PISA Bootcamp: Upping Your Game

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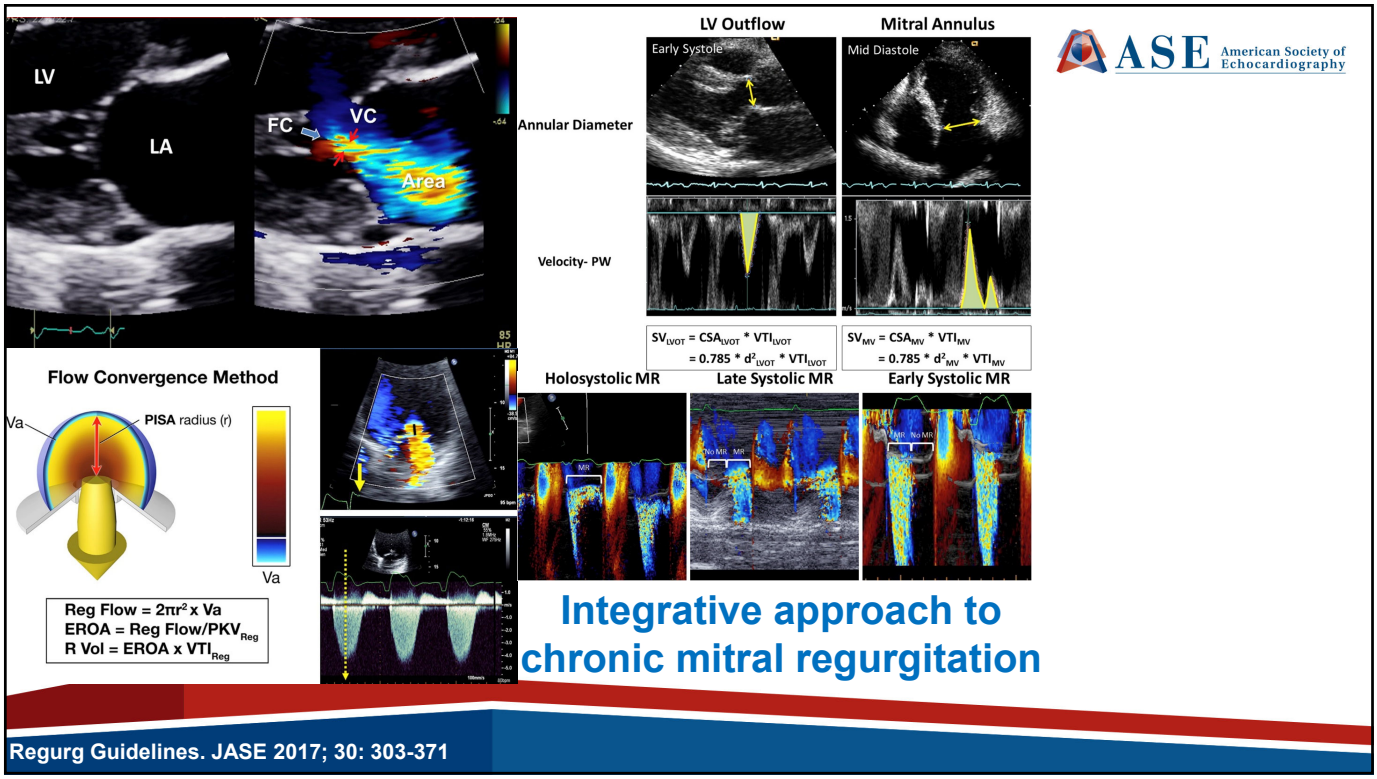
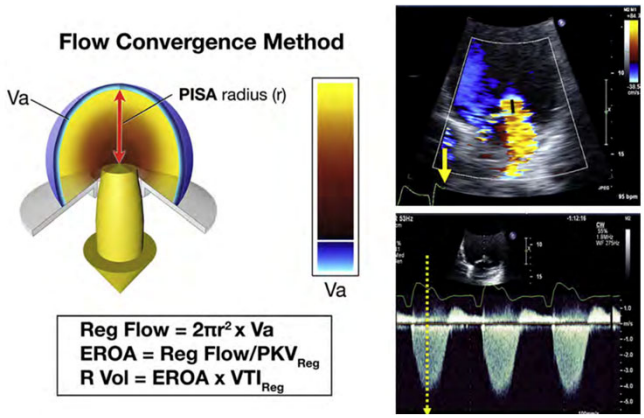
Disclosures:
JT: Abbott, GE Healthcare (Research Grant Support); Caption Health (Consultant/Advisor)
MJ: Caption Health, Bristol Myers Squibb (honorarium)



Integrative approach to chronic mitral regurgitation

Regurg Guidelines. JASE 2017; 30: 303-371

PISA: Based on Flow Conservation



Flow thru any isovelocity shell is equal to instantaneous orifice flow

Advantages of PISA Method

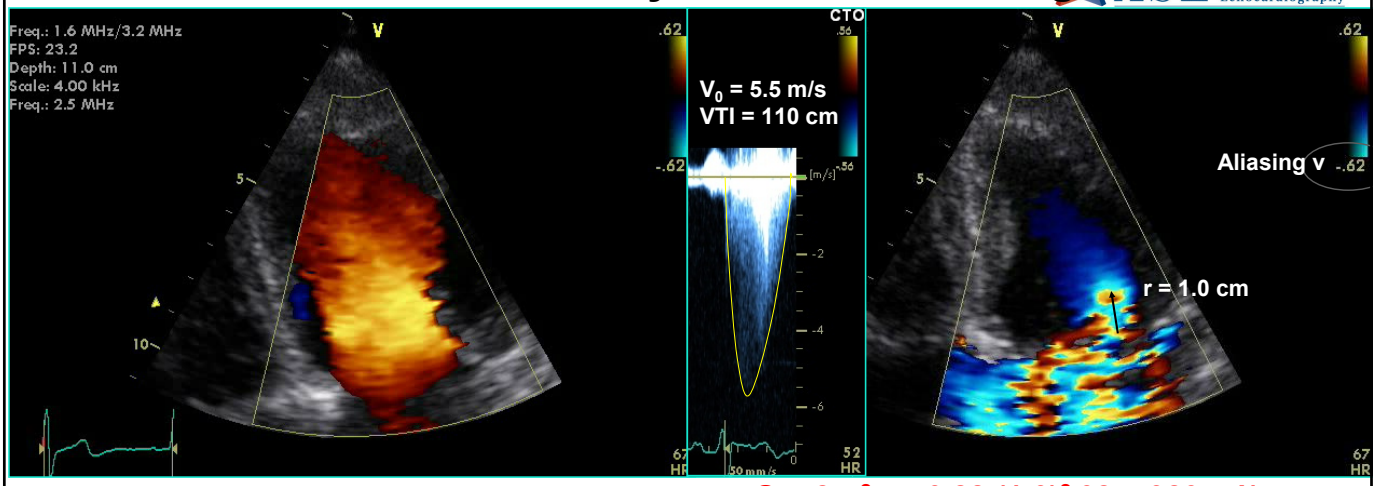
- Depends essentially on single measurement (aliasing radius) since v_{max} is relatively constant (and can even be estimated from SBP)
- Less subject to propagation of errors than volumetric approach
- Uses axial resolution which is finer than lateral resolution used by vena contracta method
- Well-suited for rapid quantification during interventions
- Less dependent on BP and instrument factors than jet area

Disadvantages of PISA Method

- [Need to finish this]
- Depends essentially on single measurement (aliasing radius) since v_{max} is relatively constant (and can even be estimated from SBP)
- Less subject to propagation of errors than volumetric approach
- Uses axial resolution which is finer than lateral resolution used by vena contracta method
- Well-suited for rapid quantification during interventions
- Less dependent on BP and instrument factors than jet area

