change in 6-min walk distance	-8.1 ± 10.5	-25.2 ± 10.3	17.1 (-12.0 – 46.1)	0.25

Sorajja et al. NEJM. 2023

TriClip for Severe TR

TRILUMINATE Pivotal trial (TEER vs Medical Therapy)

84 patients, RCT

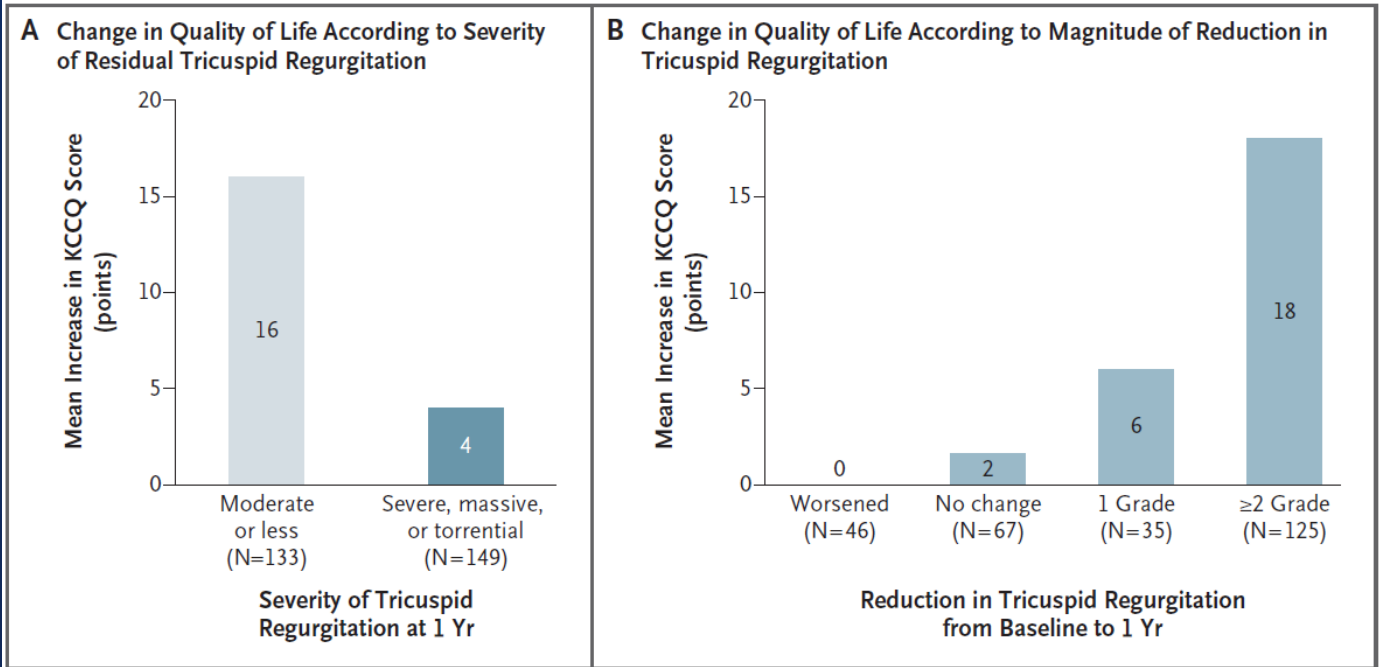


Figure 2. Changes in Quality of Life from Baseline to 1 Year, Stratified According to the Severity of Residual Tricuspid Regurgitation and the Magnitude of the Reduction in Tricuspid Regurgitation.

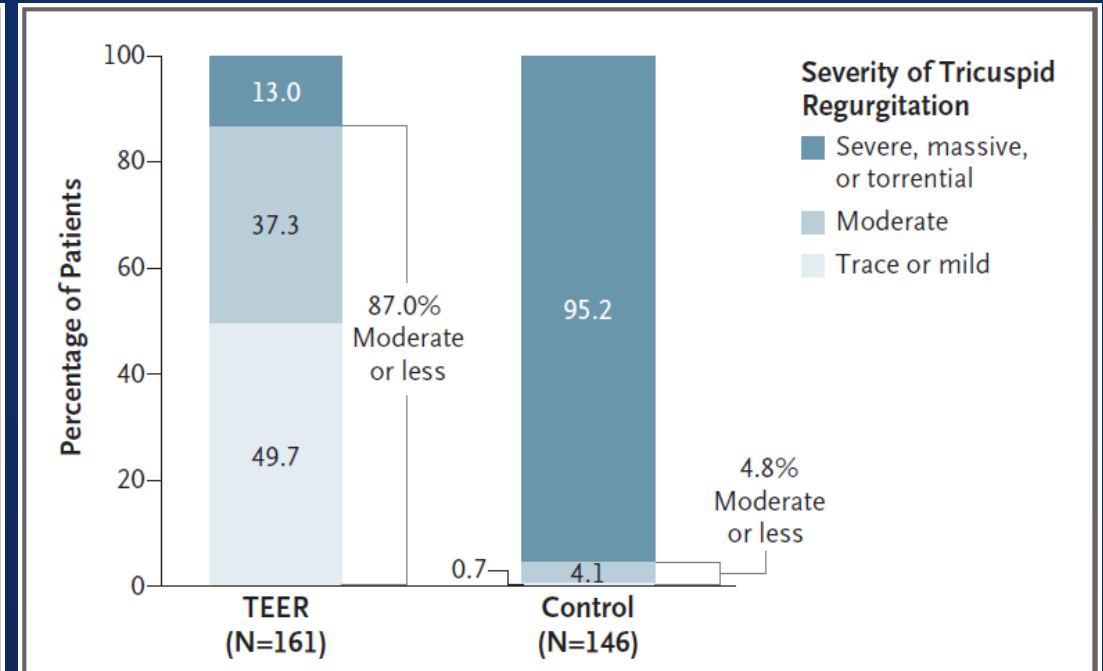


Figure 3. Severity of Tricuspid Regurgitation at 30 Days.

