CardioVascular Learning Network | CME

The Value of Invasive Pressure Gradients in TAVR

Supported by an educational grant from Haemonetics Corporation.

Faculty

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Faculty Disclosures

- **Rahul Sharma, MBBS, FRACP**: Consultant—Abbott, Boston Scientific, Edwards Lifesciences, Medtronic
- **Nicolas M. Van Mieghem, MD, PhD, FESC, FACC:** Research/Grant Support—Abbott, Boston Scientific, Medtronic, Teleflex, Meril, Pie Medical; Consultant/Advisory Board—Abbott, Luma Vision, Abiomed, Materialise, Alleviant Medical, Medtronic, AnchorValve, Pie Medical, Anteris, Polares, Approxima Srl, PulseCath BV, Supira, Siemens, Boston Scientific, Adjust Medical, Vivasure, Haemonetics

Program Information

- This program is provided by HMP Education, an HMP Global company
- Supported by an educational grant from Haemonetics Corporation

Learning Objectives

- Evaluate the impact of prosthesis-patient mismatch (PPM) and paravalvular leak (PVL) on post-TAVR hemodynamics and patient outcomes
- Compare invasive pressure gradient measurements with echocardiographic assessment, highlighting key findings from recent studies and their clinical relevance
- Apply device-specific insights and procedural experience to optimize valve selection and post-implantation assessment strategies

TAVR = transcatheter aortic valve replacement.

CardioVascular Learning Network | CME

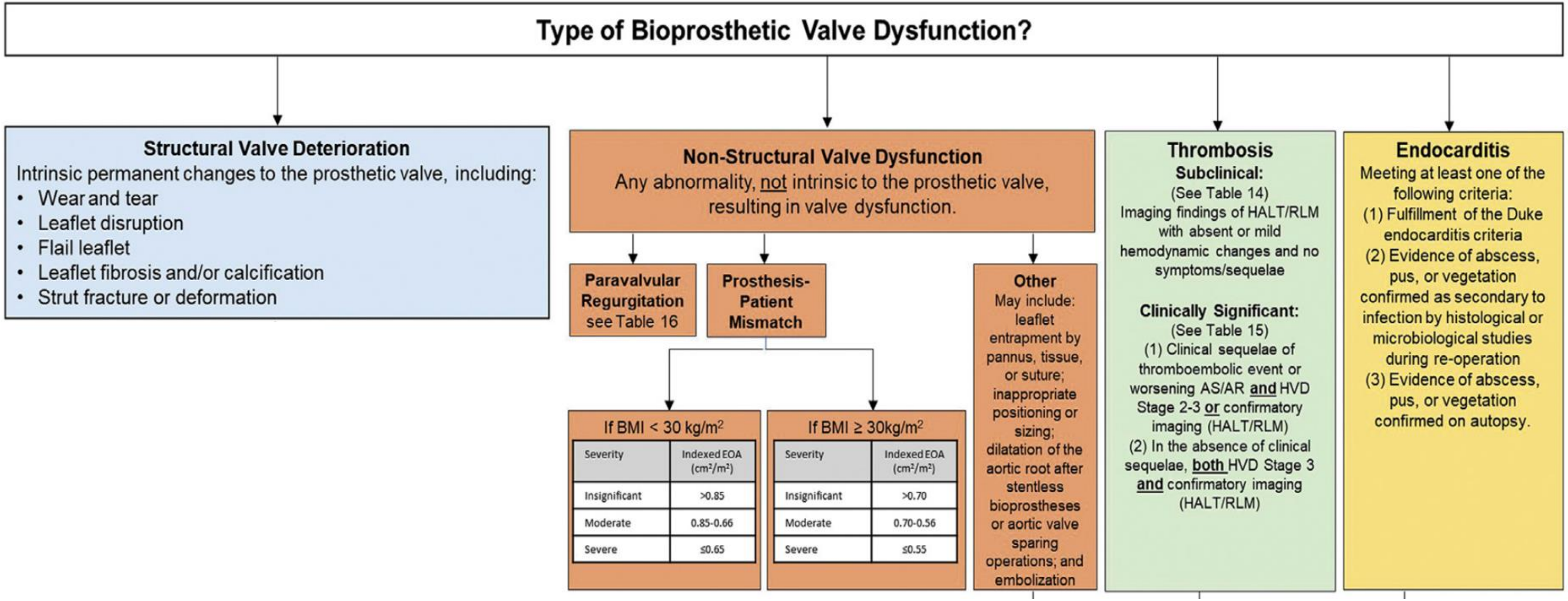
Understanding Prosthesis Patient Mismatch and Paravalvular Leak

Nicolas M. Van Mieghem, MD, PhD, FESC, FACC
Department of Interventional Cardiology
Thoraxcenter, Erasmus University Medical Center
Rotterdam, Netherlands

Outline

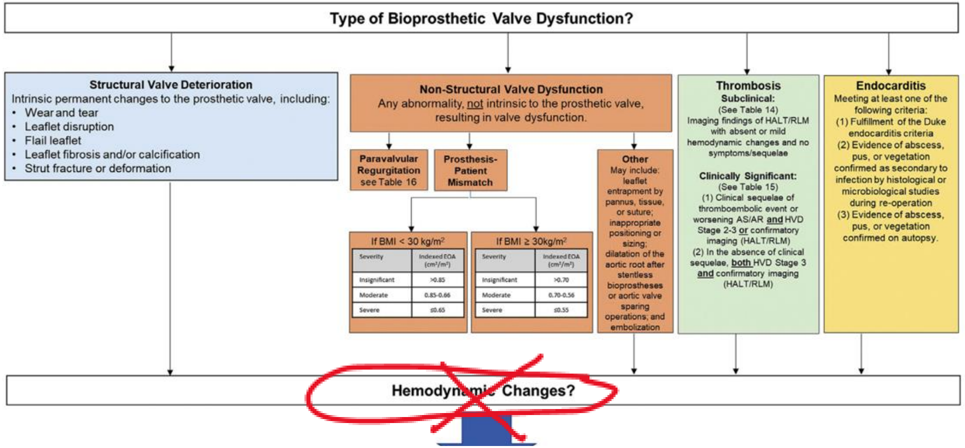
- Incidence and clinical significance of PPM and PVL
- Diagnostic strategies for PPM/PVL
- Long-term outcomes and reintervention rates

Non-Structural Valve Dysfunction



Généreux P, et al. ***J Am Coll Cardiol*****. 2021;77(21):2717-2746.**

Non-Structural Valve Dysfunction



Non-structural valve dysfunction =

planning and/or technique related

<u>immediately</u> present @ index procedure

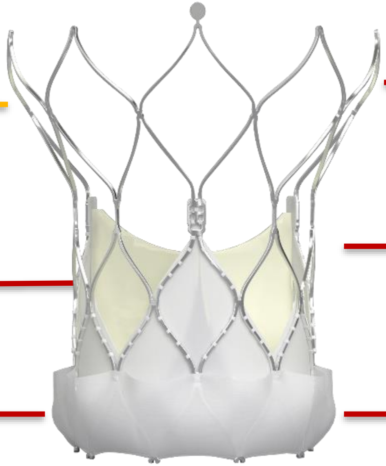
Généreux P, et al. *J Am Coll Cardiol*. 2021;77(21):2717-2746.

Contemporary Valves: Sealing Fabric

STENT DESIGN
Curved Aortic Cells
Reduce risk of injury to native structures

INNER CUFF MATERIAL
New Polyethylene Fabric Material
Maintain lower profile & durability

OUTER PVL FEATURE
New Polyethylene Outer Fabric Cuff
New feature designed to reduce paravalvular leak rates and severity



LARGE CELL DESIGN
Minimize coronary obstruction and improve coronary access and blood flow

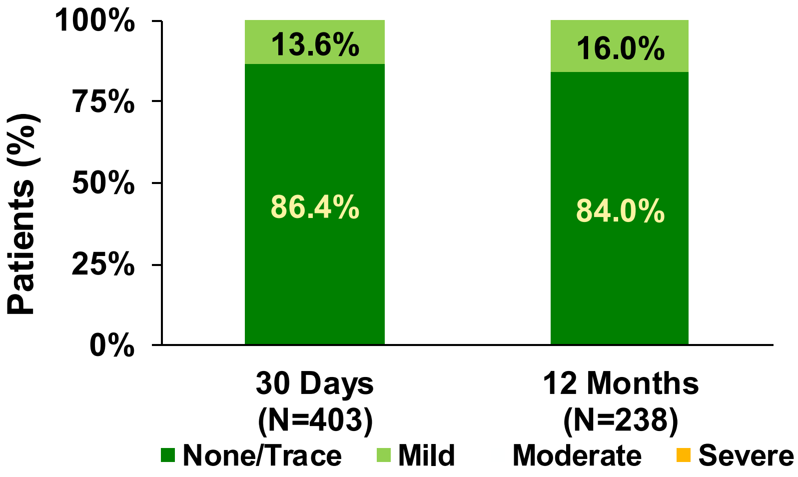
STENT DESIGN
Optimized Radial Force
Improve expansion, anchoring, stability, and sealing across all sizes

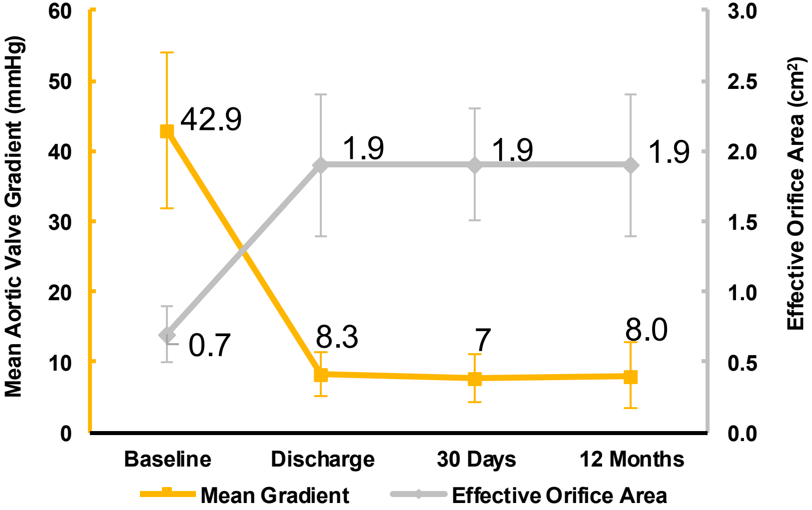
SEALING ZONE
Increased Sealing Zone
Larger sealing zone

VALVE DIMENSIONS
Annulus Treatment Range
19 to 30 mm annulus diameters

Recent Data

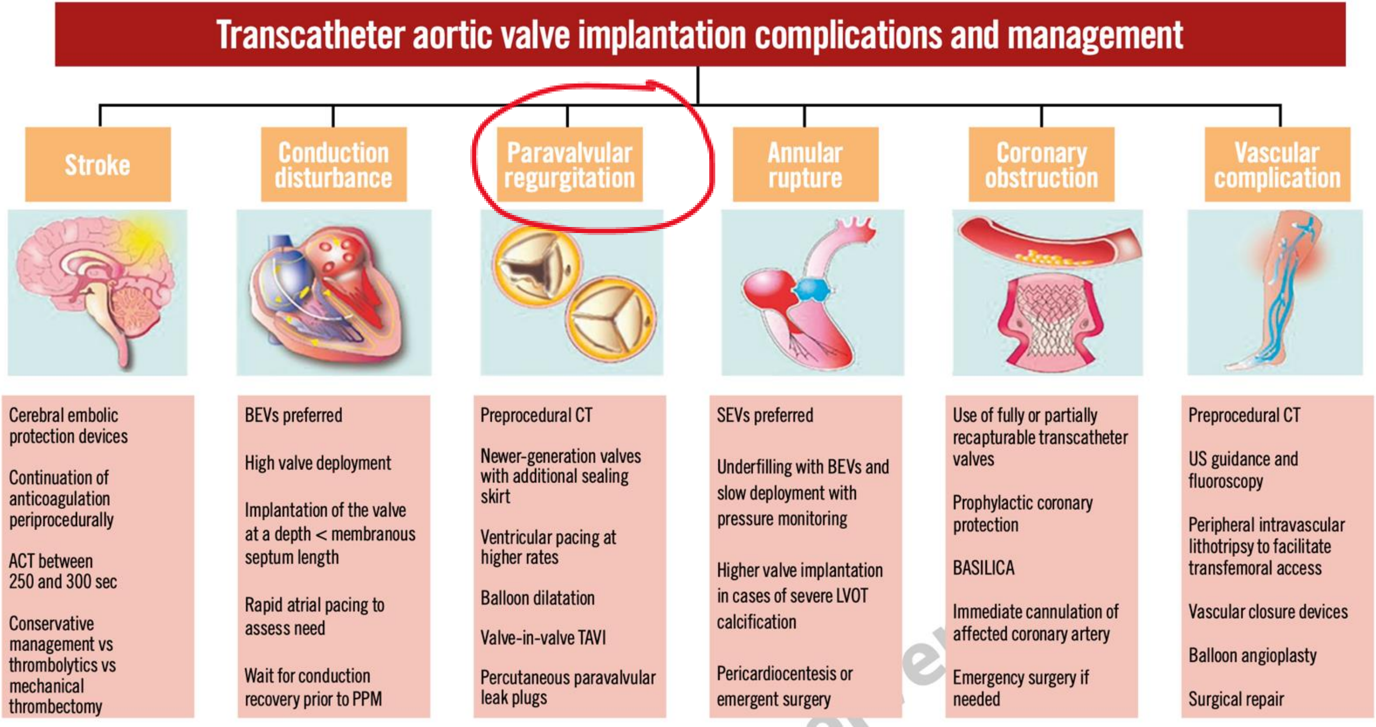
NSVD with new THV and delivery system in VANTAGE Trial (n = 434)





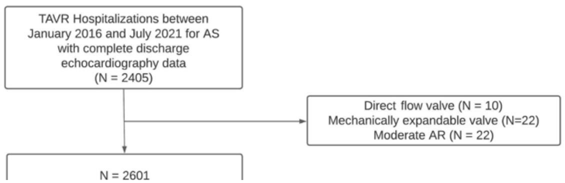
NSVD = non-structural vale dysfunction.
Van Mieghem NM, et al. Presented at European Society of Cardiology (ESC) Conference 2025; August 29-September 1; Madrid, ES.

