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HALT After TAVR: What Are We Really Seeing on CT?

Pathophysiological and Mechanical Perspectives

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Disclosure of Relevant Financial Relationships

Within the prior 24 months, I have had a financial relationship with a company producing, marketing, selling, re-selling, or distributing healthcare products used by or on patients:

Nature of Financial Relationship

Consultant Fees/Honoraria

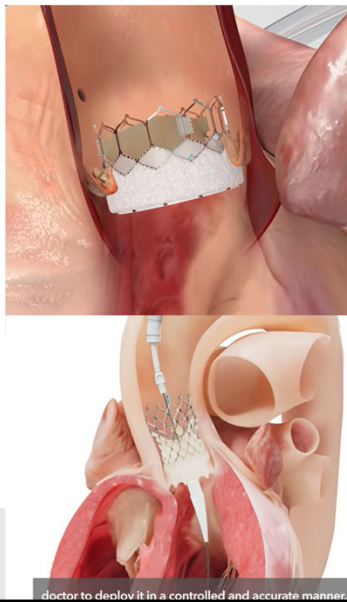
Ineligible Company

Medtronic
Edwards Lifescience
Materialize

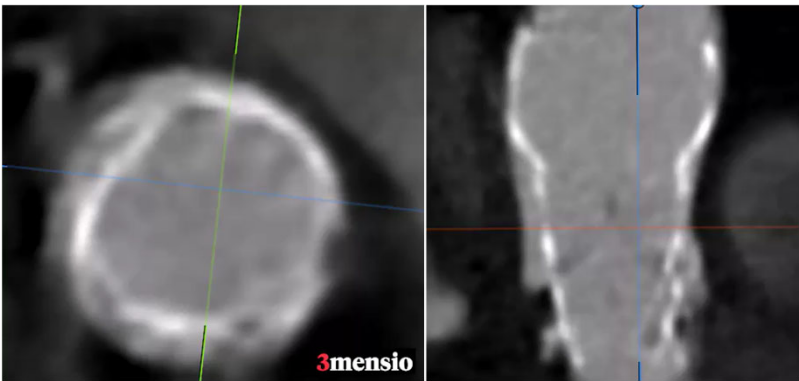


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What is HALT?: Hypoattenuating leaflet thickening



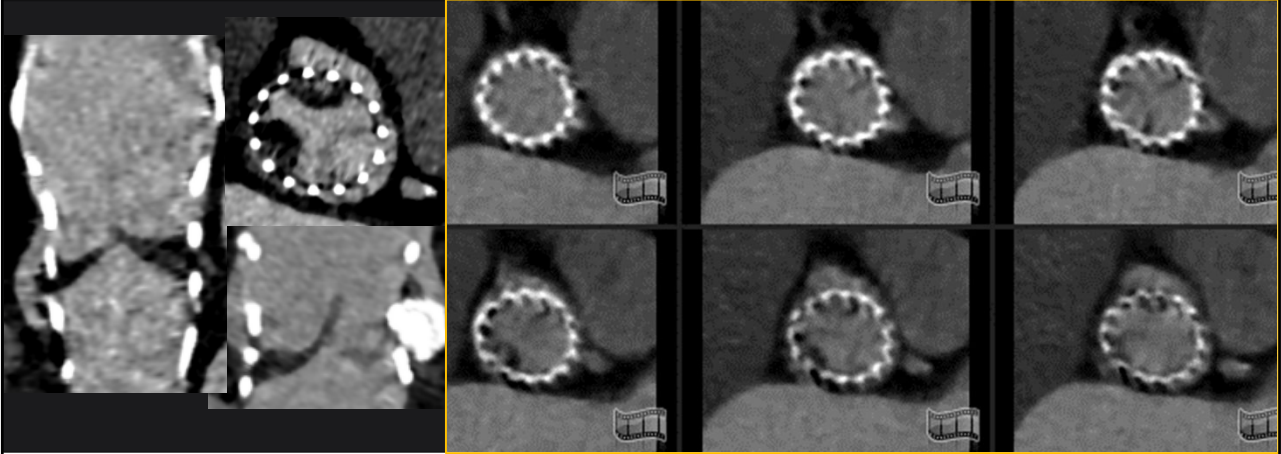
How look like “NORMAL” prosthesis leaflets



4

HALT: Hypoattenuating leaflet thickening

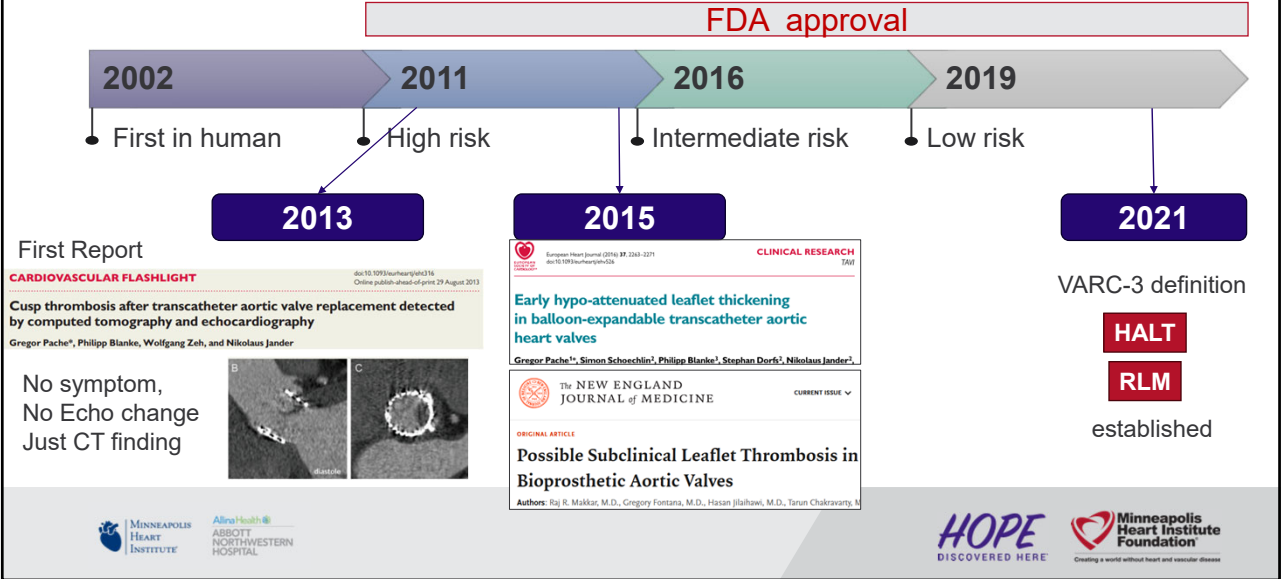
HALT can occur in any of the bioprosthetic valve leaflets





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From an incidental CT finding to a new concept



2002

First in human

2011

High risk

2016

Intermediate risk

2019

Low risk

2013

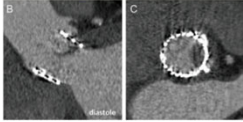
First Report

CARDIOVASCULAR FLASHLIGHT

Cusp thrombosis after transcatheter aortic valve replacement detected by computed tomography and echocardiography

Gregor Pache^a, Philipp Blanke^a, Wolfgang Zeh^a, and Nikolaus Jander^a

No symptom,
No Echo change
Just CT finding



2015

Early hypo-attenuated leaflet thickening in balloon-expandable transcatheter aortic heart valves

Gregor Pache^{1,2}, Simon Schoechlin¹, Philipp Blanke¹, Stephan Dorfl¹, Nikolaus Jander²

THE NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

Possible Subclinical Leaflet Thrombosis in Bioprosthetic Aortic Valves

Authors: Raj R. Makkar, M.D., Gregory Fontana, M.D., Hasan Jilali, M.D., Tarun Chakravarty, M.D.

2021

VARC-3 definition

HALT

RLM

established



6

HALT is CT finding: Can occur without symptom or hemodynamic change

HALT is hypo-attenuating thickening of bioprosthetic leaflets on contrast CT, with meniscal configuration that is thickest at the leaflet insertion and tapers toward the free edge

MPR aligned with center of leaflet

Sapien 3

Evolut

% leaflet involvement

No HALT	HALT ≤25%	HALT 26-50%	HALT 51-75%	HALT >75%
A	F	K	P	U
B	G	L	Q	V

MINNEAPOLIS HEART INSTITUTE
ABBOTT NORTHWESTERN HOSPITAL

VARC-3 Criteria JACC 2021
Blanke et al., JACC 2020
Makkar et al., JACC 2020

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HALT ≠ RLM ≠ clinical valve thrombosis

A spectrum, not a single entity

HALT

→

HALT + RLM

→

Hemodynamic dysfunction

→

Clinical thrombosis

Anatomical CT finding

RLM: Reduced leaflet motion

Morphology + Impaired leaflet function

Clinical consequence:
Symptoms and/or clinically relevant valve dysfunction

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4 of 27

What is HALT?

