#ASEchoJC Twitter Chat
Tuesday, March 2, 2021 – 8 PM ET

- **Estimation of Stroke Volume and Aortic Valve Area in Patients with Aortic Stenosis: A Comparison of Echocardiography versus Cardiovascular Magnetic Resonance** (JASE, VOLUME 33, ISSUE 8, P953-963.E5, August 2020)

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Co-Authors: Ezequiel Guzetti (@E_Guzzetti) & Philippe Pibarto (@PPibarot)

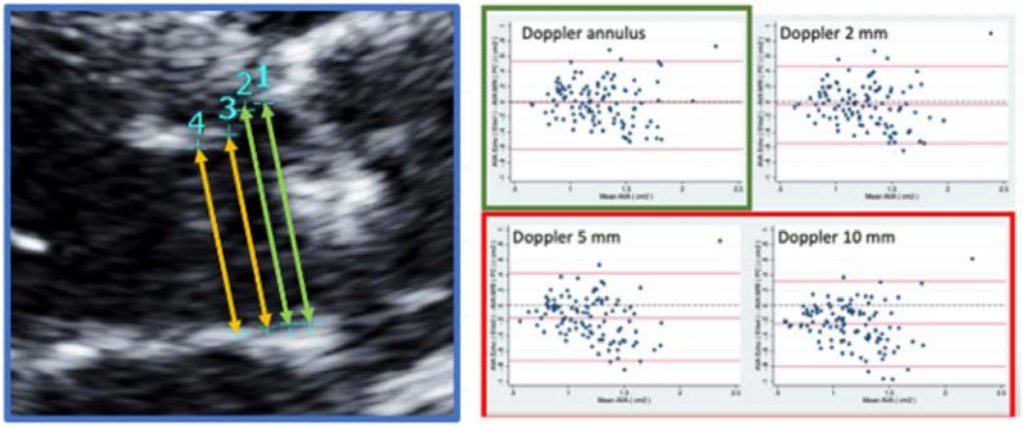
Introduction and Welcome: Welcome everyone to tonight's #ASEchoJC with @PPibarot @E_Guzzetti whose Memo @JournalASEcho https://bit.ly/305OhFF is to be discussed w @rajdoc2005 @ash71us as my co-moderators #echofirst @VLSorrellImages

Tweetorial: https://twitter.com/iamritu/status/1366870496126640128?s=20

Q1: Which location of LVOT diameter measurement yields the best agreement for AVA between Doppler TTE & phase-contrast (CMR) imaging (the referent method)? A1 Notable Responses:

@iamritu: A1. the #echofirst Doppler method using LVOT diameter measured at or very close to the annulus provides the most accurate & reproducible estimates of SV & AVA c/w phase-contrast

@E_Guzzetti: Best agreement between Doppler TTE and PC-CMR for AVA calculation was when LVOTd was measured at the annular level (or very close to it: levels 1-2). Measuring 5-10 mm below (levels 3-4, as per guidelines) led to significant overestimation of AVA (up to 0.16 cm2/ 20%)



@rajdoc2005: Location! Location! Location!!!! This is a really critical point - since we get slightly different values depending on where we measure!!

@VLSorrellImages: Why is PC CMR the reference standard? What GOLD standard was phase contrast compared to?

@kgzimmerman: So why are we using a 2D LVOT dimension for a 3 dimensional object?

@iamritu: Ideally we should use 3D - #echofirst better reproducibility and correlation with #Whycmr

@ash71us: It appears that the Simpson's method with CMR overestimated the stroke volume over PC CMR because muscle bundles and Pap muscles were included