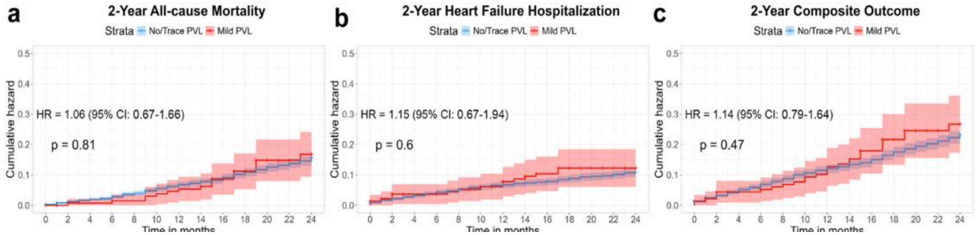
Main TAVI Related Complications 2025



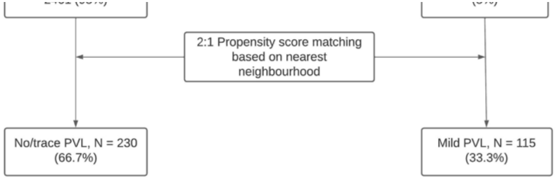
TAVI = transcatheter aortic valve implantation; LVOT = left ventricular outflow tract; BEV = balloon expandable valve; SEV = self-expanding valve.
Bansal A, et al. *EuroIntervention*. 2025;21:390-410.

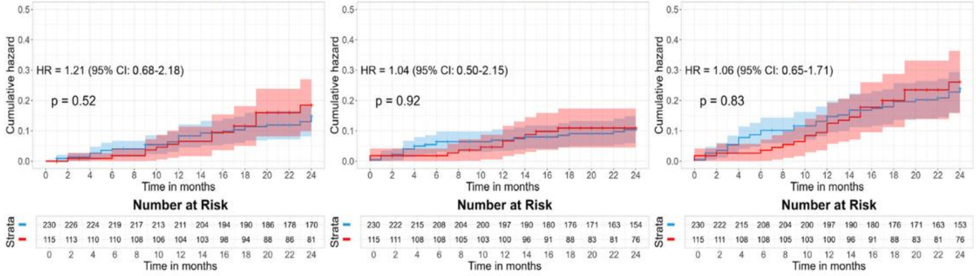
PVL Severity & Outcome





Mild PVL had zero clinical impact out to 2 years





Cleveland Clinic Database

Rosensveig EB, et al. *Structural Heart.* 2025.

Main TAVI Related Complications 2025

Original Research

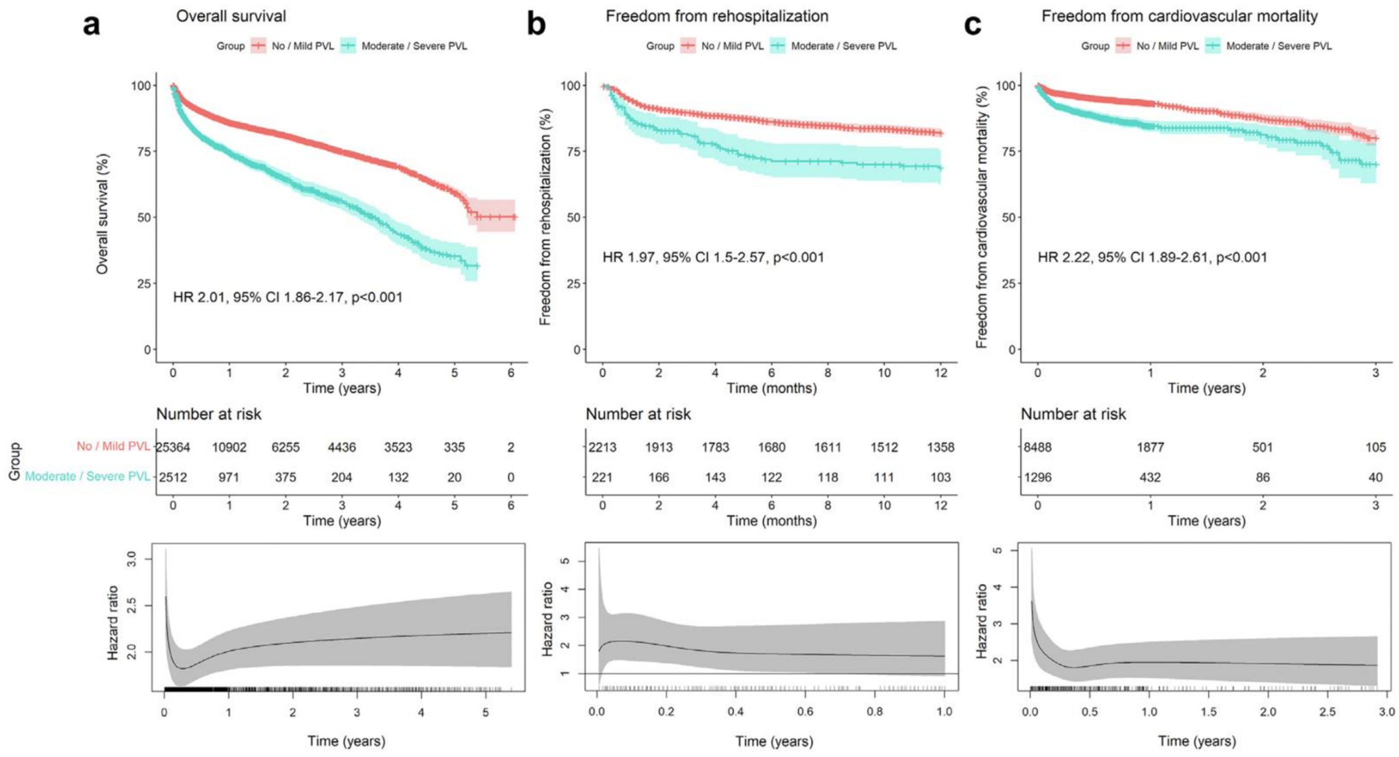
Impact of Paravalvular Leak on Outcomes After Transcatheter Aortic Valve Implantation: Meta-Analysis of Kaplan-Meier-derived Individual Patient Data

Michel Pompeu Sá, MD, MSc, MHBA, PhD [a,b,*,1], Xander Jacquemyn, BSc [c,1], Jef Van den Eynde, BSc [c], Panagiotis Tasoudis, MD [b], Ozgun Erten, MD [b], Serge Sicouri, MD [b], Francisco Yuri Macedo, MD, MSc [d], Tilak Pasala, MD, MRCP [d], Ryan Kaple, MD [d], Alexander Weymann, MD, MHBA, PhD [e], Arjang Ruhparwar, MD, PhD [e], Marie-Annick Clavel, DVM, PhD [f,g], Philippe Pibarot, DVM, PhD [f,g], Basel Ramlawi, MD [a,b]

- 38 studies
- N > 25,000 patients

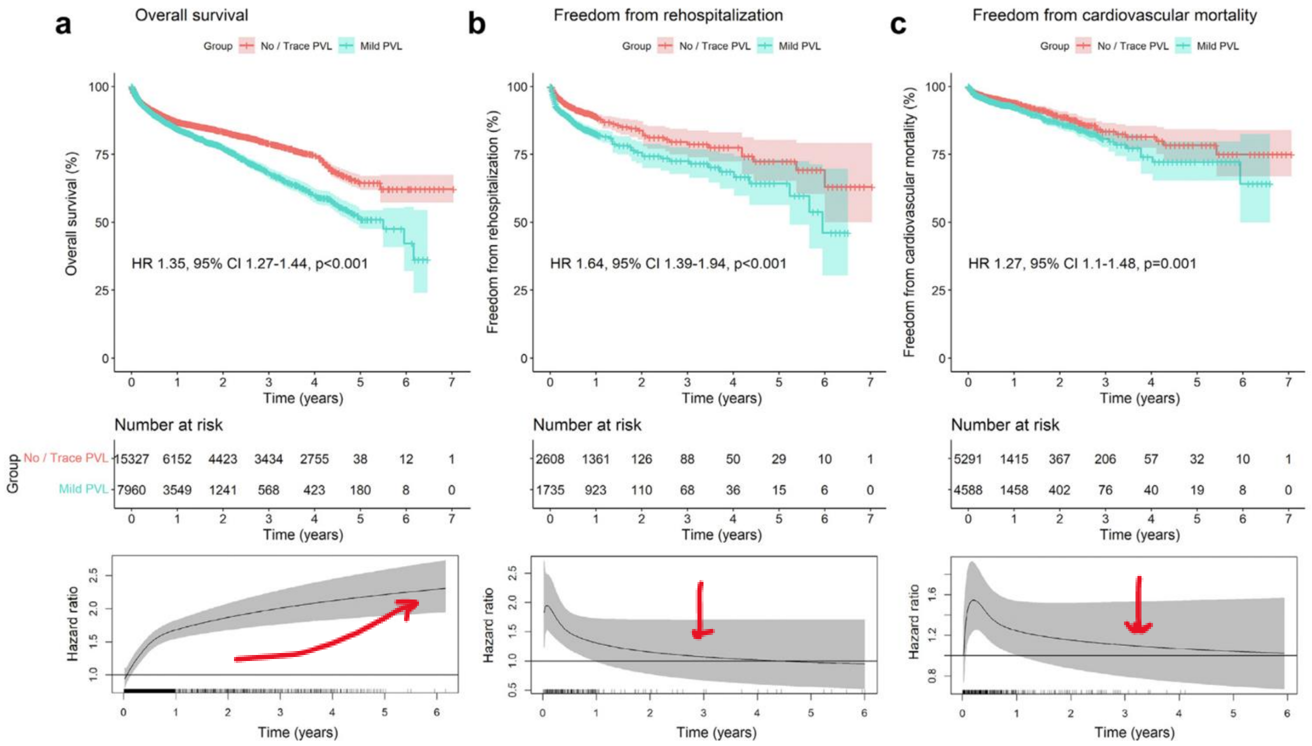
Sá MP, et al. *Struct Heart*. 2022;7(2):100118.

PVL Severity & Outcome



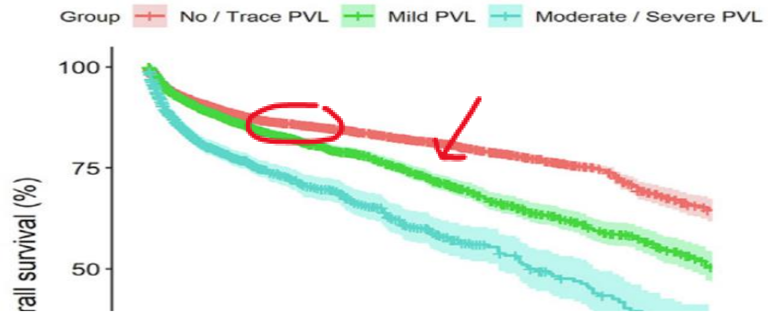
***Echocardiography assessment.**
Sá MP, et al. *Struct Heart*. 2022;7(2):100118.

