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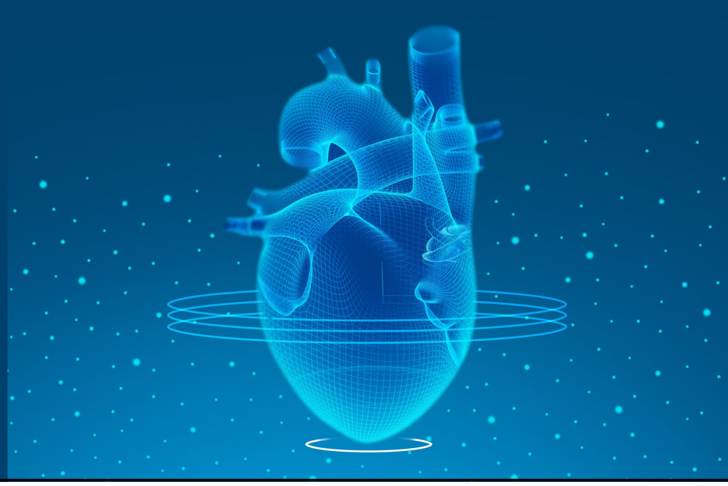
GRAND ROUNDS



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Survival of Patients Paced with Leadless Versus Conduction System Pacemakers

Maya Palmer, Anne Wong, Robert Hauser, John Zakaib, Sarah Schwager, Susan Casey, Melanie Kapphahn-Bergs, Dawn Witt, Evan Walser-Kuntz, Jay Sengupta

The Joseph F. Novogratz Family Heart Rhythm Center Minneapolis Heart Institute Foundation, Minneapolis, Minnesota

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Disclosures

- N/A

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Background

Electrophysiology: studying arrhythmias of the heart

Indications

- Atrial fibrillation
- Heart block
- Symptomatic bradycardia
- Sinus node dysfunction

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Treatments

- Pacemakers
  - Single chamber
  - Dual chamber
- Leadless pacing devices

→

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Electrophysiology: studying arrhythmias of the heart

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- Atrial fibrillation
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Treatments

- Pacemakers
  - Single chamber
  - Dual chamber
- Leadless pacing devices

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Complications

- Cardiac dyssynchrony
- Pacing-induced cardiomyopathy
- Tricuspid valve dysfunction
- Implant/device complications
- Lead complications

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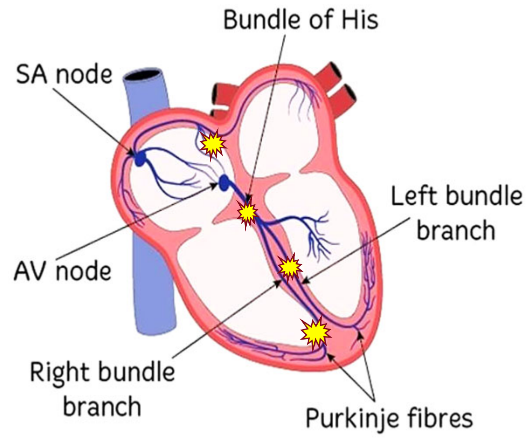
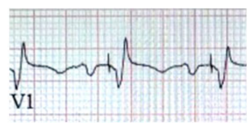
Background: Pacing Types



Atrial pacing

Ventricular pacing

Conduction system pacing



LBB pacing

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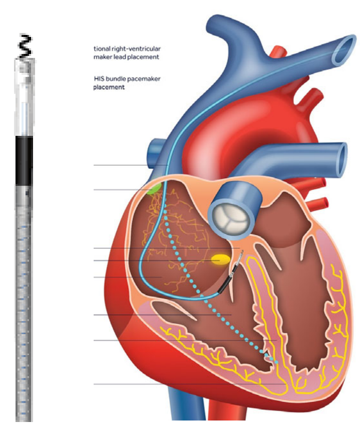
Background: Conduction System Pacing (CSP)



3830

Fig 1. *Image of CSP and 3830 lead.*

- CSP utilizes the body's natural conduction system opposed to pacing in the myocardium.
- Procedural difficulty has limited CSP use in clinical practice.
- CSP is often achieved with a 3830 4Fr lead.
- Ventricular synchrony is preserved but a transvenous lead is required.

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Background: Micra Leadless Pacemaker

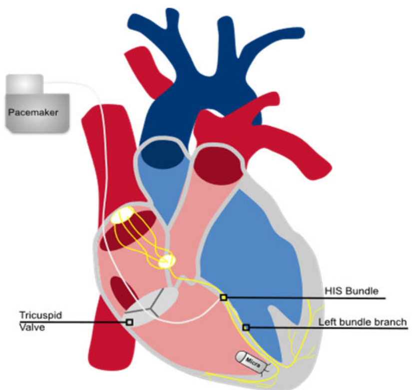

Fig 2. *Diagram of CSP and Micra devices.*
Image Credit: Maya Palmer

- Leadless pacemakers (LP) avoid pocket and transvenous lead complications.
- LPs are useful for patients with severe TR, limited vascular access, or high risk of infection.
- LPs are placed in the RV septum and do not provide synchronous pacing.
- Survival benefit of LPs versus CSP is unknown.

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Methods

- All patients with Micra LP or CSP implants from Jan 2010 – March 2022 were included.
- Kaplan-Meier survival curves were generated to compare patients with conduction system and lead-less pacemakers.
- A Cox proportional hazards model was used to assess the association between various comorbidities with 1 year mortality.

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Results: Patient Characteristics

Patient Demographics			
Variable	Conduction System Pacing (3830) N = 89	Leadless Pacing (Micra) N = 196	P-value
Age, years	78 (72, 84)	78 (71, 84)	0.7
Sex, Male (%)	44 (49%)	124 (63%)	0.028
BMI	27.8 (23.8, 32.0)	28.2 (24.7, 31.9)	0.9
Coronary artery disease	35 (39%)	90 (46%)	0.3
Valvular heart disease	27 (30%)	48 (24%)	0.3
Heart failure	46 (52%)	104 (53%)	0.8
Diabetes	25 (28%)	67 (34%)	0.4
Hypertension	66 (74%)	156 (79%)	0.4
Atrial fibrillation	56 (63%)	166 (85%)	**<0.001**
Left bundle branch block	14 (16%)	22 (11%)	0.3
Ventricular tachycardia	8 (9%)	5 (3%)	0.03

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Results: Patient Characteristics

Patient Demographics			
Variable	Conduction System Pacing (3830) N = 89	Leadless Pacing (Micra) N = 196	P-value
Baseline LV ejection fraction	60 (55, 65)	55 (50, 60)	**0.007**
≤35%	2 (2%)	7 (4%)	
36-54%	18 (20%)	47 (24%)	
≥55%	69 (78%)	140 (72%)	
Chronic kidney disease	40 (45%)	103 (53%)	0.2
stage III	28 (31%)	70 (36%)	0.5
stage IV-V	3 (3.4%)	38 (19%)	**<0.001**
Dialysis	2 (2.3%)	23 (12%)	0.010
Post implant			
Ventricular pacing ≥50%	66 (74.2%)	126 (65.0%)	0.2
Paced QRS duration (msec)	141 (123, 152)	171 (158, 184)	**<0.001**

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Results

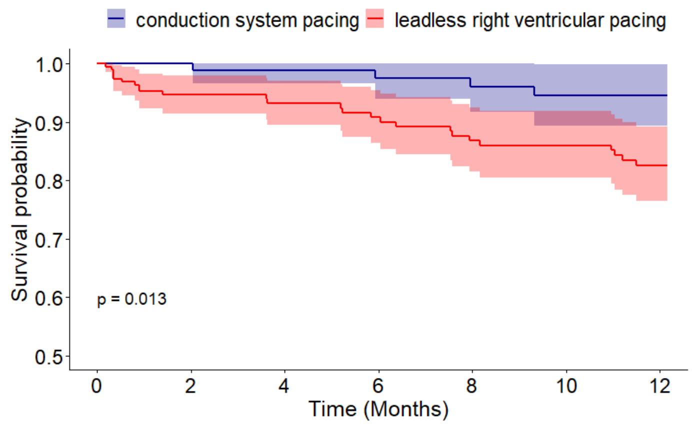

Fig 3. *Survival of leadless vs. conduction system pacing patients.*

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Results

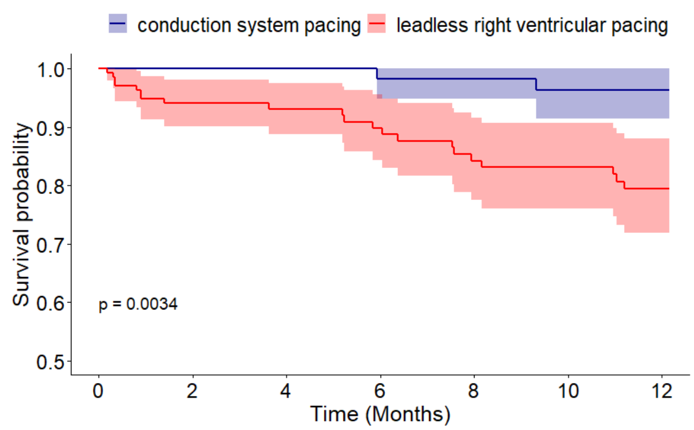

Fig 4. *Survival of leadless vs. conduction system pacing patients with baseline EF > 55.*

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Results

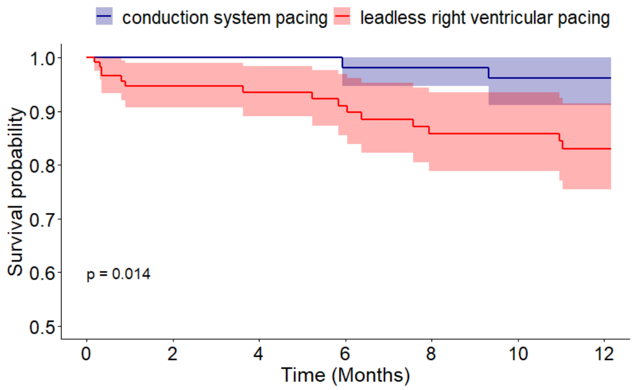

Fig 5. *Survival of leadless vs. conduction system pacing patients with baseline EF>55 and CKD stage < 4.*

Cox Proportional Hazards Model

	Hazard Ratio	95% Confidence Interval	P-value
Device Type (LP)	4.44	0.99, 19.9	0.051
Age	0.98	0.92, 1.03	0.4
Sex (male)	1.10	0.40, 3.01	0.8
Heart Failure	8.19	1.79, 3.01	**0.007**
CKD, Stage III	1.18	0.44, 3.18	0.7

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Limitations and Future Directions

Limitations

- Relatively short retrospective single-center study
- CSP candidacy restrictions
- Selection bias against CSP

Future Work

- Characterize differences in HF between the two cohorts
- Apply Charlson co-morbidity score
- Increase amount and length of follow-up

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Conclusions

- Results of this study suggest that CSP improves short-term survival compared to LP regardless of EF.
  - This implies that preservation of ventricular synchrony is important in our patient population.
- History of HF was particularly impactful on patient survival in the LP population.
- A leadless pacemaker capable of pacing the conduction system is needed.

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Acknowledgements

- We would like to acknowledge the Joseph F. Novogratz Family Heart Rhythm Center at the Minneapolis Heart Institute Foundation for their support on this study.

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Questions?

