REVIEW ARTICLE

QUALITY CONTROL IN ECHOCARDIOGRAPHY REPORTING (PART B)

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This is the second part of the article under same head (published in the same issue of this journal). 'Quality control measures in echocardiography reporting' with regard to ventricular function assessment, cardiac thrombi and valvular assessment are described as a continuum of the previously described measures for study analysis.

Keywords: Transthoracic echocardiography, Echocardiography report and Quality control

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VENTRICULAR SYSTOLIC FUNCTION ASSESSMENT

1 **Left Ventricle:** The parameters used are estimation of ejection fraction (Biplane Simpson's method), fractional shortening and wall motion analysis. Wall motion analysis should be done in 17 segment model,[1] and graded on a scale of 1-4. A bull's eye view shows the wall motion score, Figure 1. Adding up the individual segments' score and dividing by the total number of segments scored will give the 'wall motion score index'.

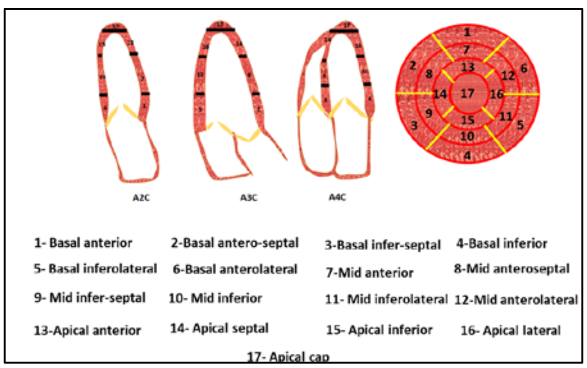

Figure 1: 17 segment model for LV wall motion analysis. The three apical views, bull's eye view and the segments

2 **Right ventricle:** Normal values of RV function parameters, Figure 2 are shown in Table 1.[2] Precautions for TAPSE recording have already been elucidated. While measuring Fractional area change, apical moderator band and trabeculae should be especially taken care of. RV free wall strain can be recorded by LV software but it is better to have an RV strain software. General precautions of TDI recording are observed while measuring S' velocity.

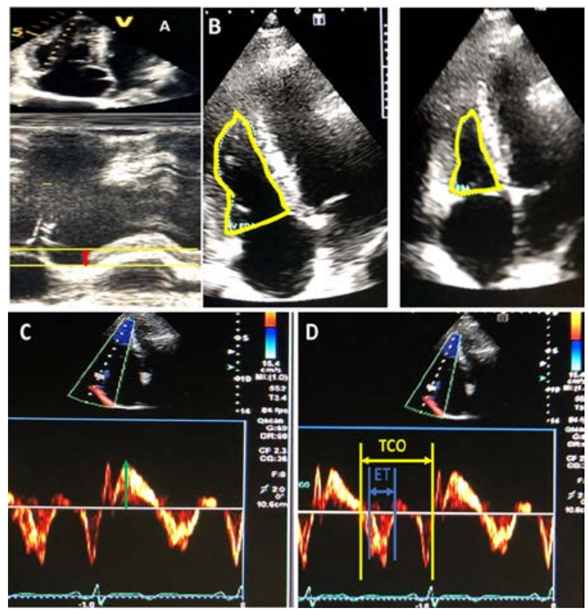

Figure 2: Parameters of right ventricular function assessment. A: TAPSE B: Fractional area change C: S' velocity D: RIMP (TEI INDEX)

Table 1: Parameters for the functional assessment of Right ventricle with cut-off values for normality[2]

Parameter	Normal Range
TAPSE	>1.6
RV Fractional area change	>35%
Tei index (RIMP)	>0.54
RV S' velocity	>10.5 cm/s
RV isovolumic relaxation time	60-100 msec
RV free wall strain	>26%

LEFT VENTRICLE- DIASTOLIC FUNCTION ASSESSMENT

If EF is normal, 4 parameters are assessed viz: E' velocity (< 10 cm/s) (Figure 3 C and D), E/E' ratio (> 14), left atrial volume (> 34 ml/m^2) and Tricuspid regurgitation velocity (> 2.8 m/s). If 3 parameters are abnormal diastolic dysfunction is present (group A), if 2 are present it cannot be determined (group B) and if less than two, diastolic function is normal (group C). In patients with reduced EF diastolic dysfunction is always present.

In group A of patients with normal EF (and myocardial disease) and in patients with reduced EF the next step is to decide the grade of diastolic dysfunction.