Sorajja et al. NEJM. 2023

PASCAL
(Edwards Lifesciences)

PASCAL for Severe TR

Multicenter, Prospective, Observational, First-in-Human study

23 patients, 7 Centers from 5 Countries

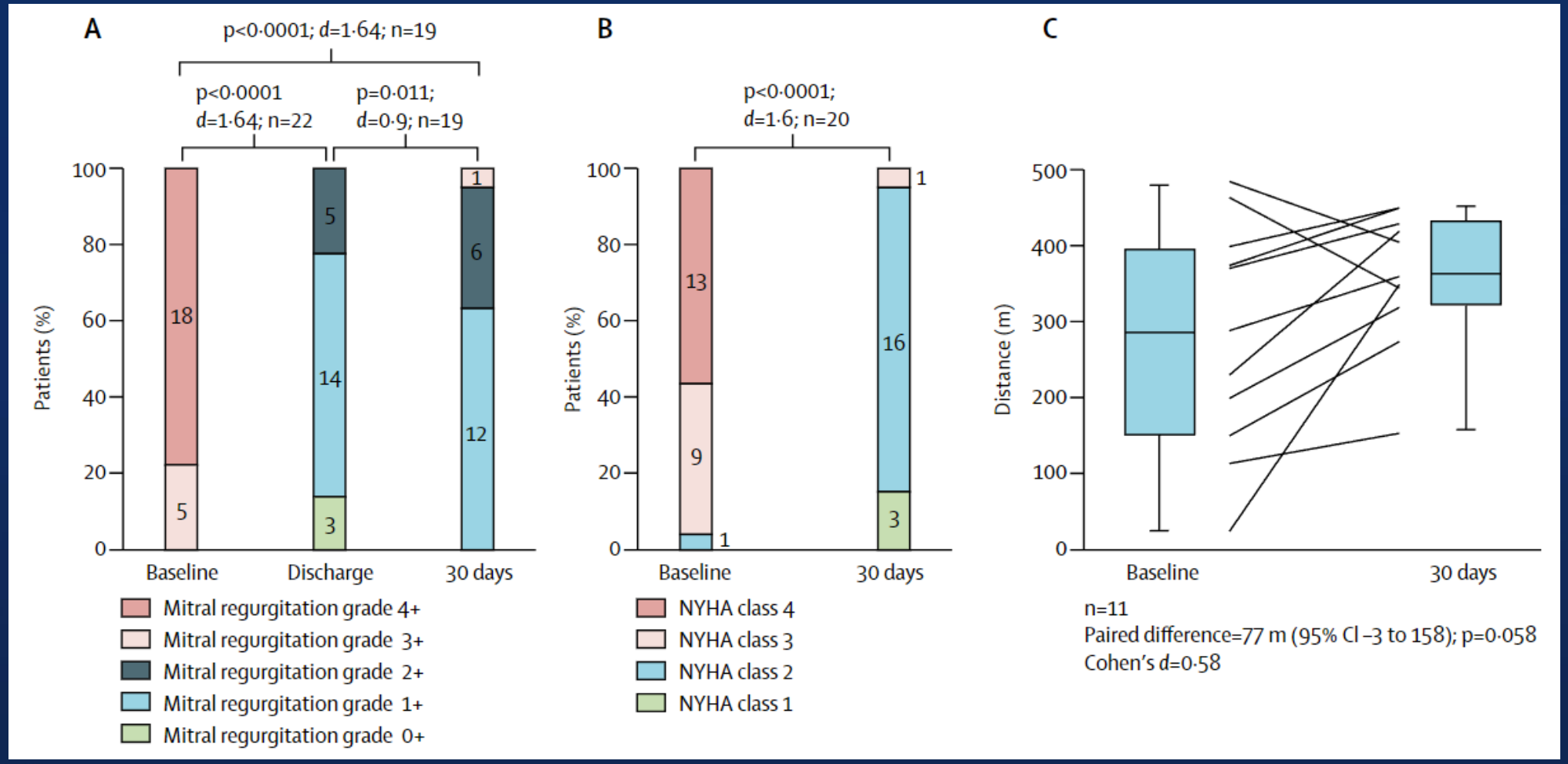
Clinical outcomes at 30 day F/U	N = 23
Device success	18 (78.0%)
All cause mortality	3 (13.0%)
CV mortality	3 (13.0%)
Hospital admission for HF	0 (0.0%)
Reintervention for MV dysfunction	0 (0.0%)
Minor access site bleeding	1 (4.0%)
Major access site bleeding	0 (0.0%)
TIA	1 (4.0%)
Stroke	0 (0.0%)
Myocardial infarction	0 (0.0%)
Renal failure requiring dialysis	0 (0.0%)
Thrombus formation on device	0 (0.0%)