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March, 2023

Usefulness of preprocedural computed tomography in surgical aortic valve sizing

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Research Scholar
Minneapolis Heart Institute Foundation

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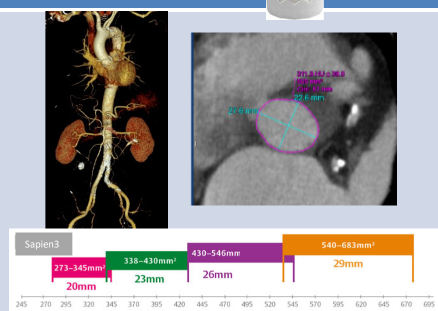
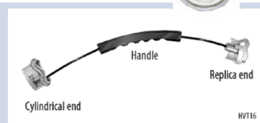
Background

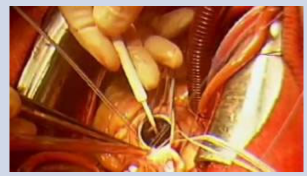
- Valve size selection methods are different between transcatheter aortic valve replacement (TAVR) and surgical aortic valve replacement (SAVR)

TAVR



SAVR





Usefulness of CT annulus sizing for SAVR is not understood

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Hypothesis / Aims

- Hypothesis:
  - Applying CT sizing for SAVR would lead to less operator bias and improved valve selection compared to the conventional sizer method
- Aims:
  - <u>Cohort 1 (2019-2021)</u>: Retrospectively evaluate the relationship between CT annulus size and implanted SAVR valve label size
  - <u>Cohort 2 (Jun 2022-Dec 2022)</u>: Compared CT annulus size and true annulus size (using Hegar dilators) during SAVR, and the classification of valve selection

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Methods - Cohort 1

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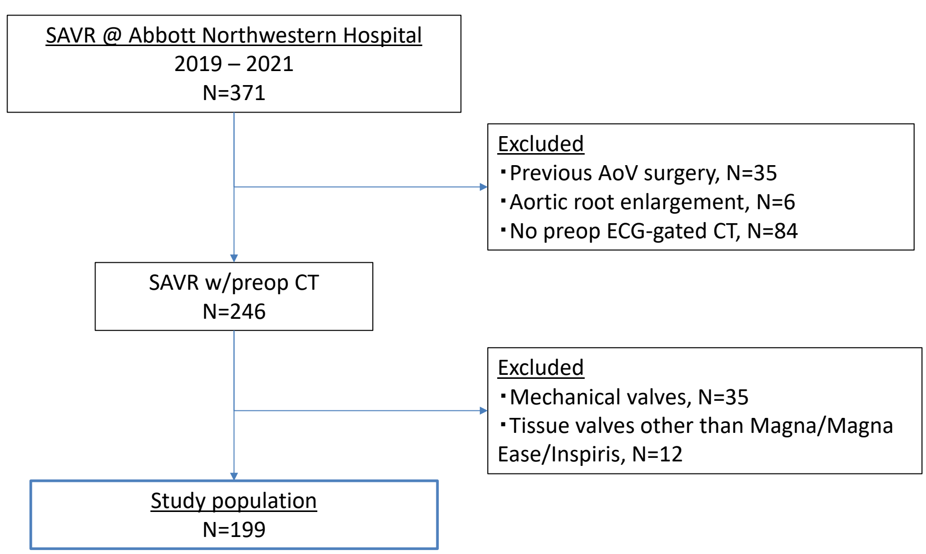
Study population



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Methods: CT prediction

- CT predicted minimum SAVR size

CT derived Annulus diameter	*Minimum* SAVR valve label size (Stent outer diameter)	External diameter of the valve (Magna or Magna Ease / Inspiris)
19.9 mm or smaller	19	24 / 25 mm
20.0 - 21.9 mm	21	26 / 27 mm
22.0 - 23.9 mm	23	28 / 29 mm
24.0 - 25.9 mm	25	30 / 32 mm
26.0 - 27.9 mm	27	32 / 34 mm
28.0 mm of larger	29	34 / 36 mm

- Classification of valve selection
  1. $SAVR_{CTpredicted}$ > SAVR (CT predicted minimal label size *larger than* SAVR received)
  2. $SAVR_{CTpredicted}$ = SAVR (CT predicted minimal label size *equal to* SAVR received)
  3. $SAVR_{CTpredicted}$ < SAVR (CT predicted minimal label size *smaller than* SAVR received)

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Results – Cohort 1

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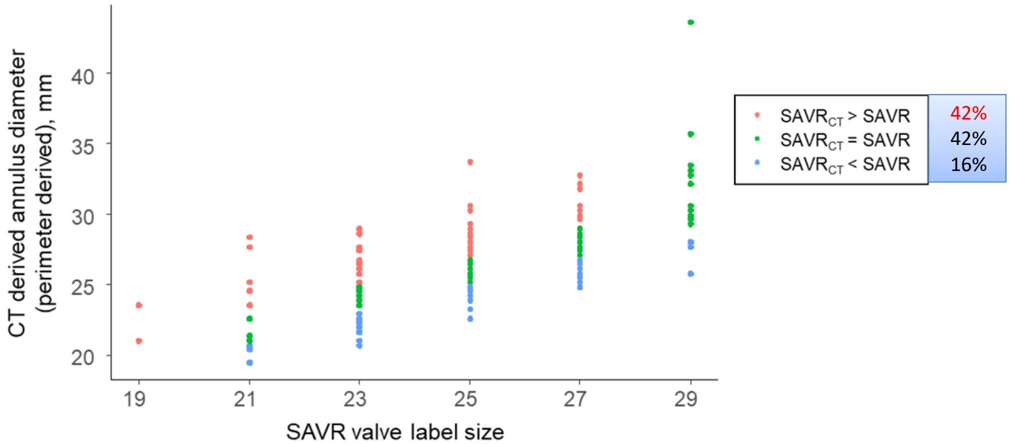
Results

Cohort 1 (Conventional sizing cohort)



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Results

	SAVR$_{CT}$ > SAVR N = 76	SAVR$_{CT}$ = SAVR N = 76	SAVR$_{CT}$ < SAVR N = 28	P value
Age, years	70 (65, 74)	70 (64, 76)	71 (66, 73)	0.99
Male	47 (61.8%)	48 (63.2%)	17 (60.7%)	0.97
Body surface area, m^2	2.03 (1.82, 2.16)	2.03 (1.88, 2.18)	1.97 (1.81, 2.05)	0.17
Bicuspid valve	37 (48.7%)	36 (47.4%)	10 (35.7%)	0.48
CT annulus measurements				
Area, mm^2	560 (510, 610)	487 (426, 555)	408 (361, 485)	**<0.001**
Area derived diameter, mm	26.7 (25.5, 27.9)	24.9 (23.3, 26.6)	22.8 (21.5, 24.9)	**<0.001**
Perimeter, mm	86 (82, 90)	81 (75, 85)	74 (69, 79)	**<0.001**
Perimeter derived diameter, mm	27.4 (26.1, 28.7)	25.8 (23.9, 27.2)	23.6 (22.0, 25.2)	**<0.001**
Ellipticity (Dmax/Dmin)	1.28 (1.22, 1.37)	1.26 (1.18, 1.33)	1.28 (1.24, 1.36)	0.33
CT other measurements				
Aortic valve calcium score, AU	2921 (1551, 4247)	2244 (1440, 3457)	2173 (1044, 3146)	0.065
SoV diameter (mean), mm	35.0 (32.1, 37.0)	33.3 (30.7, 37.0)	32.3 (29.5, 34.6)	**0.032**
SoV height (mean), mm	23.0 (21.3, 24.7)	22.3 (20.4, 25.0)	22.2 (19.6, 24.5)	0.33
ST junction diameter (mean), mm	30.8 (28.5, 32.6)	30.8 (28.0, 33.6)	28.3 (26.4, 30.7)	**0.014**
Ascending aorta, mm	36.0 (33.0, 38.0)	36.9 (33.0, 39.0)	34.2 (32.0, 37.1)	0.12

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Results

	$SAVR_{CT}$ > SAVR N = 76	$SAVR_{CT}$ = SAVR N = 76	$SAVR_{CT}$ < SAVR N = 28	P value
SAVR valve label size, mm	24.4 ± 2.1	25.5 ± 2.5	25.2 ± 2.1	0.016
Valve model				0.003
Inspiris Resilia	55 (72.4%)	68 (89.5%)	28 (100%)	
Magna	8 (10.5%)	1 (1.3%)	0 (0%)	
Magna Ease	13 (17.1%)	7 (9.2%)	0 (0%)	
Operators				<0.001
A	18 (23.7%)	8 (10.5%)	0 (0%)	
B	7 (9.2%)	12 (15.8%)	12 (42.9%)	
C	8 (10.5%)	1 (1.3%)	0 (0%)	
D	11 (14.5%)	4 (5.3%)	1 (3.6%)	
E	11 (14.5%)	13 (17.1%)	0 (0%)	
F	15 (19.7%)	19 (25.0%)	7 (25.0%)	
G	2 (2.6%)	6 (7.9%)	0 (2%)	
H	4 (5.3%)	13 (17.1%)	8 (28.6%)	

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Summary of Cohort 1

- The relationship between CT annulus size and implanted SAVR valve label size
  - showed a large variation
  - 42% of cases were classified as $SAVR_{CT}$ > SAVR (i.e. CT predicted minimal label size larger than SAVR received)
- Anatomical factors (larger aortic annulus) and operator dependency were associated with $SAVR_{CT}$ > SAVR.

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Cohort 2

(CT sizing cohort)

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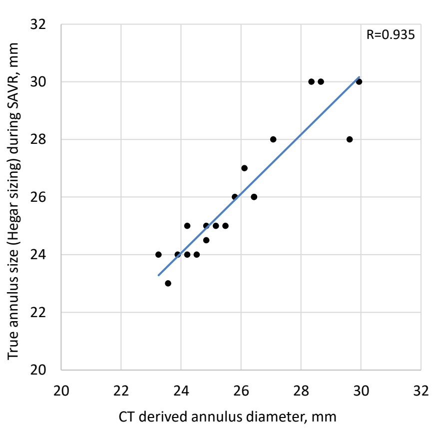
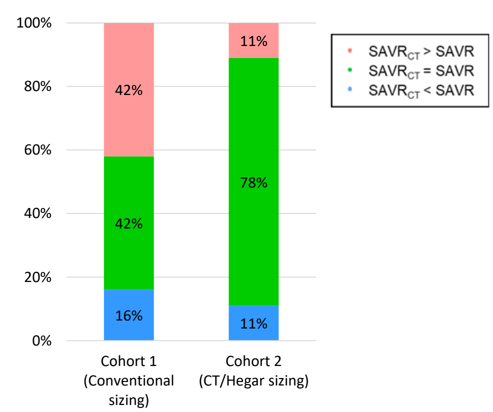
Cohort 2 (CT sizing)

- Jun 2022-Dec 2022, SAVR for bicuspid aortic disease
- Compared CT annulus size and true annulus sizing using Hegar dilators during SAVR, and the classification of valve selection
- Results





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Cohort 2 (CT sizing)

- CT-derived annulus size showed strong correlation with Hegar sizing during SAVR
  - Validates that CT sizing corresponds to the annulus size
- Applying CT sizing led to lower rates of $SAVR_{CT}$ > SAVR

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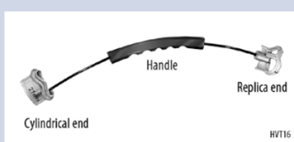
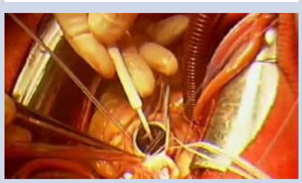
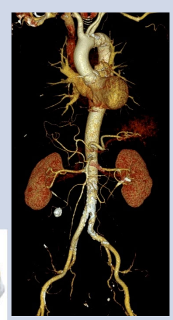
Conclusions

Conventional method (using sizers during surgery)