Regurg Guidelines. JASE 2017; 30: 303-371

Assessment of MR by Proximal Convergence

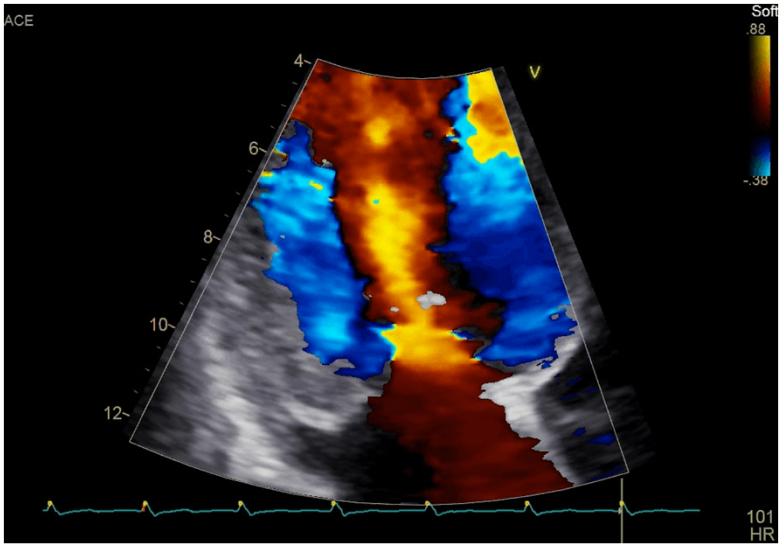


$Q = 2\pi r^2 v = 6.28\ (1.0)^2\ 62 = 389$ ml/sec

$ROA = Q/v_0 = 389/550 = 0.7$ cm^2

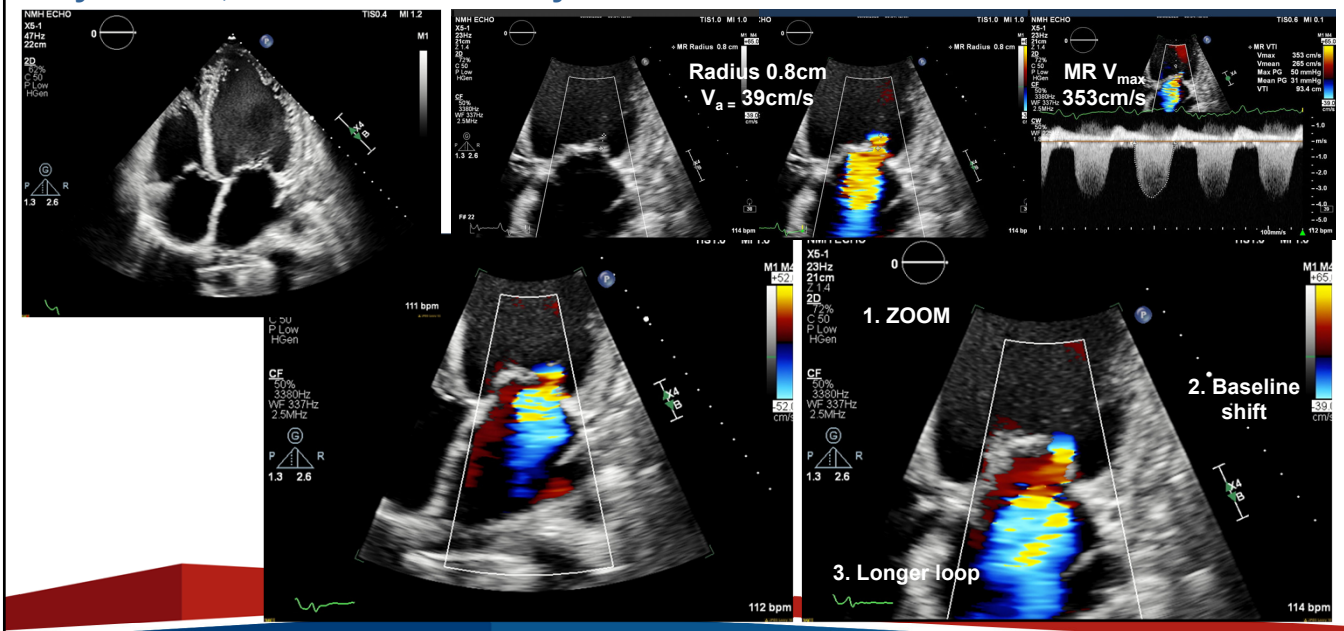
$RVol = ROA \times VTI = 0.7 \times 110 = 77$ ml

It's easy to see where the color changes from blue to yellow; not so easy to see where it's converging. Hint: suppress the color to see the anatomy and use the color to see the "pinch" of the vena contracta.

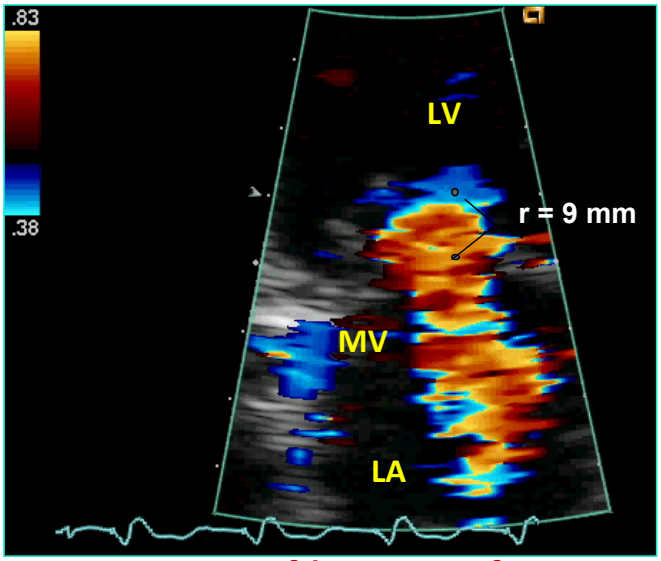


When all things cooperate..

41 y.o. male, COVID+ with history of cocaine abuse

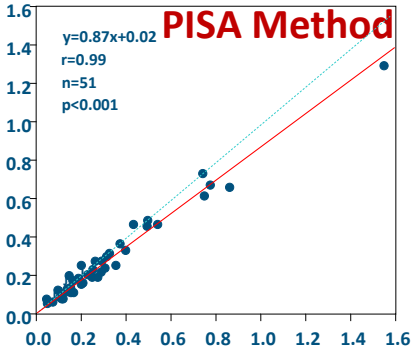


ROA by Simplified PISA Method: $r^2/2$



ROA = $9^2/2$ = 40 mm^2

ROA (cm^2) by Simplified PISA Method

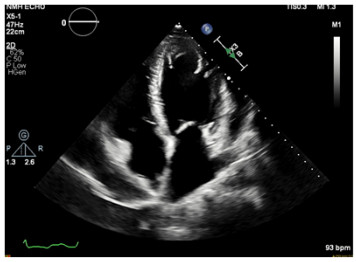


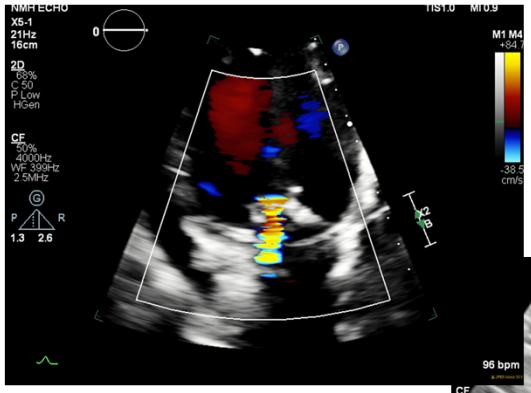
ROA (cm^2) by Conventional PISA Method

- *Assume LV-LA Δp is 100 mmHg*
- *Set aliasing velocity to (near) 40 cm/sec*
- *Then ROA = $r^2/2$*

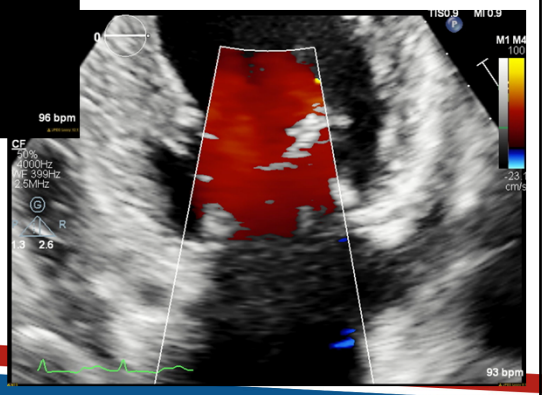
When the MR is mild..