Fabien, P. et al. Lancet; 390:773-80

PASCAL for Severe TR

Multicenter, Prospective, Observational, First-in-Human study

23 patients, 7 Centers from 5 Countries



Fabien, P. et al. Lancet; 390:773-80

PASCAL for Severe TR

Multicenter, Observational, First-in-Human experience

28 patients, Compassionate-use, 6 Centers

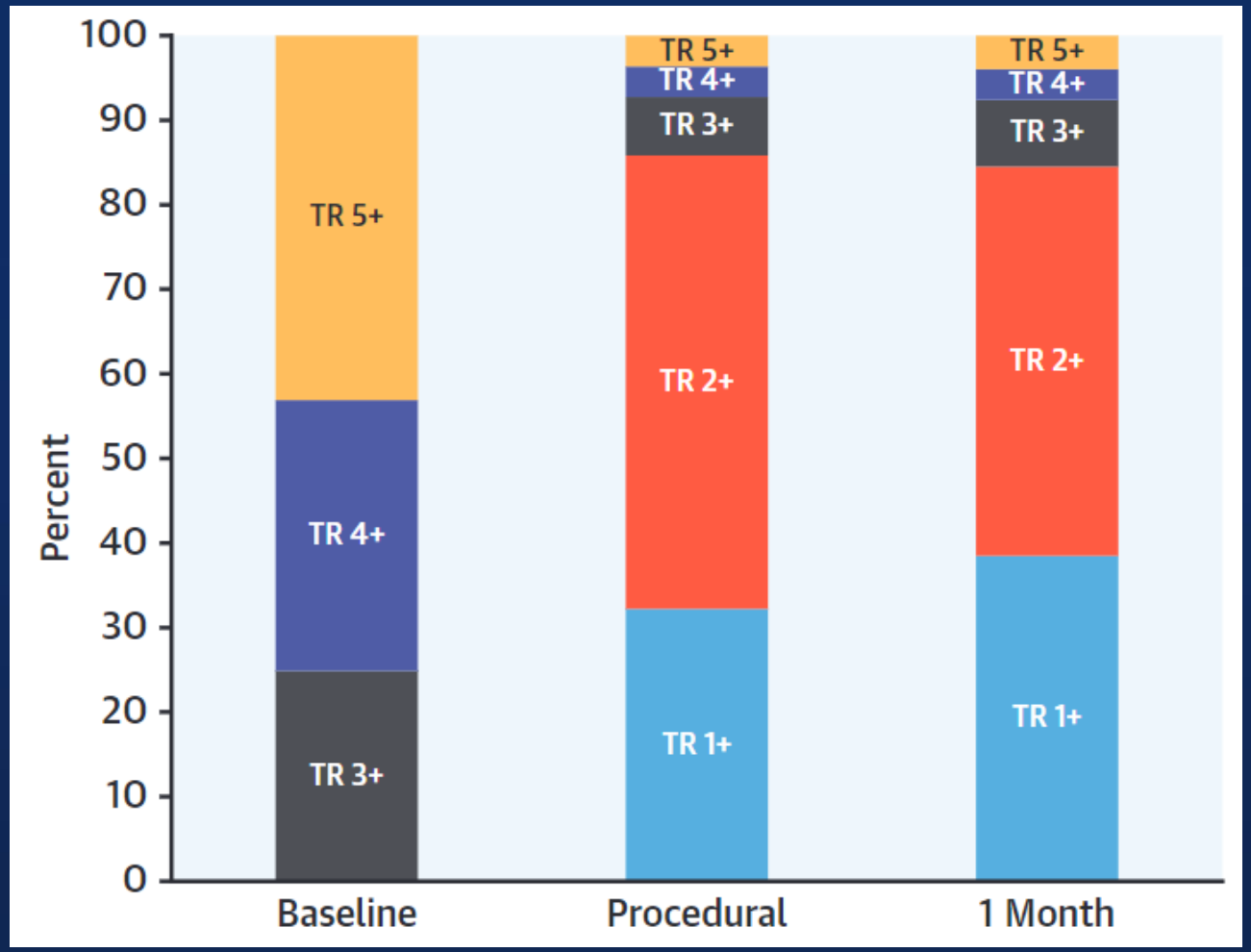
Clinical outcomes at 30 day F/U	N = 28
Mortality	2 (7.1%)
Myocardial infarction	0 (0.0%)
Stroke	0 (0.0%)
Major bleeding	0 (0.0%)
Tamponade	0 (0.0%)
Acute kidney injury	0 (0.0%)
Conversion to surgery	0 (0.0%)
Reintervention	0 (0.0%)
HF hospitalization	1 (3.5%)
Single-leaflet device attachment	2 (7.1%)