CT annulus sizing for SAVR



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Association Of Extracellular Volume And Global Longitudinal Strain Assessment by CT With Post TAVR Outcomes

HIDEKI KOIKE, MIHO FUKUI, AMR IDRIS, VICTOR Y. CHENG, HIROTOMO SATO, ATSUSHI OKADA, MAURICE ENRIQUEZ-SARANO, VINAYAK NILKANTH BAPAT, PAUL SORAJJA, JOHN R. LESSER, JOÃO L. CAVALCANTE

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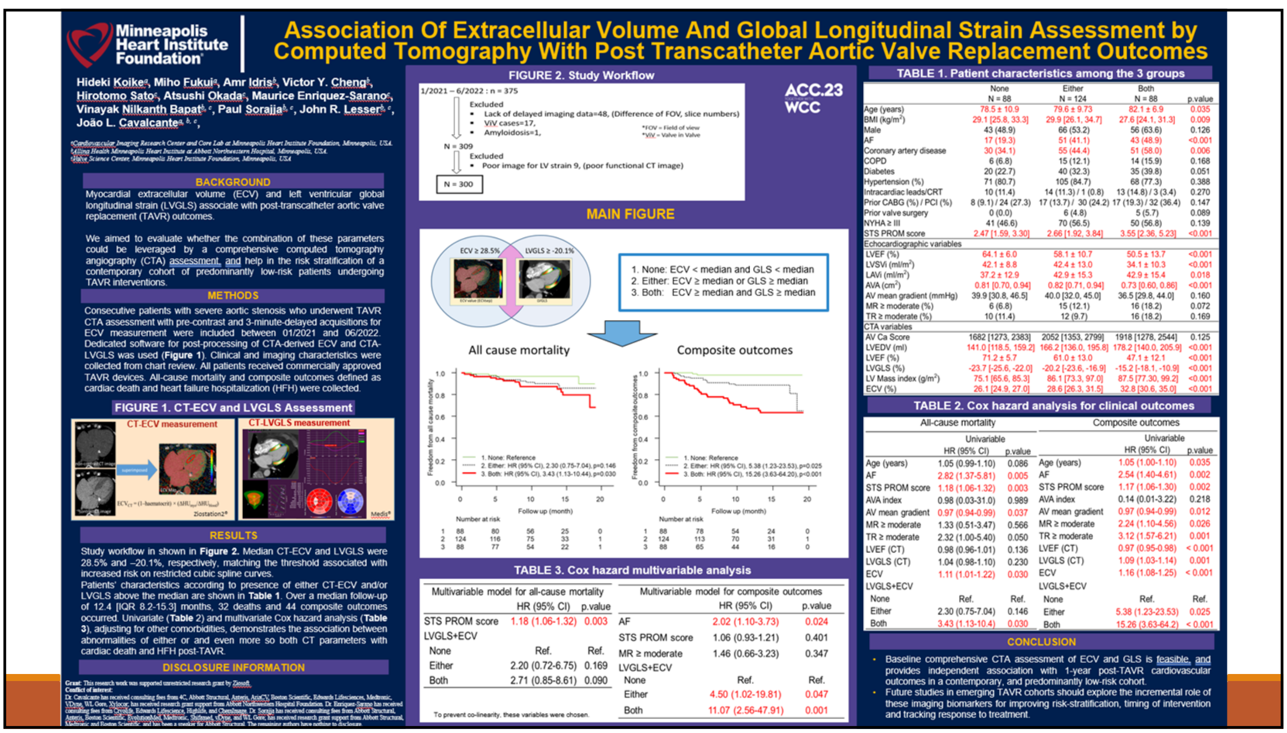

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Association Of Extracellular Volume And Global Longitudinal Strain Assessment by Computed Tomography With Post Transcatheter Aortic Valve Replacement Outcomes

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BACKGROUND

Myocardial extracellular volume (ECV) and left ventricular global longitudinal strain (LVGLS) associate with post-transcatheter aortic valve replacement (TAVR) outcomes.

We aimed to evaluate whether the combination of these parameters could be leveraged by a comprehensive computed tomography angiography (CTA) assessment, and help in the risk stratification of a contemporary cohort of predominantly low-risk patients undergoing TAVR interventions.

METHODS

Consecutive patients with severe aortic stenosis who underwent TAVR CTA assessment with pre-contrast and 3-minute-delayed acquisitions for ECV measurement were included between 01/2021 and 06/2022. Dedicated software for post-processing of CTA-derived ECV and CTA-LVGLS was used (**Figure 1**). Clinical and imaging characteristics were collected from chart review. All patients received commercially approved TAVR devices. All-cause mortality and composite outcomes defined as cardiac death and heart failure hospitalization (HFH) were collected.

FIGURE 1. CT-ECV and LVGLS Assessment

RESULTS

Study workflow in shown in **Figure 2.** Median CT-ECV and LVGLS were 28.5% and −20.1%, respectively, matching the threshold associated with increased risk on restricted cubic spline curves.
Patients' characteristics according to presence of either CT-ECV and/or LVGLS above the median are shown in **Table 1**. Over a median follow-up of 12.4 [IQR 8.2-15.3] months, 32 deaths and 44 composite outcomes occurred. Univariate (**Table** 2) and multivariate Cox hazard analysis (**Table 3**), adjusting for other comorbidities, demonstrates the association between abnormalities of either or and even more so both CT parameters with cardiac death and HFH post-TAVR.

DISCLOSURE INFORMATION

Grant: This research work was supported unrestricted research grant by Ziosoft.
Conflict of interest:
Dr. Cavalcante has received consulting fees from 4C, Abbott Structural, Anteris, AriaCV, Boston Scientific, Edwards Lifesciences, Medtronic, VDyne, WL Gore, Xylocor; has received research grant support from Abbott Northwestern Hospital Foundation. Dr. Enriquez-Sarano has received consulting fees from Cryolife, Edwards Lifescience, Highlife, and ChemImage. Dr. Sorajja has received consulting fees from Abbott Structural, Anteris, Boston Scientific, EvolutionMed, Medtronic, Shifamed, vDyne, and WL Gore; has received research grant support from Abbott Structural, Medtronic and Boston Scientific, and has been a speaker for Abbott Structural. The remaining authors have nothing to disclose.

FIGURE 2. Study Workflow

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MAIN FIGURE

TABLE 3. Cox hazard multivariable analysis

Multivariable model for all-cause mortality

	HR (95% CI)	p.value
STS PROM score	1.18 (1.06-1.32)	0.003
LVGLS+ECV		
None	Ref.	Ref.
Either	2.20 (0.72-6.75)	0.169
Both	2.71 (0.85-8.61)	0.090

To prevent co-linearity, these variables were chosen.

Multivariable model for composite outcomes

	HR (95% CI)	p.value
AF	2.02 (1.10-3.73)	0.024
STS PROM score	1.06 (0.93-1.21)	0.401
MR ≥ moderate	1.46 (0.66-3.23)	0.347
LVGLS+ECV		
None	Ref.	Ref.
Either	4.50 (1.02-19.81)	0.047
Both	11.07 (2.56-47.91)	0.001

TABLE 1. Patient characteristics among the 3 groups

	None N = 88	Either N = 124	Both N = 88	p.value
Age (years)	78.5 ± 10.9	79.6 ± 9.73	82.1 ± 6.9	0.035
BMI (kg/m²)	29.1 [25.8, 33.3]	29.9 [26.1, 34.7]	27.6 [24.1, 31.3]	0.009
Male	43 (48.9)	66 (53.2)	56 (63.6)	0.126
AF	17 (19.3)	51 (41.1)	43 (48.9)	<0.001
Coronary artery disease	30 (34.1)	55 (44.4)	51 (58.0)	0.006
COPD	6 (6.8)	15 (12.1)	14 (15.9)	0.168
Diabetes	20 (22.7)	40 (32.3)	35 (39.8)	0.051
Hypertension (%)	71 (80.7)	105 (84.7)	68 (77.3)	0.388
Intracardiac leads/CRT	10 (11.4)	14 (11.3) / 1 (0.8)	13 (14.8) / 3 (3.4)	0.270
Prior CABG (%) / PCI (%)	8 (9.1) / 24 (27.3)	17 (13.7) / 30 (24.2)	17 (19.3) / 32 (36.4)	0.147
Prior valve surgery	0 (0.0)	6 (4.8)	5 (5.7)	0.089
NYHA ≥ III	41 (46.6)	70 (56.5)	50 (56.8)	0.139
STS PROM score	2.47 [1.59, 3.30]	2.66 [1.92, 3.84]	3.55 [2.36, 5.23]	<0.001
Echocardiographic variables				
LVEF (%)	64.1 ± 6.0	58.1 ± 10.7	50.5 ± 13.7	<0.001
LVSVi (ml/m²)	42.1 ± 8.8	42.4 ± 13.0	34.1 ± 10.3	<0.001
LAVi (ml/m²)	37.2 ± 12.9	42.9 ± 15.3	42.9 ± 15.4	0.018
AVA (cm²)	0.81 [0.70, 0.94]	0.82 [0.71, 0.94]	0.73 [0.60, 0.86]	<0.001
AV mean gradient (mmHg)	39.9 [30.8, 46.5]	40.0 [32.0, 45.0]	36.5 [29.8, 44.0]	0.160
MR ≥ moderate (%)	6 (6.8)	15 (12.1)	16 (18.2)	0.072
TR ≥ moderate (%)	10 (11.4)	12 (9.7)	16 (18.2)	0.169
CTA variables				
AV Ca Score	1682 [1273, 2383]	2052 [1353, 2799]	1918 [1278, 2544]	0.125
LVEDV (ml)	141.0 [118.5, 159.2]	166.2 [136.0, 195.8]	178.2 [140.0, 205.9]	<0.001
LVEF (%)	71.2 ± 5.7	61.0 ± 13.0	47.1 ± 12.1	<0.001
LVGLS (%)	-23.7 [-25.6, -22.0]	-20.2 [-23.6, -16.9]	-15.2 [-18.1, -10.9]	<0.001
LV Mass index (g/m²)	75.1 [65.6, 85.3]	86.1 [73.3, 97.0]	87.5 [77.30, 99.2]	<0.001
ECV (%)	26.1 [24.9, 27.0]	28.6 [26.3, 31.5]	32.8 [30.6, 35.0]	<0.001

TABLE 2. Cox hazard analysis for clinical outcomes

All-cause mortality (Univariable)

	HR (95% CI)	p.value
Age (years)	1.05 (0.99-1.10)	0.086
AF	2.82 (1.37-5.81)	0.005
STS PROM score	1.18 (1.06-1.32)	0.003
AVA index	0.98 (0.03-31.0)	0.989
AV mean gradient	0.97 (0.94-0.99)	0.037
MR ≥ moderate	1.33 (0.51-3.47)	0.566
TR ≥ moderate	2.32 (1.00-5.40)	0.050
LVEF (CT)	0.98 (0.96-1.01)	0.136
LVGLS (CT)	1.04 (0.98-1.10)	0.230
ECV	1.11 (1.01-1.22)	0.030
LVGLS+ECV		
None	Ref.	Ref.
Either	2.30 (0.75-7.04)	0.146
Both	3.43 (1.13-10.4)	0.030

Composite outcomes (Univariable)

	HR (95% CI)	p.value
Age (years)	1.05 (1.00-1.10)	0.035
AF	2.54 (1.40-4.61)	0.002
STS PROM score	1.17 (1.06-1.30)	0.002
AVA index	0.14 (0.01-3.22)	0.218
AV mean gradient	0.97 (0.94-0.99)	0.012
MR ≥ moderate	2.24 (1.10-4.56)	0.026
TR ≥ moderate	3.12 (1.57-6.21)	0.001
LVEF (CT)	0.97 (0.95-0.98)	< 0.001
LVGLS (CT)	1.09 (1.03-1.14)	0.001
ECV	1.16 (1.08-1.25)	< 0.001
LVGLS+ECV		
None	Ref.	Ref.
Either	5.38 (1.23-23.53)	0.025
Both	15.26 (3.63-64.2)	< 0.001

CONCLUSION

- Baseline comprehensive CTA assessment of ECV and GLS is feasible, and provides independent association with 1-year post-TAVR cardiovascular outcomes in a contemporary, and predominantly low-risk cohort.
- Future studies in emerging TAVR cohorts should explore the incremental role of these imaging biomarkers for improving risk-stratification, timing of intervention and tracking response to treatment.