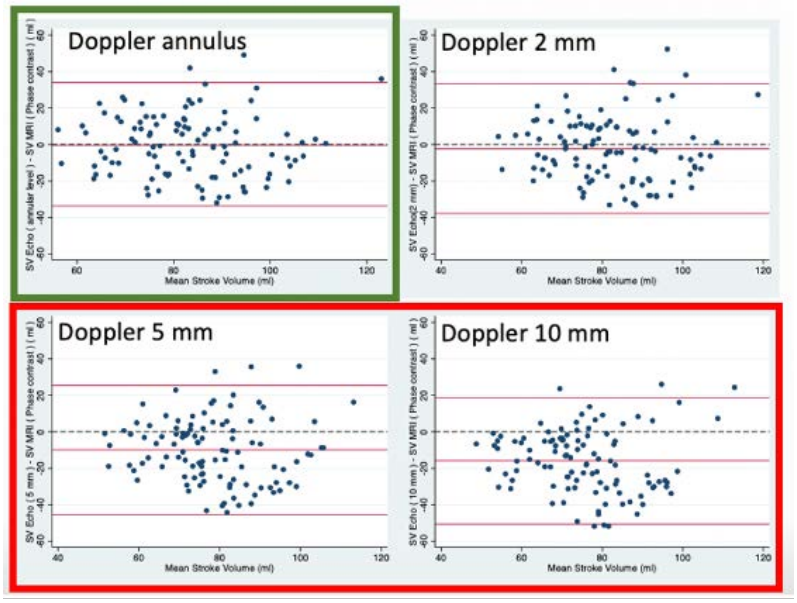
@iamritu: Was this overestimation of AVA related to size or shape more?

@E_Guzzetti: Mostly to underestimation of LVOTd (related mainly to an hourglass Hourglassshape)

Q2: Where was the LVOT measured for best agreement b/w #echofirst & #whyCMR for SV measurement

A2 Notable Responses:

@E_Guzzetti: As for AVA, best agreement between TTE and PC-CMR for SV calculation was when LVOTd was measured at the annular level or very close to it. Measuring 5-10 mm below led to significant underestimation of SV (up to 16 ml or 20%).



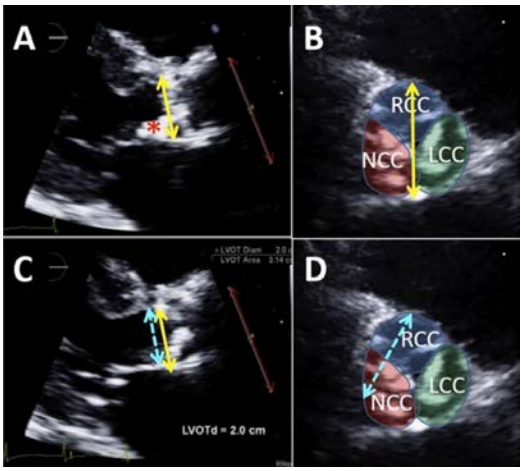
@iamritu: A2. There was fairly good reproducibility b/w LVOT diameter at annulus or just below it.

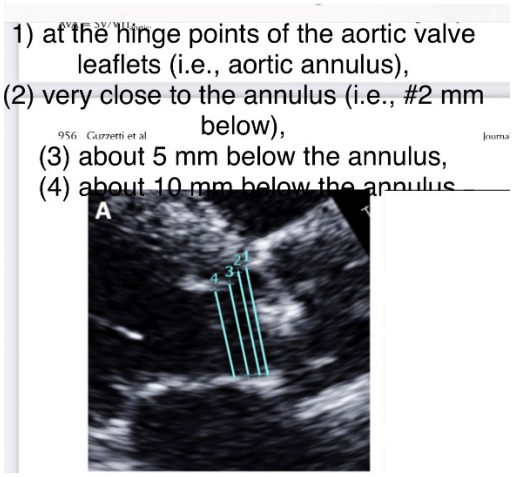
@PPibarot: Yes reproducibility is generally better when LVOT is measured at or closed to the annulus because we have clear anatomical landmarks (base of cusps) to guide measurement.

Q3: Where is the LVOT diameter the largest? Where should we measure LVOT area to get the most accurate measurement? Any tips and tricks to measuring LVOT diameter?

A3 Notable Responses:

@iamritu: A3. Try & get in PLAX zoomed view, the imaging plane that bisects the RCC anteriorly & commissure b/w left & noncoronary cups posteriorly to maximize the size of the LVOT. Measure as close to annulus as possible for most accurate LVOTd





@rajdoc2005: "Where is the LVOT diameter the largest"? That question tells us that the LVOT is NOT a perfect cylinder!!! This is an important concept to understand.

@VLSorrellImages: and please resist the urge to simply use 2.0cm2. That is rarely the true LVOT - despite what you have heard!

