MASTERING HEART VOLUMES:
ADVANCED ECHOCARDIOGRAPHIC INSIGHTS

Remembering how to look at our screens again

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Disclosures

- **Professional, non-product speaker:**
  - **Edwards Lifesciences** - Aortic Stenosis education
  - **Abbott Medical** - Mitral Regurgitation education
  - **Bristol Myers Squibb** - Hypertrophic Cardiomyopathy education

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Learning Objectives

1. **Understanding Heart Volumes -** Review the physiologic basis and clinical importance of accurate volume assessment
2. **Techniques for Accurate Measurements -** Compare echocardiographic methods, from Doppler to Simpson's biplane and 3D imaging.
3. **Overcoming Common Challenges -** Recognize and resolve pitfalls such as foreshortened views, Doppler misalignment, and image quality limitations.
4. **Advanced Applications -** Explore how volumes guide valve disease assessment, and the role of emerging AI and automated tools.

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Hemodynamic & Mechanical Stroke Volumes

By the end of this talk, you'll understand the importance of accurate volume measurements, common pitfalls, and advanced techniques to enhance precision.

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Understanding Heart Volumes

Forward Stroke Volume: LVOT Method

Stroke Volume (SV)

$$SV = CSA_{(LVOT)} \times VTI_{(LVOT)}$$ (1)

$$CSA = \pi \times (D/2)^2$$

VTI = Doppler derived velocity time integral

Represents **Forward Stoke Volume** through the LVOT / Aortic Valve

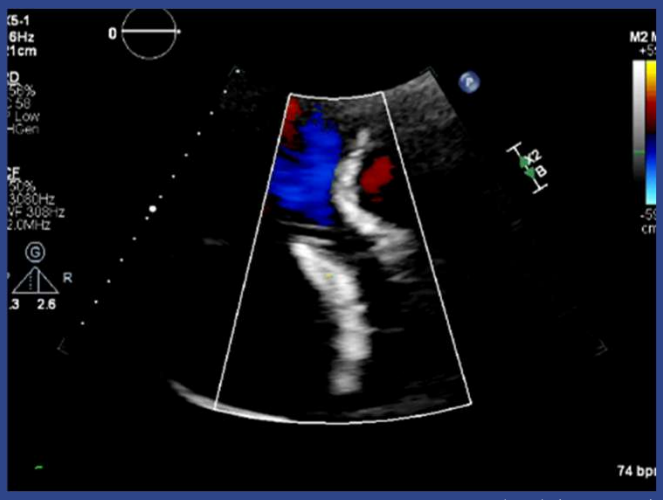

Image 1: Apical Long by (M.Trump, 2025)

(1) Lang RM, Badano LP, Mor-Avi V, et al. J Am Soc Echocardiogr. 2015;28(1):1-39.e14. doi:10.1016/j.echo.2014.10.003

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Stroke Volume (SV)

Understanding Heart Volumes

Mechanical Stroke Volume: Simpson's Method

- SV = EDV – ESV[1]
- LV endocardium in apical 4 and 2 chambers
- Measures total stroke volume
  - Forward and regurgitant
- Dependent on image quality and endocardial border definition
- Ultrasound Enhancing Agents (UEAs) reduce variability and improve accuracy[2]

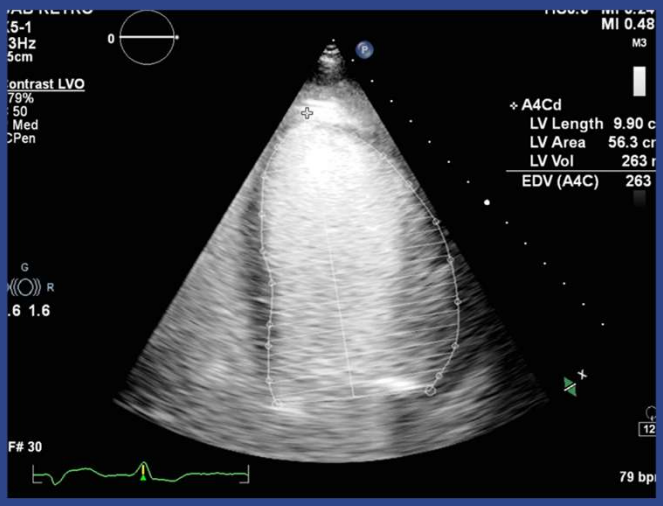

Image 2: Apical 4 Simpsons by (M.Trump, 2025)