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Association Of Extracellular Volume And Global Longitudinal Strain Assessment by Computed Tomography With Post Transcatheter Aortic Valve Replacement Outcomes

BACKGROUND

Myocardial extracellular volume (ECV) and left ventricular global longitudinal strain (LVGLS) associate with post-transcatheter aortic valve replacement (TAVR) outcomes.

We aimed to evaluate whether the combination of these parameters could be leveraged by a comprehensive computed tomography angiography (CTA) assessment, and help in the risk stratification of a contemporary cohort of predominantly low-risk patients undergoing TAVR interventions.

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METHODS

Consecutive patients with severe aortic stenosis who underwent TAVR CTA assessment with pre-contrast and 3-minute-delayed acquisitions for ECV measurement were included between 01/2021 and 06/2022. Dedicated software for post-processing of CTA-derived ECV and CTA-LVGLS was used (**Figure 1**). Clinical and imaging characteristics were collected from chart review. All patients received commercially approved TAVR devices. All-cause mortality and composite outcomes defined as cardiac death and heart failure hospitalization (HFH) were collected.

FIGURE 1. CT-ECV and LVGLS Assessment

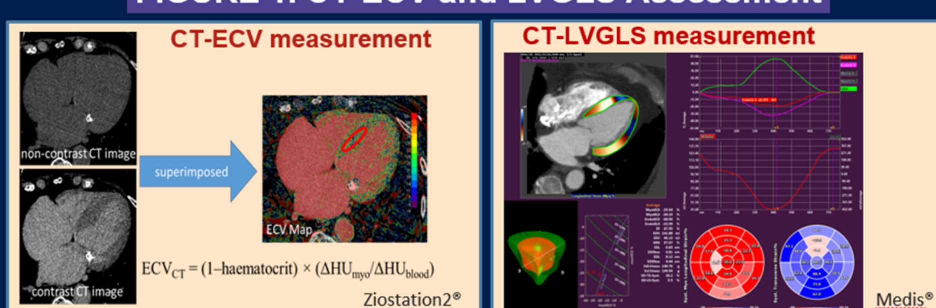

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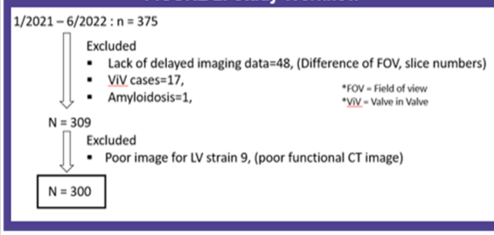
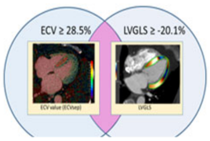
FIGURE 2. Study Workflow





1. None: ECV < median and GLS < median
2. Either: ECV ≥ median or GLS ≥ median
3. Both: ECV ≥ median and GLS ≥ median

TABLE 1. Patient characteristics among the 3 groups

	None N = 88	Either N = 124	Both N = 88	p.value
Age (years)	78.5 ± 10.9	79.6 ± 9.73	82.1 ± 6.9	0.035
BMI (kg/m^2)	29.1 [25.8, 33.3]	29.9 [26.1, 34.7]	27.6 [24.1, 31.3]	0.009
Male	43 (48.9)	66 (53.2)	56 (63.6)	0.126
AF	17 (19.3)	51 (41.1)	43 (48.9)	<0.001
Coronary artery disease	30 (34.1)	55 (44.4)	51 (58.0)	0.006
COPD	6 (6.8)	15 (12.1)	14 (15.9)	0.168
Diabetes	20 (22.7)	40 (32.3)	35 (39.8)	0.051
Hypertension (%)	71 (80.7)	105 (84.7)	68 (77.3)	0.388
Intracardiac leads/CRT	10 (11.4)	14 (11.3) / 1 (0.8)	13 (14.8) / 3 (3.4)	0.270
Prior CABG (%) / PCI (%)	8 (9.1) / 24 (27.3)	17 (13.7) / 30 (24.2)	17 (19.3) / 32 (36.4)	0.147
Prior valve surgery	0 (0.0)	6 (4.8)	5 (5.7)	0.089
NYHA ≥ III	41 (46.6)	70 (56.5)	50 (56.8)	0.139
STS PROM score	2.47 [1.59, 3.30]	2.66 [1.92, 3.84]	3.55 [2.36, 5.23]	<0.001
Echocardiographic variables				
LVEF (%)	64.1 ± 6.0	58.1 ± 10.7	50.5 ± 13.7	<0.001
LVSVi (ml/m^2)	42.1 ± 8.8	42.4 ± 13.0	34.1 ± 10.3	<0.001
LAVi (ml/m^2)	37.2 ± 12.9	42.9 ± 15.3	42.9 ± 15.4	0.018
AVA (cm^2)	0.81 [0.70, 0.94]	0.82 [0.71, 0.94]	0.73 [0.60, 0.86]	<0.001
AV mean gradient (mmHg)	39.9 [30.8, 46.5]	40.0 [32.0, 45.0]	36.5 [29.8, 44.0]	0.160
MR ≥ moderate (%)	6 (6.8)	15 (12.1)	16 (18.2)	0.072
TR ≥ moderate (%)	10 (11.4)	12 (9.7)	16 (18.2)	0.169
CTA variables				
AV Ca Score	1682 [1273, 2383]	2052 [1353, 2799]	1918 [1278, 2544]	0.125
LVEDV (ml)	141.0 [118.5, 159.2]	166.2 [136.0, 195.8]	178.2 [140.0, 205.9]	<0.001
LVEF (%)	71.2 ± 5.7	61.0 ± 13.0	47.1 ± 12.1	<0.001
LVGLS (%)	-23.7 [-25.6, -22.0]	-20.2 [-23.6, -16.9]	-15.2 [-18.1, -10.9]	<0.001
LV Mass index (g/m^2)	75.1 [65.6, 85.3]	86.1 [73.3, 97.0]	87.5 [77.30, 99.2]	<0.001
ECV (%)	26.1 [24.9, 27.0]	28.6 [26.3, 31.5]	32.8 [30.6, 35.0]	<0.001

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TABLE 2. Cox hazard analysis for clinical outcomes

	All-cause mortality Univariable HR (95% CI)	All-cause mortality p.value		Composite outcomes Univariable HR (95% CI)	Composite outcomes p.value
Age (years)	1.05 (0.99-1.10)	0.086	Age (years)	1.05 (1.00-1.10)	0.035
AF	2.82 (1.37-5.81)	0.005	AF	2.54 (1.40-4.61)	0.002
STS PROM score	1.18 (1.06-1.32)	0.003	STS PROM score	1.17 (1.06-1.30)	0.002
AVA index	0.98 (0.03-31.0)	0.989	AVA index	0.14 (0.01-3.22)	0.218
AV mean gradient	0.97 (0.94-0.99)	0.037	AV mean gradient	0.97 (0.94-0.99)	0.012
MR ≥ moderate	1.33 (0.51-3.47)	0.566	MR ≥ moderate	2.24 (1.10-4.56)	0.026
TR ≥ moderate	2.32 (1.00-5.40)	0.050	TR ≥ moderate	3.12 (1.57-6.21)	0.001
LVEF (CT)	0.98 (0.96-1.01)	0.136	LVEF (CT)	0.97 (0.95-0.98)	< 0.001
LVGLS (CT)	1.04 (0.98-1.10)	0.230	LVGLS (CT)	1.09 (1.03-1.14)	0.001
ECV	1.11 (1.01-1.22)	0.030	ECV	1.16 (1.08-1.25)	< 0.001
LVGLS+ECV			LVGLS+ECV		
None	Ref.	Ref.	None	Ref.	Ref.
Either	2.30 (0.75-7.04)	0.146	Either	5.38 (1.23-23.53)	0.025
Both	3.43 (1.13-10.4)	0.030	Both	15.26 (3.63-64.2)	< 0.001

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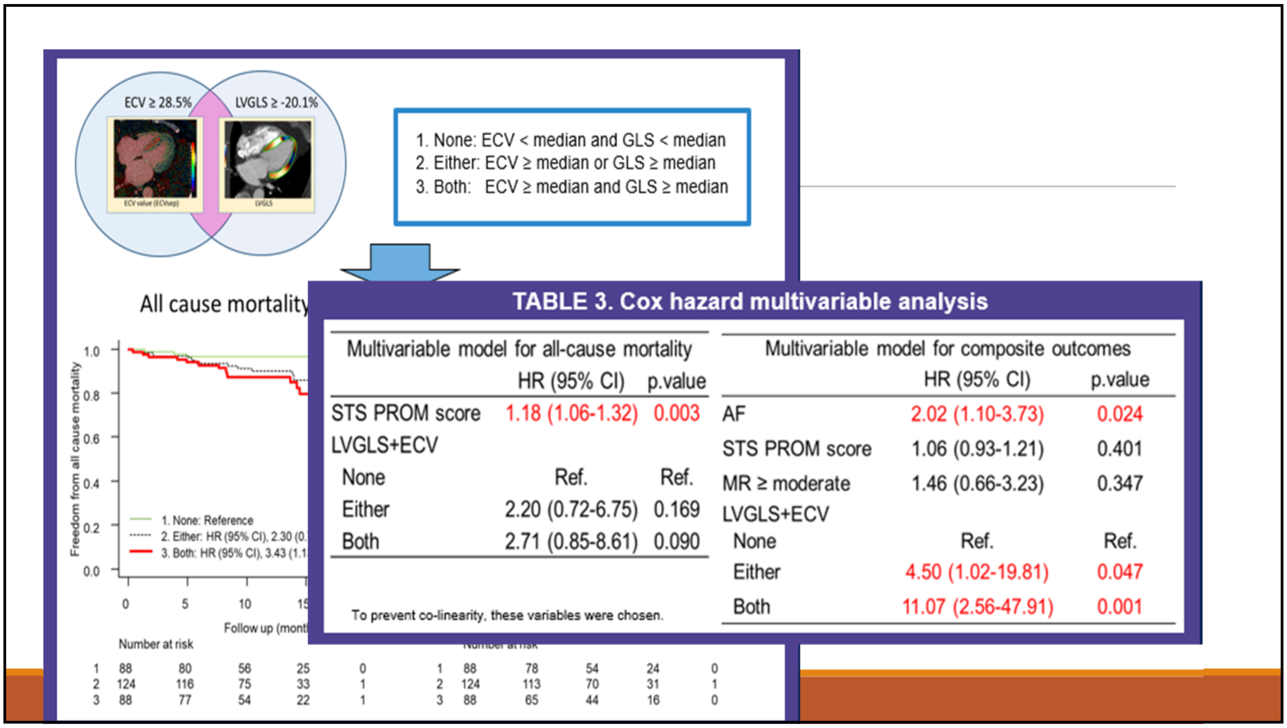

TABLE 3. Cox hazard multivariable analysis

Multivariable model for all-cause mortality	HR (95% CI)	p.value
STS PROM score	1.18 (1.06-1.32)	0.003
LVGLS+ECV		
None	Ref.	Ref.
Either	2.20 (0.72-6.75)	0.169
Both	2.71 (0.85-8.61)	0.090

To prevent co-linearity, these variables were chosen.