Thrombus?
Tissue?
Mechanical deformation?
Or some combination of these?



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What is HALT?

CT appearance

Characteristic hypoattenuating material on the aortic side of the leaflet

Reversibility

HALT / reduced leaflet motion can resolve with anticoagulation

The imaging findings strongly suggested thrombosis



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Pathology: HALT corresponds to thrombus

110 explanted TAV, 320 leaflets, Histological findings in relation to CT imaging

MicroCT

Histology

1. Confirmed: HALT on CT corresponds to "Thrombus" on histology

2. "Thrombus" classified into three: **Acute thrombus**, **Organizing thrombus**, **Organized thrombus (pannus)**

Sato et al., Circ CV interv 2025; 18

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HALT represents thrombus organization on histology

110 explanted TAV, 320 leaflets, Histological findings in relation to CT imaging

Histology

Duration of implant

Duration of implant	No. of leaflets	Acute (%)	Organizing (%)	Organized (pannus) (%)
<30 days	125	19.2	0	0
30-365 days	105	5.7	42.9	3.8
>365 days	90	5.6	53.3	18.9
Total	n=320			

HALT represents a stage of thrombus formation and organization

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If HALT is thrombus... why does it form here?

This is where biology meets mechanics.



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In 2019

Circulation

ORIGINAL

Early & Transcatheter Aortic Valve Replacement: A Multicenter Study

Run into a snag



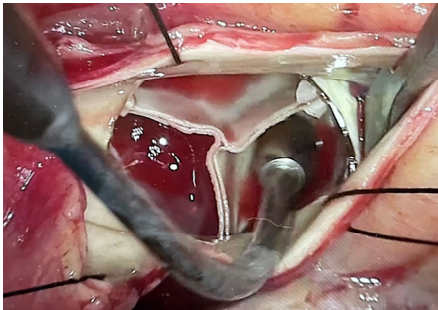
S3 #29 does not expand to the nominal?

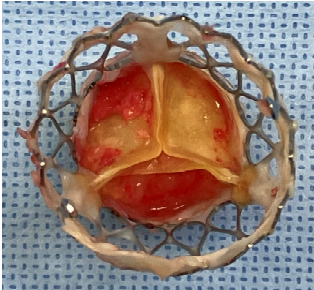


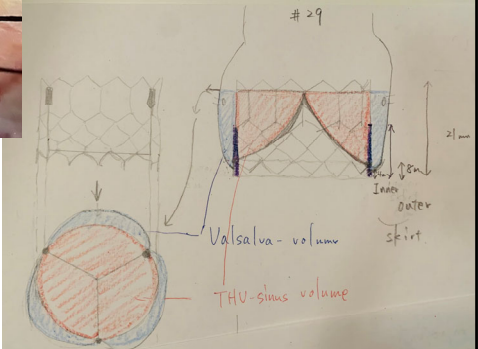
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In 2020...





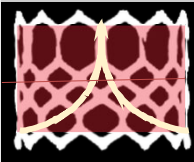
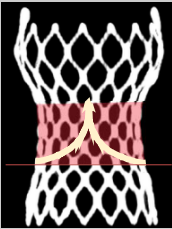
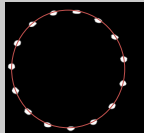
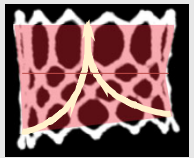
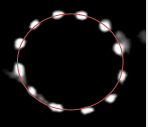
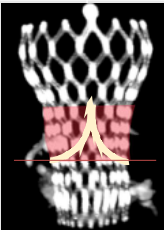
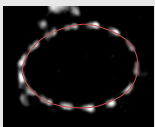






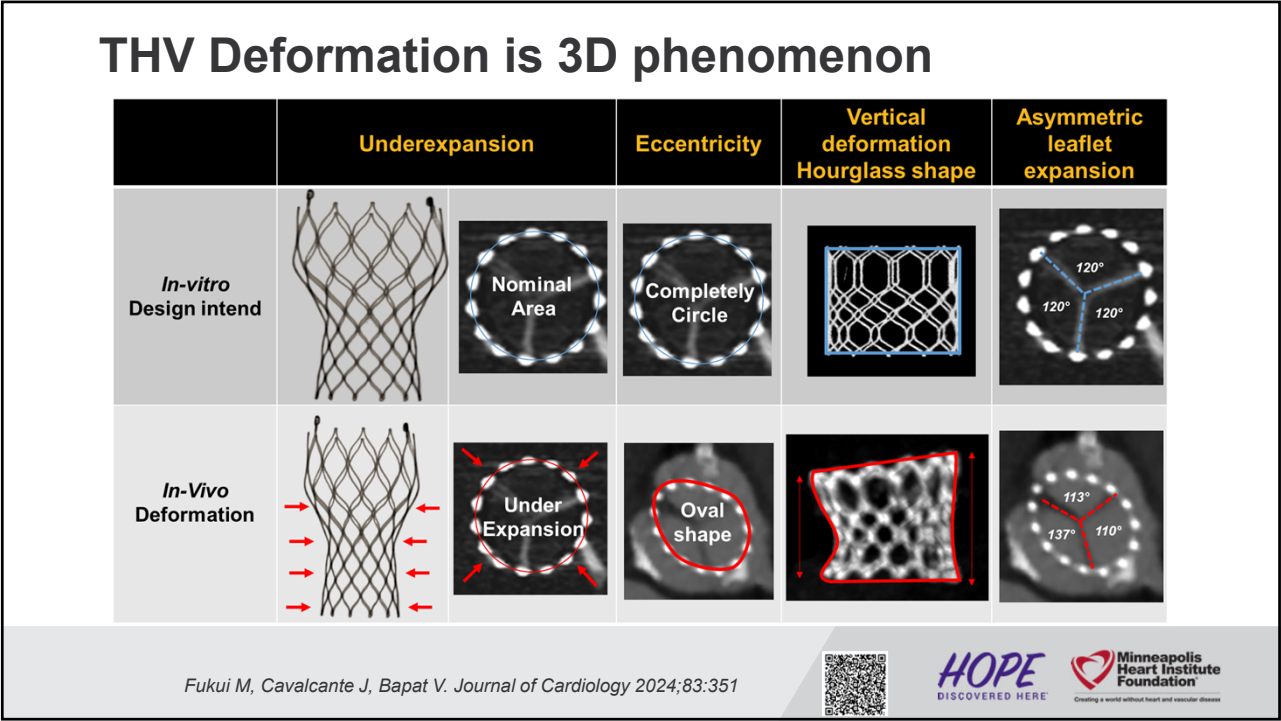
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Deformation occurs in all THVs

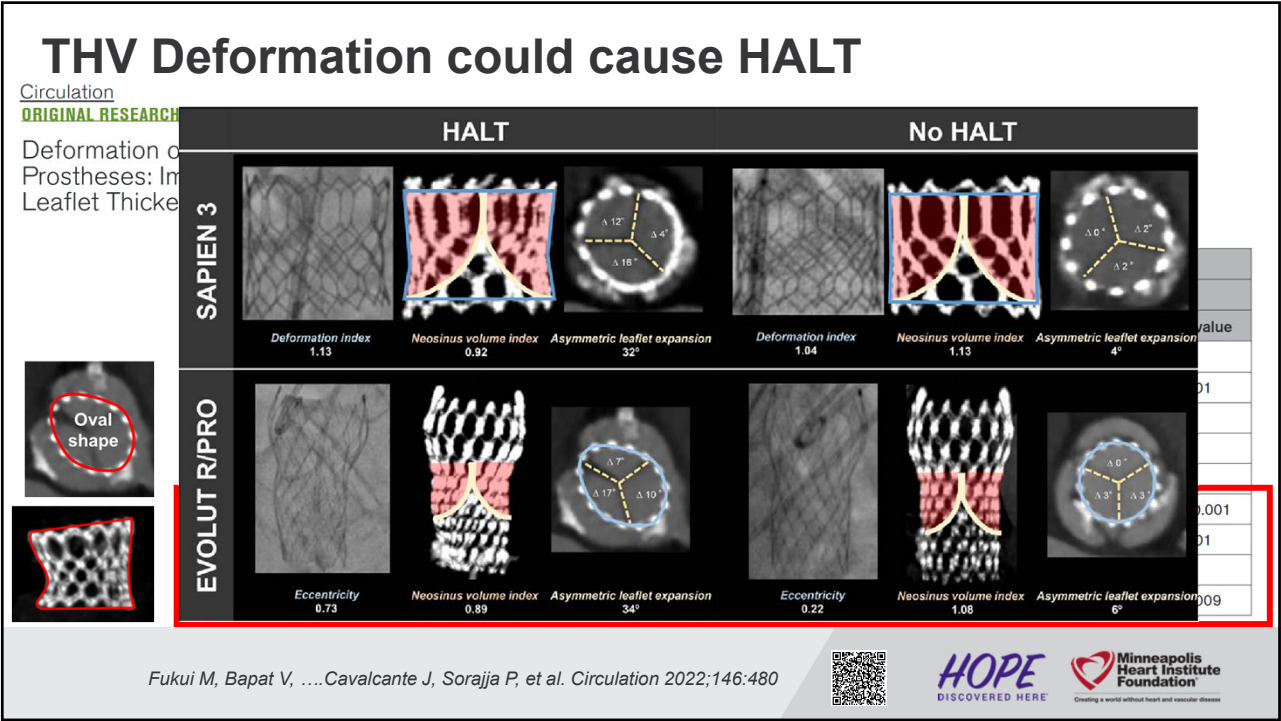
	SAPIEN 3		Evolut	
<i>In-vitro</i> Design intend				
<i>In-vivo</i> configuration In real patients' heart				