51-year-old male with new heart failure





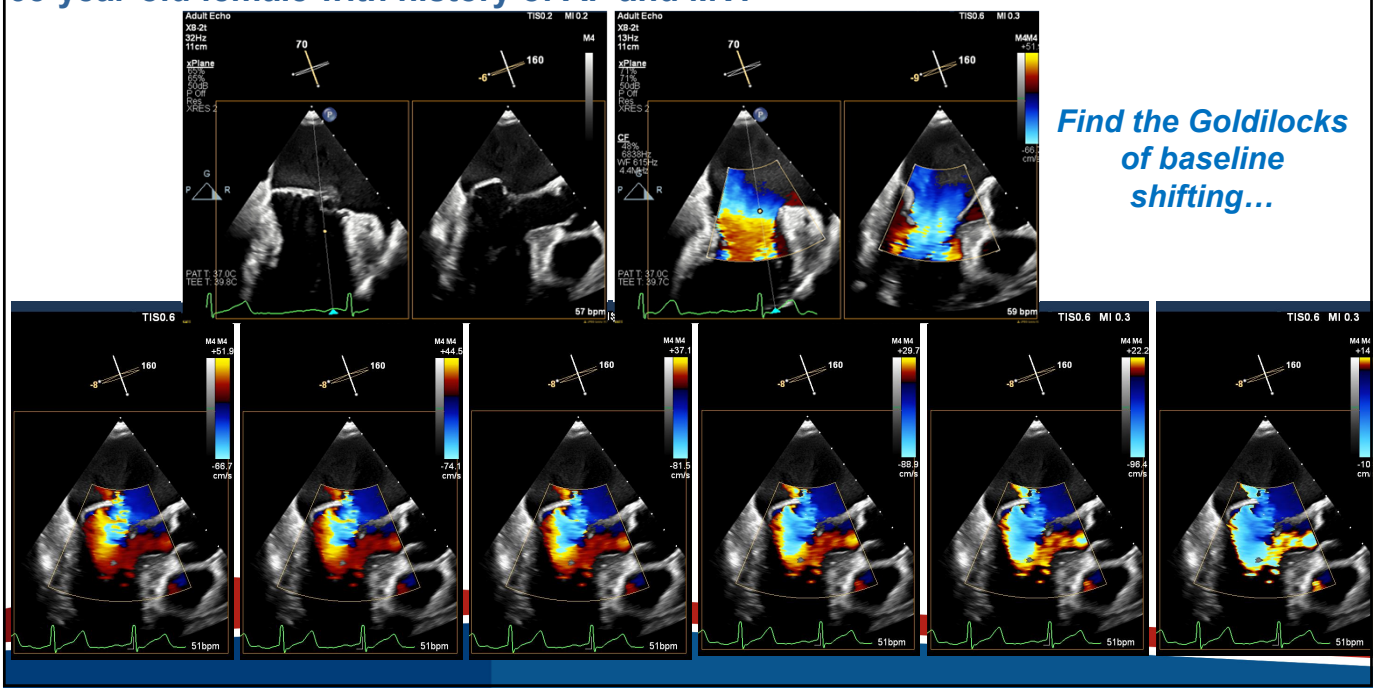
Baseline shift to ~40.. no hemisphere..



Shift the to a lower aliasing velocity!

When the MR is significant…

65-year-old female with history of AF and MVP



Find the Goldilocks of baseline shifting…

PISA Adjustments

Pitfalls and Refinements to Keep in Mind

1. Nonholosystolic MR
2. Proximal constraint distorting hemisphere
3. Contour flattening near orifice
4. Noncircular orifice

PISA Adjustments

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Dynamics of Mitral Regurgitant Flow and Orifice Area

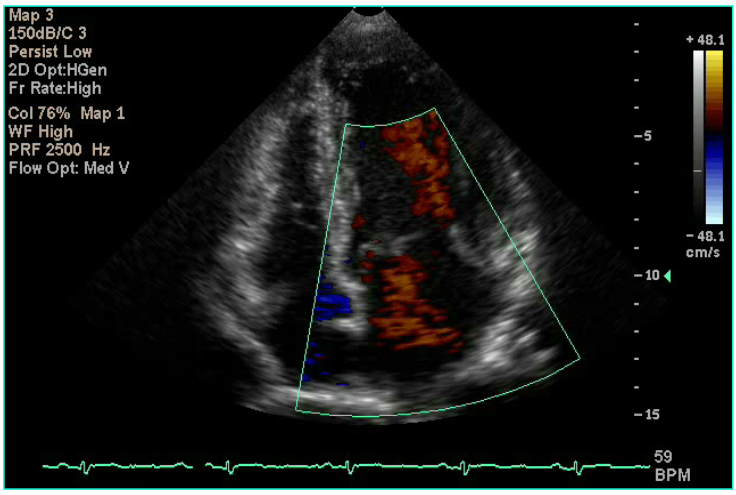
Physiologic Application of the Proximal Flow Convergence Method: Clinical Data and Experimental Testing

Circulation 1994; 90: 307-322

Ehud Schwammenthal, MD; Chunguang Chen, MD; Frank Benning, BS; Michael Block, MD; Günter Breithardt, MD, FESC, FACC; Robert A. Levine, MD, FACC

How Bad is this Regurgitation??

46 Year Old Woman Referred for Surgery

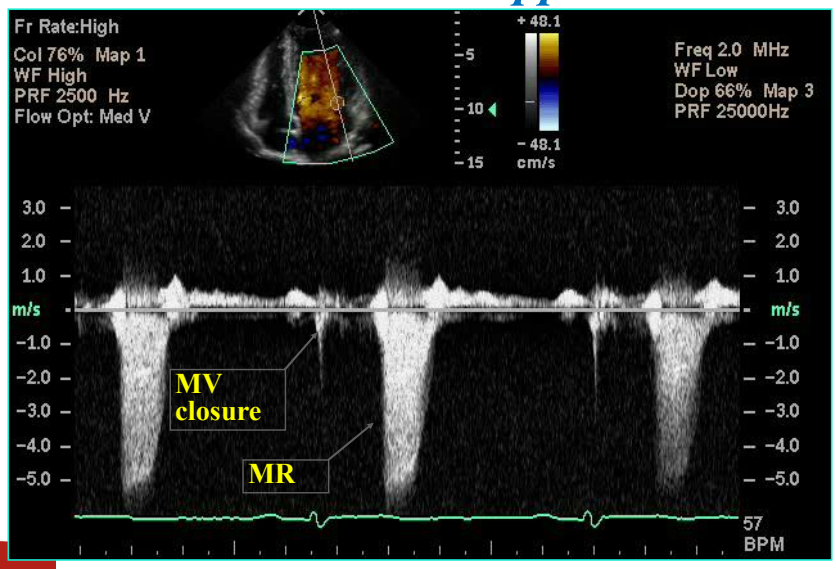


Large jet, large proximal convergence zone

ROA ~ 0.6 cm²

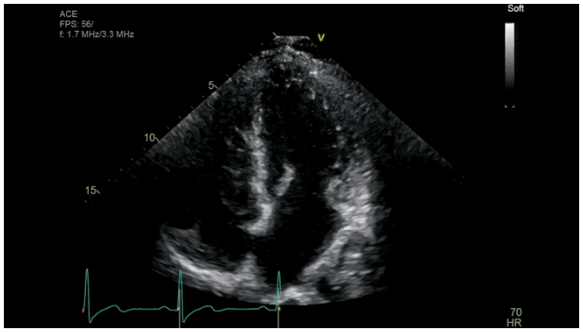
But Only Briefly!