(1)Lang RM, Badano LP, Mor-Avi V, et al. J Am Soc Echocardiogr. 2015;28(1):1-39.e14. doi:10.1016/j.echo.2014.10.003
(2) Porter TR, Mulvagh SL, Abdelmoneim SS, et al. *J Am Soc Echocardiogr.* 2018;31(3):241-274. doi:10.1016/j.echo.2017.11.013

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Stroke Volume (SV)

Understanding Heart Volumes

Gold Standard: Cardiac MRI Computed Tomography (CT) (A super close second) for LV volumes

SV = EDV – ESV[1]

High reproducibility for LV volumes[2]

Used in structural heart planning

Echo 2D and 3D are validated against these modalities[2]

Image 3: CT image from author's clinical collection, de-identified (M.Trump, 2025)

(1)Lang RM, Badano LP, Mor-Avi V, et al. J Am Soc Echocardiogr. 2015;28(1):1-39.e14. doi:10.1016/j.echo.2014.10.003
(2) Porter TR, Mulvagh SL, Abdelmoneim SS, et al. *J Am Soc Echocardiogr.* 2018;31(3):241-274. doi:10.1016/j.echo.2017.11.013

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From Absolute to Hemodynamics

Absolute Volumes (How much?)

- Columns of Blood
- End-diastolic & end-systolic volumes
- Stroke volume from Simpson's & MRI/CT

Hemodynamic Volumes (Where's it going?)

- Forward flow (LVOT) to the next chamber or systemically
- Regurgitant volumes to the previous chamber[3]
- Shunt calculations

Absolute numbers don't tell the whole story alone.

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Hemodynamic Volumes: Connecting flow to Function

Aortic Stenosis – Valve area, flow gradient

Aortic Insufficiency – Regurgitant volume & fraction

Mitral Stenosis – By VTI, stroke volume impact

Mitral Regurgitation – Regurgitant fraction, PISA

Atrial and Ventricular septal defects – Qp:Qs ratios

Right heart – RV stroke volume, closed pump system

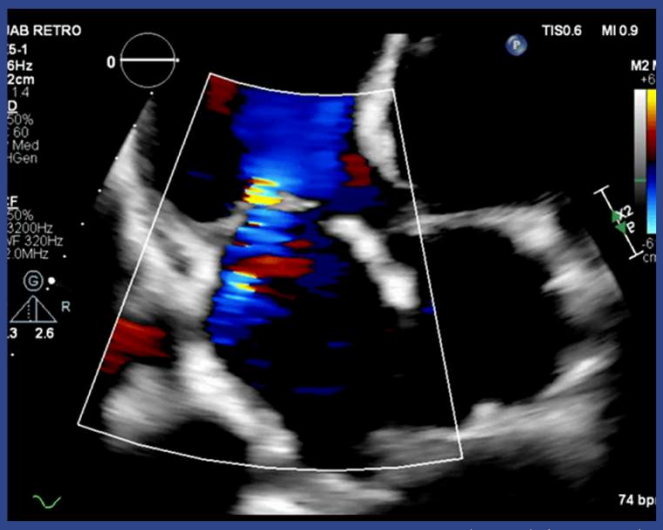

Image 4: Apical Long MV by (M.Trump, 2025)

Understanding Heart Volumes and hemodynamic

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Understanding Heart Volumes and hemodynamic