Fam, N.P. et al. JACC intervention. 2019;12(24):2488-95

PASCAL for Severe TR

Symptom and TR grade improvement

28 patients, Single arm study

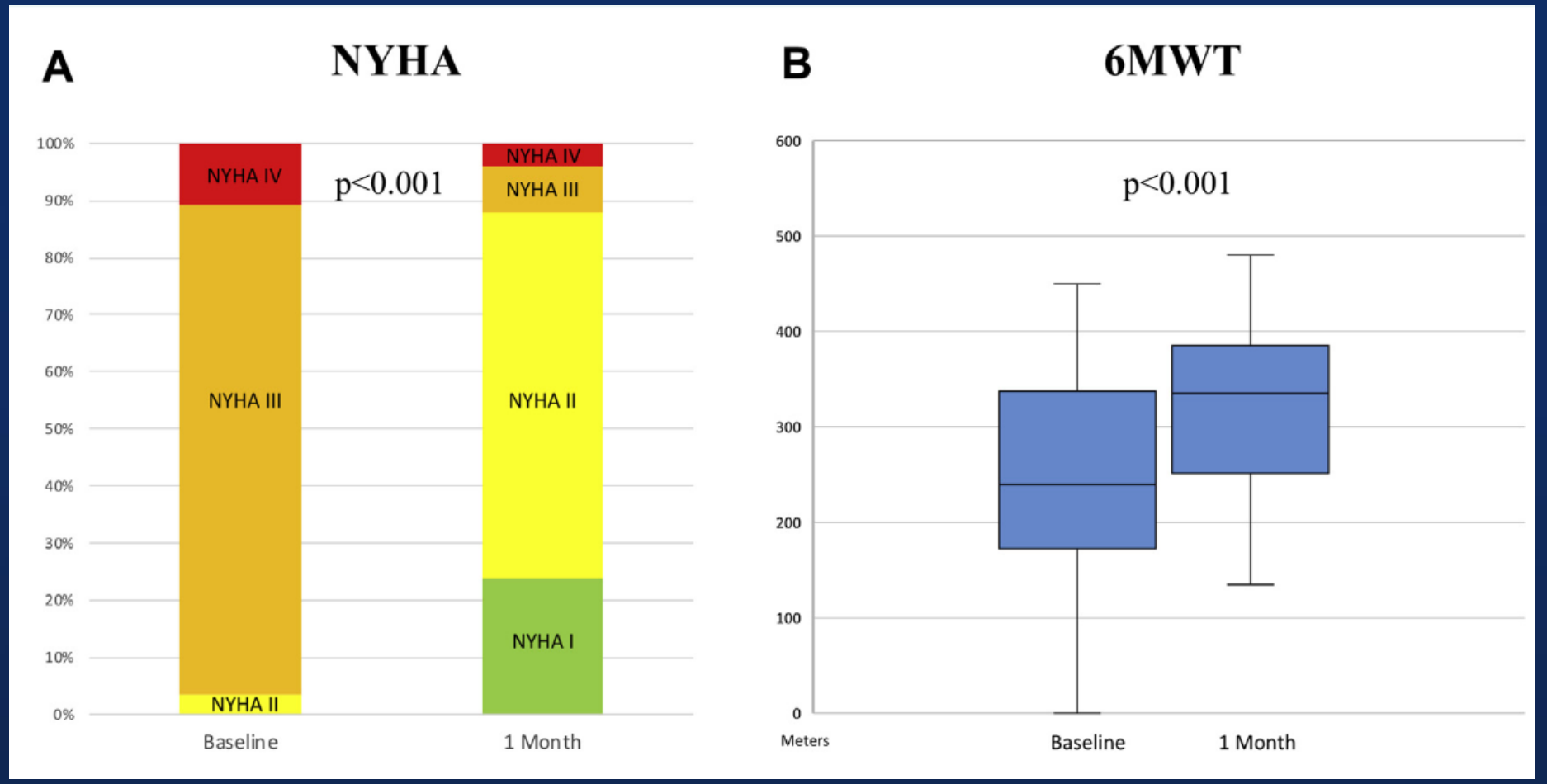


Fam, N.P. et al. JACC intervention. 2019;12(24):2488-95

PASCAL for Severe TR

Symptom and TR grade improvement

28 patients, Single arm study

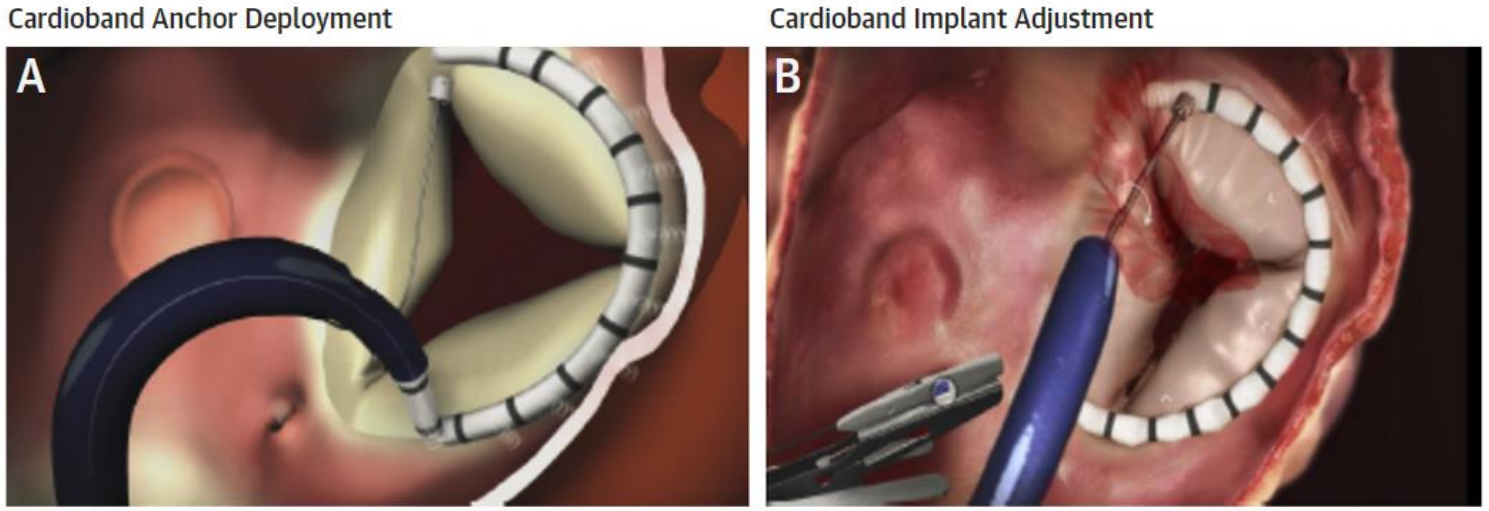


Fam, N.P. et al. JACC intervention. 2019;12(24):2488-95

Evidence of Direct Annuloplasty for Severe TR

Cardioband (Edwards Lifesciences)

FIGURE 1 The Tricuspid Valve Reconstruction System



(A) Anchor deployment through implant to the tissue. **(B)** Adjustment of implant. Image provided by Edwards Lifesciences.

6-Month Outcomes of Cardioband for Severe TR

30 patients, Single arm study, Multicenter, Prospective trial

Baseline Characteristics	N = 30
Age	75.2 ± 6.6
Female	22 (73.3%)
EuroSCORE II	4.1 ± 2.8
STS score	2.6 ± 1.6
NYHA III or IV	25 (83.3%)
Functional TR, %	30 (100%)