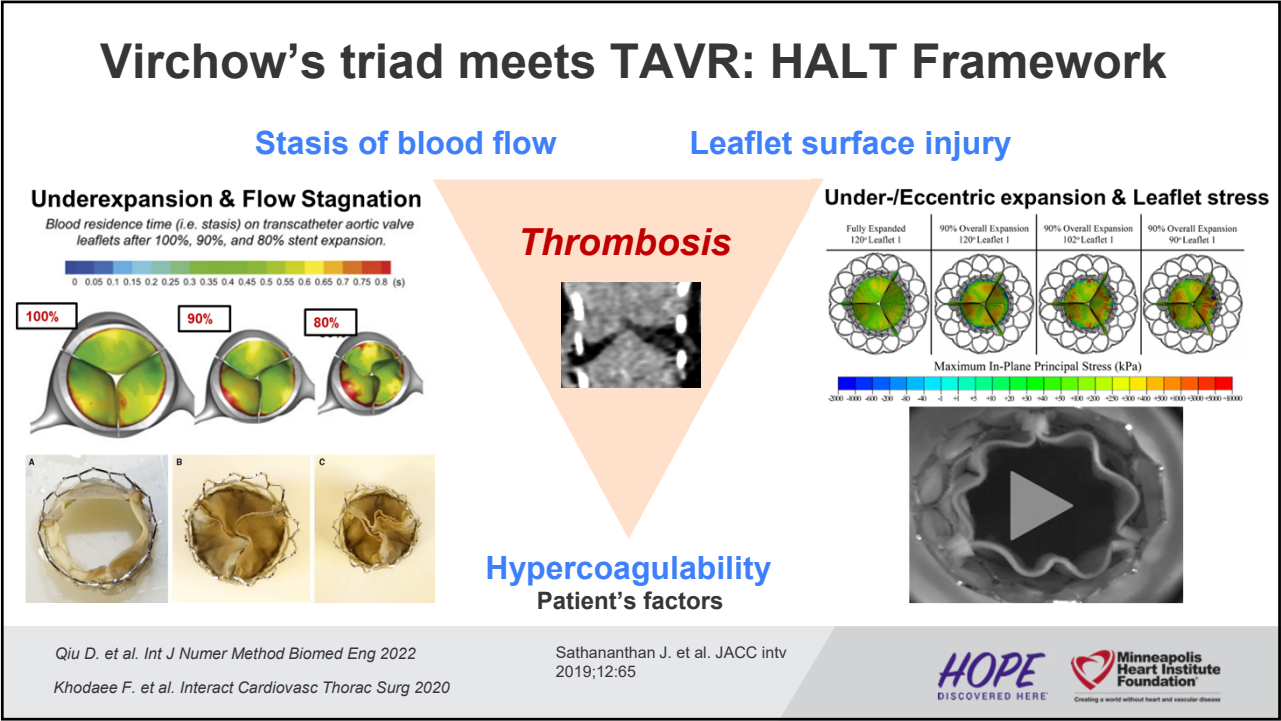
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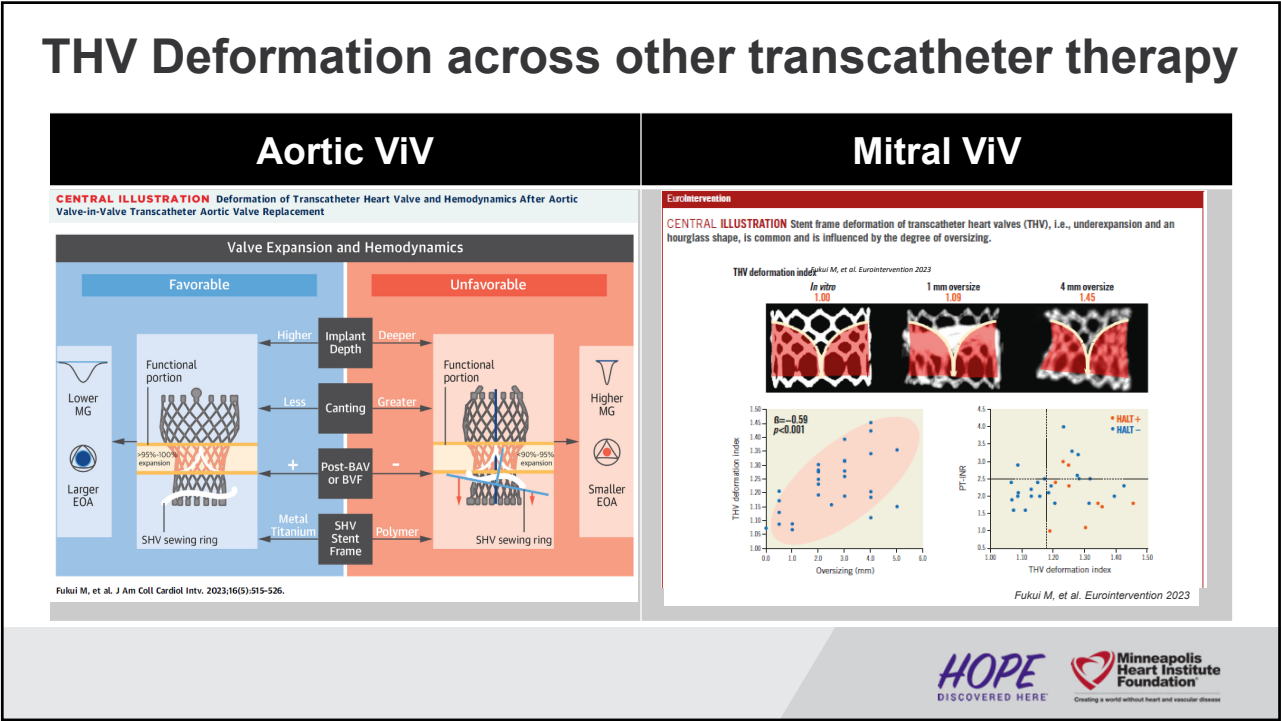
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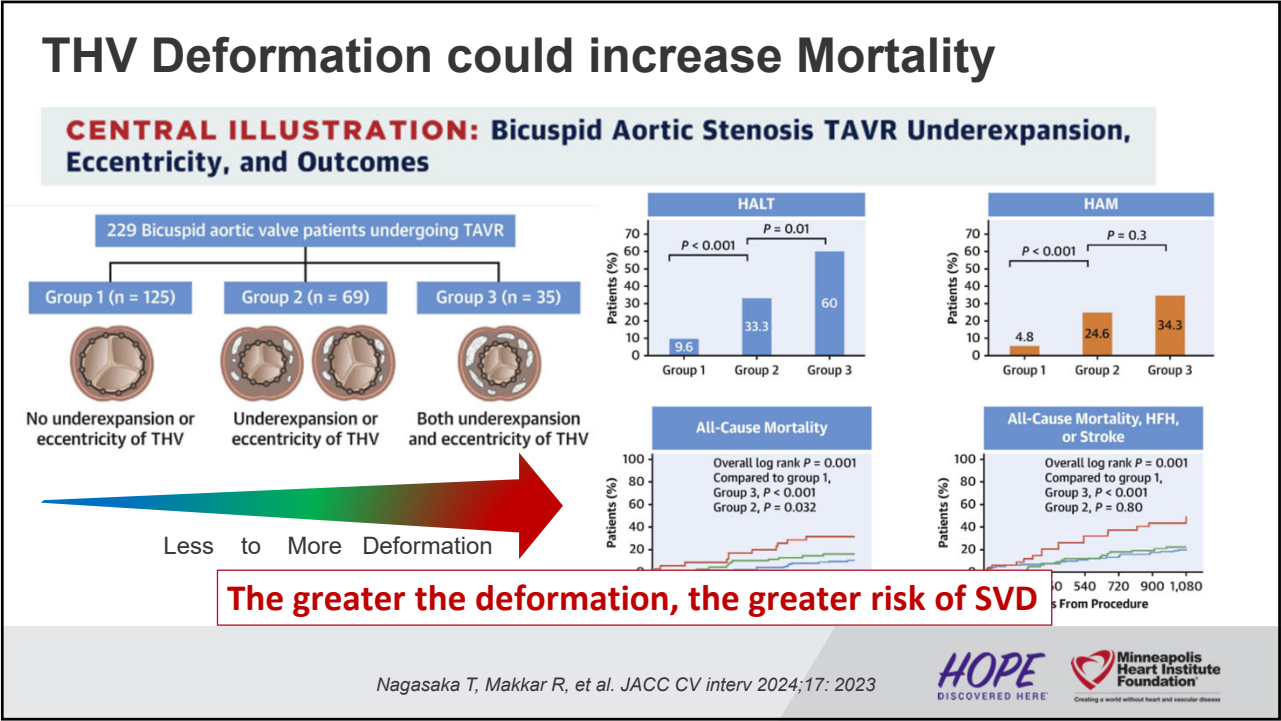
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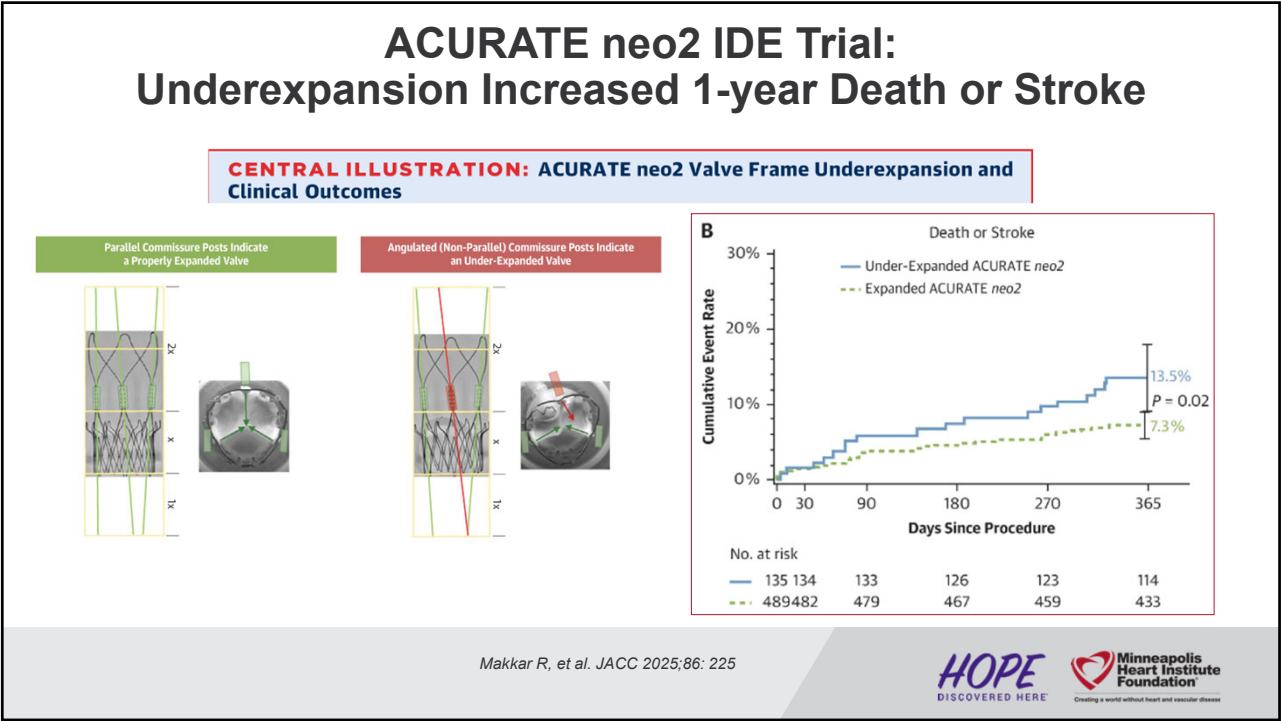
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JACC: Cardiovascular Interventions
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VOL. 19, NO. 13, 2026