Multivariable model for composite outcomes	HR (95% CI)	p.value
AF	2.02 (1.10-3.73)	0.024
STS PROM score	1.06 (0.93-1.21)	0.401
MR ≥ moderate	1.46 (0.66-3.23)	0.347
LVGLS+ECV		
None	Ref.	Ref.
Either	4.50 (1.02-19.81)	0.047
Both	11.07 (2.56-47.91)	0.001

1	88	80	56	25	0
2	124	116	75	33	1
3	88	77	54	22	1

1	88	78	54	24	0
2	124	113	70	31	1
3	88	65	44	16	0

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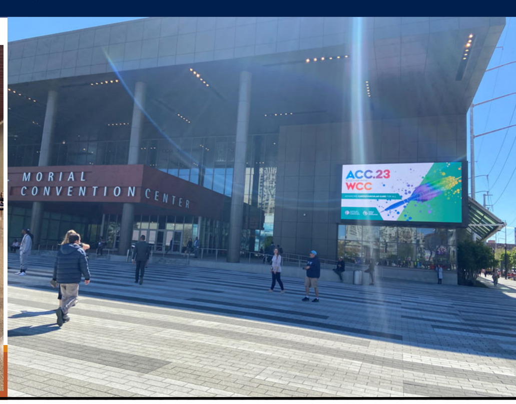
CONCLUSION

- Baseline comprehensive CTA assessment of ECV and GLS is feasible and provides independent association with 1-year post-TAVR cardiovascular outcomes in a contemporary, and predominantly low-risk cohort.
- Future studies in emerging TAVR cohorts should explore the incremental role of these imaging biomarkers for improving risk-stratification, timing of intervention and tracking response to treatment.



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Thank you so much !!

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PROGRESS CTO

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Creating a world without heart and vascular disease

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Impact of Calcium on Procedural Techniques and Outcomes of Chronic Total Occlusion Percutaneous Coronary Intervention: Insights from the PROGRESS-CTO registry

March 27, 2023

Spyridon Kostantinis, MD

(on the behalf of the PROGRESS-CTO investigators)

Research Scholar, Center for Coronary Artery Disease (CCAD),

Minneapolis Heart Institute Foundation

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Disclosure of Relevant Financial Relationships

I, Spyridon Kostantinis DO NOT have a financial interest/arrangement or affiliation with one or more organizations that could be perceived as a real or apparent conflict of interest in the context of the subject of this presentation.

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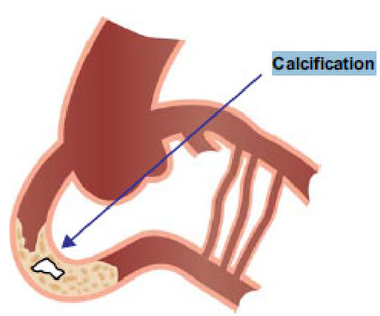
Background

Coronary calcification is common and often increases the difficulty of chronic total occlusion (CTO) percutaneous coronary intervention (PCI)



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Brilakis ES. Manual of chronic total occlusion interventions: a step-by-step approach. 3rd Edition: Academic Press, 2023.

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Goal

To examine the impact of calcium on the procedural techniques and outcomes of CTO PCI in a large multicenter registry

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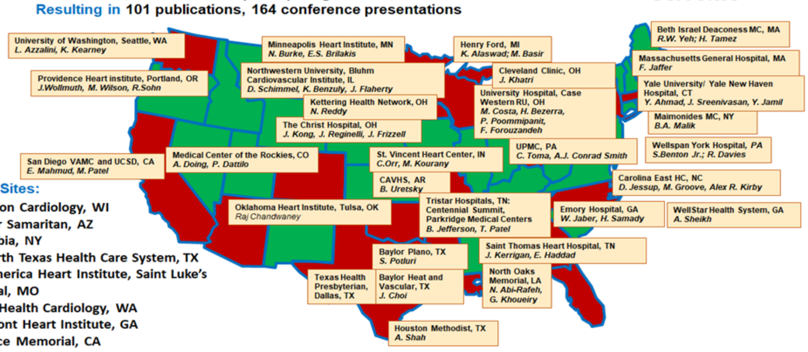
PROGRESS-CTO USA Sites

Global Coordinating Center: Chairman/PI: E. S. Brilakis; **Global Director:** B.V. Rangan;
Database Managers: Judit Karacsonyi, Spyridon Kostantinis, Bahadir Simsek, Athanasios Rempakos
Operational Support: Olga Mastrodemos
Project Impact: Data from 13,556 cases at 69 participating centers, 10 countries
Resulting in 101 publications, 164 conference presentations

PROGRESS CTO
NCT02061436



Historical Sites:

1. Appleton Cardiology, WI
2. Banner Samaritan, AZ
3. Columbia, NY
4. VA North Texas Health Care System, TX
5. MidAmerica Heart Institute, Saint Luke's Hospital, MO
6. Peace Health Cardiology, WA
7. Piedmont Heart Institute, GA
8. Torrance Memorial, CA
9. Minneapolis VA Medical Center
10. Memorial Hospital, Jacksonville, FL
11. Oklahoma VA Medical Center, OK
12. Providence Hospital, Waco, TX
13. Trinity Medical Center WNY, Buffalo, NY
14. Tulane University, LA
15. University of Texas Southwestern Medical Center

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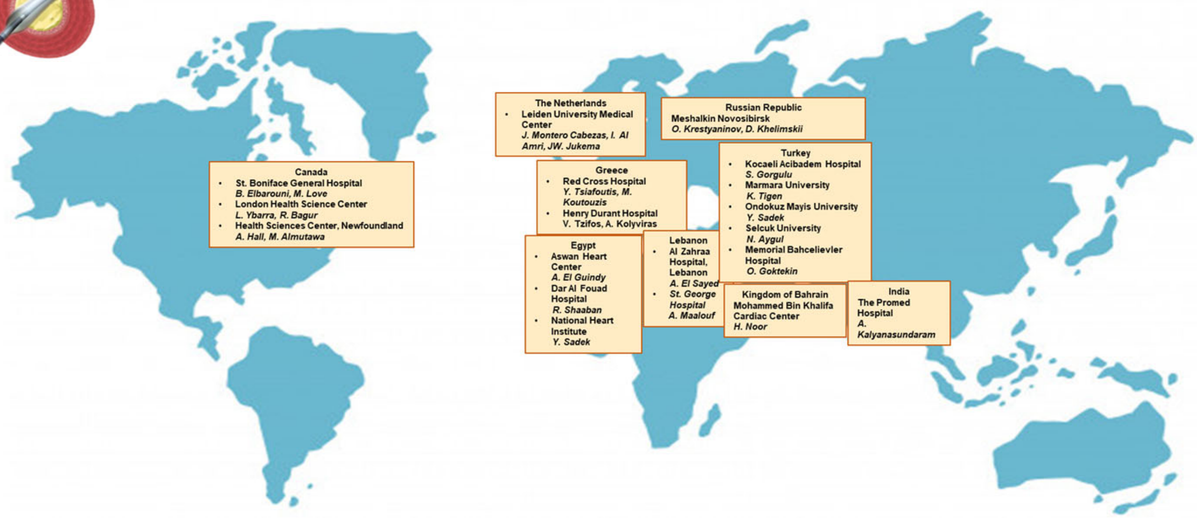
PROGRESS-CTO International Sites



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Statistical analysis

- Categorical variables are presented as percentages and compared using Pearson's chi-square test or Fisher's exact test.
- Continuous variables are presented as mean ± SD or as median (interquartile range [IQR]) and compared using the Student's t-test and the Wilcoxon rank sum test.
- A 2-sided p value of 0.05 was considered to indicate statistical significance.

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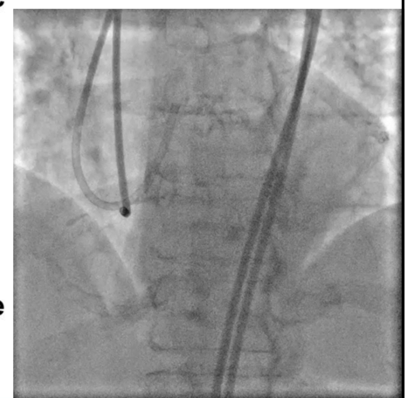
Classification of Coronary Calcification

ACC/AHA Type A Lesion

- **None:** No radiopacity
- **Mild:** Faint radiopacities noted during cardiac cycles

ACC/AHA Type B Lesion

- **Moderate:** Dense radiopacities noted during cardiac cycle before contrast injection.
- **Severe:** Dense radiopacities noted on both sides of the arterial wall ("tram-track") without cardiac motion before contrast injection.



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Smith SC Jr, Feldman TE, Hirshfeld JW Jr, Jacobs AK, Kern MJ, King SB III, Morrison DA, O'Neill WW, Schaff HV, Whitlow PL, Williams DO. ACC/AHA/SCAI 2005 guideline update for percutaneous coronary intervention: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (ACC/AHA/SCAI Writing Committee to Update the 2001 Guidelines for Percutaneous Coronary Intervention).Circulation. 2006;113:e166–e286.

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Results

- N=12,344 CTO PCIs
- 44 centers
- 2012-2022

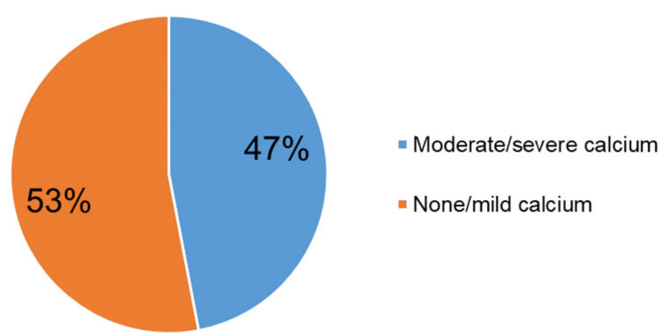

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Table 1. Baseline clinical characteristics

Variable	Moderate/severe calcium	None/mild calcium	*P* value
	n=5,747, 47%	n=6,597, 53%	
Age (years)	67 ± 13	62 ± 10	<0.001
Men	82%	81%	0.366
Hypertension	92%	87%	<0.001
Diabetes mellitus	48%	38%	<0.001
Dyslipidemia	92%	80%	<0.001
Prior MI	44%	45%	0.062
Prior CABG	40%	19%	<0.001
Prior PCI	66%	60%	<0.001
Congestive heart failure	31%	26%	<0.001
LVEF (%)	49 ± 13	51 ± 13	<0.001
Cerebrovascular disease	11%	9%	<0.001
Peripheral arterial disease	18%	11%	<0.001

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CABG: coronary artery bypass grafting; LVEF: left ventricular ejection fraction; MI: myocardial infarction; PCI: percutaneous coronary intervention.

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Table 2. Angiographic characteristics

Variable	Moderate/severe calcium	None/mild calcium	*P* value
	n=5,747, 47%	n=6,597, 53%	
CTO Target Vessel			<0.001
▪ RCA	55%	51%	
▪ LAD	25%	27%	
▪ LCX	18%	20%	
Occlusion length (mm)	35 ± 23	28 ± 19	<0.001
Proximal cap ambiguity	41%	30%	<0.001
Moderate/severe proximal tortuosity	42%	20%	<0.001
Prior attempt to open CTO	21%	17%	<0.001
J-CTO score	3.0 ± 1.1	1.9 ± 1.2	<0.001
PROGRESS-CTO score	1.4 ± 1.1	1.1 ± 1.0	<0.001

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CTO: chronic total occlusion; J: Japan; LAD: left anterior descending; LCX: left circumflex; PROGRESS-CTO: prospective global registry for the study of chronic total occlusion intervention; RCA: right coronary artery.