Hypertension	24 (80.0%)
Elevated pulmonary pressure (> 30mmHg)	15 (50.0%)
Atrial fibrillation / flutter	28 (93.3%)
Congestive HF	17 (56.7%)
Prior implanted cardiac device	4 (13.3%)
Prior stroke/TIA	5 (16.7%)
Coronary artery disease	11 (36.7%)
Chronic renal disease	16 (53.3%)

Nickenig. et al. JACC. 2019;73:1905-15

6-Month Outcomes of Cardioband for Severe TR

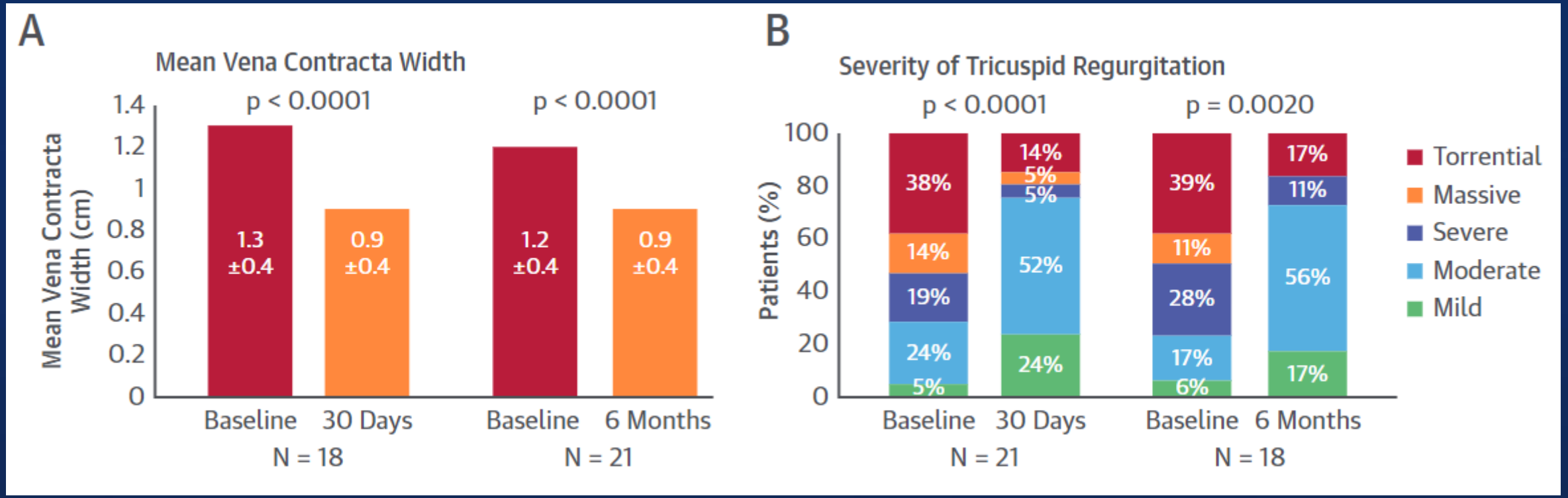
30 patients, Single arm study, Multicenter, Prospective trial

Procedural characteristics	N = 30
In-hospital death	1
Length of stay in hospital, days	8.5 ± 5.6
Length of stay in ICU, days	2.0 ± 1.8
Procedure time, min	254.5 ± 92.8
Implant size, mm (89-96)	2
Implant size, mm (97-104)	4
Implant size, mm (105-112)	6
Implant size, mm (113-120)	18
Adjudicated 30-day events, n	
Death	4 (13.23%)
Stroke	1
Myocardial infarction	0
Bleeding complications	4
Coronary complications	3
Device-related cardiac surgery	0
Renal failure	1
Conduction system disturbance	1