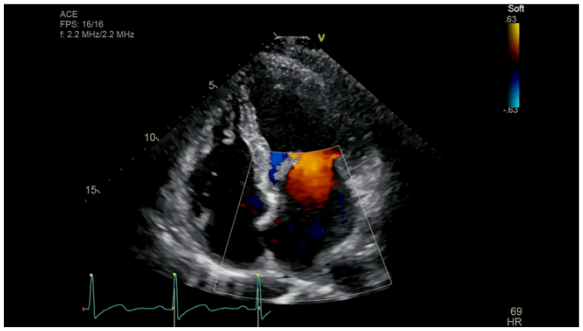
Mitral CW Doppler

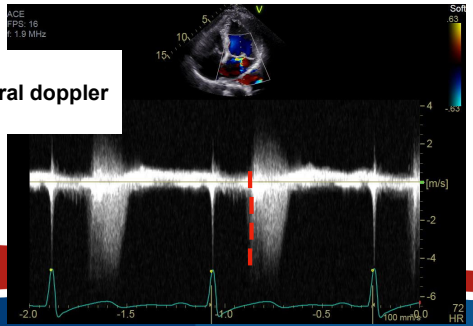


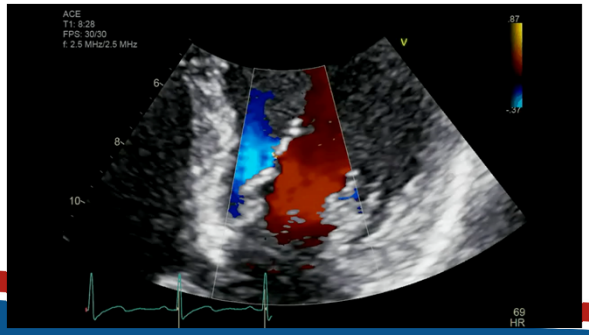
Significant MR only in latter half of systole

2018 - 53 year old very active female presents for second opinion on mitral valve regurgitation, ~10 year known history of MVP









Helpful tips:

- **Only measure the spectral doppler that is there!**

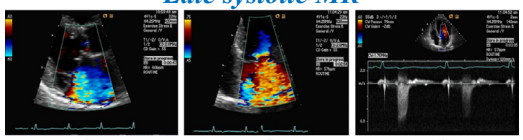
Impact of Duration of Mitral Regurgitation on Outcomes in Asymptomatic Patients With Myxomatous Mitral Valve Undergoing Exercise Stress Echocardiography

American Society of Echocardiography

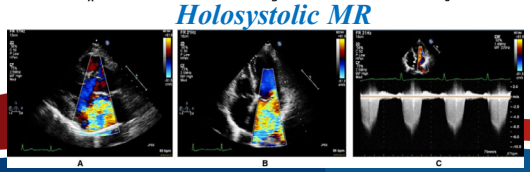
Peyman Naji, MD; Fadi Asfahan, MD; Tyler Barr; L. Leonardo Rodriguez, MD; Richard A. Grimm, MD; Shikhar Agarwal, MD, MPH; James D. Thomas, MD; A. Marc Gillinov, MD; Tomislav Mihaljevic, MD; Brian P. Griffin, MD; Milind Y. Desai, MD

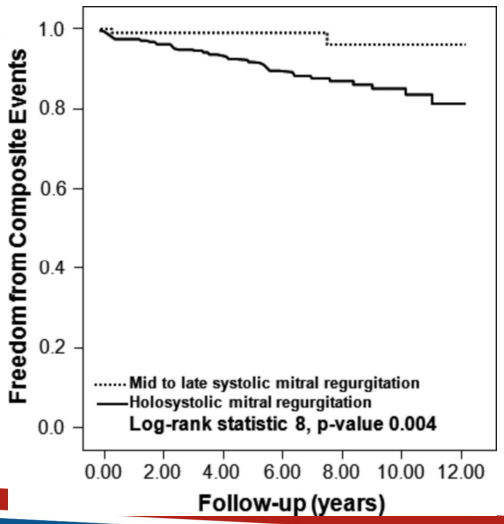
- 609 pts w/ ≥ 3+ MR (122 late systolic)
- All underwent stress echocardiography
- Late MR pts were younger and more likely female
- Endpoints: death and CHF
- HS vs LS: 4.99x more likely endpoints

Late systolic MR



Holosystolic MR





Naji et al., JAHA 2015; 4: e001348

PISA Adjustments

ASE American Society of Echocardiography

Pitfalls and Refinements to Keep in Mind

1. Nonholosystolic MR
2. **Proximal constraint distorting hemisphere**
3. Contour flattening near orifice
4. Noncircular orifice

Validation of the Proximal Flow Convergence Method

Calculation of Orifice Area in Patients With Mitral Stenosis

Leonardo Rodriguez, MD; James D. Thomas, MD; Victor Monterroso, MD; Arthur E. Weyman, MD; Pamela Harrigan, RDCS; Licia N. Mueller, RDCS; Robert A. Levine, MD

Rodriguez et al. *Circulation*. 1993;88:1157-65.

Quantification of Mitral Regurgitation by the Proximal Convergence Method Using Transesophageal Echocardiography

Clinical Validation of a Geometric Correction for Proximal Flow Constraint

Min Pu, MD, PhD; Pieter M. Vandervoort, MD; Brian P. Griffin, MD; Dominic Y. Leung, MBBS, MRCP, FRACP; William J. Stewart, MD; Delos M. Cosgrove III, MD; James D. Thomas, MD

Pu et al., *Circulation* 1995; 92: 2169-2177.

Impact of Wall Constraint on Velocity Distribution in Proximal Flow Convergence Zone

Implications for Color Doppler Quantification of Mitral Regurgitation

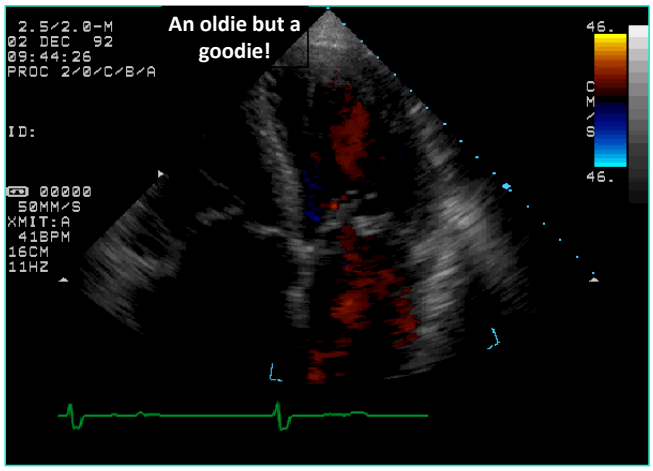
MIN PU, MD, PIETER M. VANDERVOORT, MD, NEIL L. GREENBERG, MS, KIMERLY A. POWELL, PhD, BRIAN P. GRIFFIN, MD, FACC, JAMES D. THOMAS, MD, FACC

Cleveland, Ohio

Pu et al., *JACC* 1996; 27: 706-13.