For grading diastolic dysfunction 2 parameters are observed viz; E/A ratio and E wave velocity, Figure 3A. Grade I diastolic dysfunction is said to be present if E/A < 0.8 and E velocity < 0.5 m/s. Grade II diastolic dysfunction is present if E/A < 0.8 and E velocity > 0.5 m/s or E/A ranges from 0.9 – 2.0. Grade III diastolic dysfunction exists if E/A > 2.0.

In grade I diastolic dysfunction left atrial pressure (LAP) is always normal whereas in grade III diastolic dysfunction, LAP is always increased. In grade II diastolic dysfunction again 3 parameters are examined viz; E/E' ratio, left atrial volume and TR velocity. LAP is normal or low if none or only one parameter is abnormal (in this case the grade of diastolic dysfunction would also be demoted to I). LAP is increased in case two or all three parameters are abnormal.

If only two of the three parameters are available and both are normal LAP is normal and diastolic dysfunction is grade I. If one parameter is normal LA pressure and diastolic dysfunction grade cannot be specified. In the last scenario when both the parameters are abnormal diastolic dysfunction grade is II and LA pressure is said to be elevated.

If only one parameter is available LA pressure is indeterminate and in patients with reduced EF pulmonary vein S/D <1, Figure 3B can indicate increased LA pressure.[3]

ASSESSMENT OF CARDIAC THROMBI

An echogenic mass seen throughout cardiac cycle and attached to an area of wall motion abnormality with edges clear from endocardium constitute a thrombus.[4] Depending upon the number of surfaces exposed to blood and mobility thrombi are classified as mural, protruding and mobile.

VALVE STENOSIS ASSESSMENT

Valves should be examined for number of leaflets (systolic frame for bicuspid valve in AS), commissures (if open in case of MS add to measurement of area), raphe, doming, prolapse, closure line and calcification. Bicuspid aortic valve should be reported as anterior/posterior or right/left combination of leaflets.

Valvular stenosis is assessed by measuring area, and estimating peak and mean gradients.

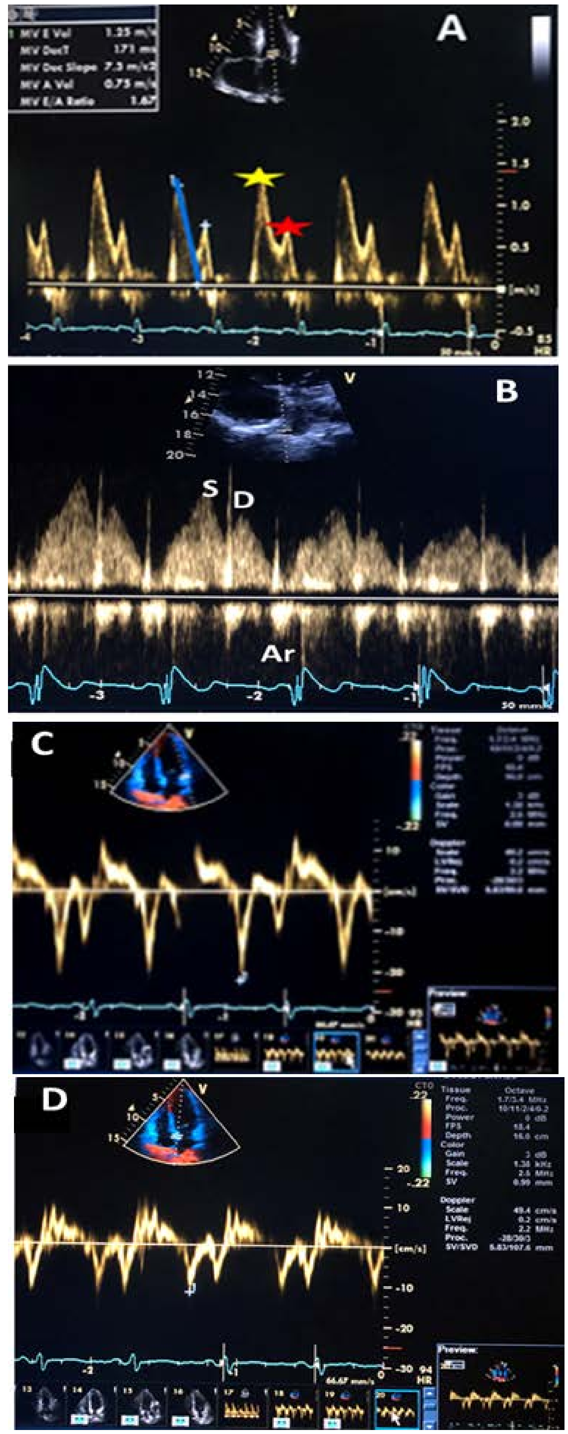

Figure 3: A: Mitral in-flow record, showing E wave (yellow star), A wave (red star) and deceleration

time (blue Slant). B: Pulmonary vein flow C and D are TDI record E’ from lateral wall and IVS

AREA MEASUREMENT: Done by 2D, PHT and continuity equation.