Nickenig. et al. JACC. 2019;73:1905-15

6-Month Outcomes of Cardioband for Severe TR

30 patients, Single arm study, Multicenter, Prospective trial



Nickenig. et al. JACC. 2019;73:1905-15

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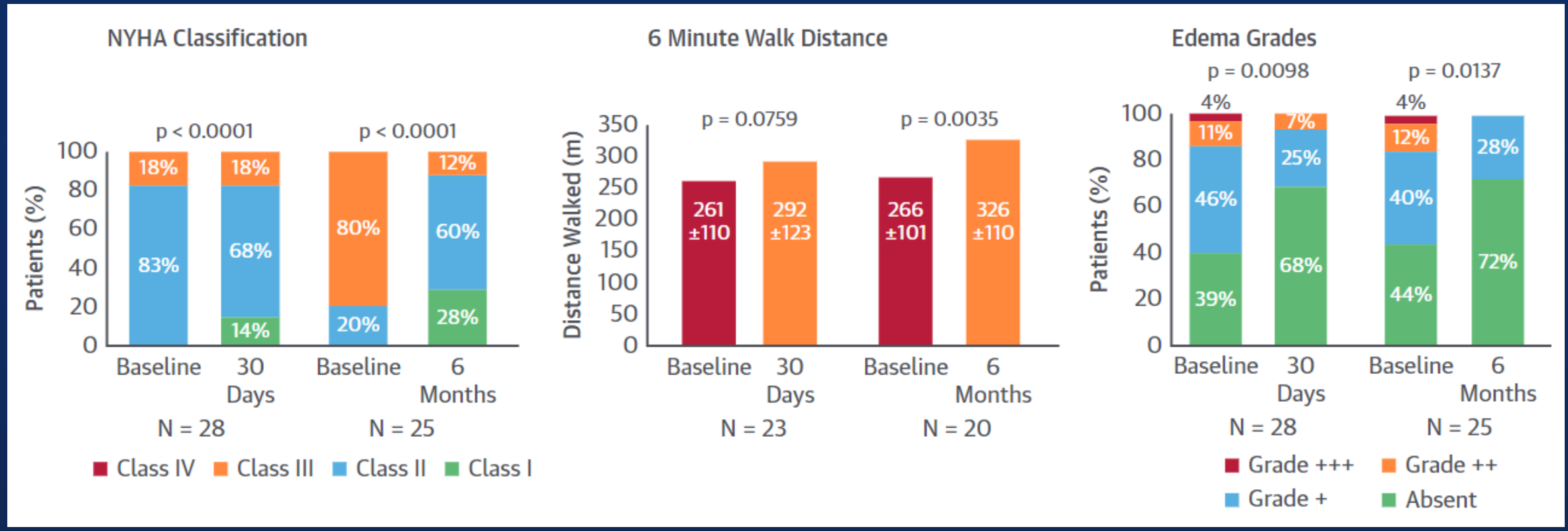
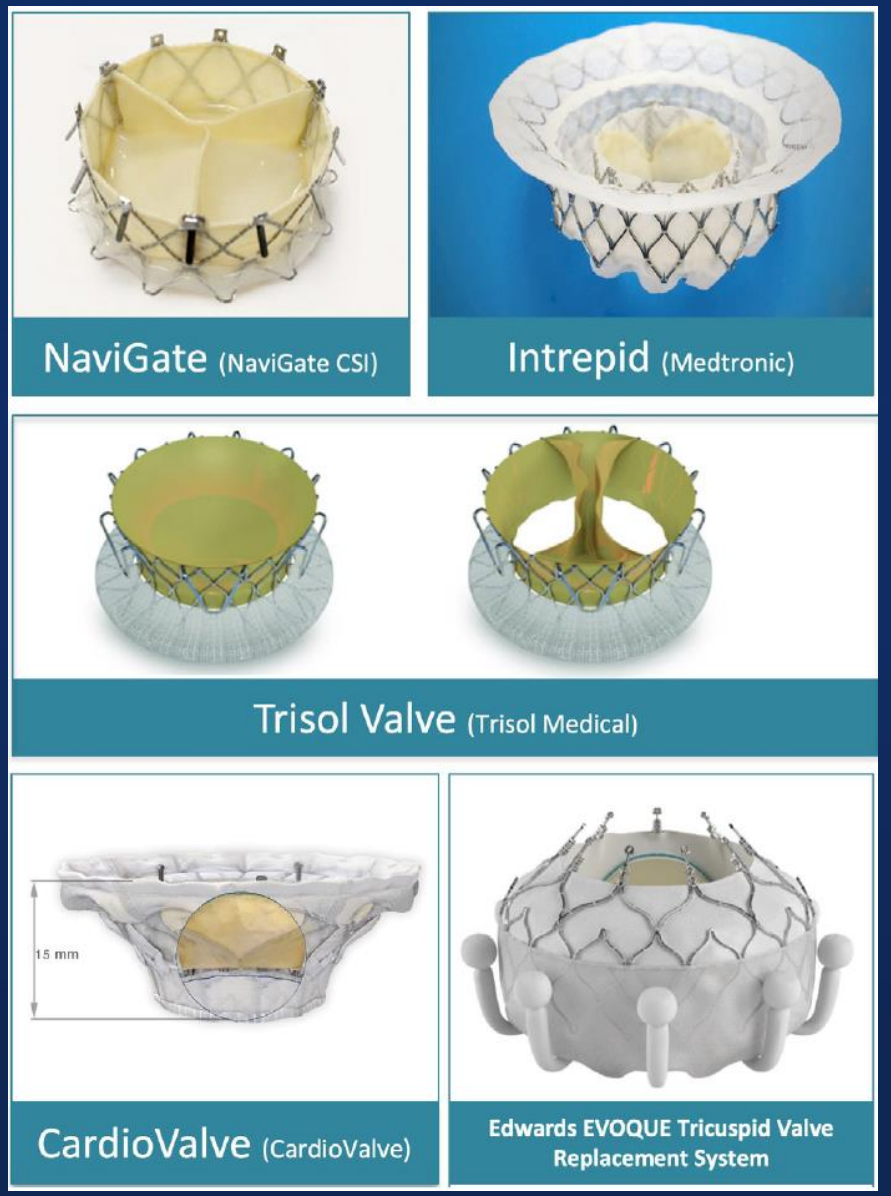