STATE-OF-THE-ART REVIEW

Procedural Strategies for Optimal Transcatheter Aortic Valve Replacement

An International Position Statement

Annette Maznyczka, MD, PhD,¹ Thomas Pilgrim, MD, MSc,² David Hildick-Smith, MD,³ Antonio Mangieri, MD,⁴ Azeem Latib, MD,⁵ Mohamed Abdel-Wahab, MD,⁶ Mohamad Alkhouli, MD,⁷ John G. Webb, MD,⁸ Michael J. Reardon, MD,⁹ Howard C. Hermann, MD,¹⁰ Daniel J. Blackman, MD,¹¹ Luis Nombela-Franco, MD,¹² Tanja K. Rudolph, MD,¹³ Joanna J. Wykrzykowska, MD, PhD,¹⁴ Marco Barbanti, MD,¹⁵ Michael Joner, MD,¹⁶ Philippe Gègneux, MD,¹⁷ Kristoffer Russell, MD, PhD,¹⁸ Christophe Saint-Etienne, MD,¹⁹ Mariama Akodad, MD, PhD,²⁰ Yusuke Kobori, MD, PhD,²¹ David Meier, MD,²² Nicolas Van Mieghem, MD, PhD,²³ Toby Rogers, MD,²⁴ Susheel Kodali, MD,²⁵ Yohel Ohno, MD,²⁶ Domenico Angelotti, MD,²⁷ Bernard Prendergast, MD,²⁸ Danny Dvir, MD,²⁹ Darren Mylotte, MD, PhD,³⁰ Didier Tchétché, MD,³¹ Nicolo Piazza, MD, PhD,³² Ole De Backer, MD, PhD³³

CENTRAL ILLUSTRATION Optimizing TAVR Outcomes

TAVR CODE Framework (Coaxiality, Orientation, Depth, and Expansion), and Procedural Strategies

Practical Steps to Optimize TAVR Implants

- Lesion Preparation**
Predilate when needed
Modification of leaflet calcification
- Precise Positioning**
Steerable delivery system and/or wire manipulation
Optimal fluoroscopic views defined by CT
- Postdilatation if Needed**
↓ Paravalvular AR
↓ Transprosthetic gradient
↑ Expansion
- Imaging for THV Expansion**
Fluoroscopy (2 orthogonal views)
IVUS
TOE

Intraprocedural Fluoroscopic Evaluation of Optimal Index TAVR

- Symmetrical implant depth between non (right) and left coronary cusps
- Alignment of native commissures and THV commissures
- Coaxiality (C)
- Orientation (O)
- Depth (D)
- Expansion (E)

Maznyczka A, et al. JACC Cardiovasc Interv. 2026;19(13):1713-1734.

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What do we know now?

CT finding

HALT can occur without obvious hemodynamic dysfunction

Thrombotic substrate

Pathology supports thrombus formation and organization

Mechanical contribution

Frame deformation, leaflet asymmetry, and neosinus geometry are associated with HALT

But does HALT matter clinically?

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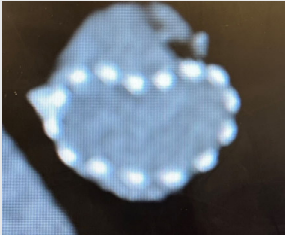
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From “What is HALT?”

to

“What does HALT mean for our patients?”



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HALT Following TAVR: Reassessing HALT's Clinical Impact Through the MHIF Experience

Maroun Chedid, MD
MHIF Grand Rounds
10/5/2026



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I. Epidemiology of HALT following TAVR

- Hypoattenuation leaflet thickening (HALT) is common following TAVR
- Incidence 12-40%
- RESOLVE/SAVORY Registries: more common after TAVR than SAVR (13% vs 4%)
- 24% to 30.9% at one year (PARTNER 3, EVOLUT Low Risk)



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II. Clinical Impact of HALT

1. Hemodynamic effects

- HALT did not significantly affect mean gradients or LVEF at 6 months¹ and at 1 year² (including patients with 1 year all cause mortality)
- Findings consistent across multiple registries/cohorts, including BAV³

1. Jang et al. Impact of leaflet thrombosis on valve haemodynamic status after transcatheter aortic valve replacement. BMJ Heart, 2023
2. Fukui et al. Circulation. 2022;146:480-493.
3. Qiao et al. Incidence, Predictors, and Outcomes of Subclinical Valve Thrombosis After TAVR in Bicuspid Aortic Valve Stenosis. AJC 2026

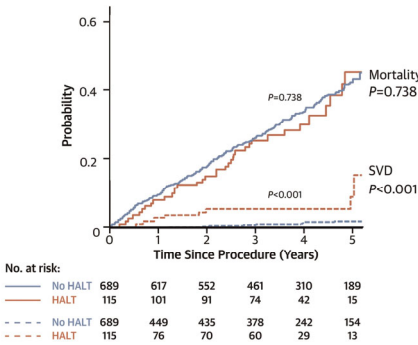


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II. Clinical Impact of HALT

2. Bioprosthetic Valve Deterioration (BVD)

- Strong data linking HALT to BVD¹
- Risk factors included higher age, BMI, and small valve size $\leq 23 \text{ mm}^2$



¹Hein M, et al. J Am Coll Cardiol Interv. 2022;15(11):1113-1122.