Aortic Stenosis VS Aortic Insufficiency

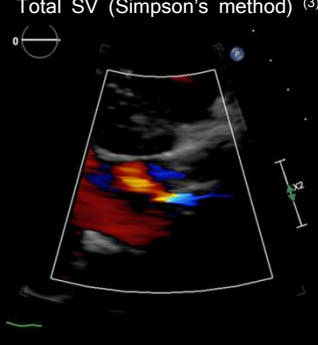
Stroke Volume is a Volume

Aortic Stenosis
- Valve area
- Low Flow Low Gradient

Aortic Insufficiency (AI or AR)
- Regurgitant volume
- Regurgitant fraction

Regurgitant Volume = LVOT SV - Total SV (Simpson's method) [3]

$AVA=(CSA_{LVOT} \times VTI_{LVOT}) / VTI_{Aotic\ Valve}$ [1]



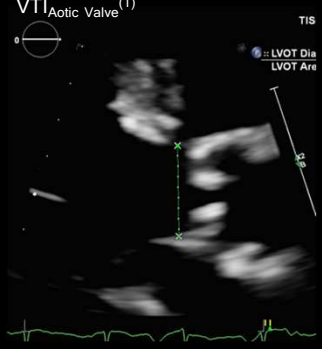


Image 5: Aortic regurgitation PLAX zoomed & Image 6: LVOT diameter PLAX zoomed. from author's clinical collection, de-identified (M.Trump, 2025)

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Understanding Heart Volumes and hemodynamic

Stroke Volume in Aortic Stenosis

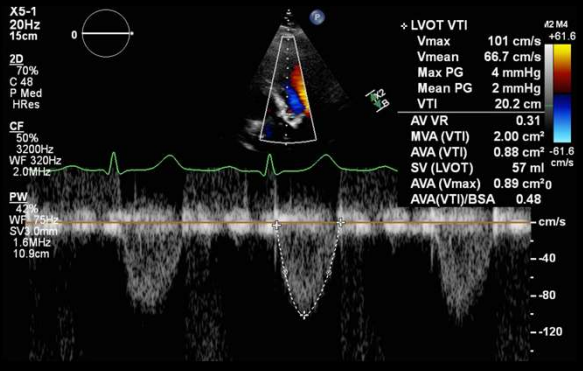

Image 7: Apical 5 LVOT VTI from author's clinical collection, de-identified (M.Trump, 2025)

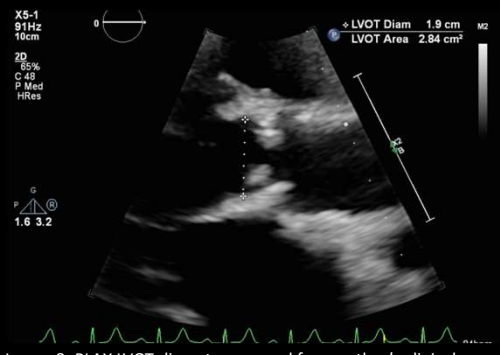

Image 8: PLAX LVOT diameter zoomed from author's clinical collection, de-identified (M.Trump, 2025)

- $SV = CSA_{LVOT} \times VTI_{LVOT}$ [4]
- Low flow, low gradient

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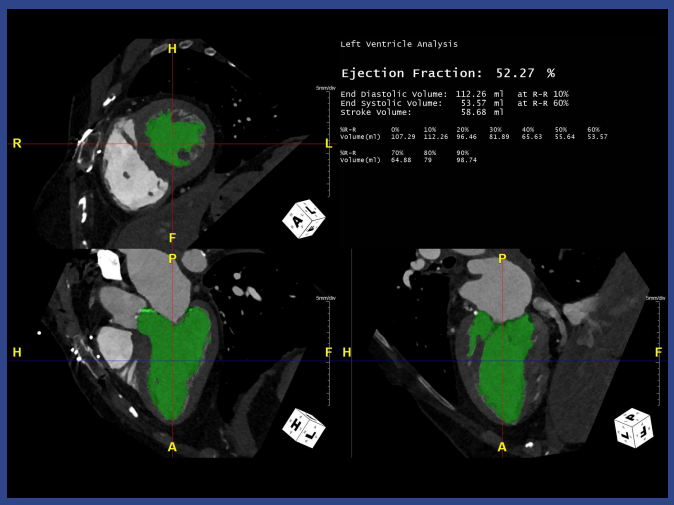

Image 9: CT image from author's clinical collection, de-identified (M.Trump, 2025)

Find ways to check your work

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Let's Have Some Examples Please

- Let's say:
  - Total SV (Simpson's) = 120 mL
  - Forward SV (LVOT Doppler) = 80 mL
  - Regurgitant Volume:
    RV= 120ml - 80ml = 40ml
  - Regurgitant Fraction:
  - RF = (40/120) x 100 =
    - 33.3%

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Let's Have Some Examples Please

But sometimes there is Mitral Regurgitation!