Nickenig. et al. JACC. 2019;73:1905-15

Evidence of Catheter-based Valve Replacement for Severe TR

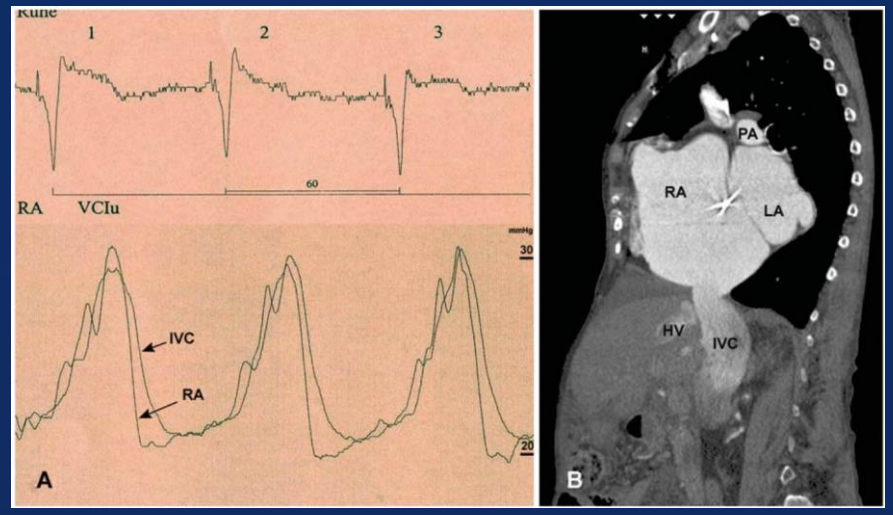
Transcatheter Tricuspid Valve Replacement

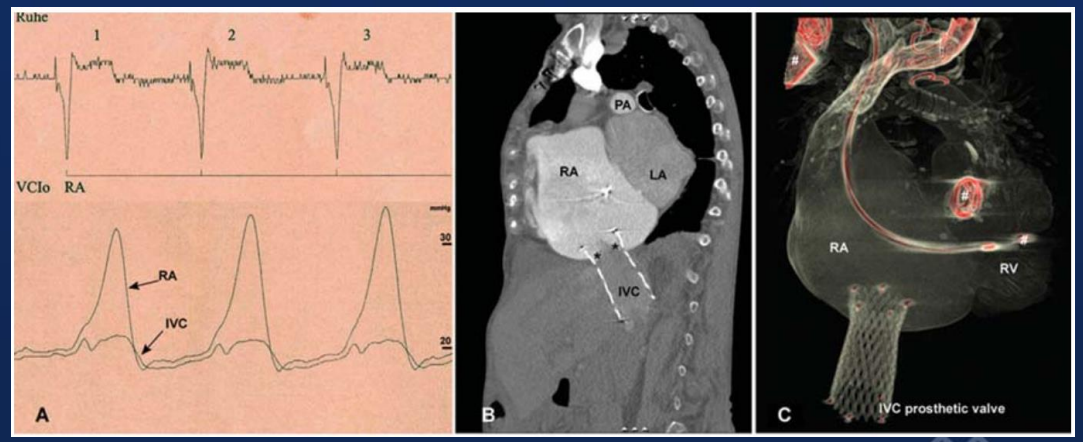


Interventional Valve Implantion in Caval position (CAVI) for Severe TR

First-in-Human application

Hemodynamic parameters	Before implantation	After implantation
HR, (bpm)	60	60
RA pressure, (mmHg)	28/10	38/13
IVC pressure, (mmHg)	29/19	19/12
TV annulus (mm)	46	46 (after 8 wks)
TAPSE (mm)	16	15 (after 8 wks)
TASV (cm/s)	6.3	6.8 (after 8 wks)