@E_Guzzetti: Key question, magnifically addressed by @PPibarot and @hahn_rt in an Editorial: https://onlinejase.com/article/S0894-7317(17)30443-1/abstract In our cohort, in up to 95% of patients, LVOT diameter was largest at the annulus. Some tips and tricks for accurate LVOTd measurement by TTE (1/3)

@E_Guzzetti: 1.Mid-systolic image that bisects largest dimension of aortic annulus (RC hinge point and interleaflet triangle of LC/NC cusps)

2.Measure LVOTd at the annulus (not 0.5-1 cm below)

3.Exclude LVOT calcifications if present (2/3)

@E_Guzzetti: 4. Calculate predicted LVOTd using the formula: LVOTd = (5.7 x BSA) + 12.1

5.#yesCCT remains gold standard for LVOT measurement, but hybrid-AVA thresholds should be used (i.e., <1.2 cm2 for severity) (3/3)

@aliciarangosch: The CSA derived by 2d assumes a circular geometry where the anteroposterior diameter is measured. We now have evidence that the LVOT is more oval than circular and that the largest or major (orthogonal) diameter might be out of plane in PLAX. Biplane/3D can be more accurate

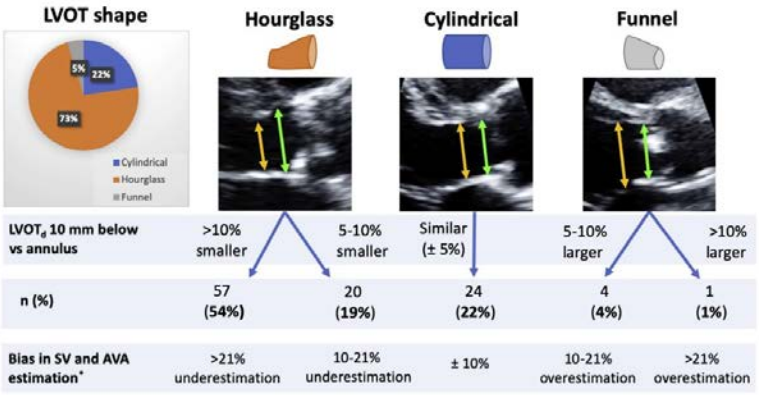
@alsannifecho: For me measure at the leaflet insertion when the valve open. If I have TEE then the resolution much better for LVOT diameter. And with 3D- I go for LVOT area from MPR.

Q4: What is the most frequent SHAPE of LVOT in this study? How does the shape of the LVOT affect the LVOT diameter and the severity of aortic stenosis?

A4 Notable Responses:

@EGarciaSayan: LVOT is most commonly "hourglass" shaped (widest at the annulus). Hence the importance of measuring as close to the leaflet insertion as possible. And of course, PWD sample volume has to be placed at the same location when performing stroke volume calculations.

@E_Guzzetti: Hourglass (i.e., largest LVOTd at the annulus) was by large the most frequent shape (73%). 22% had relatively "rectangular" shape and 5% had funnel shape. The site of LVOTd measurement has a significant impact on accurate AS (and LF state) diagnosis. #ASEchoJC

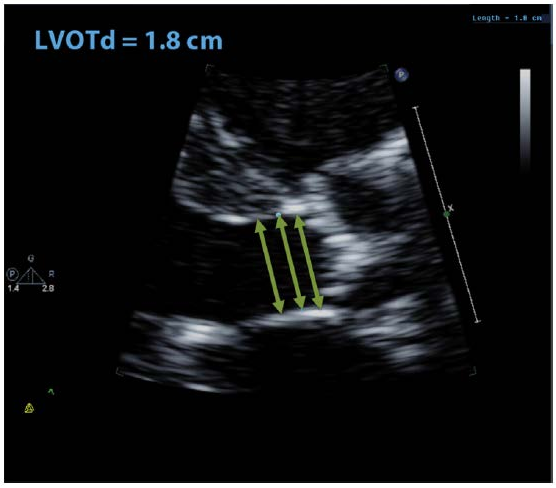


@PPibarot: Oh yes, what the clinicians did at the Bernoulli formula is a massacre: we neglect 2 terms and in the last remaining term, we neglect V1. This is an OVER-simplification of the formula. This is OK for severe AS, probably not so for mild AS or normal prosthetic valves.