Regurgitant Volume MR

- MR volume (PISA) = 45ml
- Total SV (Simpson's) = 110ml
- Forward SV (LVOT Doppler) = 65ml
- End Systolic volume = 55
- End Diastolic volume = 210

Regurgitant Volume:

= (SB)110ml – (LVOTSV)65ml = 45ml

If severe MR by PISA contributes 45ml to the regurgitant volume; we should be able to add it to our LVOT stroke volume and the total should be less than our EDV, equal-ish to our Simpsons SV.

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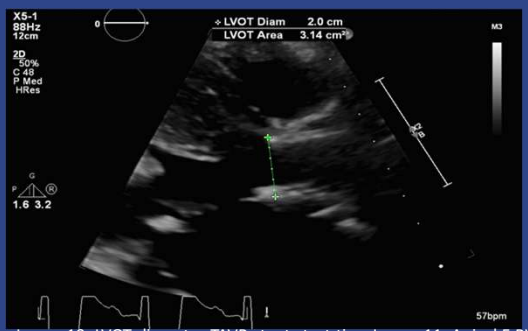
We Understand Forward Flow now

LVOT Diameter



LVOT Pulsed wave

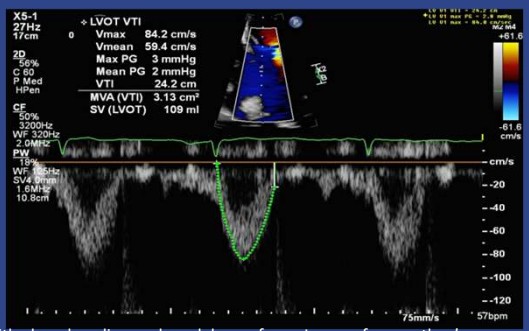


Image 10: LVOT diameter TAVR stent strut tips. Image 11: Apical 5 PW with clean baseline and modal waveform. Images from author's clinical collection, de-identified (M.Trump, 2025)

Understanding Heart Volumes and hemodynamic

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We Understand Forward Flow now?

Image 12: UEA apical four Simpson's end diastolic volume. Image from author's clinical collection, de-identified (M.Trump, 2025)

Understanding Heart Volumes and hemodynamic

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Mechanical Volumes

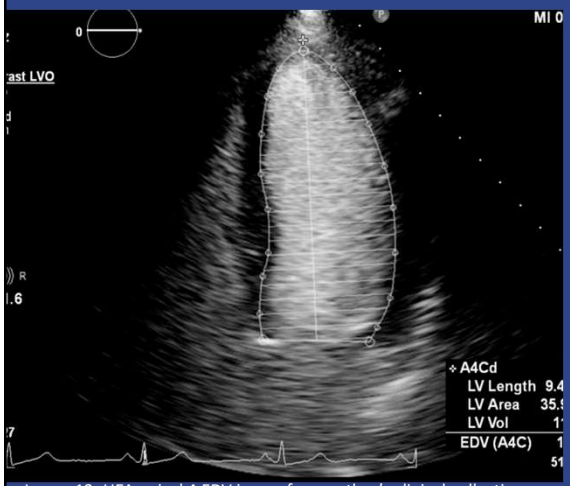

Image 13: UEA apical 4 EDV image from author's clinical collection, de-identified (M.Trump, 2025)