PISA Pitfalls

Constraint by Surrounding Structures



Flail posterior leaflet leads to constraint by posterolateral wall

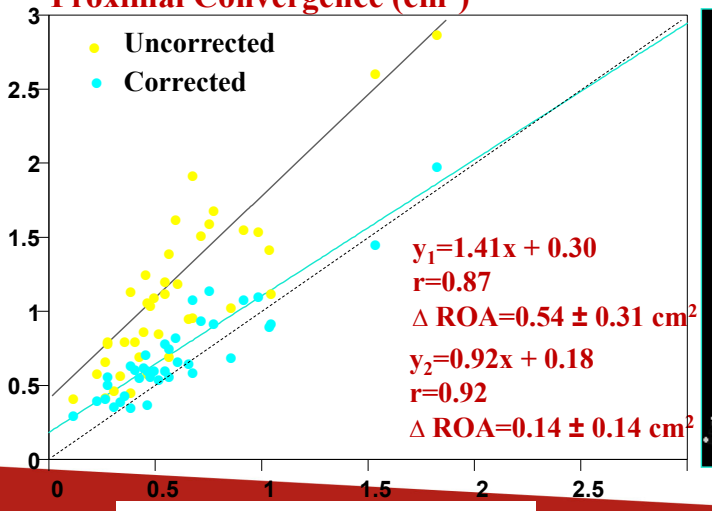
Pu et al., *Circulation* 1995; 92: 2169-2177.

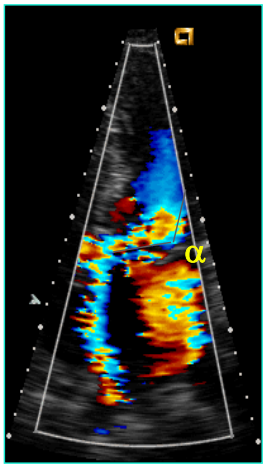
Angle Correction for Constrained Flow

Regurgitant Orifice Area

Proximal Convergence (cm^2)

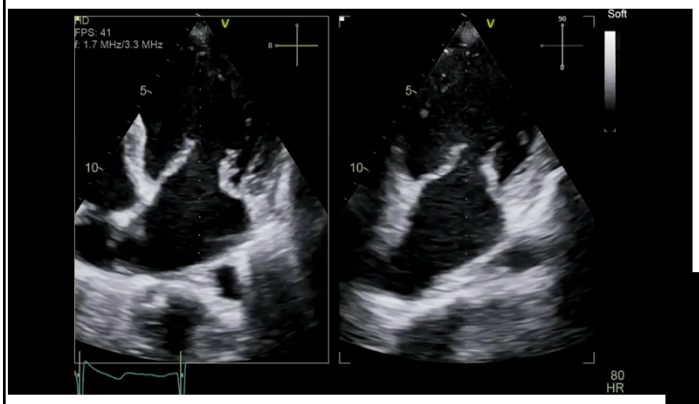
$Q = 2\pi r^2 v(\alpha/180)$

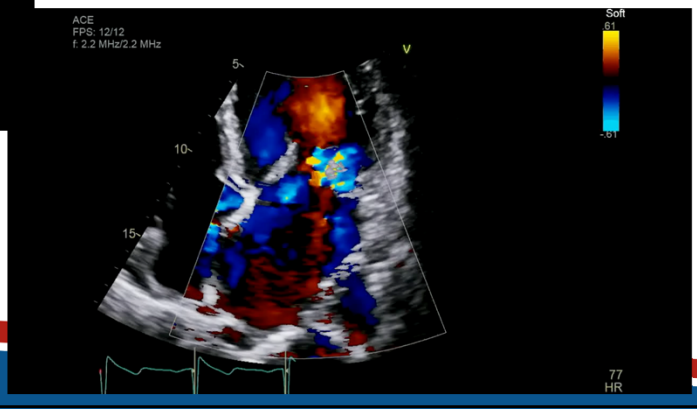




Pu et al., *Circulation* 1995; 92: 2169-2177.

2021- Same patient, still very active and asymptomatic but prolapse evolved to flail

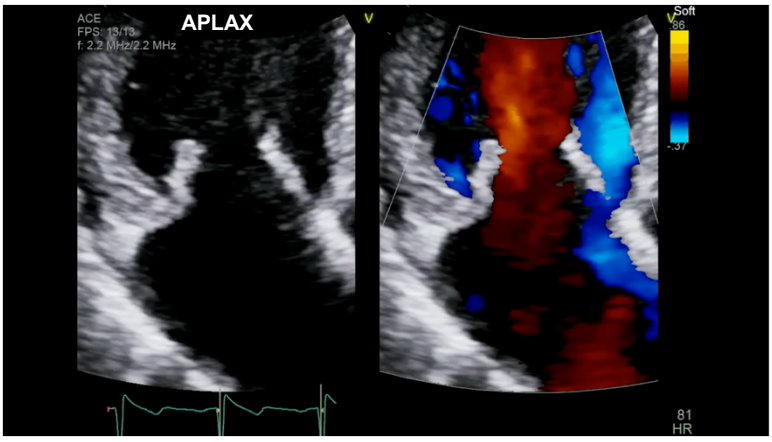


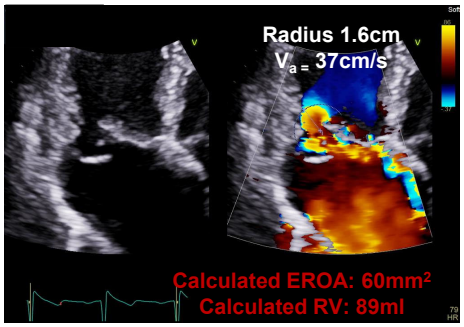


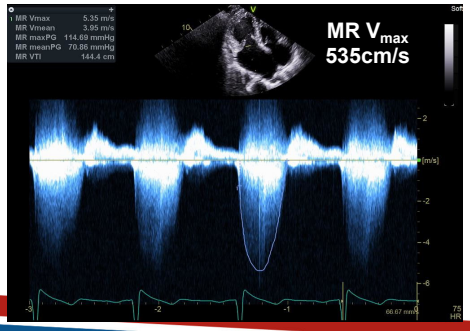
Helpful tips:

- **Use biplane method to locate lesion**
- **If you can already see a PISA hemisphere without baseline shift…probably severe.**

Mitral Regurgitation







Helpful tips:

- **Measure PISA radius in the direction of jet**
- **Suppress color or use color-compare to see the anatomy**

PISA Adjustments

Pitfalls and Refinements to Keep in Mind

1. Nonholosystolic MR
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3. **Contour flattening near orifice**
4. Noncircular orifice

Impact of Finite Orifice Size on Proximal Flow Convergence

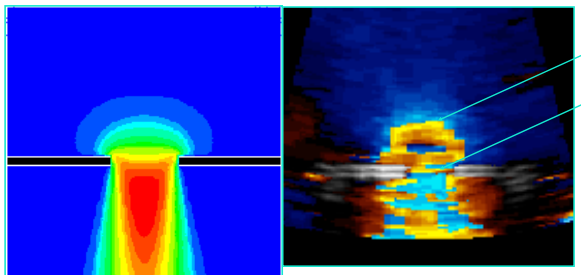
Implications for Doppler Quantification of Valvular Regurgitation

Leonardo Rodriguez, Joseph Anconina, Frank A. Flachskampf, Arthur E. Weyman, Robert A. Levine, and James D. Thomas