SVD 9.4% vs 1.5% Adjusted HR 6.10
(95% CI 2.59-14.29), P < 0.001

2. Jang et al. Impact of leaflet thrombosis on valve haemodynamic status after transcatheter aortic valve replacement, BMJ Heart, 2023



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MHI early BVD study: cohort and endpoint

Retrospective cohort, December 2013–March 2022

VARC-3 stage 2 or 3 hemodynamic valve deterioration within 5 years of TAVR
Controls required at least 3 years of follow-up

Study population	Patients
TAVR procedures screened	1,291
Patients meeting follow-up / BVD criteria	306
Early BVD within 5 years (median time to BVD = 1.5 years)	44
No early BVD	262

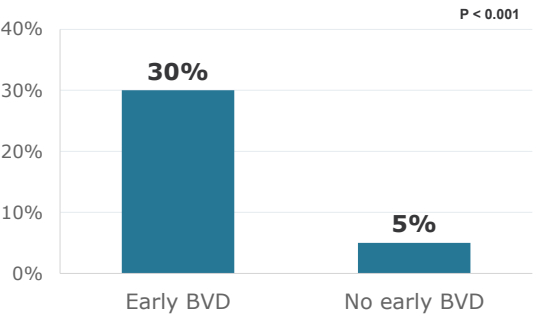
Chedid, Bapat, Gössl et al. Early Bioprosthetic Valve Deterioration Within 5 Years Following TAVR.CJCA.9/2025



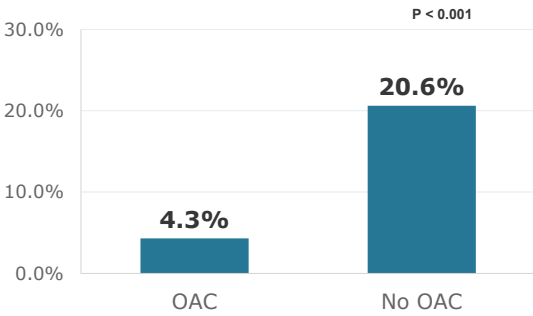
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MHI early BVD study: HALT and anticoagulation

HALT prevalence by BVD status



Early BVD by baseline anticoagulation



HALT occurred in 4.3% of patients on AC and 11.1% not on AC, p=0.6



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MHI early BVD study: associated characteristics

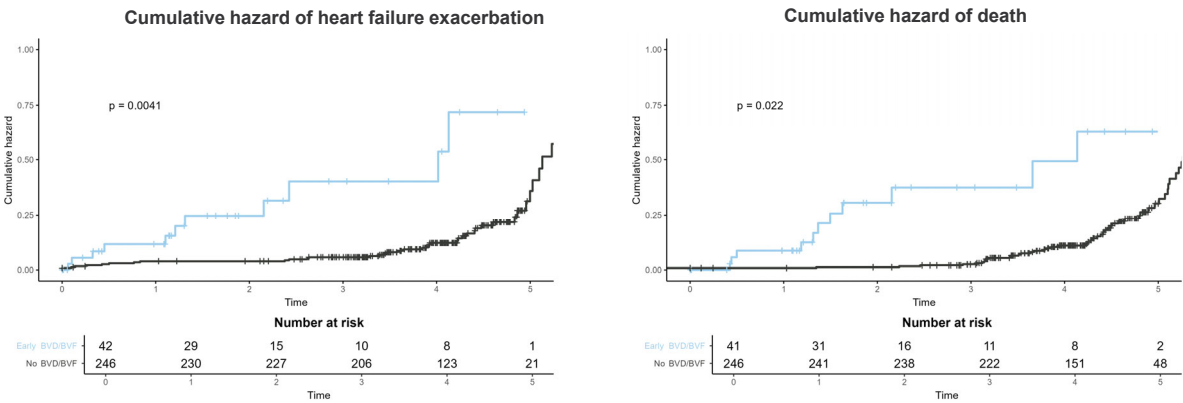
Unadjusted comparisons between early BVD and no early BVD

Characteristic	Early BVD	No early BVD	P
Female sex	59%	43%	0.044
NYHA class III–IV	50%	33%	0.031
BMI >30 kg/m ²	45%	29%	0.034
Valve size 20–23 mm	25/44	64/262	<0.001
Balloon-expandable valve	84%	69%	0.038



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MHI early BVD study: outcomes