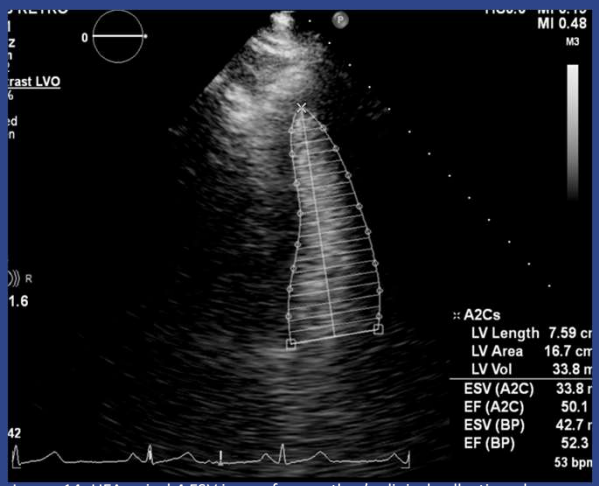

Image 14: UEA apical 4 ESV image from author's clinical collection, de-identified (M.Trump, 2025)

•ISN'T THIS JUST FOR EF?

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Image 15: Philip's Heart Model image from author's clinical collection, de-identified (M.Trump, 2025)

•Don't Forget about 3D

Can we put this all together without Stroking out?

We are telling a story:

- Aortic Stenosis
- Aortic Insufficiency
- Mitral Stenosis
- Mitral Regurgitation

We have to be able to support our claims

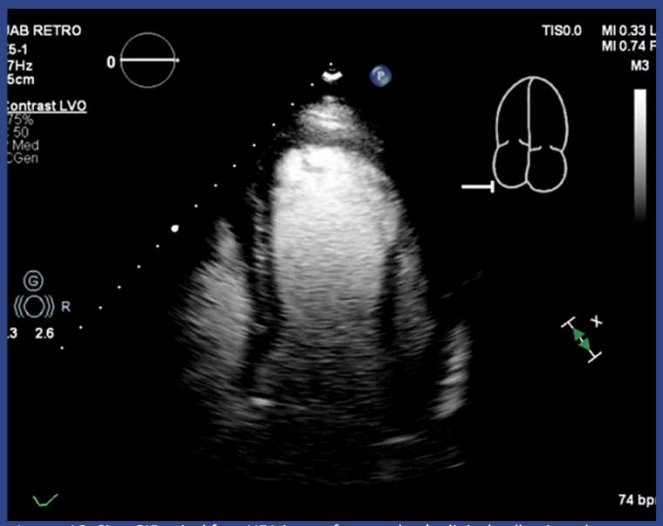


Image 16: Cine GIF apical four UEA image from author's clinical collection, de-identified (M.Trump, 2025)

Can we put this all together without Stroking out?

- If you think it's low flow AS prove it
- Quantify your AI with pressure half time, look for descending flow reversal, quantify your volumes
- If there is MR see if your regurgitant volumes line up

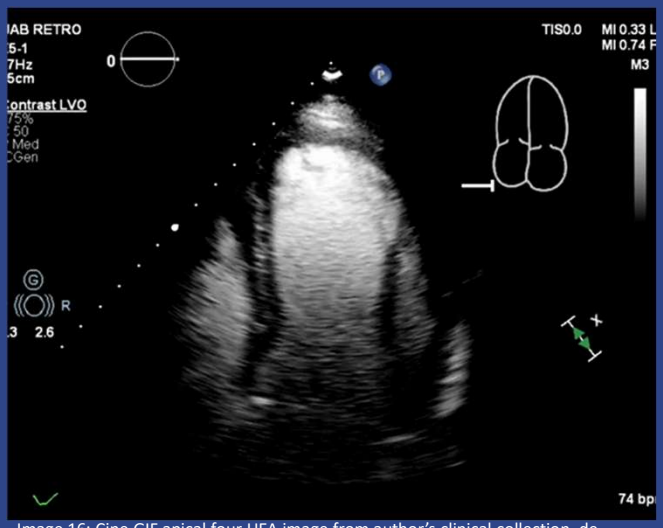


Image 16: Cine GIF apical four UEA image from author's clinical collection, de-identified (M.Trump, 2025)

Can we put this all together without Stroking out?