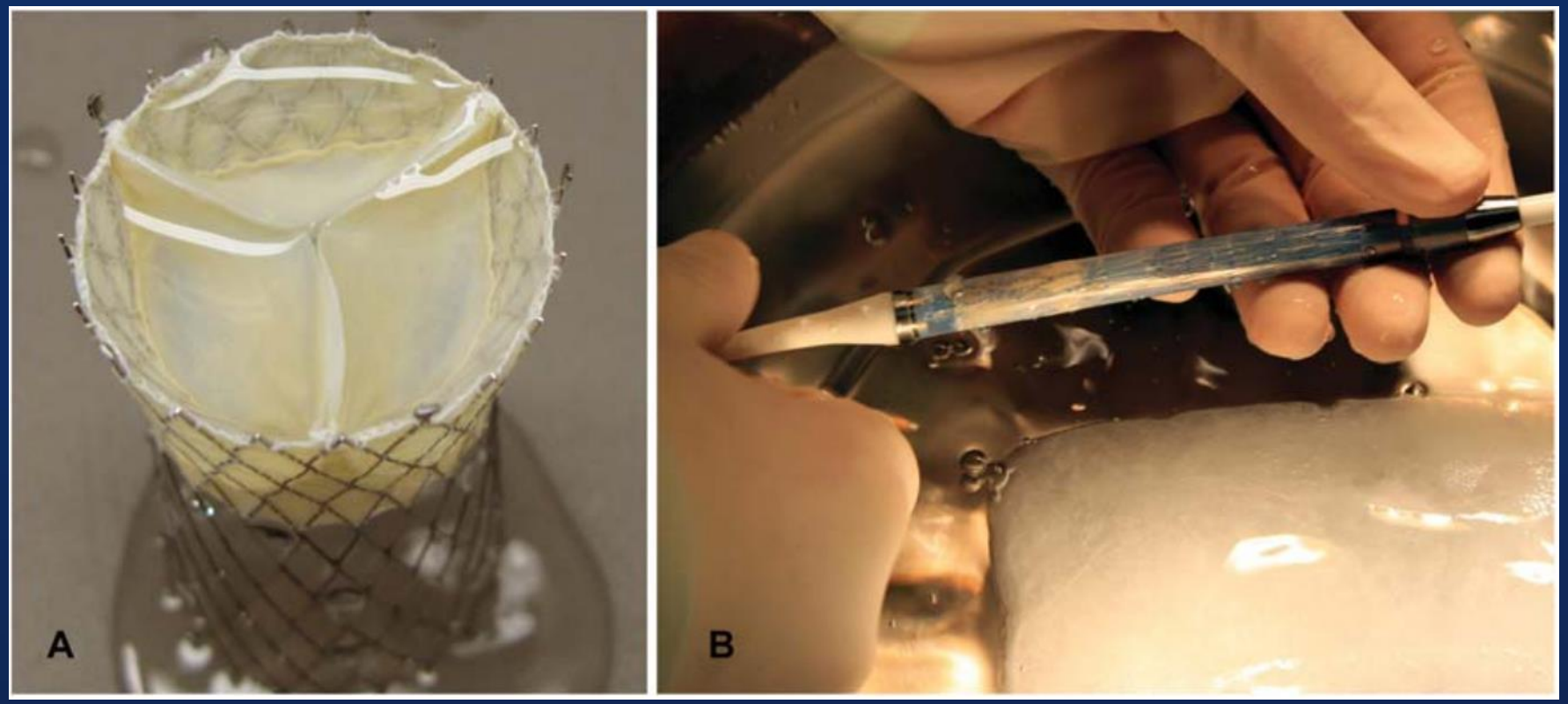




A. Lauten et al. EHJ. 2011;32:1207-1213

Interventional Valve Implantion in Caval position (CAVI) for Severe TR

First-in-Human application



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Ongoing Clinical Trials

Key Ongoing Clinical Trials

Device	Study title	Study design	No. of patients	Description
TriClip (Abbott)	TRI-FR (NCT04646811) Multicenter rancomized trial	Multicenter, Prospective, Interventional, Randomized	300	RCT; aim: demonstrate safety and effectiveness of TTVR with TriClip (TriClip + OMT vs OMT)
TriClip (Abbott)	bRIGHT (NCT04483089) Observational real-world	Multicenter, Prospective, Single-arm, Observational, Postmarket registry	200	Postapproval study to confirm safety and performance of the TriClip in a real-world setting
PASCAL (Edwards)	CLASP TR EFS (NCT03745313) Early feasibility study	Multicenter, Prospective, Single-arm, Interventional	65	Aim: evaluate the safety and performance of the Edwards PASCAL
PASCAL (Edwards)	CLASP II TR (NCT04097145) PASCAL Pivotal trial	Multicenter, Prospective, Randomized, Parallel assignment	825	Aim: evaluate the safety and effectiveness of the Edwards PASCAL (PASCAL + OMT vs OMT)
Cardioband (Edwards)	TriBAND (NCT03779490) Cardioband post market	Multicenter, Prospective, Single-arm, Observational, Postmarket registry	150	Aim: assess the safety and the effectiveness of the Cardioband
TTVR with either TriClip, PASCAL, or Cardioband	TRICuspid Intervention in Heart Failure Trial (NCT04634266)	Multicenter, Prospective, Randomized	360	RCT; aim: assess the concept that TTVR will translate into a reduced morbidity and mortality TTVR + OMT vs OMT alone
Edwards EVOQUE Tricuspid Valve Replacement System	TRISCEND II Pivotal Trial (NCT04482062) Edwards EVOQUE TTVR	Multicenter, Prospective, Open-label, Randomized interventional	675	RCT; aim: evaluate the safety and effectiveness of the EVOQUE system + OMT vs OMT

Thank you for your attention!