@DavidWienerMD: An important point made by @PPibarot about V1 when it is high, which I point out to my fellows

@iamritu: A4. LVOT shape from LV cavity to aortic valve is not cylindrical rectangular, as suggested in guidelines, but Hourglass in most of patients in this study 73%; anteroposterior LVOT diameter measured on #echofirst is generally larger at annulus than at 5 to 10 mm below annulus

@PPibarot: Interesting to note that in the 2017 ASE recommendations for assessment of AS published, it is mentioned in the legend of Figure 5 that: "In many patients, as in this case, the LVOT is rectangular within 1 cm of the annulus". Our study shows that this is not the case, in AS pts.



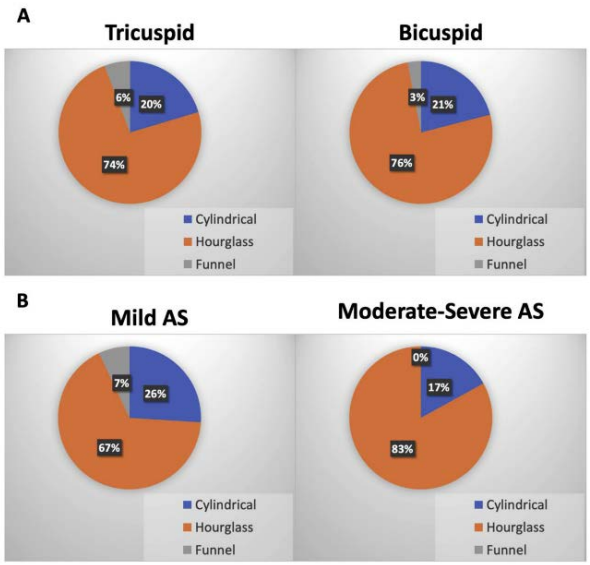
@echoguru: I had always taught that if it wasn't rectangular, then we are prob wasting our time...and AVA should be interpreted in context. The sample volume is not at a fixed point in the LVOT, so we need it to be a rectangle (or cylinder) through the section that is sampled....

@ PPibarot: Only 22 % were rectangular. >70% were hourglass.

Q5: Does the shape of the LVOT vary in prevalence between tricuspid or bicuspid aortic valves? Does the LVOT shape vary between mild moderate or severe AS?

A5 Notable Responses:

@E_Guzzetti: Distribution of LVOT shapes was comparable in bicuspid (76% hourglass, 21% cylindrical, 3% funnel) and tricuspid valves (74%, 20% and 6% respectively, p=0.88), as well as in those with mild vs moderate/severe AS, p=0.12).



@rajdoc2005: So much to be thankful - that Bicuspid valves did not alter the shape of the LVOT. Things would have gotten more complicated!!! Key point: Hour Glass LVOT shape - commonest for BOTH tricuspid and bicuspid AV.

@VLSorrellImages: Maybe that helps to explain the HIGH success rate that was unanticipated in early TAVI data on BAV

Q6: Why does "CMR-only" (i.e., both SV and aortic valve VTI derived from phase-contrast CMR) method lead to significant overestimation of AVA?

A6 Notable Responses:

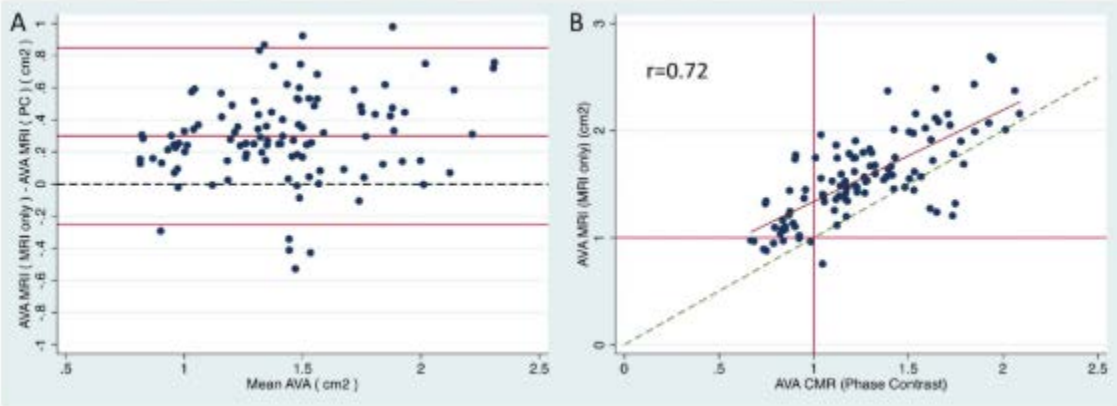
@iamritu: A6. CMR-only both SV & AV VTI derived from phase-contrast CMR leads to overestimation of AVA, mostly due to underestimation of AV VTI caused by its lower temporal resolution relative to Doppler, difficulty finding exact perpendicular position/ angle)of vena contracta