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Table 3. Procedural characteristics

Variable	Moderate/severe calcium n=5,747, 47%	None/mild calcium n=6,597, 53%	*P* value
Crossing strategies used			<0.001
▪ AW	85%	90%	
▪ Retrograde	40%	24%	
▪ ADR	27%	16%	
IVUS	60%	42%	<0.001
Procedure time (min)	138 (94, 195)	95 (64, 137)	<0.001
Fluoroscopy time (min)	53 (33, 81)	35 (22, 56)	<0.001
AK radiation dose (Gray)	2.4 (1.3, 4.1)	2.0 (1.1, 3.5)	<0.001
Contrast volume (ml)	210 (150, 300)	210 (150, 300)	0.932
LV assist device	6%	2%	<0.001

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ADR: antegrade dissection and re-entry; AK: air kerma; AW: antegrade wiring; IVUS: intravascular ultrasound; LV: left ventricular.

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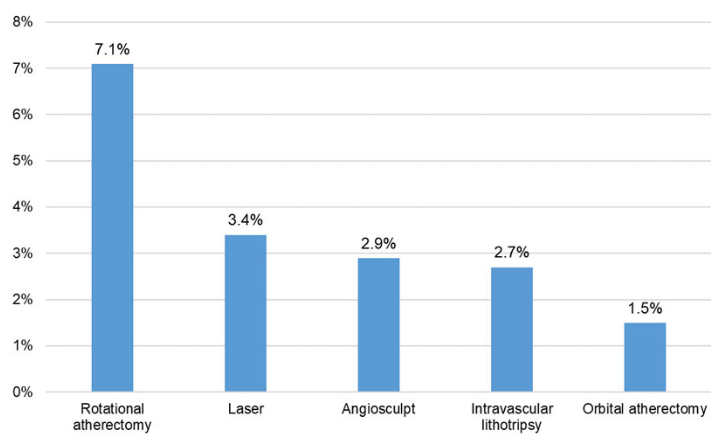
Lesion preparation for calcified lesions

Balloon angioplasty was the most common lesion preparation technique for moderate to severe calcified lesions (76.1%)



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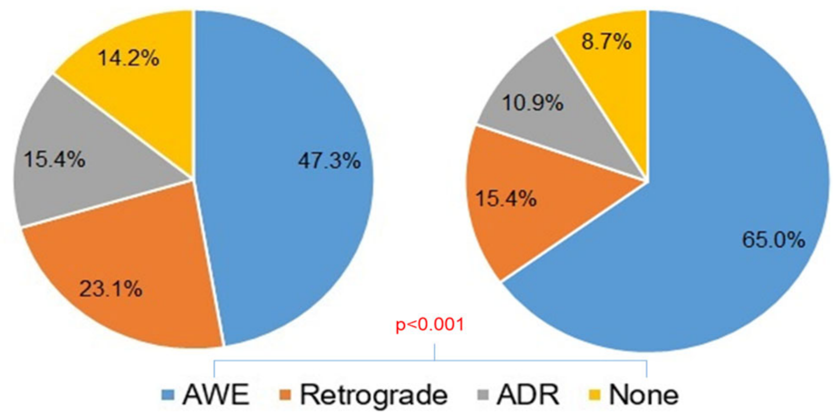
Final crossing strategy



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ADR: antegrade dissection and re-entry; AWE: antegrade wire escalation.

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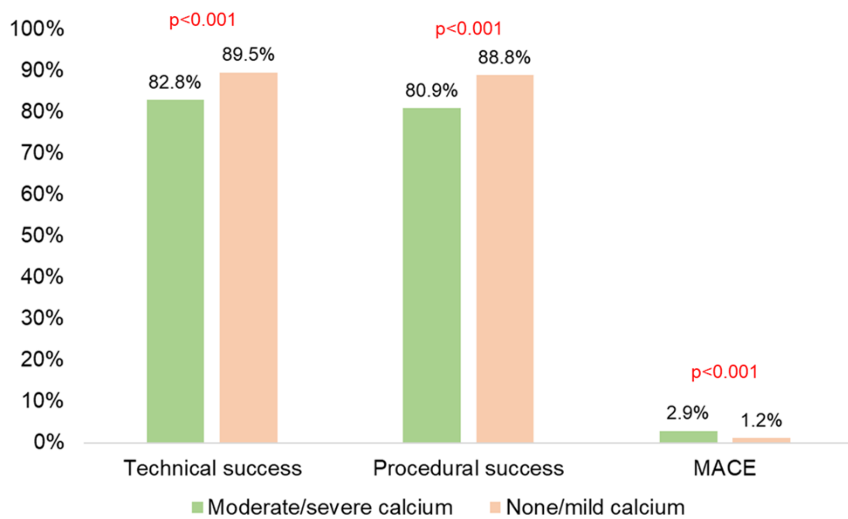
Procedural outcomes



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MACE: major adverse cardiovascular events.

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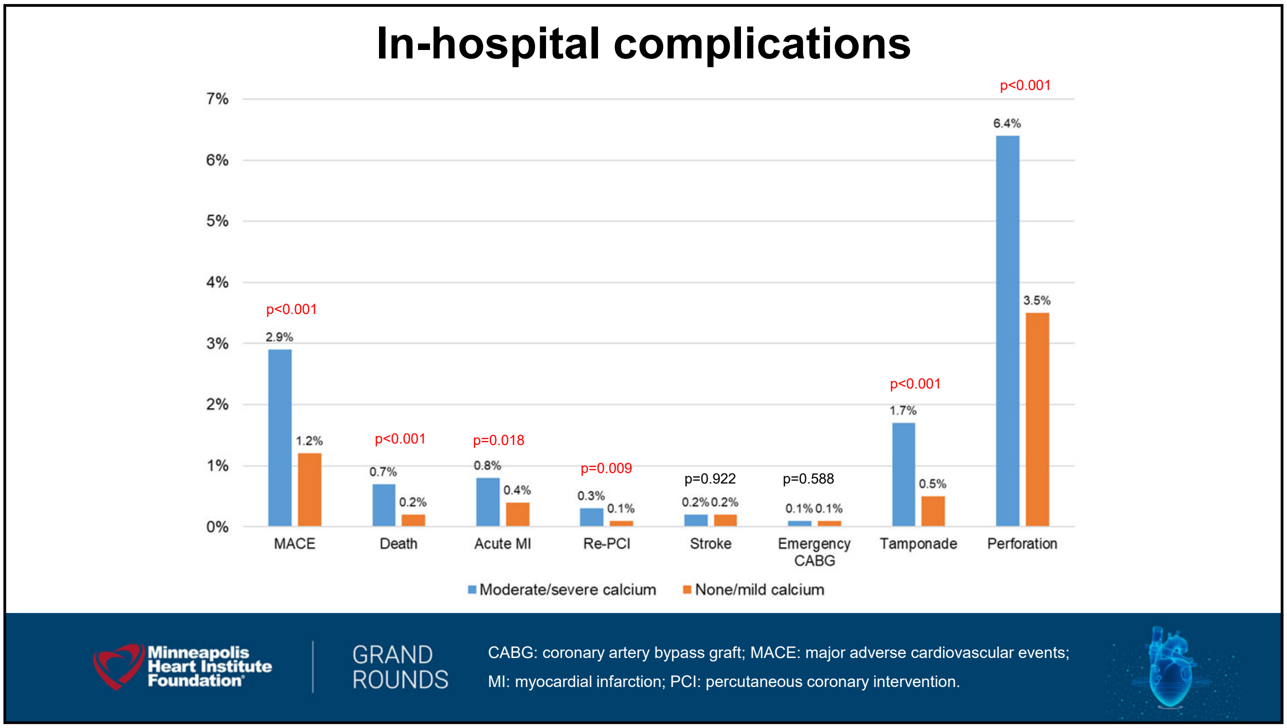
In-hospital complications
7%
6%
5%
4%
3%
2%
1%
0%
p<0.001
2.9%
1.2%
MACE
p<0.001
0.7%
0.2%
Death
p=0.018
0.8%
0.4%
Acute MI
p=0.009
0.3%
0.1%
Re-PCI
p=0.922
0.2% 0.2%
Stroke
p=0.588
0.1% 0.1%
Emergency CABG
p<0.001
1.7%
0.5%
Tamponade
p<0.001
6.4%
3.5%
Perforation
Moderate/severe calcium
None/mild calcium
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CABG: coronary artery bypass graft; MACE: major adverse cardiovascular events; MI: myocardial infarction; PCI: percutaneous coronary intervention.

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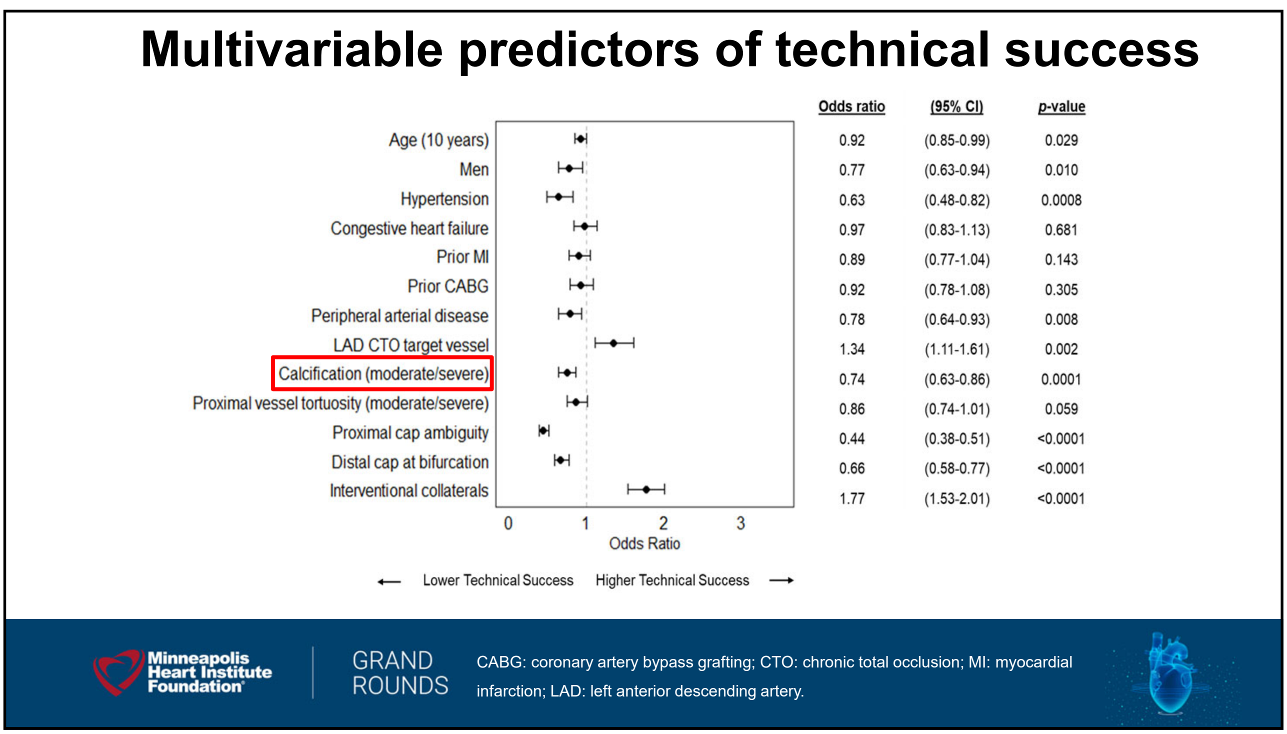
Multivariable predictors of technical success
Odds ratio (95% CI) p-value
Age (10 years) 0.92 (0.85-0.99) 0.029
Men 0.77 (0.63-0.94) 0.010
Hypertension 0.63 (0.48-0.82) 0.0008
Congestive heart failure 0.97 (0.83-1.13) 0.681
Prior MI 0.89 (0.77-1.04) 0.143
Prior CABG 0.92 (0.78-1.08) 0.305
Peripheral arterial disease 0.78 (0.64-0.93) 0.008
LAD CTO target vessel 1.34 (1.11-1.61) 0.002
Calcification (moderate/severe) 0.74 (0.63-0.86) 0.0001
Proximal vessel tortuosity (moderate/severe) 0.86 (0.74-1.01) 0.059
Proximal cap ambiguity 0.44 (0.38-0.51) <0.0001
Distal cap at bifurcation 0.66 (0.58-0.77) <0.0001
Interventional collaterals 1.77 (1.53-2.01) <0.0001
0
1
2
3
Odds Ratio
Lower Technical Success
Higher Technical Success
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CABG: coronary artery bypass grafting; CTO: chronic total occlusion; MI: myocardial infarction; LAD: left anterior descending artery.