PVL Severity & Outcome

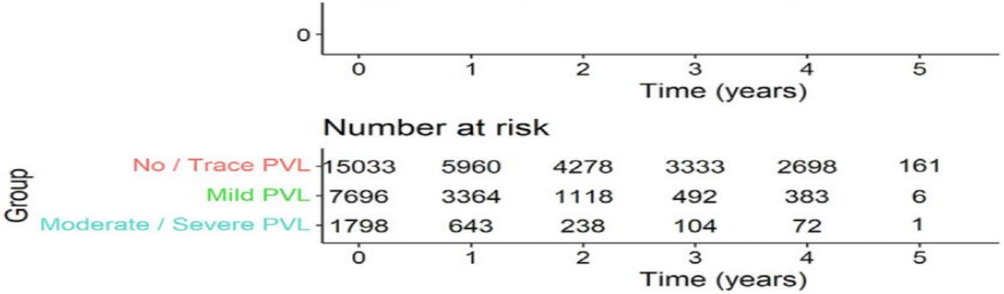


***Echocardiography assessment.**
Sá MP, et al. *Struct Heart*. 2022;7(2):100118.

PVL Severity & Outcome

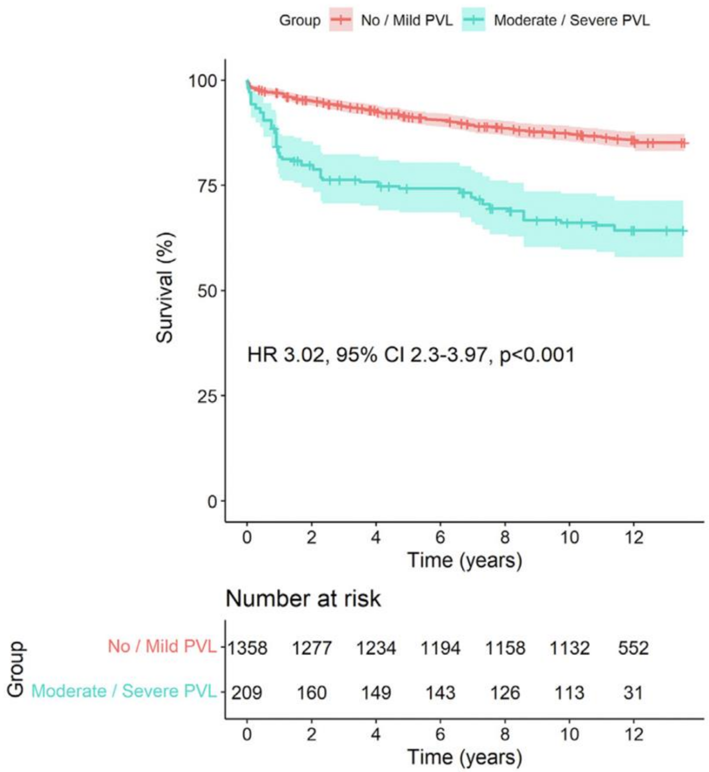


Mild PVL may only become relevant beyond 2 years of follow up



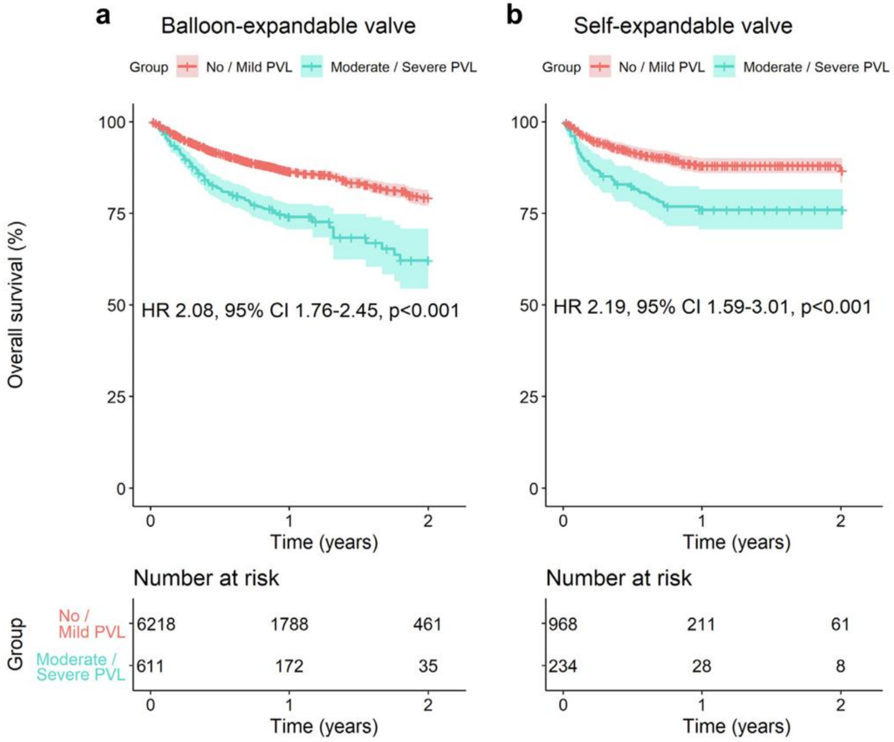
*Echocardiography assessment.
Sá MP, et al. *Struct Heart*. 2022;7(2):100118.

PVL Severity & Outcome



*** Aortography assessment.**
Sá MP, et al. *Struct Heart*. 2022;7(2):100118.

PVL Severity & Outcome



***Echocardiography assessment.**
Sá MP, et al. *Struct Heart*. 2022;7(2):100118.

TTE Accuracy in the Cathlab

Contents lists available at ScienceDirect
International Journal of Cardiology
journal homepage: www.elsevier.com/locate/ijcard
ELSEVIER

How accurate is intraprocedural transthoracic echocardiography in assessing aortic regurgitation after transcathether aortic valve implantation? A single center experience

Claire B. Ren*, Mark M.P. van den Dorpel, Marcel Geleijnse, Nicolas M. van Mieghem
Department of Cardiology, Thoraxcenter, Cardiovascular Institute, Erasmus University Medical Center, Rotterdam, the Netherlands

- N = 404 patients with TAVI
- Balloon expandable n = 180 & self-expanding THV n = 224
- Transthoracic echocardiography (TTE) in cathlab & pre-discharge
- Intraprocedural AR
  - None or trace in 310 cases (76.7%)
  - Mild in 88 (21.8%)
  - Moderate in 6 (1.5%)

Ren CB, et al. *Int J Cardiol*. 2025;438:133565.

TTE Accuracy in the Cathlab

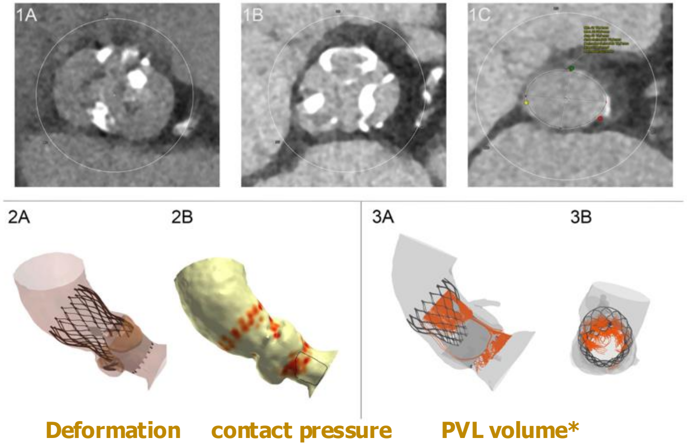
- AR severity was concordant (same grade) with the discharge TTE assessments in 2/3 cases
- Discordance in 143 cases (35.4%)
  - Intraprocedural underestimation (125 cases (87.4%)
    - Of one grade lower in 93%
    - Of two grades lower in 7%
  - Intraprocedural overestimation (18 cases 12.6%)
- Concordance between the intraprocedural and discharge TTEs was higher when no/trace PVL
  - When intraprocedural AR was none or trace: 66%
  - When mild: 59%
  - > Mild: 50%
- AR severity *concordance was higher in the BE cohort* (71.1%) than in the SE cohort (59.4%)
- Suboptimal acoustic windows in the supine position, hemodynamic lability and solely qualitative
- Assessments may explain this tendency of AR underestimation with intraprocedural TTE

Ren CB, et al. *Int J Cardiol*. 2025;438:133565.

Procedure Simulation & PVL

Clinical value of CT-derived simulations of transcatheter-aortic-valve-implantation in challenging anatomies the PRECISE-TAVI trial

- N = 77 patients with severe AS & complex anatomy
- Post TAVI: PPI in 13%, new LBBB in 14%, mild PVL 22%, moderate PVL 6.5%
- FEops HEARTguide™
  - Changed preprocedural planning in 35% of cases
  - Well predicted the risk for PVL
  - Identified the risk for new PPI post-TAVI



*> 12.2 mL predicts > trace PVL.
LBBB = left bundle branch block.
Hokken TW, et al. *Catheter Cardiovasc Interv*. 2023;102(6):1140-1148.

PVL & TAVR Procedure

Planning

- ✓ MSCT in all
- ✓ Optimal sizing (% oversizing)
- ✓ Calcifications
  - ○ Severity
  - ○ Distribution (Leaflet, commissure, raphe, LVOT)
- ✓ Valve phenotype (bicuspid >< tricuspid)
- ✓ THV selection

Procedure

- ✓ Consider balloon predilatation
- ✓ Implantation depth (target depth)
- ✓ Multiparametric PVL assessment
  - ○ Invasive gradient
  - ○ AR index
  - ○ Echocardiography
- ✓ Postdilatation 1:1 sized if needed

Prosthesis Patient Mismatch (PPM)

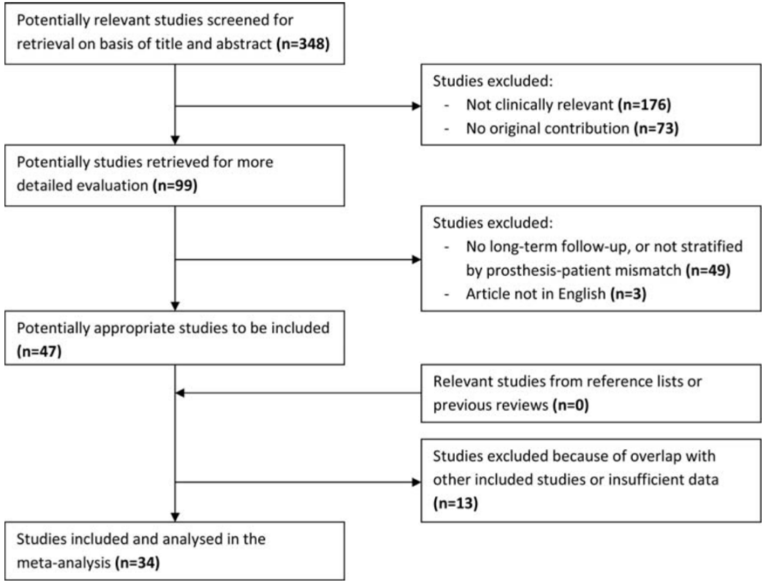
- PPM = prosthesis with an EOA that is *too small for an individual's BSA* → relative obstruction of the outflow of the left ventricle (LV) → no reverse remodeling of the hypertrophied LV

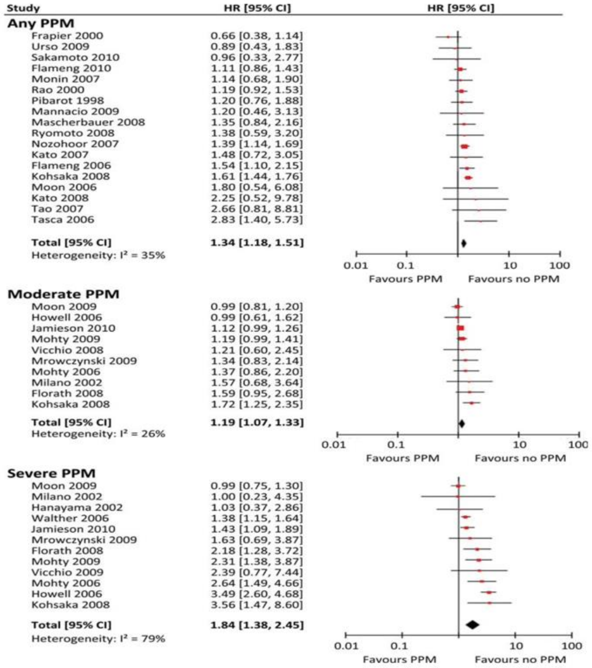
- PPM is considered moderate when the iEOA is between 0.65 and 0.85 cm^2/m^2 (obese: 0.55 – 0.70 cm^2/m^2) and severe when <0.65 cm^2/m^2 (obese: < 0.55 cm^2/m^2)

*** Obese = BMI ≥ 30 kg/m2**
*** PPM may be overestimated inlow flow state (pseudo-PPM).**
BSA = body surface area; iEOA = indexed effective orifice area.