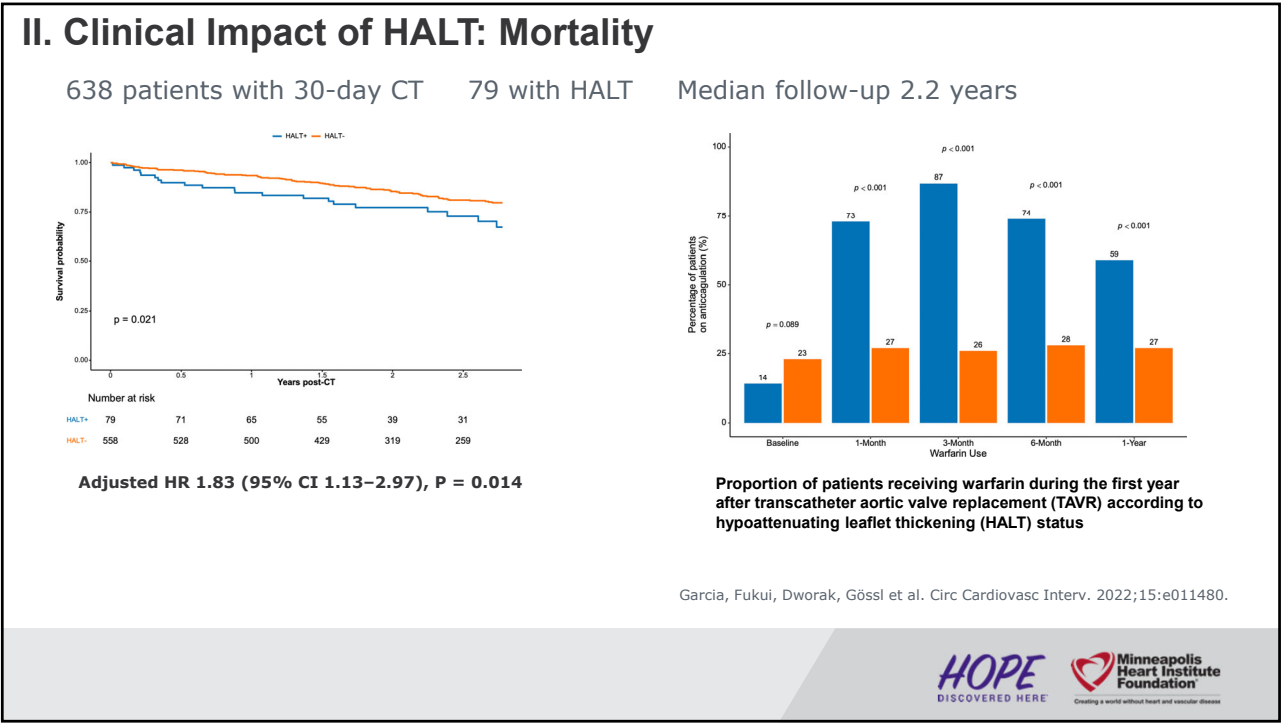
Re-intervention: 11.0 vs 0.8%, p<0.001

Earlier HF admission following TAVR: 1.1 yr vs 4.8 years, p<0.001

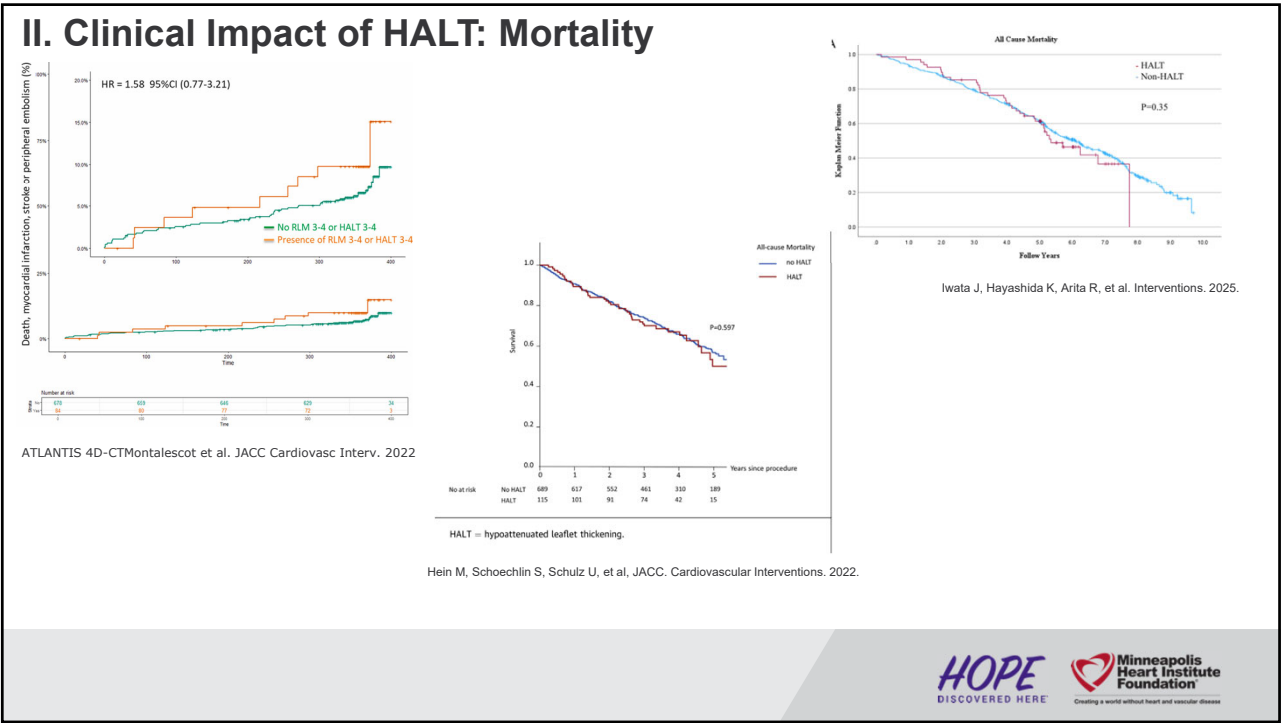
No difference in terms of MI, stroke, and infective endocarditis



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III. Insights on HALT Treatment

- Prevention vs treatment of established HALT
- Risk and benefits of anticoagulation
- Benefit of anticoagulation beyond imaging resolution (hard outcomes: death, BVD, stroke...)

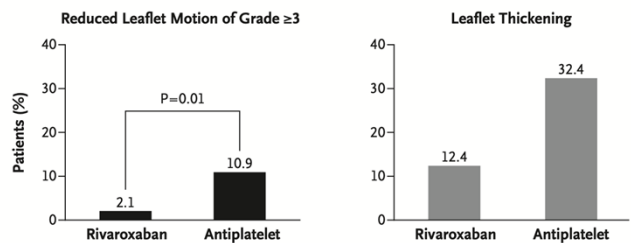


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GALLILEO CT: imaging and clinical outcomes

Early Rivaroxaban strategy vs dual antiplatelet (DAPT) strategy after TAVR

Reduced Leaflet Motion and Leaflet Thickening, Intention-to-Treat Analysis



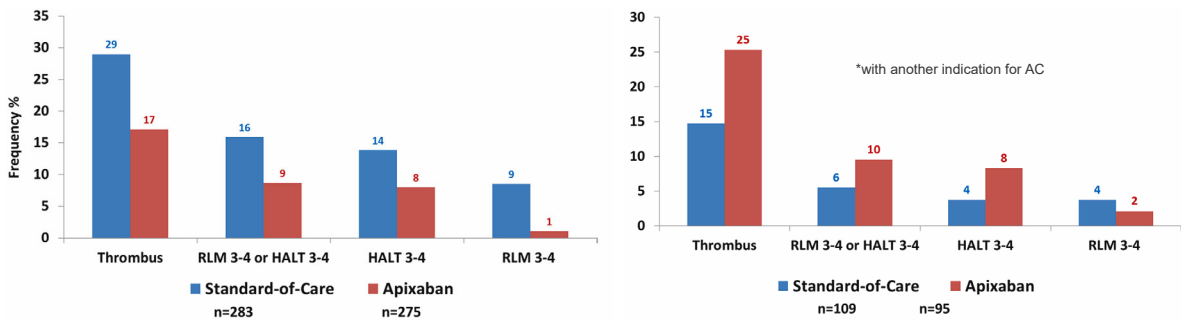
Endpoint	Rivaroxaban vs AP
Death / thromboembolism	HR 1.35 (95% CI 1.01–1.81)
Major Bleeding	HR 1.50 (95% CI 0.95-2.37)
All-cause death	HR 1.69 (95% CI 1.13–2.53)



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ATLANTIS 4D CT: apixaban vs anti-platelet and CT-detected thrombosis

762 patients with complete CT at approximately 3 months

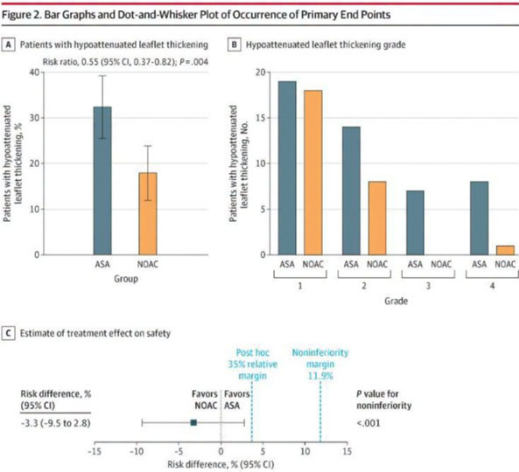


Grade 3–4 HALT or reduced leaflet motion:
Vs Anti-platelets: OR 0.51 (95% CI 0.30–0.86)
No significant reduction versus VKA in patients with another indication for AC

Montalescot et al. JACC Cardiovasc Interv. 2022



ACASA-TAVI: DOAC vs SAPT for 1 year



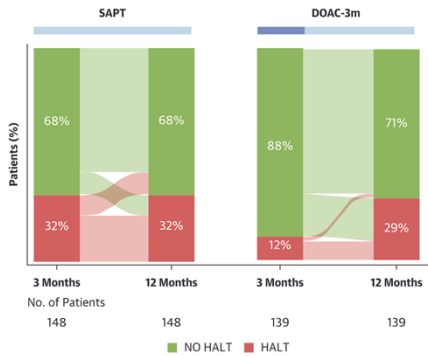
Dodgson et al. JAMA. 2026



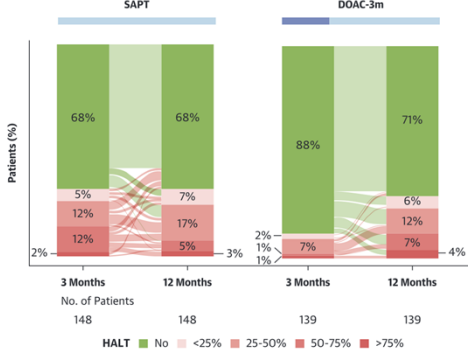
NOTION-4: 3 mo DOAC followed by SAPT vs SAPT

352 patients with TAVR

Alluvial Plots Showing the Incidence Rate of THVs With HALT at 3 and 12 Months Across Both Treatment Arms



Alluvial Plots Showing the Incidence Rate of Varying Degrees of HALT at 3 and 12 Months Across Both Groups



Jørgensen et al. JACC. 2026



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Treatment of established leaflet thrombosis

RESOLVE / SAVORY: repeat CT after detection of leaflet thrombosis

Management	CT outcome
Anticoagulation	Resolution in 36/36
No anticoagulation	Persistent thrombosis in 20/22

Warfarin for 3–6 months
Observational

Chakravarty et al. Lancet. 2017;389:2383–2392. Garcia et al. Circ Cardiovasc Interv. 2022;15:e011480.



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Treatment of established leaflet thrombosis

Warfarin vs DOAC

Management	CT outcome
Warfarin	Resolution in 15/16 (94%)
DOAC	Resolution in 26/30 (87%)

Non-randomized, underpowered.