@EGarciaSayan: #ASEchoJC, though this is mostly due to underestimation of Vmax and VTI by #WhyCMR as the authors point out, one must also consider the differences in annular area measurements that also overestimate AVA in "hybrid methods". Cutoff of 1.2 cm2 for CT.

@VLSorrellImages: CMR phase contrast is NOT instantaneous like Doppler. It is averaged. Therefore, PC gradients with CMR represent a type of "Max-Mean", for lack of a better comparison. Terms like "over-" & "under-" are less meaningful than "estimation" - it comes back to outcomes.

@VLSorrellImages: Luckily, like @DavidWienerMD says, we have many studies with excellent associations with outcomes. Comparing values that predict outcomes makes inter-study comparisons better aligned (e.g. 'critical' AS echo <0.7cm2 becomes closer to 'severe' AS <1.0cm2 CMR).

@E_Guzzetti: Though #whyCMR is the gold standard for flow and volumes/LVEF, it significantly underestimates Vmax due mostly to partial volume averaging and lower temporal resolution vs Doppler. Therefore, aortic VTI is underestimated, leading to overestimation of AVA. #ASEchoJC



@EGarciaSayan: #ASEChoJC. #WhyCMR only AVA calculation overestimates AVA when compared to #EchoFirst, mostly due to underestimation of LVOT velocity and VTI

@rajdoc2005: I cannot emphasize this point enough re: UNDER-ESTIMATION of VMax on #WhyCMR. Always a good practice to review TTE/TEE when available when reading #WhyCMR for AS. Important to know the strengths and weaknesses of each technique!!

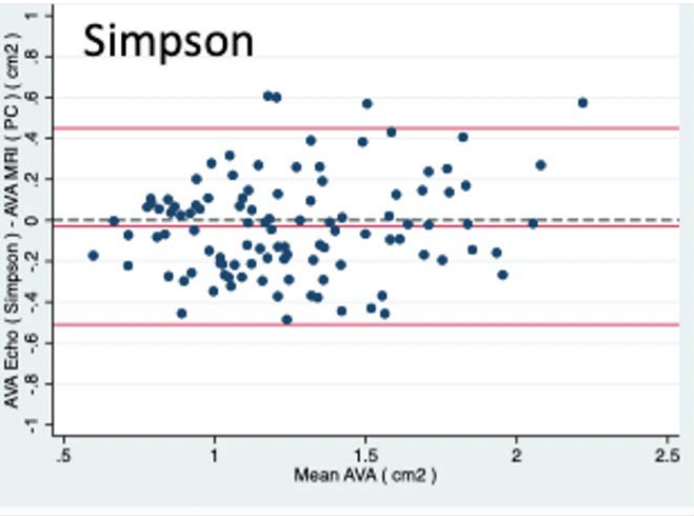
Q7: How can one use biplane Simpson method as an "internal control" for SV?

A7 Notable Responses:

@VLSorrellImages: Such an important concept. ALL fellows / students / junior faculty should make this their routine!

@E_Guzzetti: SV derived from biplane Simpson (LVEDV-LVESV) showed excellent agreement with PC-CMR and Doppler TTE at the annulus. Thus, a careful (i.e., no foreshortening) Simpson is a useful corroborative method if Doppler TTE not feasible (e.g., flow acceleration in the LVOT) (1/2)