***Circ Res* 1992; 70: 923-30**

Computational Fluid Dynamics Aids Analysis

Contour Flattening Near the Orifice



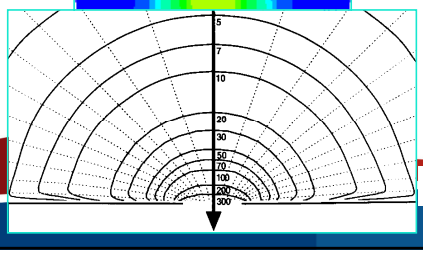
Contour velocity: v_a

Orifice velocity: v_0

Conventional PISA

$$Q = 2\pi r^2 v_a$$

Flow underestimated by v_a/v_0

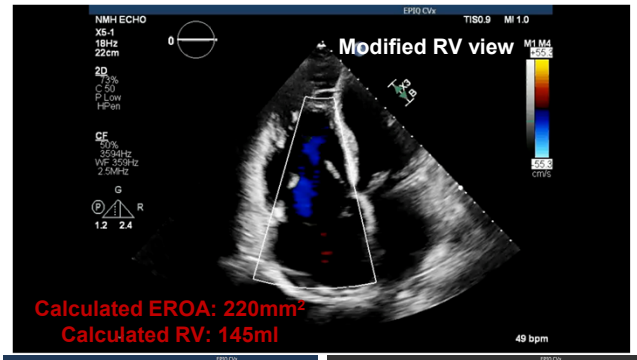


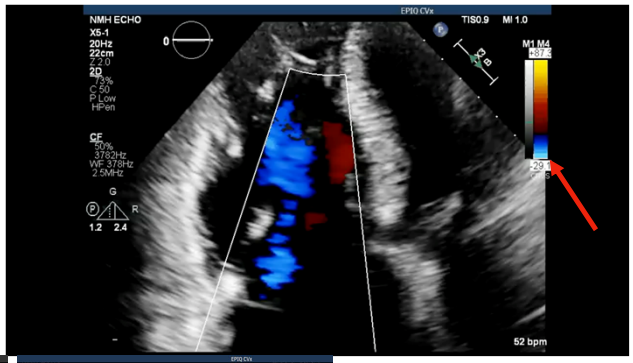
Corrected PISA

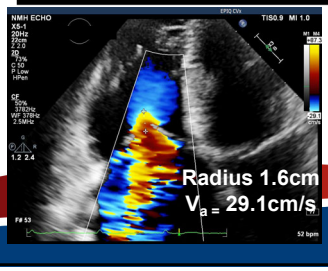
$$Q = 2\pi r^2 v_a \frac{v_0}{v_0 - v_a}$$

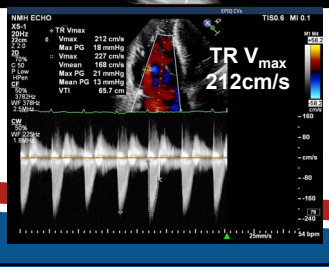
Rodriguez et al. Circ Res 1992; 70: 923-30

83 year old male with occasional LEE presents to valve clinic for evaluation of tricuspid regurgitation





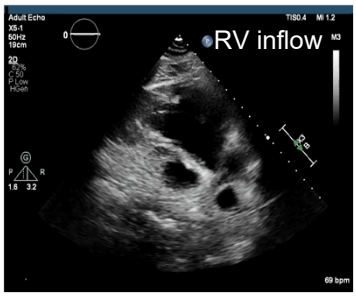


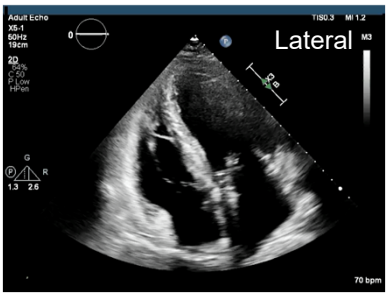


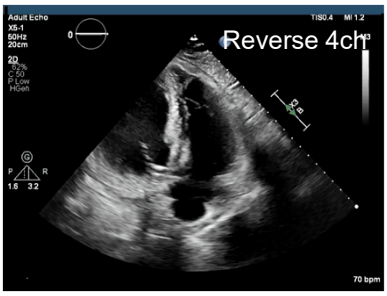
Helpful tips:

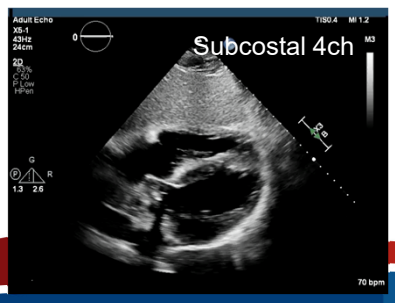
- Baseline shift to ~25-30cm/s for tricuspid regurgitation
- Suppress color to ensure proper measurement

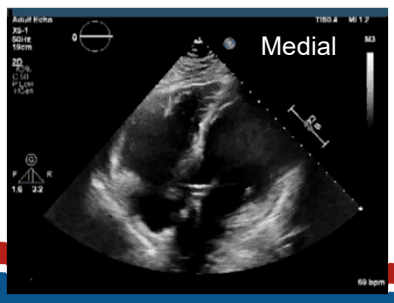
Using multiple windows

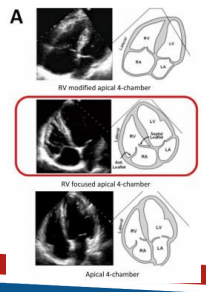




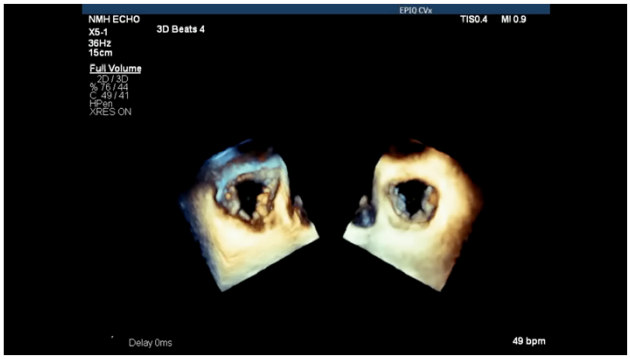


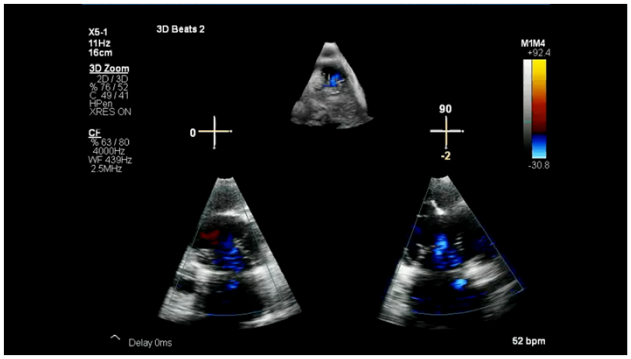






Can we use 3D for PISA?





Helpful tips:

- **Take color image with and without baseline shift**
- **Use suppress color to ensure accurate measurement**
- **Use multi-beat acquisition for highest frame rate**
- **Come to the 3D workshop for more helpful hints!**

PISA Adjustments

Pitfalls and Refinements to Keep in Mind

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2. Contour flattening near orifice
3. Proximal constraint distorting hemisphere
4. **Noncircular orifice**

Valvular and Congenital Heart Disease

Geometry of the proximal isovelocity surface area in mitral regurgitation by 3-dimensional color Doppler echocardiography: Difference between functional mitral regurgitation and prolapse regurgitation

Yoshiki Matsumura, MD, Shota Fukuda, MD, Hung Tran, RDCS, Neil L. Greenberg, PhD, Deborah A. Agler, RDCS, Nozomi Wada, MD, Manatomo Toyono, MD, James D. Thomas, MD, and Takahiro Shiota, MD *Cleveland, OH*

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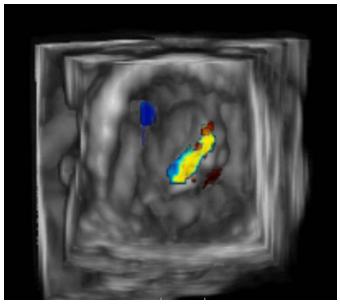