PPM: After SAVR

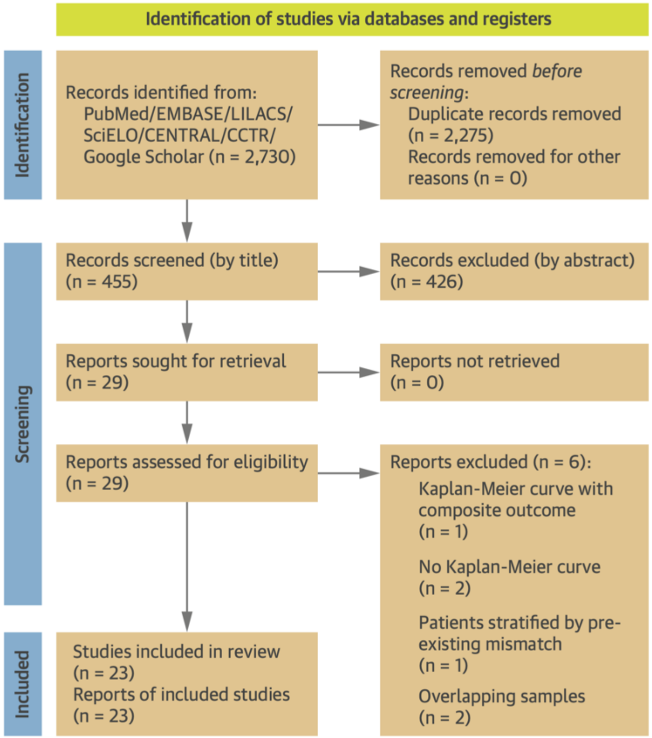
N = 27186 patients



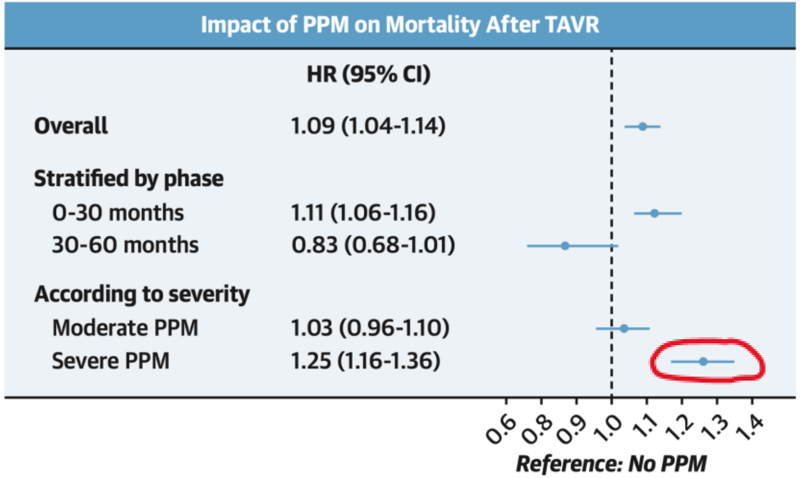


SAVR = surgical aortic valve replacement.
Head SJ, et al. *Eur Heart J*. 2012;33(12):1518-29.

PPM: After TAVR



N = 81969 patients



Sá MP, et al. *JACC Cardiovasc Imaging*. 2023;16(3):298-310

Predicted or Measured PPM???

Keynote Lecture Series

Prosthesis-patient mismatch in transcatheter and surgical aortic valve replacement

Rebecca T. Hahn[1], Philippe Pibarot[2]

The measurement of PPM is nuanced with multiple hemodynamic variables affecting quantitation of prosthetic EOA. The identification and grading of PPM should preferably use the predicted EOAi and apply different cutoffs depending on body size. Other confounders such as pseudo-PPM due to low flow, and pressure recovery, require further study. However, when using the predicted EOAi to assess PPM, it is critical to use reliable sources for the normal reference values of EOAs for the different models and sizes of TAVR or SAVR valves.

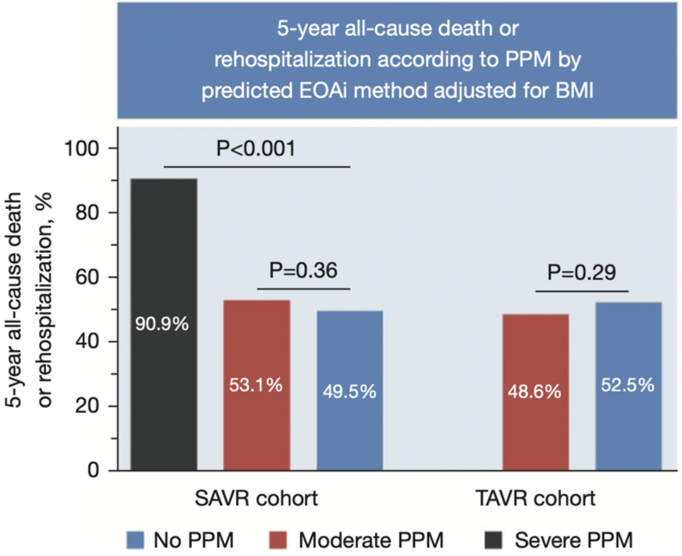
TAVR is associated with less PPM than SAVR and severe PPM in SAVR is associated with increased mortality. Thus, an individualized approach to valve choice should always be made, considering these differences in outcomes related to PPM, as well as differences in incidence and outcomes associated with other complications.

The fallacy of indexed effective orifice area charts to predict prosthesis–patient mismatch after prosthesis implantation

Michiel D. Vriesendorp[1], Rob A.F. De Lind Van Wijngaarden[1], Stuart J. Head[2], Arie-Pieter Kappetein[2], Graeme L. Hickey[2], Vivek Rao[3], Neil J. Weissman[4], Michael J. Reardon[5], Michael G. Moront[6], Joseph F. Sabik III[7], and Robert J.M. Klautz[1*]

Conclusion The use of echocardiographic normal reference values for EOAi charts to predict PPM is unreliable due to the large proportion of misclassifications.

Predicted PPM and Outcome: SAVR & TAVR

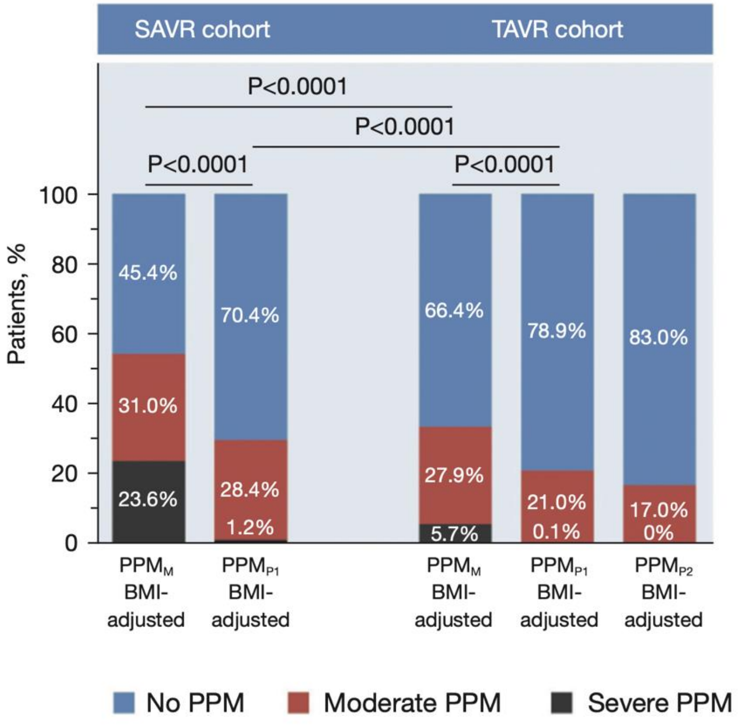


Impact of prosthesis-patient mismatch on outcomes

1. In SAVR, severe PPM by the predicted EOAi method is rare but independently associated with worse outcomes.
2. In TAVR, severe PPM by the predicted EOAi method is absent.
3. In both SAVR and TAVR, moderate PPM is not associated with worse outcomes.

Hahn RT, Pibarot P. *Ann Cardiothorac Surg*. 2024;13(3):211-223.

Incidence of Measured or Predicted PPM: SAVR & TAVR

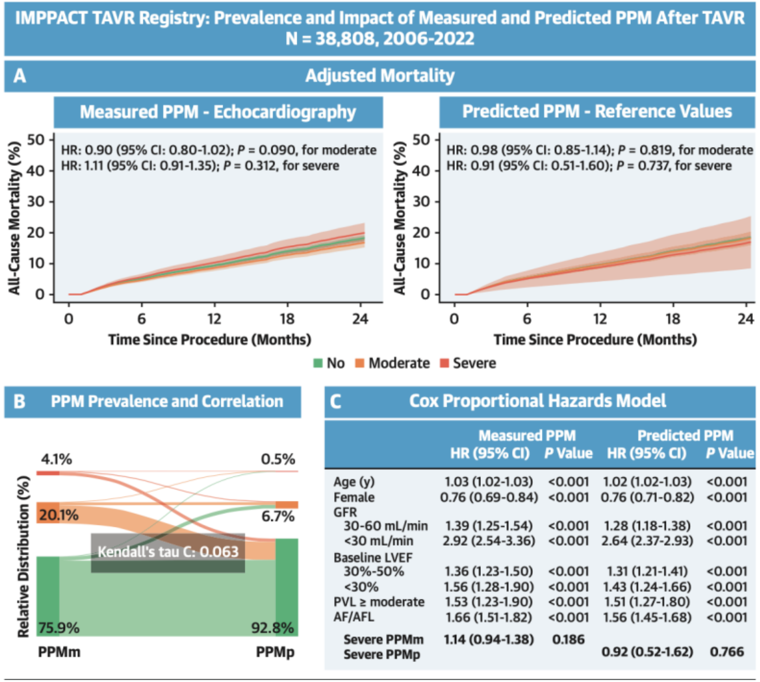


Incidence of prosthesis-patient mismatch

1. Incidence of severe PPM is markedly lower with predicted *vs.* measured EOAi.
2. TAVR has lower incidence of severe PPM compared to SAVR, regardless of the EOAi method used to identify PPM.

Hahn RT, Pibarot P. *Ann Cardiothorac Surg*. 2024;13(3):211-223.

Measured vs Predicted PPM: After TAVR



	Measured PPM HR (95% CI)	Measured PPM P Value	Predicted PPM HR (95% CI)	Predicted PPM P Value
Age (y)	1.03 (1.02-1.03)	<0.001	1.02 (1.02-1.03)	<0.001
Female	0.76 (0.69-0.84)	<0.001	0.76 (0.71-0.82)	<0.001
GFR				
30-60 mL/min	1.39 (1.25-1.54)	<0.001	1.28 (1.18-1.38)	<0.001
<30 mL/min	2.92 (2.54-3.36)	<0.001	2.64 (2.37-2.93)	<0.001
Baseline LVEF				
30%-50%	1.36 (1.23-1.50)	<0.001	1.31 (1.21-1.41)	<0.001
<30%	1.56 (1.28-1.90)	<0.001	1.43 (1.24-1.66)	<0.001
PVL ≥ moderate	1.53 (1.23-1.90)	<0.001	1.51 (1.27-1.80)	<0.001
AF/AFL	1.66 (1.51-1.82)	<0.001	1.56 (1.45-1.68)	<0.001
Severe PPMm	1.14 (0.94-1.38)	0.186		
Severe PPMp			0.92 (0.52-1.62)	0.766

- After a 2-year follow-up, neither measured nor predicted PPM significantly affected mortality in adjusted analyses
- PPMm and PPMp categorize different patient populations with negligible correlation between the methods
- Given the high competing risks of death, the significance of PPM, irrespective of definition and severity, appears negligible in contemporary TAVR

Guthoff H, et al. *JACC Cardiovasc Interv*. 2024;17(22):2626-2635.

Predictors for PPM: SAVR & TAVR

SAVR predictors of PPM	
Dayan *et al.* (8): older age, female sex, diabetes, hypertension, renal failure, large BSA and BMI, bioprosthesis (*vs.* mechanical) valves	
Kim *et al.* (29): intra-annular prostheses (*vs.* supra-annular) bioprosthesis	
Tavakoli *et al.* (30): stented (*vs.* stentless) bioprosthesis	
TAVR predictors of PPM	
Herrmann *et al.* (9): younger age, female sex, atrial fibrillation, severe MR or TR, small THV (≤23-mm diameter), valve-in-valve procedure, larger BSA, non-white/Hispanic race, lower EF	
Miyasaka *et al.* (31): younger age, larger BSA, smaller aortic valve area, smaller annulus area, no balloon post-dilatation, and use of balloon-expandable valve	
Stamou *et al.* (32): age <70 years, BMI >30 kg/m^2, history of atrial fibrillation, black race, and small THV (≤23-mm diameter)	
Leone *et al.* (28): intra-annular valves (note: post-dilation and valve oversizing protects against PPM)	

Hahn RT, Pibarot P. *Ann Cardiothorac Surg*. 2024;13(3):211-223.