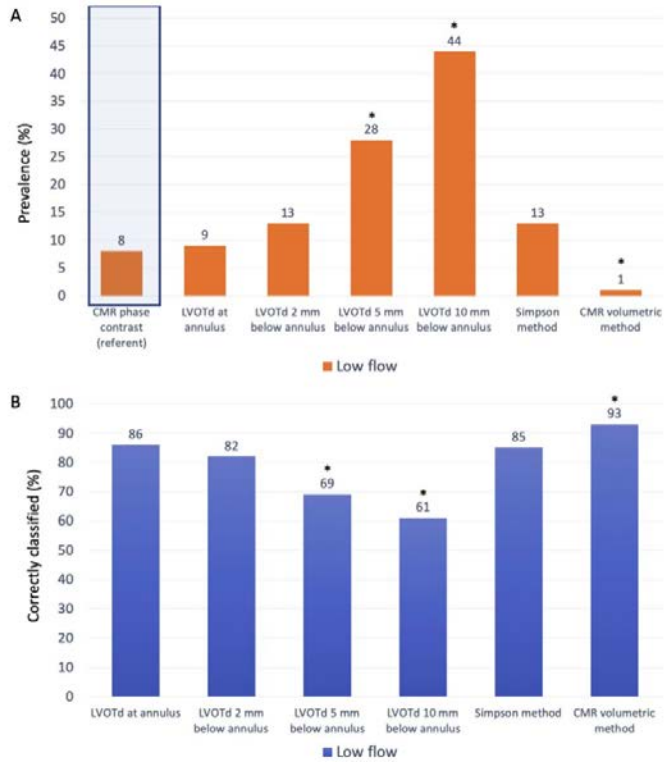
@E_Guzzetti: This is valid if there is no greater than trace/mild mitral regurgitation (as for #whyCMR). As mentioned, use of UEA might improve Simpson estimation of SV #ASEchoJC



Q8: What is the Prevalence of Low-Flow Status according to different measurement methods? What is the clinical significance of this?

A8 Notable Responses:

@E_Guzzetti: Prevalence varied from 9% when LVOT was measured at the annulus to 44% when measured 1 cm below (vs 8% using the referent method PC-CMR). This has huge clinical and research implications, as it may explain the variability of LF prevalence reported in various studies.



@PPibarot: This is why it so critical to obtain an accurate measure of SV by TTE and rule out measurement errors. If you measure and LVEDV of 140 ml and the LVEF is 60% (total SV: 85 ml) and there is no MR and you measure a SV in LVOT of 50 mL, you obviously underestimate the SV by 35 ml.

Q9: What was the Prevalence of severe AS (as defined by AVA < 1 cm2) according to different methods? What is the clinical significance of this?

A9 Notable Response:

@E_Guzzetti: Prevalence ranged from 20% when LVOT was measured at the annulus to 48% when LVOTd was measured 1 cm below (vs 25% using the referent method PC-CMR). Once again, this has enormous clinical (indication for aortic valve intervention) and research implications.

Q10: What was the interobserver variability b/w #whyCMR and #Echofirst ?

A10 Notable Response:

@E_Guzzetti: Intra- and interobserver reproducibility were very high for both CMR and TTE. Reproducibility was significantly higher when LVOTd measured at the annulus vs 10 mm below, due to clear anatomical landmark, which is another argument for LVOTd measurement at the annulus

Supplemental Table 1 Intraobserver and interobserver reproducibility

Measurement	Intraobserver ICC (95% CI)	Interobserver ICC (95% CI)
CMR		
SV (phase contrast)	0.93 (0.75–0.98)	0.89 (0.64–0.97)
SV (volumetric)	0.94 (0.77–0.98)	0.91 (0.68–0.97)
LVEDV	0.99 (0.95–1.00)	0.95 (0.80–0.98)
LVESV	0.93 (0.73–0.98)	0.83 (0.41–0.96)
Echocardiography		
LVOT diameter (annulus)	0.99 (0.96–1.00)	0.98 (0.91–0.99)
LVOT diameter (2 mm below)	0.98 (0.92–0.99)	0.96 (0.84–0.99)
LVOT diameter (5 mm below)	0.96 (0.86–0.99)	0.89 (0.62–0.97)
LVOT diameter (10 mm below)	0.94 (0.51–0.99)	0.80 (0.39–0.95)
LVEDV (Simpson biplane)	0.89 (0.61–0.97)	0.87 (0.56–0.97)
LVESV (Simpson biplane)	0.83 (0.48–0.95)	0.92 (0.72–0.98)

Q11: Why do the current guidelines suggest the current recommendation to measure LVOT diameter at 5 to 10 mm below the annulus?