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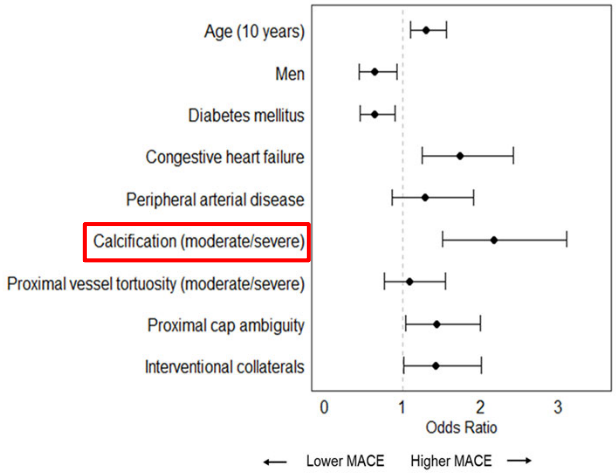
Multivariable analysis on MACE



Variable	Odds ratio	(95% CI)	*p*-value
Age (10 years)	1.30	(1.09-1.55)	0.002
Men	0.64	(0.44-0.92)	0.017
Diabetes mellitus	0.63	(0.45-0.89)	0.009
Congestive heart failure	1.73	(1.24-2.42)	0.001
Peripheral arterial disease	1.28	(0.86-1.91)	0.236
Calcification (moderate/severe)	2.16	(1.50-3.10)	<0.0001
Proximal vessel tortuosity (moderate/severe)	1.08	(0.76-1.54)	0.657
Proximal cap ambiguity	1.43	(1.03-1.99)	0.034
Interventional collaterals	1.42	(1.01-2.01)	0.047

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MACE: major adverse cardiovascular events.

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Limitations

- Observational study without adjudication of clinical events by an independent committee
- Quantitative coronary angiographic analyses were not performed.
- CTO PCIs in the PROGRESS-CTO registry are performed at dedicated, high-volume CTO centers with experienced operators, limiting the generalizability of the findings to centers with limited CTO PCI experience.

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Conclusion

Moderate/severe calcification was present in 47% of CTO lesions and was associated with:

- higher utilization of the retrograde approach and ADR
- lower technical and procedural success rates
- higher incidence of in-hospital MACE

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Acknowledgments

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PROGRESS CTO

www.progresscto.org

Thank you!

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PROGRESS CTO

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Impact of lesion length on the outcomes of chronic total occlusion percutaneous coronary intervention: Insights from the PROGRESS-CTO registry

March 27, 2023

Athanasios Rempakos, MD
(on the behalf of the PROGRESS-CTO investigators)

Research Scholar, Center for Coronary Artery Disease (CCAD),
Minneapolis Heart Institute Foundation

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Disclosure of Relevant Financial Relationships

I, Athanasios Rempakos DO NOT have a financial interest/arrangement or affiliation with one or more organizations that could be perceived as a real or apparent conflict of interest in the context of the subject of this presentation.

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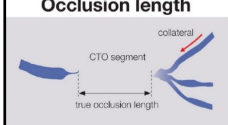
Background

O2HYT xhtwj

Occlusion length



Using good collateral images, try to measure "true" distance of occulusion, which tends to be shorter than the first impression.

Occl.Length
☐ <20mm (0)
☐ ≥20mm (1)

point

Morino Y et al. Predicting successful guidewire crossing through chronic total occlusion of native coronary lesions within 30 minutes: the J-CTO (Multicenter CTO Registry in Japan) score as a difficulty grading and time assessment tool. JACC Cardiovasc Interv. 2011;4:213-21.

OPEN-CLEAN score

Variables	Points
CABG	1
Occlusion length	
20 to <60 mm	1
≥60 mm	2
Ejection fraction <50%	1
Age	
50 to <70	1
≥70	2
CalcificatioN	1

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Hirai T et al. Development and validation of a prediction model for angiographic perforation during chronic total occlusion percutaneous coronary intervention: OPEN-CLEAN perforation score. Catheter Cardiovasc Interv. 2022 Feb;99(2):280-285.

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Goal

- Patient and angiographic characteristics associated with **longer CTO lesions**
- Impact of **occlusion length** on the outcomes of CTO PCI

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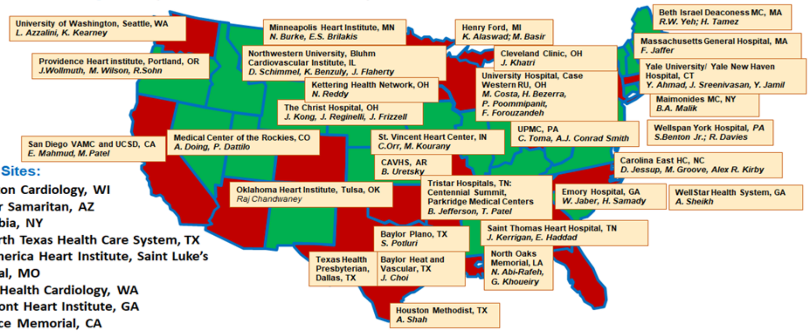
PROGRESS-CTO USA Sites

Global Coordinating Center: Chairman/PI: E. S. Brilakis; Global Director: B.V. Rangan;
Database Managers: Judit Karacsonyi, Spyridon Kostantinis, Bahadir Simsek, Athanasios Rempakos
Operational Support: Olga Mastrodemos
Project Impact: Data from 13,556 cases at 69 participating centers, 10 countries
Resulting in 101 publications, 164 conference presentations

PROGRESS CTO
NCT02061436

USA Sites



Historical Sites:

1. Appleton Cardiology, WI
2. Banner Samaritan, AZ
3. Columbia, NY
4. VA North Texas Health Care System, TX
5. MidAmerica Heart Institute, Saint Luke's Hospital, MO
6. Peace Health Cardiology, WA
7. Piedmont Heart Institute, GA
8. Torrance Memorial, CA
9. Minneapolis VA Medical Center
10. Memorial Hospital, Jacksonville, FL
11. Oklahoma VA Medical Center, OK
12. Providence Hospital, Waco, TX
13. Trinity Medical Center WNY, Buffalo, NY
14. Tulane University, LA
15. University of Texas Southwestern Medical Center

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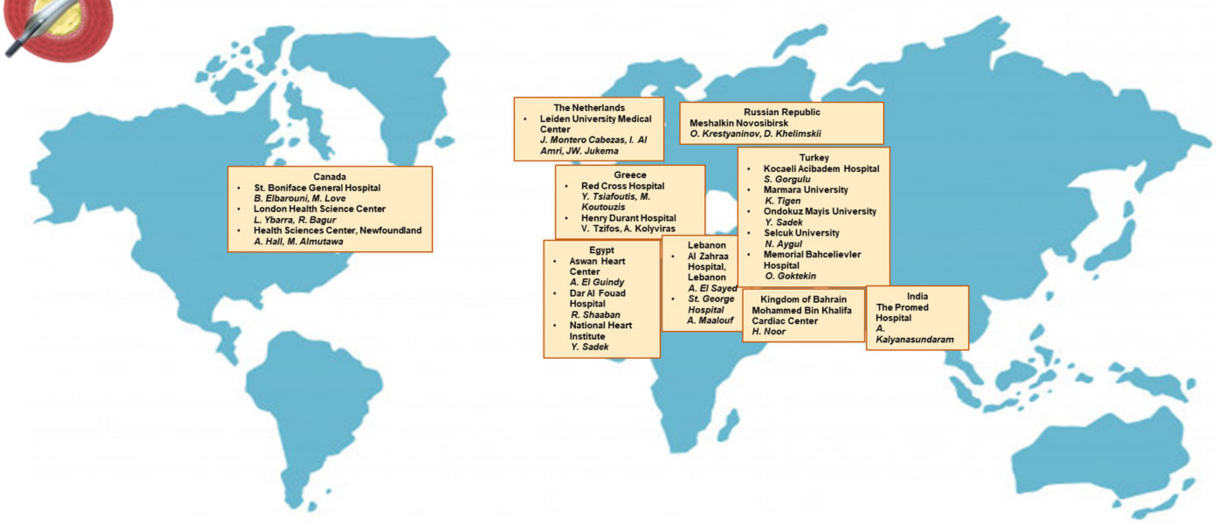
PROGRESS-CTO International Sites



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Statistical analysis

- Categorical variables are presented as percentages and compared using Pearson's chi-square test or Fisher's exact test.
- Continuous variables are presented as mean ± SD or as median (interquartile range [IQR]) and compared using the Student's t-test and the Wilcoxon rank sum test.
- A 2-sided p value of 0.05 was considered to indicate statistical significance.
- **Long lesions** defined as lesions with length ≥20 mm and **short lesions** were defined as lesions with length <20 mm

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Results

- 10,335 CTO PCIs
- 42 centers
- From 2012 to 2022

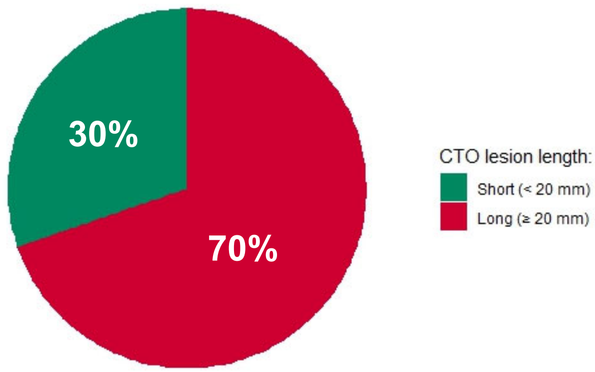

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Table 1. Baseline clinical characteristics

Variable	Long Lesion n=7208, 70%	Short Lesion n=3127, 30%	*P* value
Age (years)	64.2 ± 10.2	64.5 ± 10.5	0.331
Men	82.5%	78.2%	<0.001
BMI (kg/m2)	30.5 ± 6.3	30.3 ± 6.3	0.082
Diabetes mellitus	45.3%	37.6%	<0.001
Hypertension	90.1%	87.5%	<0.001
Dyslipidemia	88.7%	78.6%	<0.001
Prior MI	45.7%	42.5%	0.004
Prior CABG	32.7%	19.5%	<0.001
Congestive heart failure	29.3%	26.2%	0.002
LVEF (%)	49.6 ± 13.2	52.2 ± 12.2	<0.001
Peripheral arterial disease	15.0%	11.2%	<0.001

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CABG: coronary artery bypass grafting; LVEF: left ventricular ejection fraction; MI: myocardial infarction; PCI: percutaneous coronary intervention.