Predictors for PPM: SAVR & TAVR

Reasons for discrepant incidence of PPM following AVR
Method of EOA calculation (measured *vs.* predicted)
Failure to correct cutoffs for obesity
Timing of measurement (immediate *vs.* later)
Effect of underlying flow state
Method of gradient determination (invasive *vs.* non-invasive)
Reasons for discrepant outcomes of PPM following AVR
Method of EOA calculation (measured *vs.* predicted)
Incomplete correction for confounding and competing outcomes variables (i.e., paravalvular aortic regurgitation, low flow state, other survival limitations)
Underpowered analysis (i.e., in setting of low disease incidence)
Limited follow-up (i.e., ≤1 year)

Hahn RT, Pibarot P. *Ann Cardiothorac Surg*. 2024;13(3):211-223.

Conclusions

- Incidence of non-structural valve dysfunction ⇩
- Clinical consequences of mild PVL seem marginal but may become apparent after 2 years
- Prosthesis patient mismatch remains a controversial entity
  - No consensus on how to determine
  - More likely with SAVR than TAVR
  - Only severe PPM seems to matter
- MSCT planning for *all* patients with AS can & should eradicate non-structural valve dysfunction

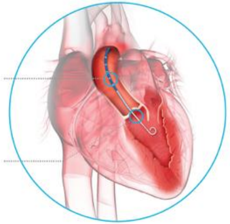
AS = aortic valve stenosis; MSCT = multislice computer tomography.

CardioVascular Learning Network | CME

Invasive vs Echocardiography Gradient Assessment: What the Evidence Tells Us

Nicolas M. Van Mieghem, MD, PhD, FESC, FACC
Department of Interventional Cardiology
Thoraxcenter, Erasmus University Medical Center
Rotterdam, The Netherlands

Echocardiography ⇔ Invasive



- Indirect measurement per
- Direct pressure measurement

Good correlation/agreement in normal flow native AS severity assessment

- Gradient = 4 X v^2
- Scan to obtain maximal
- Simultaneous recording (no pullback)

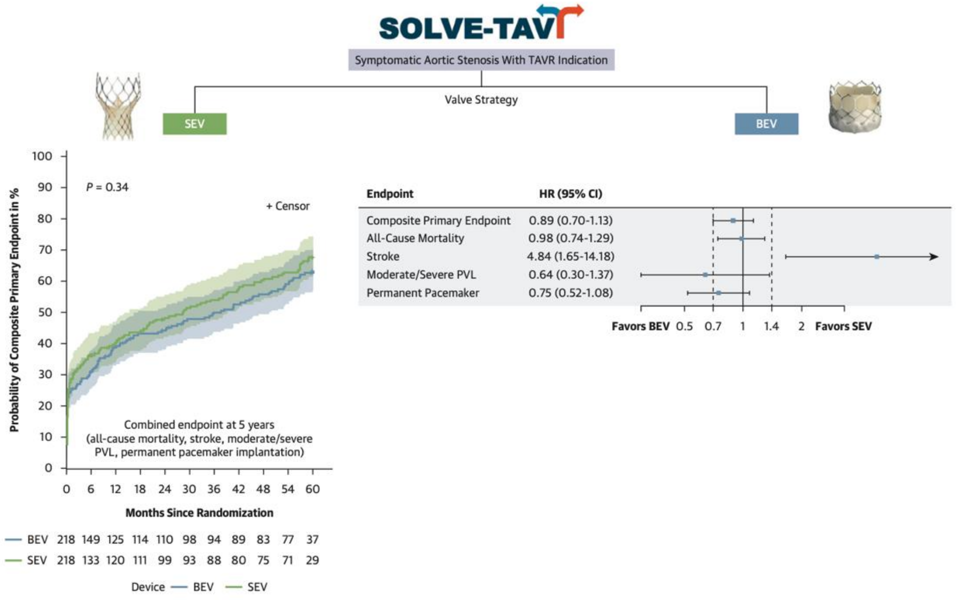
Pressure recovery is not measured with echocardiography

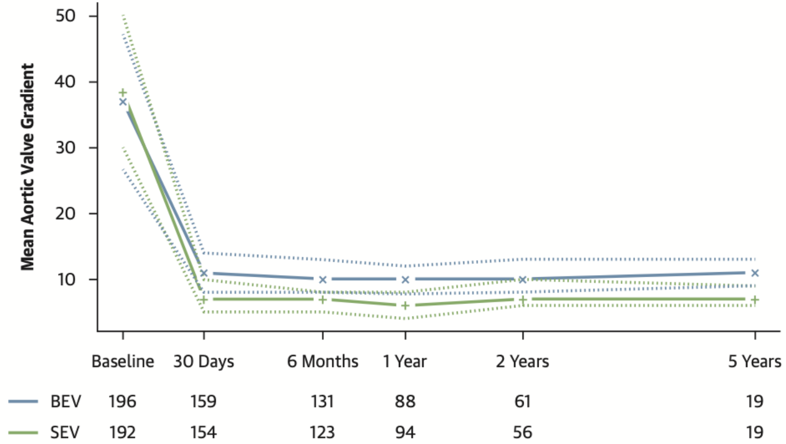
tips

  – 1 @ ≈3cm above leaflet opening

[a]Or dedicated dual-lumen catheter
LVOT = left ventricular outflow tract; AS = aortic stenosis.

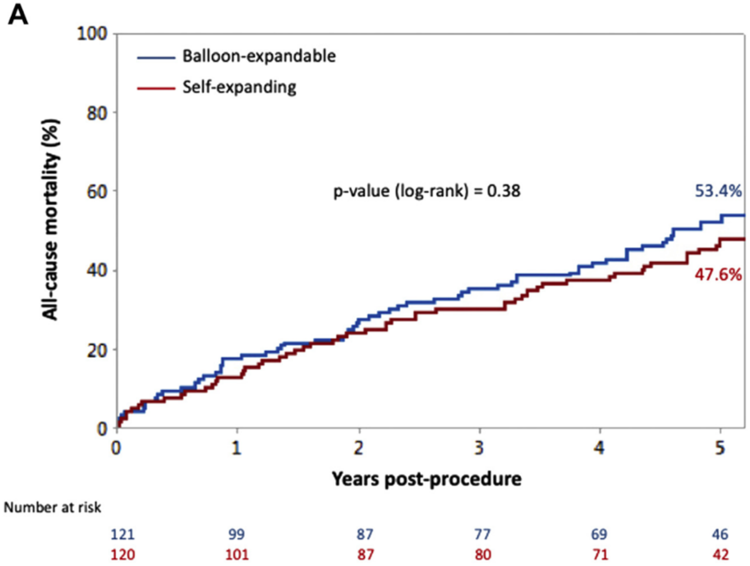
SOLVE-TAVI

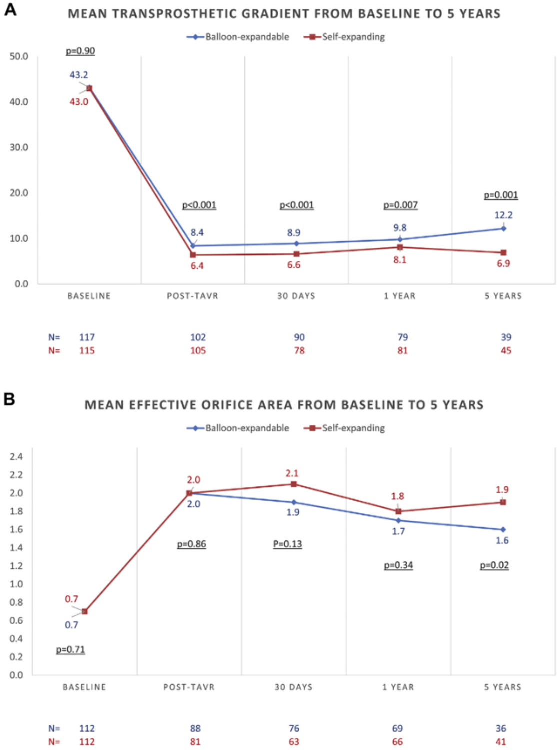




SEV = self-expanding valves; BEV = balloon-expandable valves.
Feistritzer HJ, et al. *J Am Coll Cardiol*. 2025;85(1):74-82.

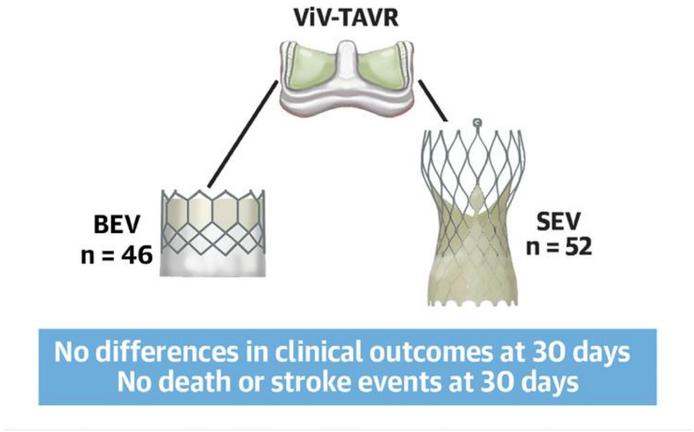
CHOICE RCT

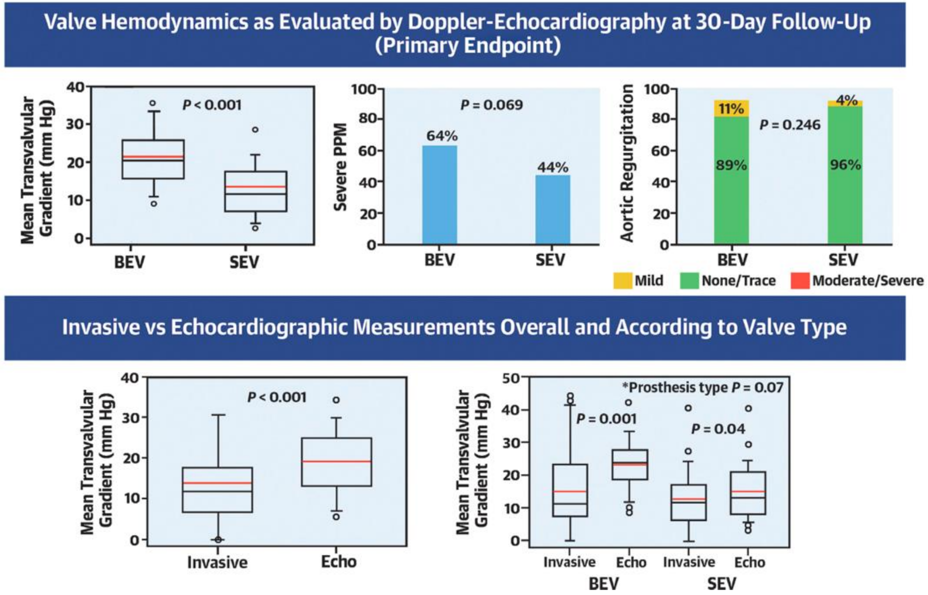




RCT = randomized controlled trial.
Abdel-Wahab M, et al. *J Am Coll Cardiol Intv*. 2020;13:1071-1082.