Petrescu I et al. JACC 2020



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Current treatment recommendations

Presentation	Management
Incidental HALT, normal gradients	Individualized decision
HALT + restricted motion Elevated gradients	Consider OAC until resolution. OAC > S/DAPT Class IIa, level B
AC Agent	Warfarin and DOAC “equally effective” based on observational/registry/review data
Clinically relevant valve thrombosis	VKA as first-line therapy
Duration of anticoagulation	Imaging response, bleeding risk and other indications

Routine anticoagulation for all post-TAVR patients without HALT is not supported: better imaging outcomes vs potential worse clinical adverse events

2025 ESC/EACTS Guidelines.



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III. HALT Treatment-MHI Experience



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MHI management analysis: study design

Retrospective study, January 2016–December 2024

Population	Patients
TAVR cohort	1,311
CT-confirmed HALT	177
Complete resolution	96 (54.2%)
Persistent HALT	81 (45.8%)

Primary endpoint: complete HALT resolution on follow-up CT
Secondary endpoint: effect of AC duration on HALT resolution



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MHI management analysis: cohort characteristics

Median age 82 years 67% balloon-expandable valves 92% third generation

Characteristic	Resolved HALT	Persistent HALT	P
Prior stroke	4.2%	14%	0.025
Atrial fibrillation / flutter	24%	40%	0.026
Multivalvular disease	25%	49%	<0.001
Heart failure	55%	69%	0.058

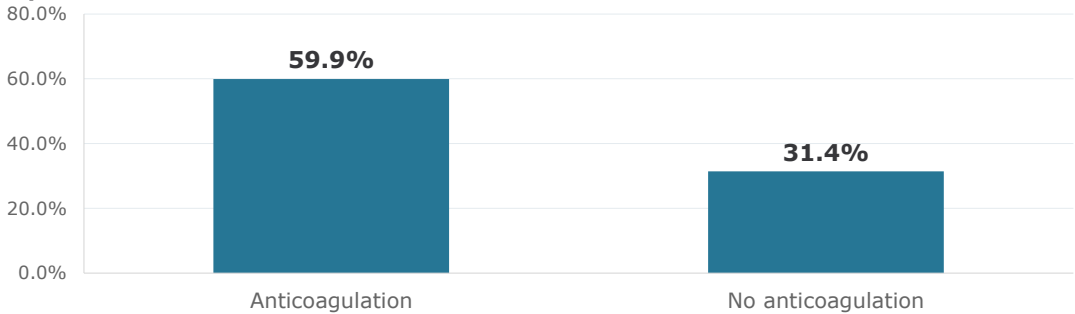
Persistent HALT occurred in patients with greater comorbidity

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MHI management analysis: anticoagulation

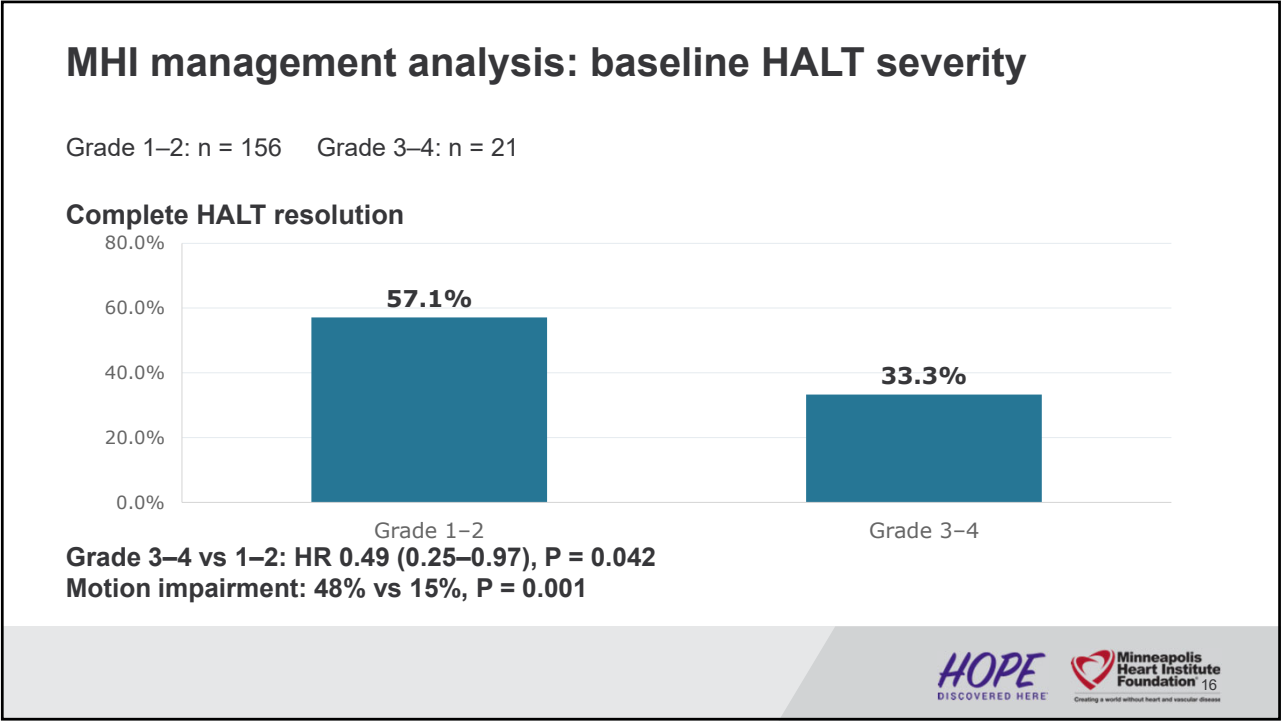
Warfarin preferred 142 anticoagulated 35 without anticoagulation