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Table 2. Angiographic characteristics

Variable	Long Lesion n=7208, 70%	Short Lesion n=3127, 30%	*P* value
CTO Target Vessel			<0.001
▪ RCA	57.3%	43.5%	
▪ LAD	23.4%	32.3%	
▪ LCX	17.3%	21.8%	
Vessel diameter (mm)	2.9 ± 0.5	2.8 ± 0.5	<0.001
Proximal cap ambiguity	39.7%	22.8%	<0.001
Side branch at the proximal cap	56.9%	51.6%	<0.001
Blunt/no stump	60.0%	35.9%	<0.001
Moderate/severe calcification	50.3%	34.9%	<0.001
Moderate/severe proximal tortuosity	31.4%	21.6%	<0.001

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CTO: chronic total occlusion; J: Japan; LAD: left anterior descending; LCX: left circumflex; PROGRESS-CTO: prospective global registry for the study of chronic total occlusion intervention; RCA: right coronary artery.

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Table 3. Procedural characteristics

Variable	Long Lesion n=7208, 70%	Short Lesion n=3127, 30%	*P* value
First crossing strategy			<0.001
▪ AWE	78.6%	93.5%	
▪ ADR	5.0%	1.2%	
▪ Retrograde	15.5%	4.0%	
Successful crossing strategies			<0.001
▪ AWE	47.7%	74.6%	
▪ ADR	14.8%	8.1%	
▪ Retrograde	22.8%	8.2%	
▪ None	14.7%	9.2%	
Balloon undilatable CTO lesion	9.5%	6.3%	<0.001
Procedure time (min)	123 [82, 178]	91 [60, 134]	<0.001
Fluoroscopy time (min)	47.1 [28.8, 73.2]	32.2 [20.2, 51]	<0.001
AK radiation dose (Gray)	2.4 [1.4, 4.1]	1.7 [0.9, 2.9]	<0.001
Contrast volume (ml)	218 [150, 300]	200 [140, 270]	<0.001

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ADR: antegrade dissection and re-entry; AK: air kerma; AW: antegrade wiring; IVUS: intravascular ultrasound; LV: left ventricular.

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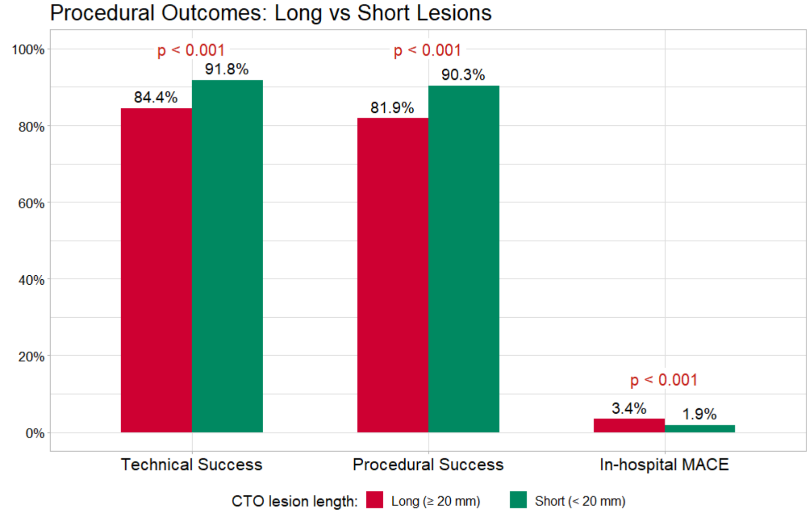
Procedural outcomes



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MACE: major adverse cardiovascular events.

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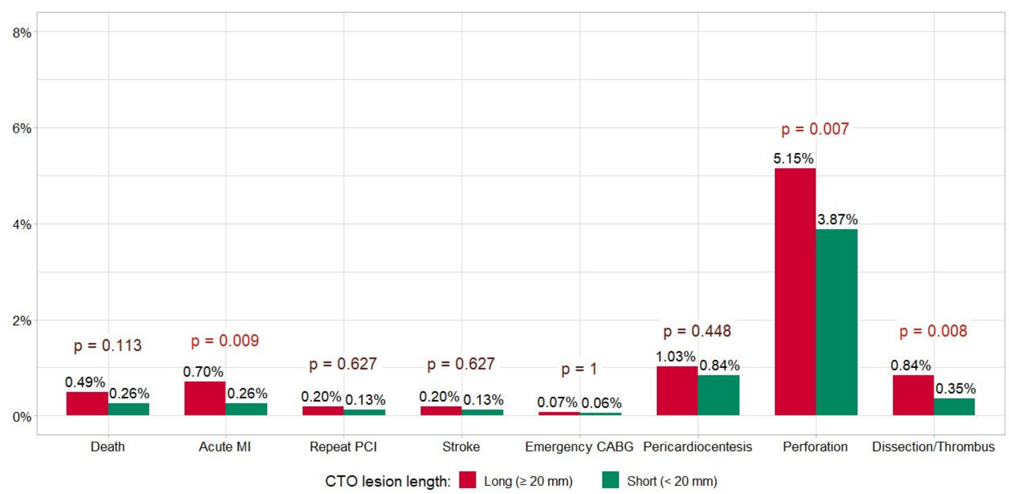
In-hospital complications



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CABG: coronary artery bypass graft; MACE: major adverse cardiovascular events; MI: myocardial infarction; PCI: percutaneous coronary intervention.

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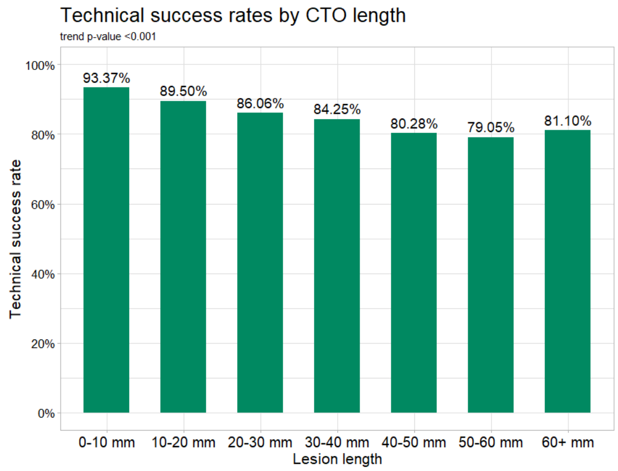
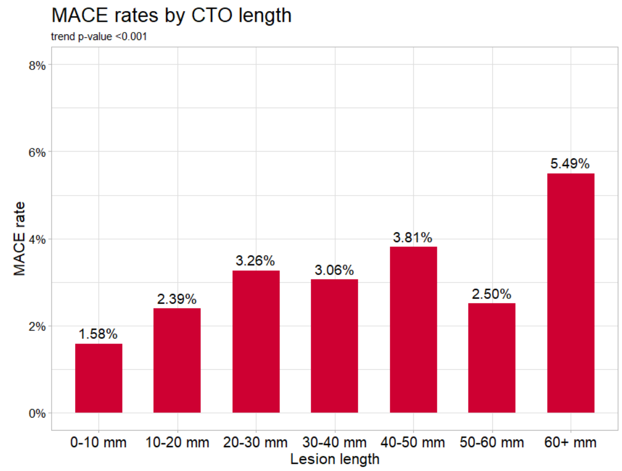
Success and MACE by lesion length





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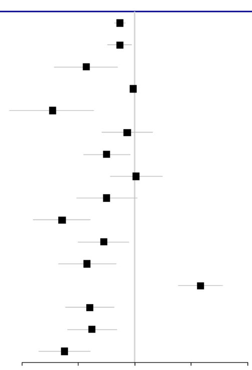
Logistic Regression Analysis

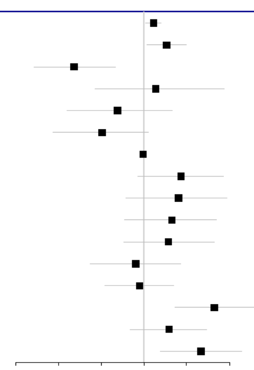
Technical success

Characteristic	OR	95% CI	p-value
Occlusion length (10 mm)	0.91	0.88, 0.94	<0.001
Age (10 years)	0.91	0.85, 0.98	0.014
Gender (male)	0.74	0.61, 0.90	0.002
BMI (kg/m2)	0.99	0.98, 1.00	0.079
Hypertension	0.60	0.46, 0.78	<0.001
Congestive heart failure	0.95	0.82, 1.11	0.6
Prior MI	0.84	0.73, 0.97	0.017
Prior CABG	1.01	0.86, 1.18	>0.9
Peripheral arterial disease	0.84	0.70, 1.02	0.069
Proximal cap ambiguity	0.64	0.54, 0.76	<0.001
Side branch at the proximal cap	0.83	0.71, 0.96	0.015
Blunt/no stump	0.75	0.63, 0.89	0.001
Vessel diameter (mm)	1.50	1.31, 1.72	<0.001
Calcification (moderate/severe)	0.76	0.65, 0.88	<0.001
Tortuosity (moderate/severe)	0.77	0.66, 0.89	<0.001
Retrograde strategy used	0.65	0.56, 0.76	<0.001



MACE

Characteristic	OR	95% CI	p-value
Occlusion length (10 mm)	1.08	1.02, 1.15	0.012
Age (10 years)	1.20	1.03, 1.41	0.022
Gender (male)	0.57	0.41, 0.79	<0.001
Hypertension	1.10	0.67, 1.91	0.7
Dyslipidemia	0.81	0.54, 1.25	0.3
Smoking (current)	0.71	0.48, 1.04	0.086
Left ventricular ejection fraction	0.99	0.98, 1.01	0.3
Congestive heart failure	1.35	0.95, 1.90	0.090
Cerebrovascular disease	1.32	0.87, 1.96	0.2
Peripheral arterial disease	1.25	0.85, 1.80	0.2
Proximal cap ambiguity	1.22	0.85, 1.76	0.3
Blunt/no stump	0.93	0.65, 1.35	0.7
Vessel diameter (mm)	0.96	0.73, 1.27	0.8
Calcification (moderate/severe)	1.77	1.29, 2.44	<0.001
Tortuosity (moderate/severe)	1.23	0.90, 1.66	0.2
Retrograde strategy used	1.59	1.14, 2.21	0.006



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MACE: major adverse cardiovascular events.

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Limitations

- Observational study without adjudication of clinical events by an independent committee.
- Core laboratory analysis of the study's angiograms was not performed.
- The operators in the PROGRESS-CTO registry are more experienced in performing CTO PCI, potentially limiting the external validity of the study's results.

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Conclusions

- Long CTO lesions (≥20 mm) made up **70% of CTO PCIs** in our registry
- **Comorbidities** and **complex angiographic characteristics** were more common in patients with longer occlusions
- **Advanced crossing techniques** were more frequently required in long CTOs
- Long lesions were independently associated with **lower technical success**, and **increased incidence of complications**

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Acknowledgments

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Thank you!

Simsek B, Kostantinis S, Karacsonyi J, Choi JW, Poommipanit P, Khatri JJ, Jaber W, Rinfret S, Nicholson W, Gorgulu S, Jaffer FA, Chandwaney R, Koutouzis M, Tsiafoutis I, Alaswad K, Krestyaninov O, Khelimskii D, Karmpaliotis D, Uretsky BF, Patel MP, Mahmud E, Potluri S, Rangan BV, Mastrodemos OC, Allana S, Sandoval Y, Burke NM, Brilakis ES.

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