LYTEN RCT

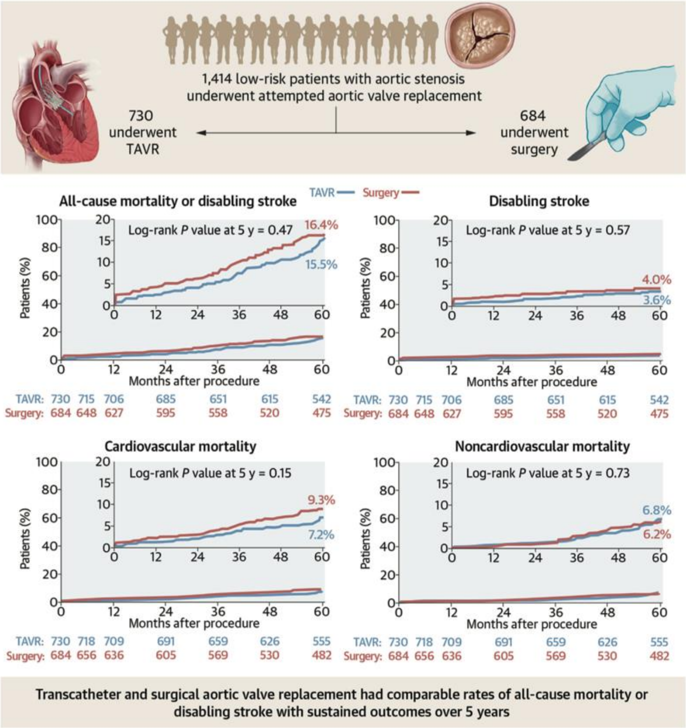


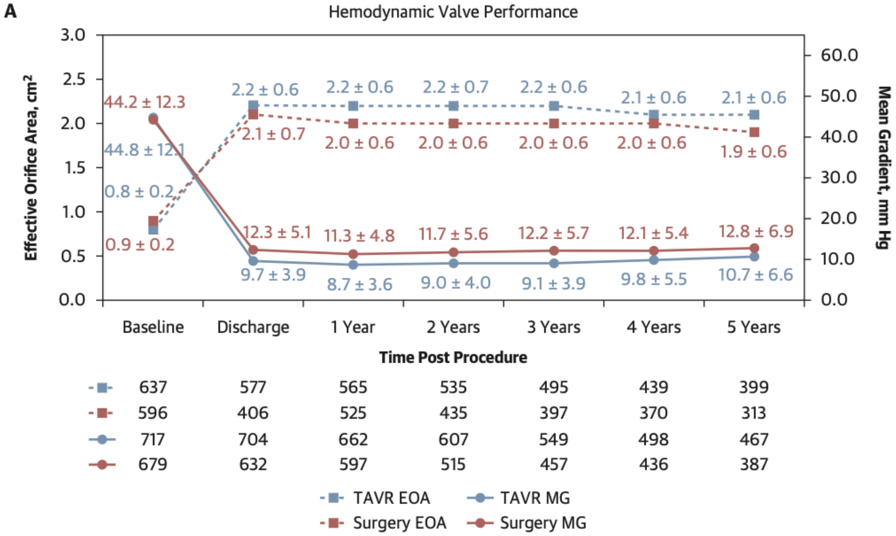


- In a failed small (#23 mm) surgical valve
- In patients with small failed aortic bioprostheses, ViV-TAVR with an SEV was associated with improved valve hemodynamics as evaluated by echocardiography. There were no differences between groups in invasive valve hemodynamics and 30-day clinical outcomes

Rodés-Cabau J, et al. *J Am Coll Cardiol*. 2022;80(7):681-693.

Evolut LR RCT





EOA = effective orifice area.
Forrest JK, et al. *J Am Coll Cardiol*. 2025;85(15):1523-1532.

INVA-SOUND Study

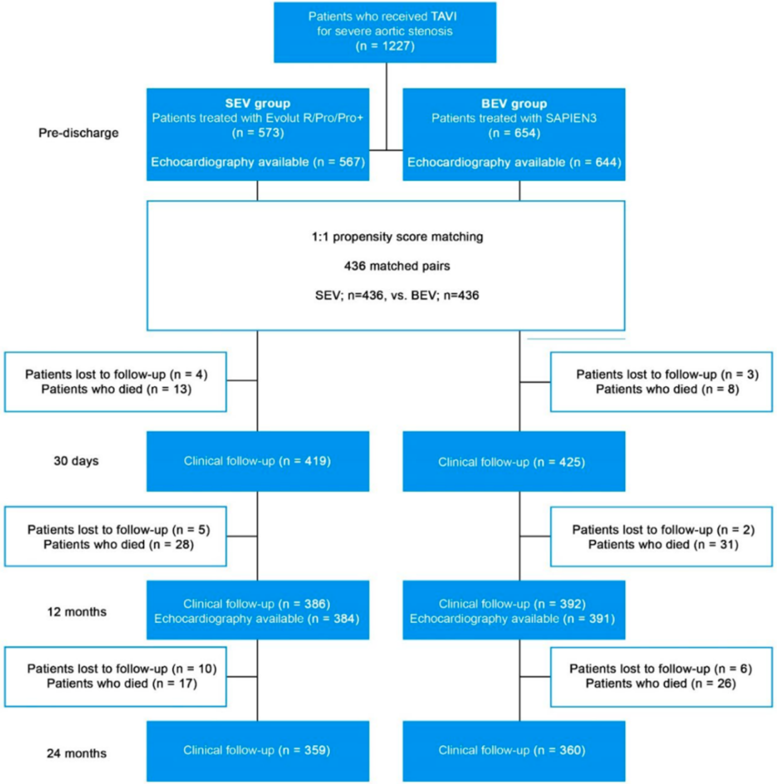
EuroIntervention
2025;21:e411-e425
published online e-edition April 2025
DOI: 10.4244/EIJ-D-24-00341

ORIGINAL RESEARCH

Prognostic value of invasive versus echocardiography-derived aortic gradient in patients undergoing TAVI

Mark M.P. van den Dorpel[1], MD; Sraman Chatterjee[1], BSc; Rik Adrichem[1], MD; Sarah Verhemel[1], MD; Isabella Kardys[1], MD, PhD; Rutger-Jan Nuis[1], MD, PhD; Joost Daemen[1], MD, PhD; Claire Ben Ren[1], MD, PhD; Alexander Hirsch[1,2], MD, PhD; Marcel L. Geleijnse[1], MD, PhD; Nicolas M. Van Mieghem[1]*, MD, PhD

CONSORT Diagram



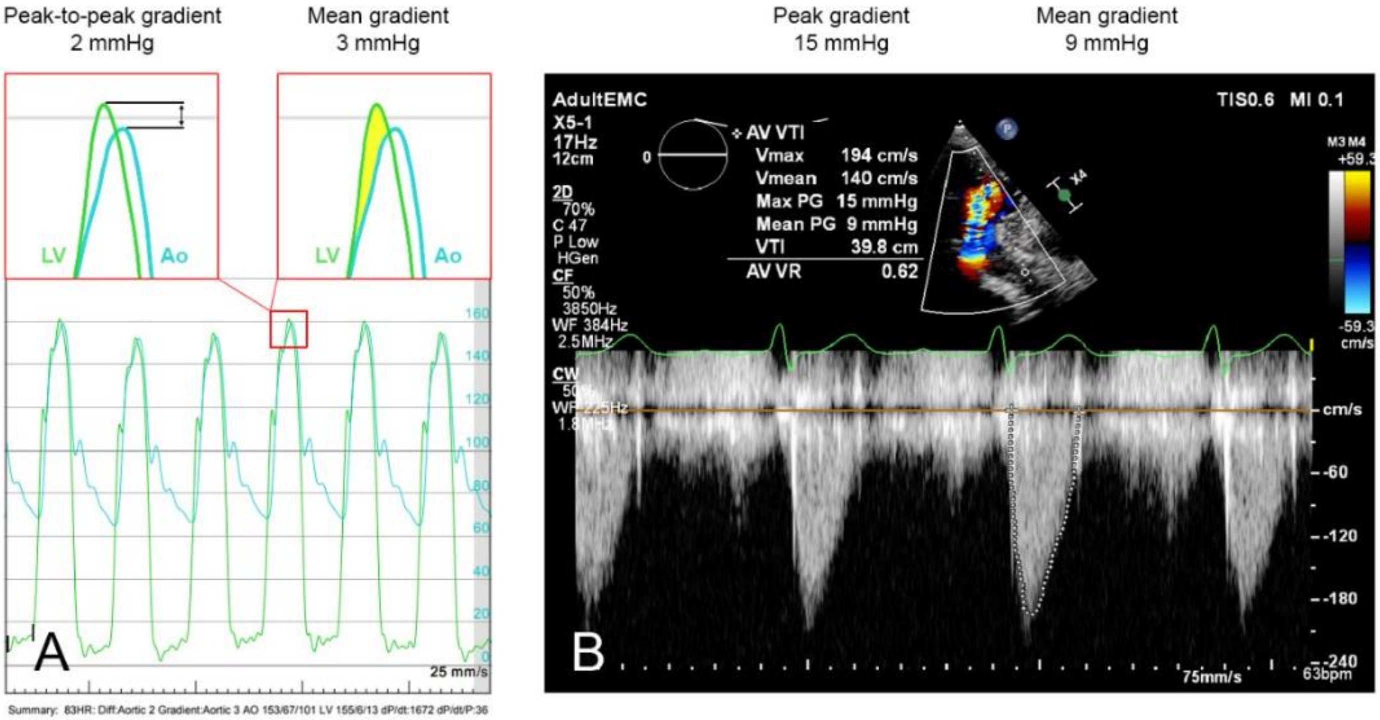
Van den Dorpel MMP, et al. *EuroIntervention*. 2025;21:e411-e425.

Objectives

- Primary objective: To compare the mean and peak gradients pre- and post-TAVI by
  - Immediate invasive assessment
  - Transthoracic echocardiography within 48 hours
- Secondary objective: To correlate hemodynamic performance (by TTE and invasively) with all-cause and cardiovascular mortality

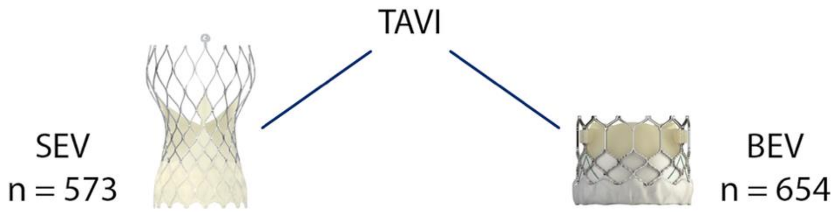
TTE = transthoracic echocardiogram.
Van den Dorpel MMP, et al. *EuroIntervention*. 2025;21:e411-e425.

Pressure Recovery Phenomenon after BEV & SEV



Van den Dorpel MMP, et al. *EuroIntervention*. 2025;21:e411-e425.

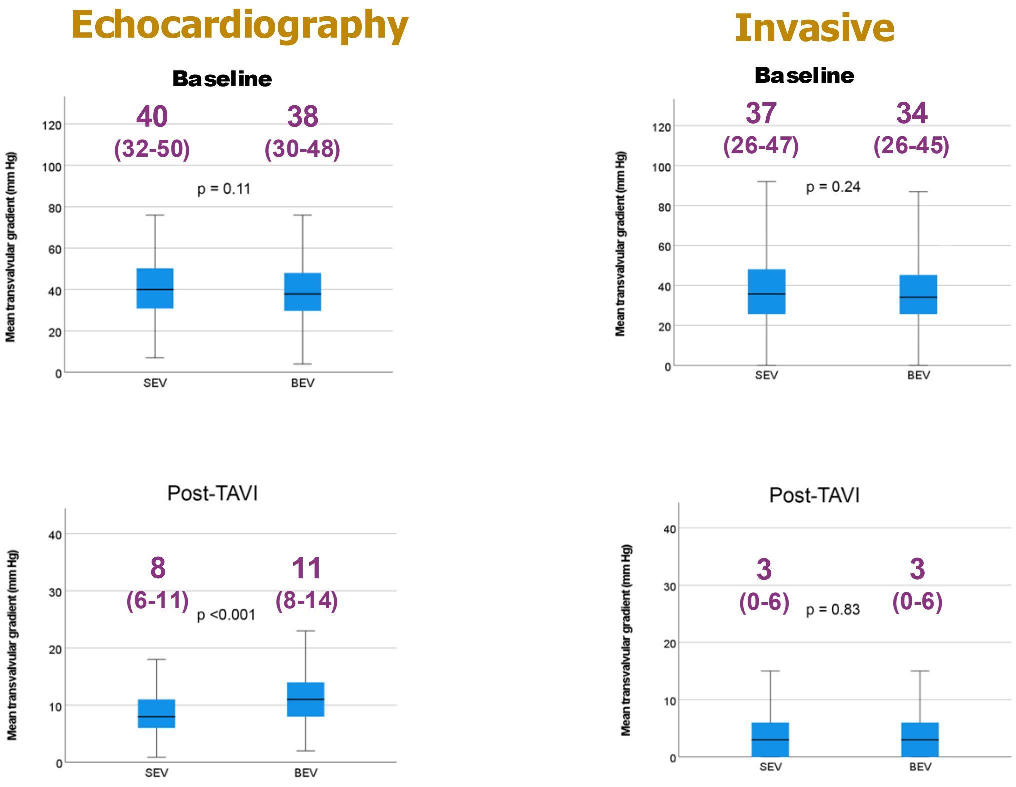
Baseline Characteristics



	SEV (n=573)	BEV (n=654)	P
Age (y)	80 (74-84)	80 (74-84)	0.93
Male	248 (43.2)	428 (65.4)	**<0.001**
STS	3.25 (2.28-4.81)	2.94 (1.90-4.70)	**0.007**
LVEF (%)	58 (50-60)	55 (45-60)	**<0.001**
>50%	393 (68.6)	378 (57.8)	**<0.001**
40-50%	115 (20.0)	174 (26.6)	**0.014**
<40%	65 (11.4)	102 (15.6)	**0.033**
Pre-procedural mean aortic gradient(mmHg)	40.0 (31.0-50.0)	38.0 (30.0-48.0)	0.11
Pre-procedural peak aortic gradient(mmHg)	67.0 (55.0-81.0)	64.0 (49.0-81.0)	0.06

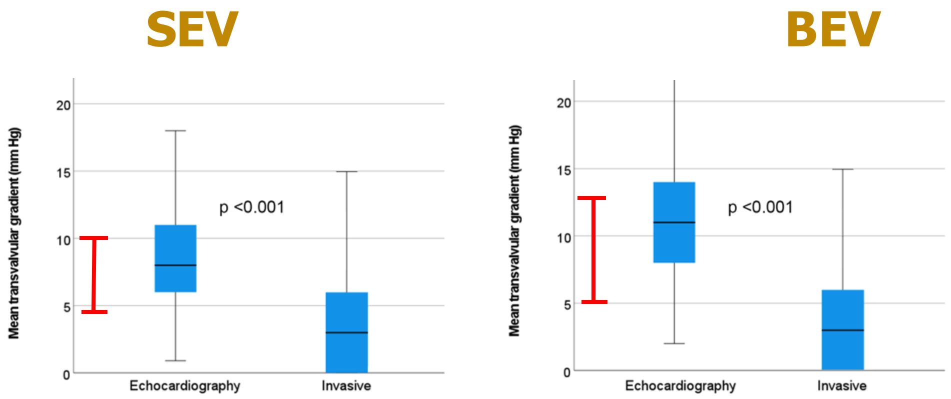
Van den Dorpel MMP, et al. *EuroIntervention*. 2025;21:e411-e425.