1. **2D planimetry:** Mitral, tricuspid and aortic valves are measured in respective SAX views, Figure 4. Pulmonary valve cannot be planimetred by TTE. 2D valve area assessment is not affected by flow state, LA compliance and other valve lesions. For mitral valve smallest area is measured in mid-diastole. Suitability of stenotic valve for PTMC should be reported by Wilkins’ score.[5] Valve thickness, mobility, sub-valve apparatus and calcification are the features analyzed. Score less than 8 signifies suitability.

Figure 4: 2D planimetry of mitral and aortic stenotic valves in PS SAX views

Localization of clot in left atrium or appendage is very important and classified as per recommendations of Manunath.[6]

2. **Pressure half time (PHT)**: It is the time peak pressure takes to drop to half. In A4C view, by CW record gradient across MV and the deceleration slope is traced, Figure 5 B. Heart rate and flow across valve don’t affect the estimation much. However, the following can affect it:
   a. The slope of the curve (non-linear convex/concave pressure decay).
   b. Aortic regurgitation, LVH (diastolic dysfunction) and atrial septal defect can overestimate.
   c. LA/LV compliance, and LA contractility.
   d. Acute LA pressure changes.
   e. AV block/arrhythmias.

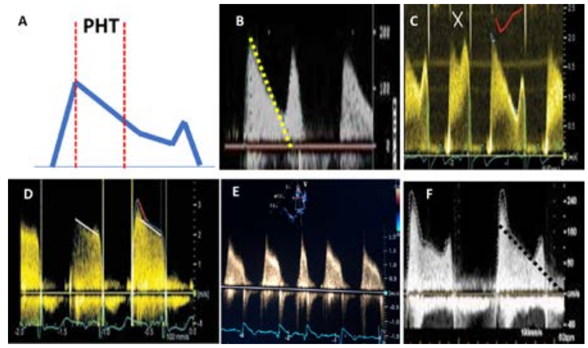

Figure 5: Pressure half time: A- diagrammatic representation, B- Measurement of slope, C- with varying length PHT is taken of the longest cycle, D- in bimodal cases the later part is measured, E- in AF average 5 cycles, F- in steep fall later part of slope is measured and extended upwards

PHT is applied for assessing the Tricuspid stenosis severity also, however the cut-off values are different.

3. **Continuity equation:** Used mainly for estimation of aortic valve area (Table 2) with the following precautions:

   Annuli diameters should be measured meticulously. The equation assumes that the orifices are circular which may not be the case for LVOT sometimes, direct planimetry of LVOT is an alternative.

   While measuring velocity in LVOT by PW doppler 3C apical view will provide a better control with sample volume placed along the septum.[7]

   Continuous wave doppler is used to record the flow across the valve in question with no feathering. The alignment of ultrasound beam to blood flow should be as parallel as possible (15% difference can still reduce the velocities by 5%).[8] Angle correction should not be used. Color doppler can be used for proper positioning.

Table 2: Application of quantitative doppler

A.	AORTIC VALVE AREA BY CONTINUITY EQUATION	
1.	Measure LVOT diameter in PS LAX view.	
2.	Calculate LVOT area	**$(\text{LVOT diameter})^2 \times 0.785$**
3.	Measure LVOT VTI from apical 5C view by PWD	
4.	Calculate LV stroke volume	**LVOT area X LVOT VTI**
5.	Measure aortic valve VTI from aortic valve spectrum obtained from A5C view by CWD	