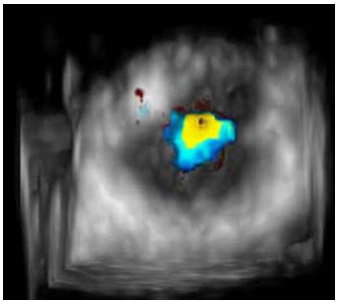

Functional mitral regurgitation **Prolapse regurgitation**

ROA highly elongated in FMR, more focal in MVP

Matsumura Y, et al. *Am Heart J* 2008;155:231-8

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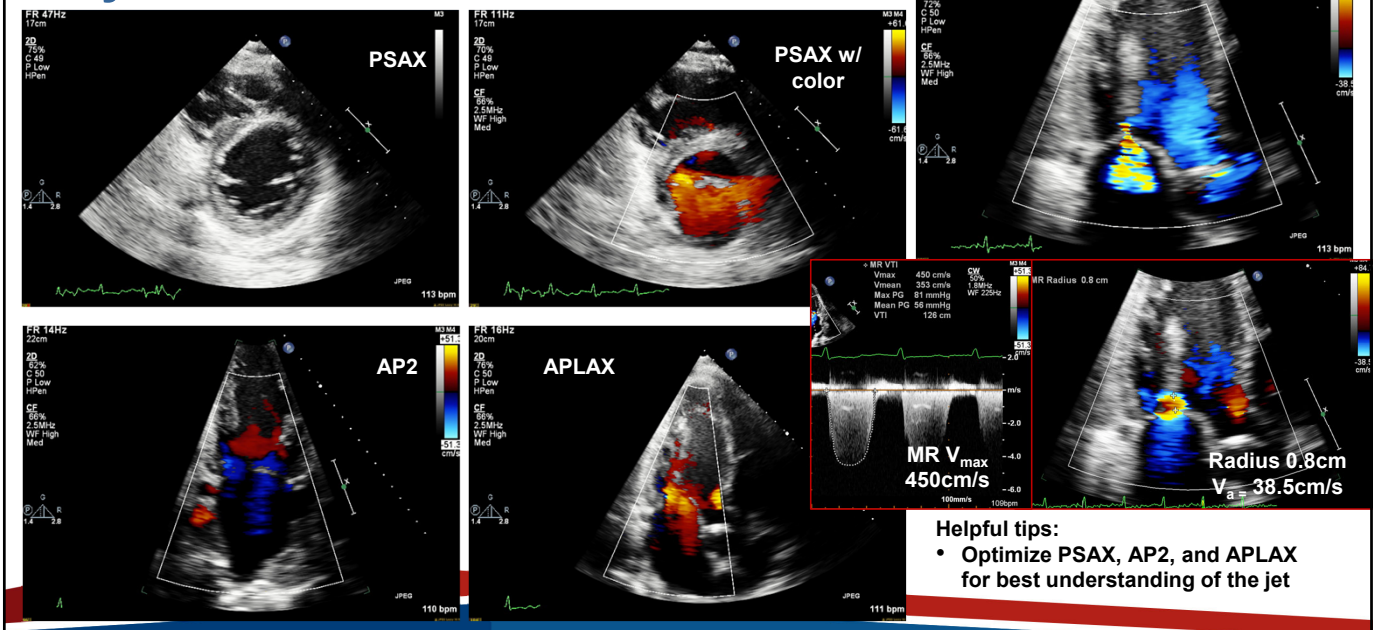
What is the impact of orifice shape on PISA accuracy?

57-year-old male with DOE

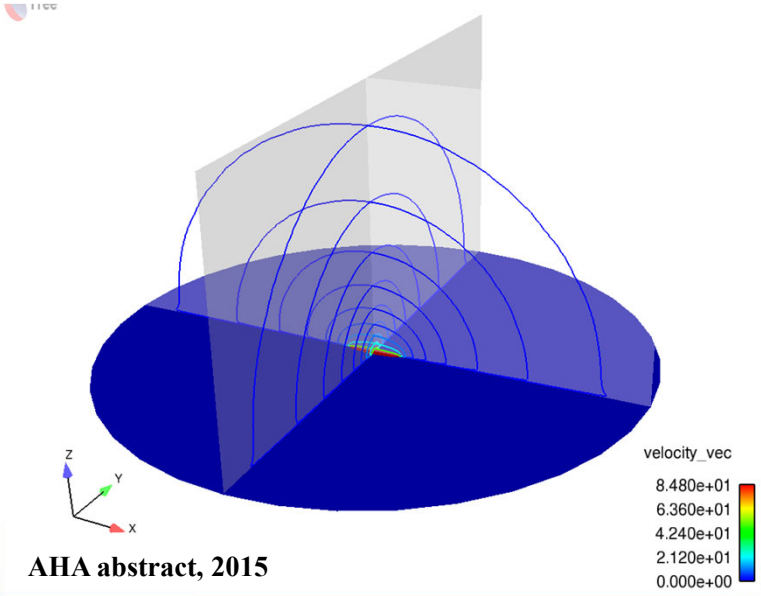


Helpful tips:

- Optimize PSAX, AP2, and APLAX for best understanding of the jet

Proximal Convergence Through Ellipses

CFD of 5:1 Ellipse

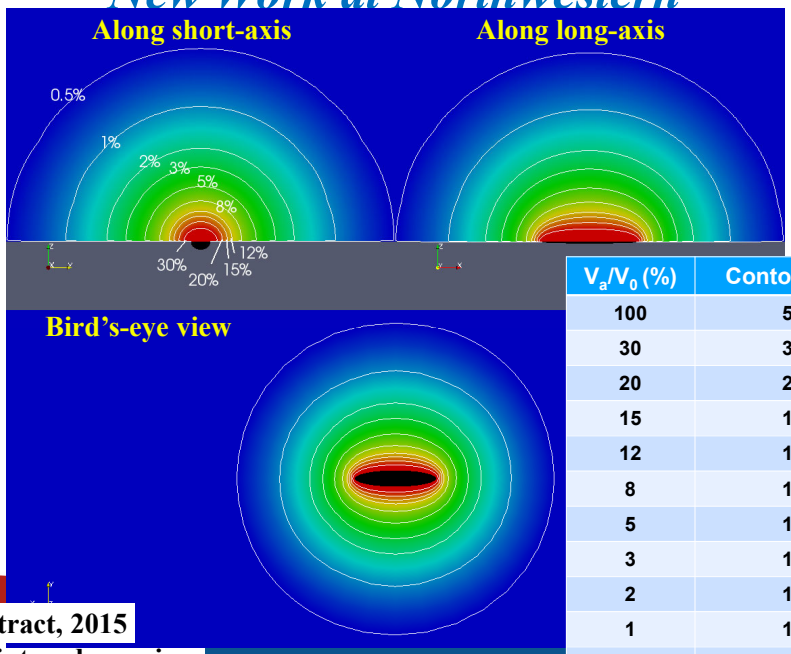


AHA abstract, 2015

Simulations courtesy of Gregory Wagner, PhD

Flow Through 5:1 Ellipse

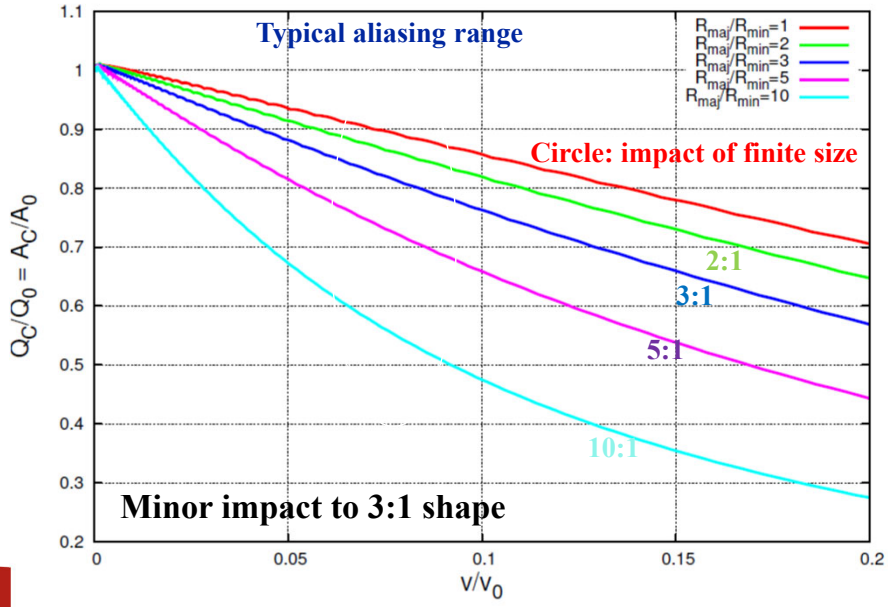
New Work at Northwestern



V_a/V_0 (%)	Contour Ratio
100	5.00
30	3.00
20	2.35
15	1.97
12	1.80
8	1.54
5	1.31
3	1.19
2	1.12
1	1.06
0.5	1.02

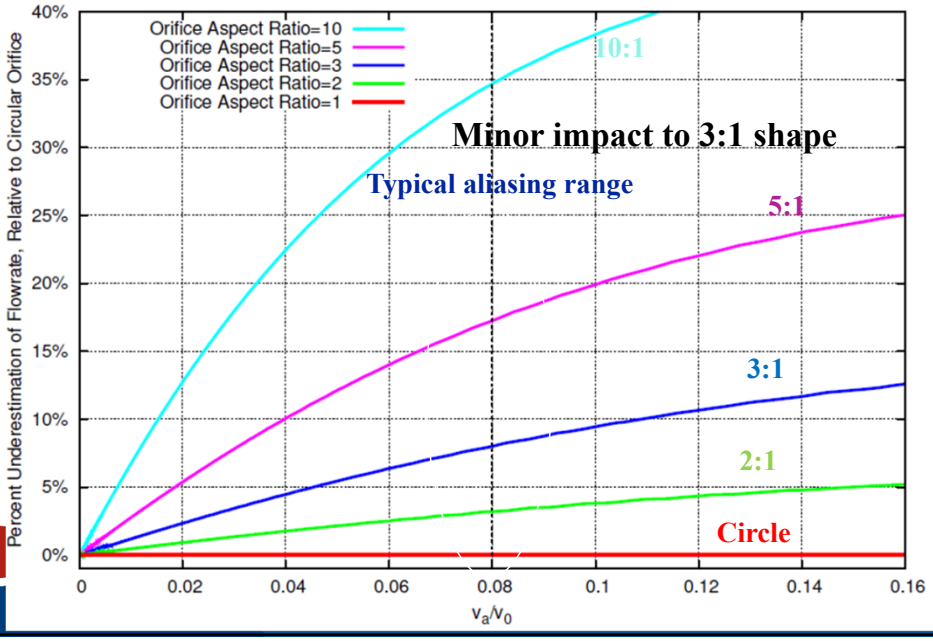
AHA abstract, 2015
Manuscript under review

Impact of Finite and Noncircular Orifices

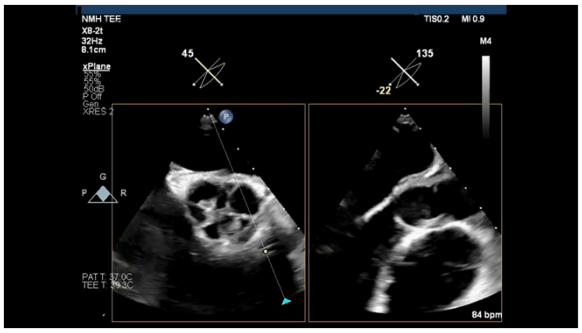


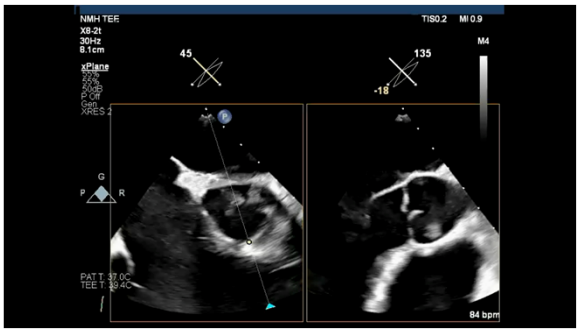
Impact of Noncircular Orifices

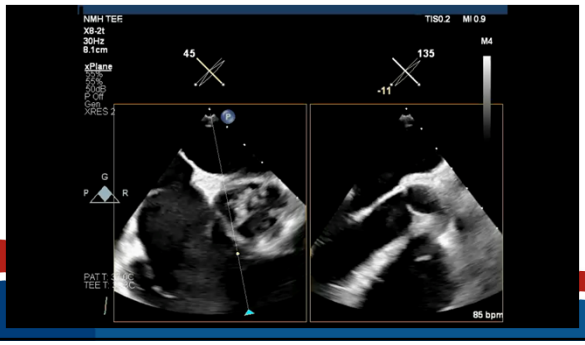
Underestimation vs Circular Orifice



21 year old male who presents with 3 weeks of fevers and blood cultures positive for Strep sanguinis







You can do PISA on the aortic valve, too!

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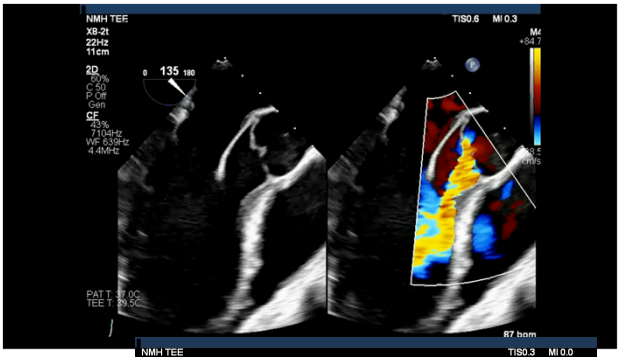

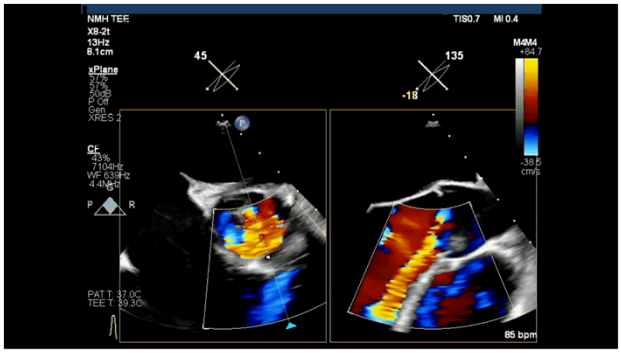

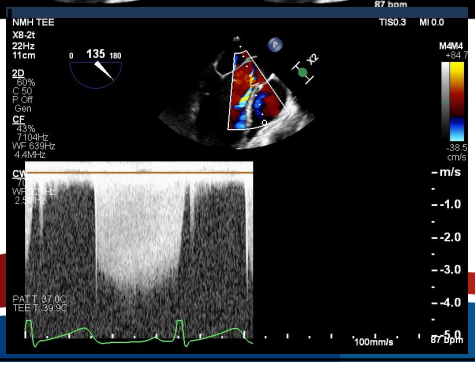

Helpful tips:

- **Shift the baseline towards the direction of the jet**
- **Align CW wherever it is most parallel to flow, may be a non-conventional image**

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Mahalo!