Gradient for SEV & BEV



Van den Dorpel MMP, et al. *EuroIntervention*. 2025;21:e411-e425.

Discordance for SEV & BEV



Post-TAVI echo mean gradient – Post TAVI invasive mean gradient (mmHg)	**5.0 (2.0-7.0)**	**7.0 (4.0-10.5)**	***P*<0.001**

Van den Dorpel MMP, et al. *EuroIntervention*. 2025;21:e411-e425.

Discordance Δ for SEV & BEV per size

Valve size	SEV (n = 573) (reference = 5.0)	*P*	BEV (n = 654) (reference = 7.0)	*P*	*P* (SEV vs. BEV)
Small (20mm/23mm)	8.0 (4.0-13.0)	reference	12.0 (7.0-16.5)	reference	0.11
Small-medium (23mm/26mm)	5.0 (2.0-8.0)	0.012	9.0 (6.0-13.0)	0.68	<0.001
Medium (26mm/29mm)	4.0 (2.0-7.0)	0.001	7.0 (4.0-10.0)	0.005	<0.001
Large (29mm/34mm)	4.0 (2.0-6.0)	0.039	6.0 (4.0-9.0)	0.018	0.013

Δ = Post-TAVI echo mean gradient – Post TAVI invasive mean gradient (mmHg)

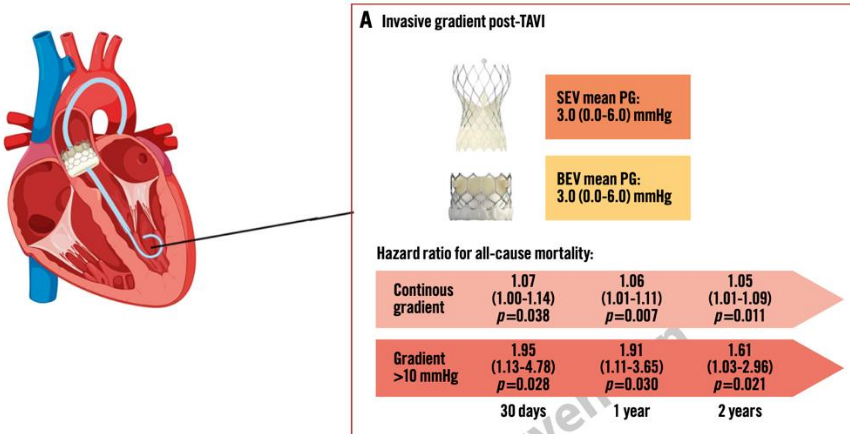
Van den Dorpel MMP, et al. *EuroIntervention*. 2025;21:e411-e425.

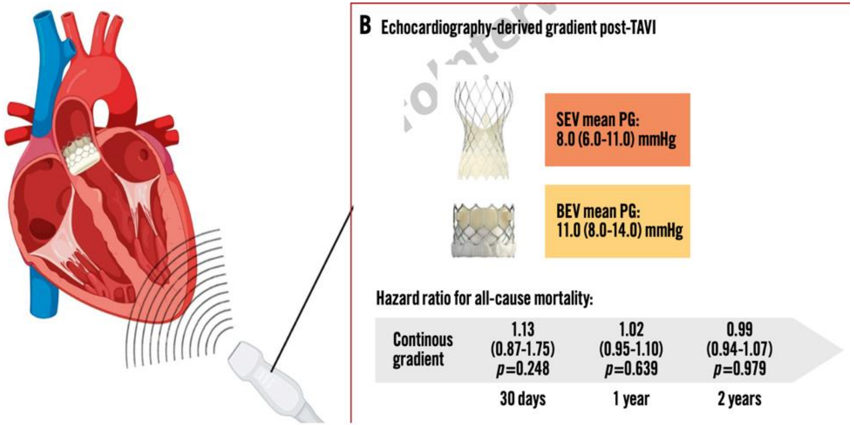
Discordance for SEV & BEV per EF or SVI

LVEF	SEV +BEV	*P*	**SEV (n = 573)** (reference = 5.0)	*P*	**BEV (n = 654)** (reference = 7.0)	*P*	*P* (SEV vs. BEV)
>50%	6.0 (3.0-10.0)	reference	5.0 (2.0-8.0)	reference	8.0 (5.0-11.0)	reference	**<0.001**
40-50%	6.0 (3.0-9.0)	0.42	4.0 (0.0-7.0)	0.10	7.0 (4.0-9.0)	0.22	**<0.001**
<40%	6.0 (2.0-9.0)	0.50	5.0 (1.0-8.0)	1.00	6.0 (3.0-9.0)	**0.020**	0.40
Stroke volume index							
>35 ml/m^2	7.0 (3.0-10.0)	reference	5.0 (2.0-7.8)	reference	9.0 (5.0-12.0)	reference	**<0.001**
<35 ml/m^2	6.0 (3.0-8.0)	**0.044**	5.0 (2.0-8.0)	0.79	7.0 (4.0-9.0)	**0.002**	**<0.001**

Van den Dorpel MMP, et al. *EuroIntervention*. 2025;21:e411-e425.

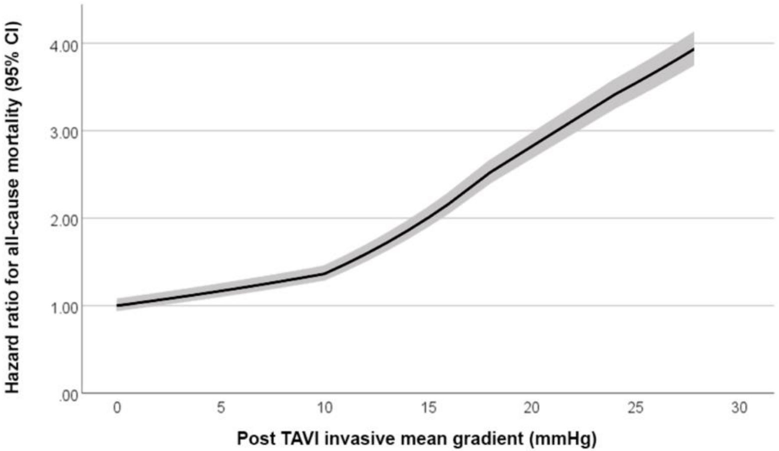
Mean Gradient and Outcome

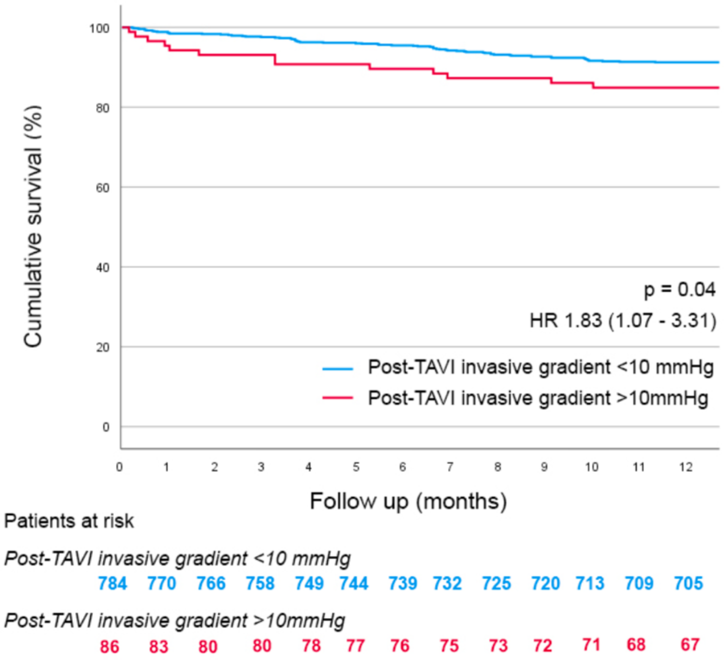




Van den Dorpel MMP, et al. *EuroIntervention*. 2025;21:e411-e425.

Invasive Mean Gradient & Mortality



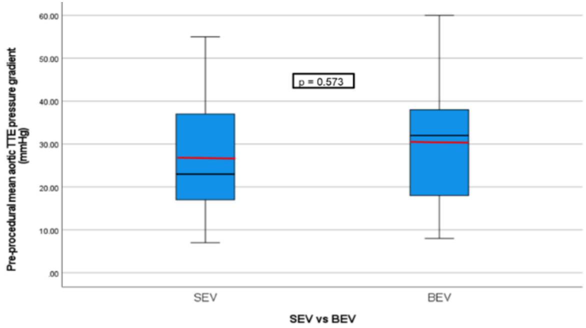


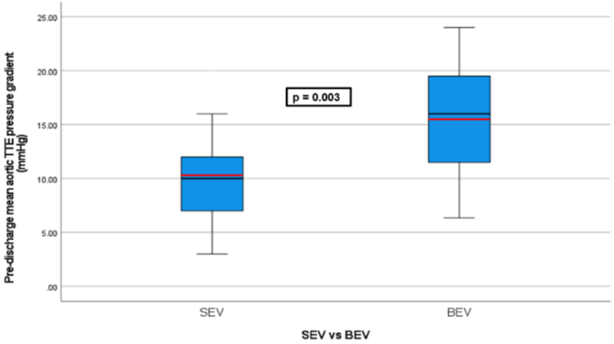
Van den Dorpel MMP, et al. *EuroIntervention*. 2025;21:e411-e425.

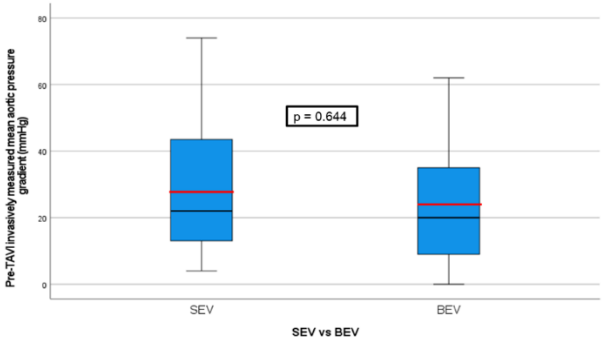
FAB TAVI Study

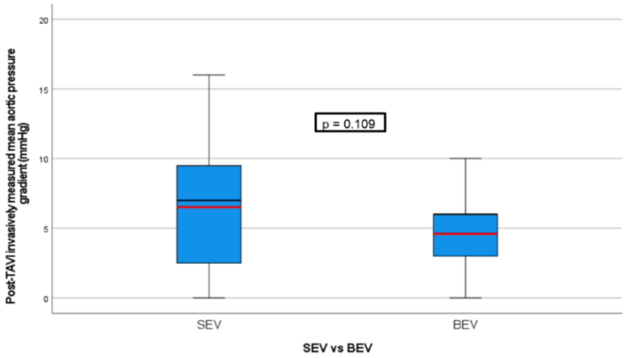
Baseline

Post TAV-in-SAV







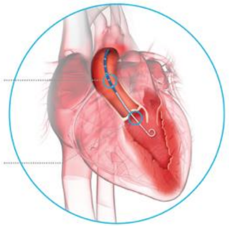


Chatterjee S. [Submitted for publication.]

Acquisition Caveats

- Ultrasound beam alignment to grab maximal velocities
- No consensus on specific acquisitions for each THV frame
- Intrinsic assumptions of echo Doppler (Bernoulli = laminar flow)

- Need to calibrate fluid-filled catheters
- Variation in catheter positioning in the ascending aorta
- Filling status, transient cardiac stunning, sedatives/anaesthesia



Van den Dorpel MMP, et al. *EuroIntervention*. 2025;21:e411-e425.