A11 Notable Responses:

@iamritu: It was based on idea that diameter should be measured at the exact same location as PWD sample vol but LVOT at 5 to 10 mm below annulus is more likely elliptical because of septal bulge & ap diameter likely smaller than sagittal diameter :underestimation of LVOT area

@E_Guzzetti: Great question! IMHO the recommendation of guidelines to measure LVOTd 5-10 mm below annulus is based on the rationale that it should be measured at the exact same location where the PW-Doppler sample is positioned

@rajdoc2005: Now that we can established the IDEAL location to measure LVOT diameter - where do you recommend we place the PW Doppler sample?

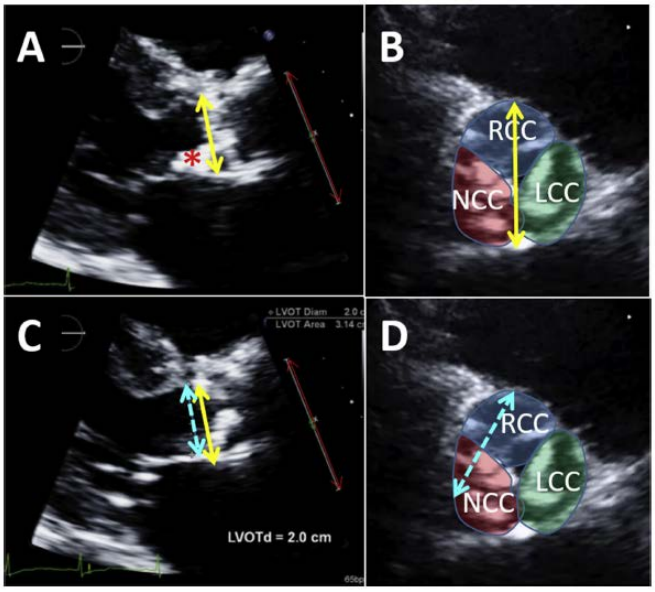
@E_Guzzetti: This makes sense from a fluid mechanics theoretical framework (once again, continuity equation), but in practice we aim to obtain a laminar flow, being hard to be precise if we're at 2, 5 or 8 mm below annulus.

@ash71us: Wonder how many people use the modified Teichholz to ensure proper stroke volume estimation in tricky cases?

@E_Guzzetti: We tested that. LOTS of underestimation when using Teichholz, especially at the basal level (more so in those with septal bulge!)

@ash71us: that's why I asked modified version - at mid-LV, below the bulge!

@EGarciaSayan: This is indeed a common critique of the current guidelines, which can lead to underestimation of AVA. LVOT has a rounder shape and widest diameter near the annulus. See excellent letter to the editor by @hahn_rt in 2017: https://onlinejase.com/article/S0894-7317(17)30443-1/pdf



Q12: Is the flow velocity profile along the LVOT in AS flat or not? How does this affect continuity equation?

A12 Notable Responses:

@iamritu: continuity equation assumes a relatively flat flow velocity pro- file (mean velocity = peak velocity), with homogeneous distribution of velocities through LVOT area But Its not flat but often skewed, with higher velocities along anterior/ right

@E_Guzzetti: This is an excellent and complex question (and crucial to understanding our results). There is growing evidence that flow at the LVOT is not flat but skewed (lot of interesting work from @JGarciaResearch, see https://jcmr-online.biomedcentral.com/articles/10.1186/1532-429X-13-25 . #ASEChoJC