Complete HALT resolution

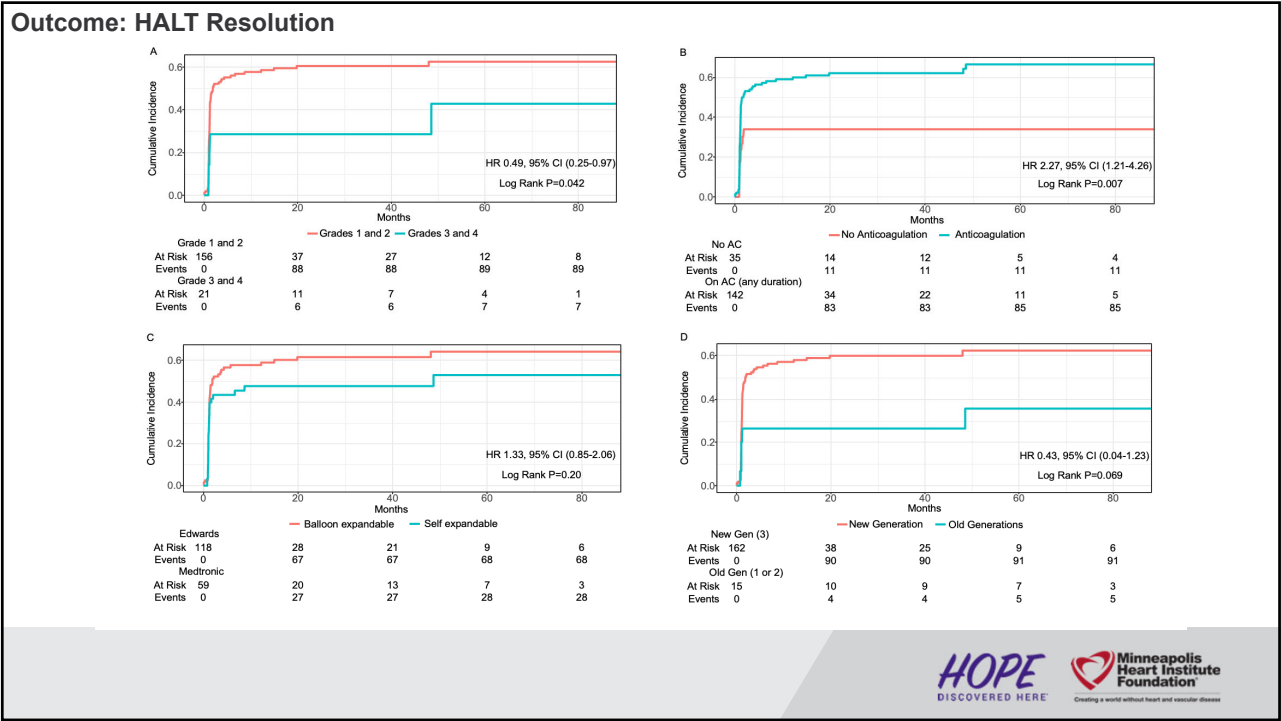


HR 2.27 (95% CI 1.21–4.26), P = 0.007

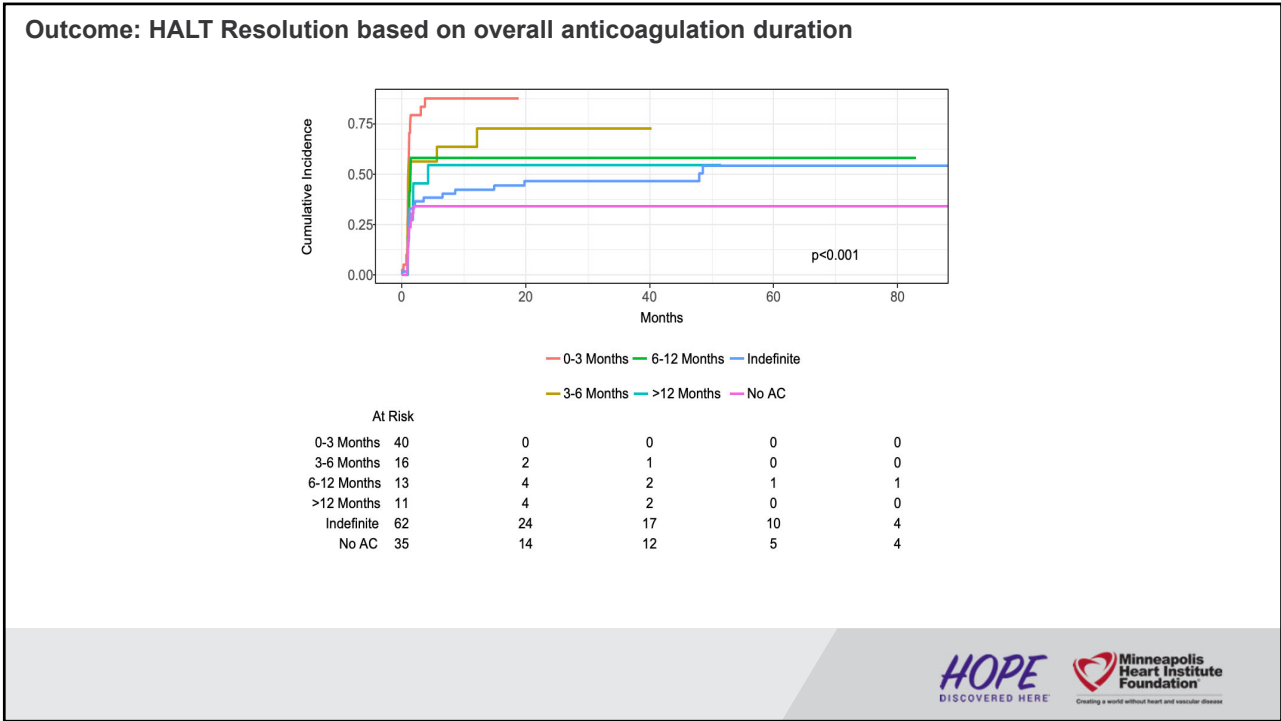
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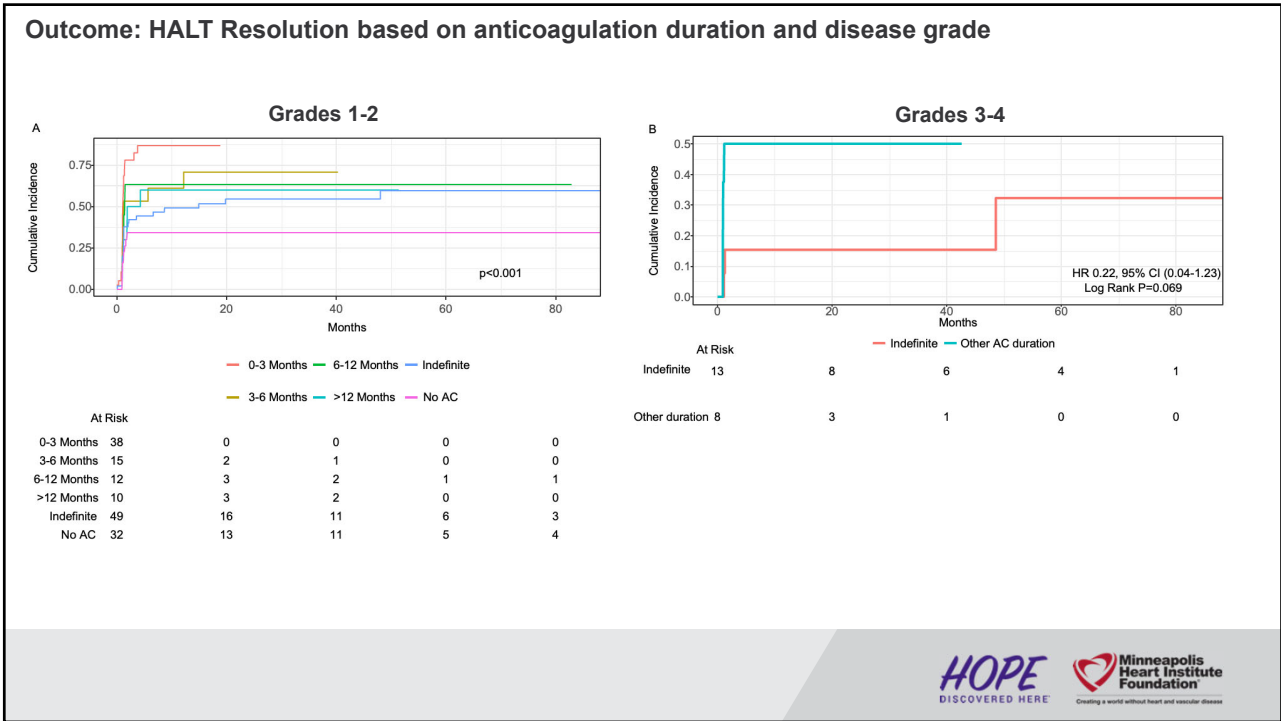
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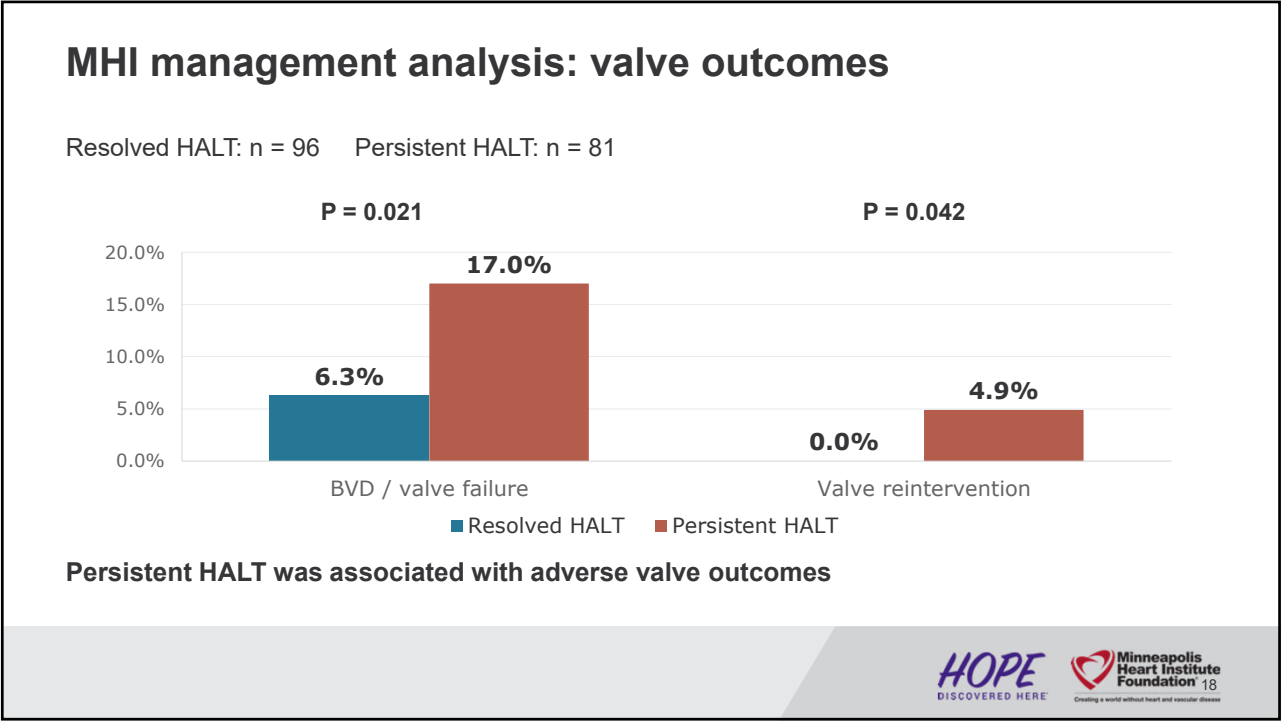
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