- If the physician asks why you think you're right. Don't hang your probe on one measurement. Prove it with multiple.

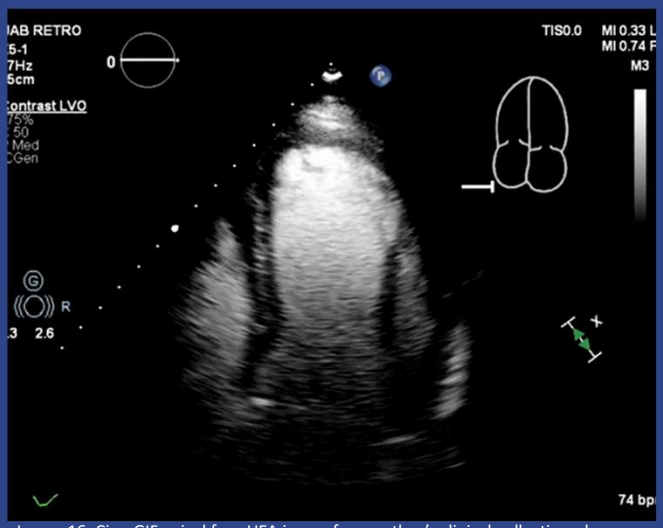
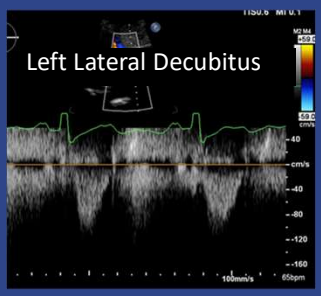


Image 16: Cine GIF apical four UEA image from author's clinical collection, de-identified (M.Trump, 2025)

FINAL THOUGHTS

- This is no way only way to think about volumes. Our heart is a closed pump. What works on one side works on the other. Find the best window and don't forget to role your patients to the right side.



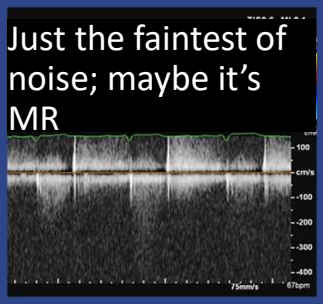


Image 17, 18, 19: Apical LVOT CW in the LLD, Faint apical CW waveform not measurable, Right Sternal Border improved CW tracing. from author's clinical collection, de-identified (M.Trump, 2025)

I am going to need you to roll to your right side so I can better here your valve.

Thank you

Image 20: AO flow reversal from author's clinical collection, de-identified (M.Trump, 2025)

Flow reversal in the descending aorta, If you say severe AI, prove it.

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References:

1. Lang RM, Badano LP, Mor-Avi V, et al. Recommendations for cardiac chamber quantification by echocardiography in adults: An update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *Journal of the American Society of Echocardiography*. 2015;28(1). doi:10.1016/j.echo.2014.10.003
2. Porter TR, Mulvagh SL, Abdelmoneim SS, et al. Clinical applications of ultrasonic enhancing agents in echocardiography: 2018 American society of echocardiography guidelines update. *Journal of the American Society of Echocardiography*. 2018;31(3):241-274. doi:10.1016/j.echo.2017.11.013
3. Zoghbi WA, Adams D, Bonow RO, et al. Recommendations for noninvasive evaluation of native valvular regurgitation. *Journal of the American Society of Echocardiography*. 2017;30(4):303-371. doi:10.1016/j.echo.2017.01.007
4. Sattin M, Burhani Z, Jaidka A, Millington SJ, Arntfield RT. Stroke volume determination by Echocardiography. *Chest*. 2022;161(6):1598-1605. doi:10.1016/j.chest.2022.01.022
5. Anjan VY, Herrmann HC, Pibarot P, et al. Evaluation of flow after transcatheter aortic valve replacement in patients with low-flow aortic stenosis. *JAMA Cardiology*. 2016;1(5):584. doi:10.1001/jamacardio.2016.0759

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Image citations:

- All images are de-identified captures in the authors clinical collection unless otherwise cited.

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