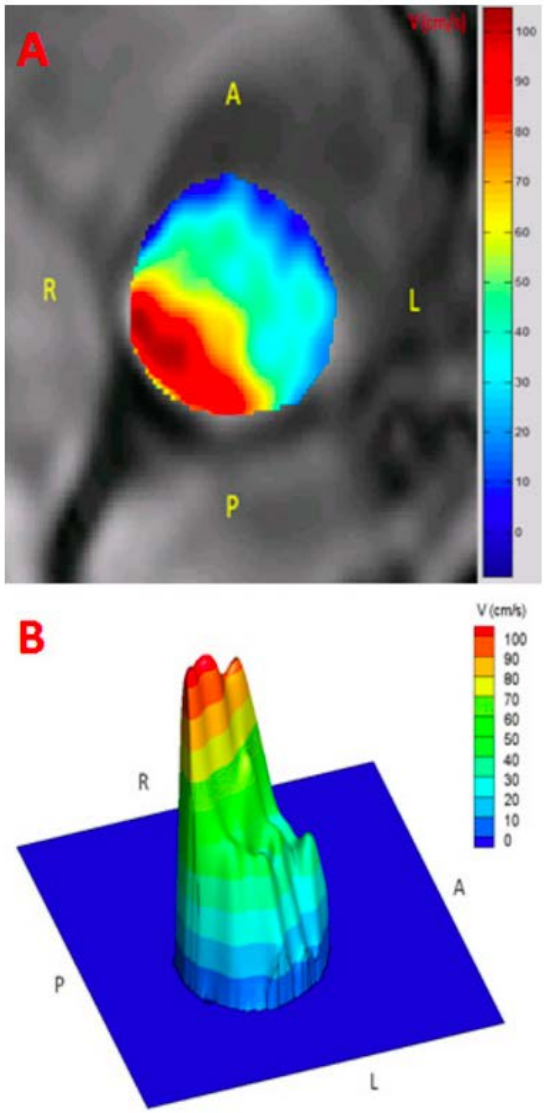


Figure 4 Flow velocity profile obtained by CMR in the LV outflow tract (LVOT). The figure shows the flow velocity profile within the LVOT in a patient with AS. Panels A and B show the 2D and 3D flow velocity profile.

@GWhalleyPhD: This may be the most important question of this #ASEchoJC so far. Flow isn't laminar and isn't evenly distributed through the LVOT and through to the Aorta. All our #echofirst measurements assume uniformity

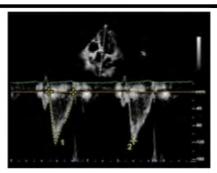
Additional Notable Responses:

@DavidWienerMD: Don't forget basic of AS: The LVOT VTI is another potential source of error:

- Sample too apical -> VTI smaller, LVOT SV underestimated, AS overestimated
- Sample too far into LVOT -> spectral broadening -> inaccurate

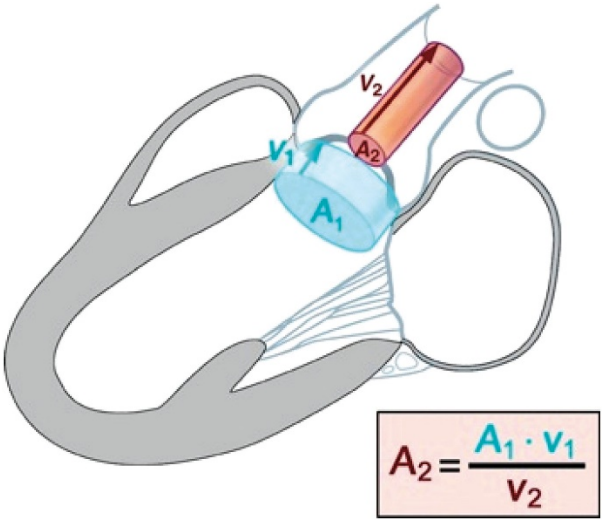
Ref: 2019 @ASE360 TTE GL: https://bit.ly/37YP9QT

Table 6 (*Continued*)

View	Spectral Doppler	Measurements to Make
6.10a. Apical window 5C view		PW of LVOT 1. LVOT VTI 2. LVOT peak velocity

D. LVOT and AV

The LVOT is best evaluated in the apical five-chamber or apical long-axis views. PW Doppler is used to obtain velocity in the LVOT. The PW Doppler sample volume is placed about 5 mm proximal to the AV in the center of the LVOT. The spectral signal should be narrow, with a rapid upstroke and an end-systolic click terminating the flow signal.[30,37] Broadening of the flow signal indicates that the sample volume is too close to the AV and should be repositioned. The



@boegel_kelly: I see too many studies with the sample volume placed too apically in the LVOT area. Important to remember that you should see the end-systolic click at the end of your waveform #ASEchoJC

@NMerke: Great & important advice. Standardized & correct performance of #echofirst protects the unique value of this imaging tool. Would like to add the importance of correct LVOTd measurements especially in FU coz often there is difference so SVI or AVA will be different

@DavidWienerMD: #ASEchoJC #echofirst underestimates LV volumes c/w #WhyCMR. Using an ultrasound enhancing agent improves measured LV volumes and gives better correspondence with CMR

https://onlinejase.com/article/S0894-7317(13)00963-2/fulltext