Bernoulli Equation in Brief…

- Based on the law of conservation of energy, the sum of pressure and kinetic energy is similar in the LV, at the aortic valve, and in the aorta

- Blood flow = product of area and velocity

- Across a stenotic area (area ⇩) kinetic energy (and velocity) of the blood increases (v_{max} ⇧) **but** a pressure gradient occurs because the pressure energy of the blood (and pressure) decreases, and there is energy decay through friction and heat losses

Bernoulli Equation in Brief…

- The Bernoulli equation describes that the pressure gradient generated across a stenosis is related to 3 forces
  - **Convective acceleration** = increase in blood-flow velocity when traversing a reduced area (this is the dominant component)
  - **Flow acceleration** (different from flow convergence) = increase blood-flow velocity with *ventricular contraction*
  - **Viscous forces** from blood viscosity and friction forces amongst blood layers and against the aorta

Bernoulli Equation in Brief…

- The simplified Bernoulli equation
  - Discards any velocity increase from flow acceleration, viscous forces, flow profile, flow convergences, LVOT velocity, and pressure recovery
  - Causes overestimation of transvalvular mean gradients
  - Explains why across normal aortic valves, the invasive but never the echocardiographic, mean gradient may be zero

Bernoulli Equation in Brief…

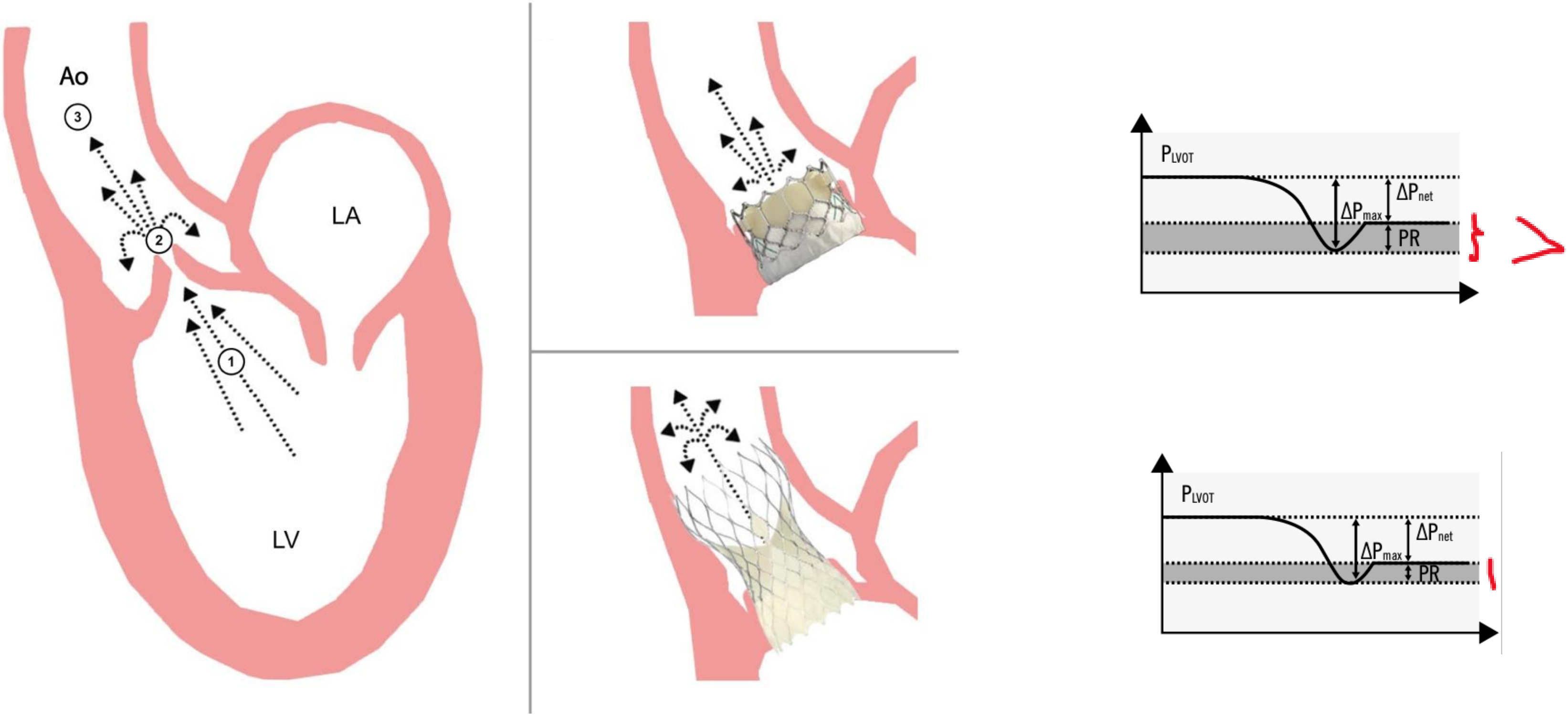
- **Non-stenotic prosthetic valve** designs have different flow profiles (turbulent versus laminar), varying lengths of stent-frames (BEV, SEV, ViV-TAVR), different levels of flow convergence (@ lower prosthetic valve struts, below leaflets, and blood-flow exit from valve frame), and varying degrees of pressure recovery

- Non-stenotic valves with different designs will generate different flow velocities, and hence echocardiographic mean gradients, for the same geometrical area and invasive mean gradients

Pressure Recovery and Mean Gradient Assessment

- Pressure recovery
  - Invasive
    - Incorporates all contributing factors to flow (including pressure recovery)
  - Echocardiography
    - Maximum velocity is measured at the level of the vena contracta (pressure recovery has not yet occurred)
    - Simplified Bernoulli equation
    - Overestimation by echocardiography

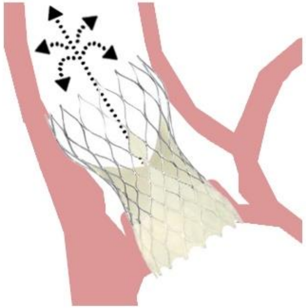
Pressure Recovery Phenomenon after BEV &SEV

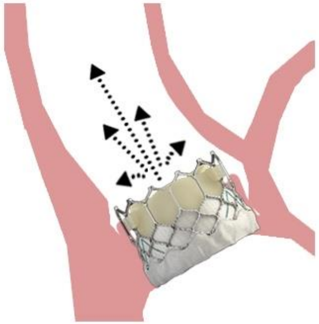


Van den Dorpel MMP, et al. *EuroIntervention*. 2025;21:e411-e425.

Different Discordance for SEV & BEV

- Explanation for smaller discordance in SEV vs BEV?
  - 1. Differences in valve frame design may affect pressure recovery differently
  - 2. Design related phenomena (apart from pressure recovery) may convert kinetic energy to potential energy

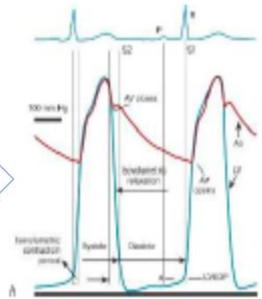




Immediate Gradient Discordance Post-TAVR: What’s Next?

Elevated MG ≥ 20 mmHg

Standardized Invasive Hemodynamics



Concordance

Consider Post Dilatation/?Balloon Valve Fracture?

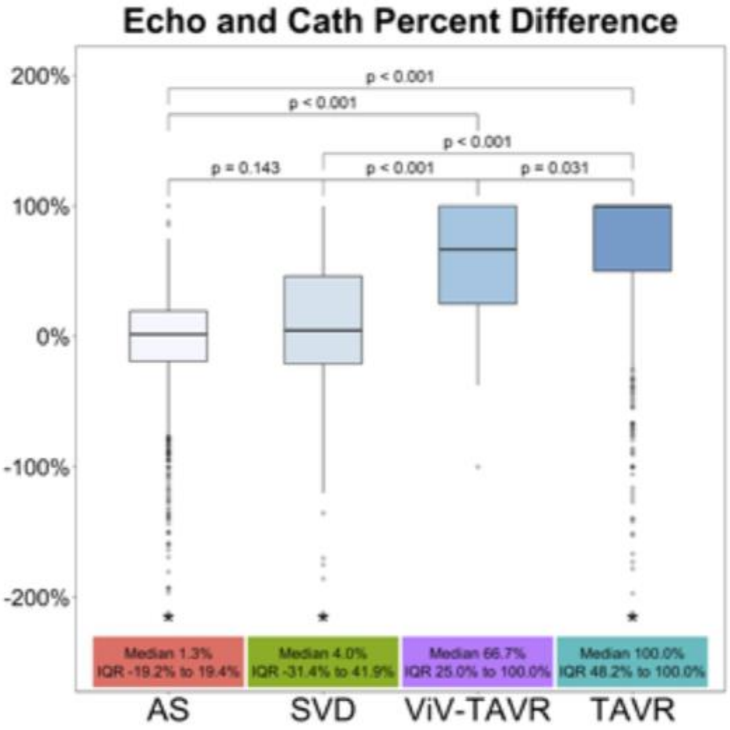
Discordance

Acceptable valve function

Recalibrate

Courtesy A Abbas, Corewell Health William Beaumont University Hospital, Royal Oak, MI.

Discordance & Setting



SVD = structural valve degeneration.
Abbas AE, et al. *J Am Soc Echocardiogr*. 2023;36(12):1302-1314.

Conclusions

- Mean aortic gradients are higher by echocardiography than by invasive assessment
- Incremental discordance for BEV than SEV
- Only invasive mean gradients correlate with clinical outcome
- **A call for systematic invasive pressure assessment @ end of each TAVR procedure**

CardioVascular Learning Network | CME

Optimizing TAVR Outcomes: Hemodynamics, Valve Design, and Device Selection

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Director of Structural Interventions
Associate Director of Cardiac Catheterization Library
Stanford Medicine
Palo Alto, CA

Presentation Overview

- Hemodynamic performance across TAVR platforms
- Role of valve design in pressure gradients and PVL
- Device selection and post-TAVR assessment
- Case-based insights

Understanding Hemodynamic Performance

- Hemodynamic performance = Valve efficiency in maintaining flow with minimal pressure gradient
- Key metrics: Mean transvalvular gradient (mm Hg), EOA (cm^2), and PPM
- Better hemodynamics = Lower LV workload and improved long-term outcomes

EOA = effective orifice area; LV = left ventricular.

Hemodynamic Comparison Across Platforms

- SAPIEN 3 (BEV): ~11 mm Hg, 1.6 cm^2, <3% moderate/severe PVL
- Evolut FX (SEV): ~8 mm Hg, 2.0 cm^2, 4-6% moderate PVL
- ACURATE neo2: ~9 mm Hg, 1.9 cm^2, <5% moderate PVL
- PORTICO/NAVITOR: ~9-10 mm Hg, 1.8-1.9 cm^2, ~3-5% moderate PVL

BEV = balloon-expandable valve; SEV = self-expanding valve.
NIH National Library of Medicine. Accessed October 6, 2025. https://clinicaltrials.gov/study/NCT02675114; NCT02207569; NCT02737150.

Key Insights on Hemodynamic Performance

- Self-expanding valves: Larger EOA and lower gradients
- Balloon-expandable valves: Precise positioning, strong annular sealing
- Clinical trade-offs depend on annular size, calcium, LVOT geometry, and access route

LVOT = left ventricular outflow tract.

Role of Valve Design in Pressure Gradients

- Frame structure: Affects radial strength and symmetry
- Leaflet position: Intra-annular (BEV) vs supra-annular (SEV) impacts EOA and gradient
- Sealing skirt: Reduces PVL but may slightly lower EOA
- Radial force: Determines resistance to recoil and sealing efficiency

Hatoum H, et al. *Ann Biomed Eng*. 2019;48(2):860-867.

Role of Valve Design in Paravalvular Leak (PVL)

- Mechanisms: Incomplete sealing, annular calcification, eccentric deployment
- Design factors reducing PVL: External skirts, adaptive sealing, precise deployment
- PVL implications: Associated with mortality and HF readmissions

HF = heart failure.
Bhushan S, et al. *Curr Probl Cardiol*. 2022;47(10):100957.

Device Selection Considerations

- Anatomic factors: Annulus size, LVOT shape, calcium, coronary height
- Clinical factors: Access route, EF, surgical risk, anticoagulation status
- BEV: Superior control, lower PVL risk
- SEV: Larger EOA, better for small annuli or low-gradient AS

EF = ejection fraction; AS = aortic stenosis.
Claessen BE, et al. *JAMA Cardiol.* 2021;6(1):102-112.

Post-TAVR Hemodynamic Assessment

- Immediate: Mean gradient <20 mm Hg, no/moderate PVL
- Echo confirmation of leaflet motion and valve area
- Follow-up: Echo at discharge, 1 month, 1 year
- Gradient rise >10 mm Hg or new PVL suggests thrombosis or degeneration

Fong FK and So KC. *JACC Asia*. 2024;4(7):545-546.

Key Takeaways

- Hemodynamics differ across platforms; understand trade-offs
- Valve design influences gradients and PVL
- Device selection integrates anatomy, hemodynamics, and experience
- Continuous post-TAVR assessment ensures optimal outcomes