6.	Calculate **aortic valve area**	**LV SV / AV VTI**		
B.	**MITRAL REGURGITATION BY CONTINUITY EQUATION**			
1.	LV stroke volume is calculated as for assessment of aortic valve area			
2.	Measure **mitral valve annulus diameter** and **VTI** in A4C view			
3.	Calculate **mitral valve stroke volume**	**(MV annulus diameter)^2 X MV VTI**		
4.	Calculate **mitral regurgitant volume**	**MV stroke volume – LV stroke volume**		
5.	Measure **MR VTI** in A4C view			
6.	Calculate **EROA**	**Mitral regurgitant volume / MR VTI**		
C.	**MITRAL REGURGITATION BY PISA METHOD**			
1.	Get an aliasing velocity (Vr) of 35- 40 cm/s. Measure the radius of PISA (r).			
2.	Calculate regurgitant flow rate (cc/s).	**6.28 X r^2 X Vr**		
3.	Record MR by CWD and measure MR peak velocity and VTI.			
4.	Calculate **EROA.**	**Regurgitant flow rate / MR peak velocity**		
5.	Calculate **mitral regurgitant volume.**	**EROA X MR VTI**		
D.	**PULMONARY ARTERY SYSTOLIC PRESSURE ESTIMATION**			
1.	Obtain an apical 4C view- RV directed to record the spectrum of tricuspid regurgitation by CWD. Measure the peak velocity of TR jet.			
2.	Using Bernoulli's equation this velocity is converted to gradient (mmHg).	$\textbf{TR Peak gradient} = 4V^2$		
3.	A good quality sub-costal long axis view is obtained to examine the size and collapse of inferior vena cava.			
4.	**Right atrial pressure** is estimated from size and collapse of inferior vena cava.	**IVC SIZE**	**COLLAPSE**	**RA PRESSURE**
		Normal	**>50%**	**3 mmHg**
		Dilated	**>50%**	**8 mmHg**
		Normal	**<50%**	**8 mmHg**
		Dilated	**<50%**	**15 mmHg**
5.	Add **right atrial pressure** and **TR gradient** to obtain **RV systolic pressure** which is equal to **Pulmonary artery systolic pressure** (in case with no RV outflow tract obstruction).			

In problematic cases when measurements of continuity equation cannot be adequately obtained, dimension less index ie ratio of LVOT and Aortic valve velocities can be used, 0.25 indicates severe stenosis.[9]

If AVA < 1 cm sq but PV < 4m/s and MPG < 40 mmHg then following points must be evaluated:

a. Measurement errors.
b. Severe hypertension.
c. Body size, for subjects with low BSA, indexation is used.
d. Inconsistency in AVA and gradient in the range of 0.8 – 1.0 cm sq.
e. Presence of low flow, low gradient with reduced EF or preserved EF (paradoxic low flow) or normal flow low gradient aortic stenosis.
f. For the assessment of these states more parameters like EF and indexed stroke volume need be taken into account.
g. Other diagnostic modalities like low dose Dobutamine stress echo (for LFLG AS with reduced EF) and MDCTS (for the other two types of AS) should be utilized along with clinical parameters.[10]
h. In cases of LFLG AS with reduced EF, DSE should be done to re-measure the components of continuity equation at peak dose, assess contractile reserve and measure the flow rate across aortic valve along with calculation of

projected Aortic valve area (not fully validated at present).

i. Other valvular lesions affect parameters of aortic stenosis severity if they are at-least in the moderate category. In aortic regurgitation, AVA estimation becomes un-reliable and severity is based on peak velocity whereas in Mitral stenosis/regurgitation the reverse is true.

j. In discrepancy of gradients between catheterization and echocardiography data the phenomenon of different timing for gradient estimation by the two methods and the pressure recovery phenomenon should be considered, the later especially if aortic size is small.[11]

PEAK VELOCITY AND MEAN GRADIENT

Bernoulli equation is used to estimate the peak gradient from the peak velocity and mean gradient is estimated from an average of instantaneous gradients over the period of flow. The factors affecting are:

1. Flow rate.
2. Cardiac output.
3. Heart rate.
4. Ventricular function (systolic for AS and Diastolic for MS).
5. Atrial compliance (for MS).
6. Arterial compliance (for AS).
7. Proximal LVOT velocity > 1.5 m/s (for AS).
8. Pressure recovery in case of aortic stenosis.

The parameters for grading severity of stenosis of the cardiac valves are shown in Table 3.[8]

Table 3: Parameters and cut-off values for stenosis severity of four cardiac valves.[8]

MITRAL VALVE				
	Pressure half time (msec)	**Mean gradient (mmHg)**	**Valve area (cm^2)**	**Pulmonary artery pressure (mm Hg)**
Mild	<139	<5	1.6-2.0	<30
Moderate	140-220	5-10	1.0-1.5	30-50
Severe	>220	>10	<1.0	>50
TRICUSPID VALVE				
	Pressure half time (msec)	**In-flow TVI (cm)**	**Valve area (cm^2)**	**Mean gradient (mm Hg)**
Significant	>190	>60	<1	≥5
AORTIC STENOSIS				
	Peak velocity (m/s)	**Mean gradient (mm Hg)**	**Valve area (cm^2)**	**Velocity ratio (dimension less index)**
Mild	2.5-2.9	<20	>1.5	>0.5
Moderate	3.0-3.9	20-39	1-1.5	0.5-0.25
Severe	4.0-4.9	40-59	0.9-0.6	<0.25
Very severe	>5	>60	<0.6	
PULMONIC VALVE				
	Peak velocity (m/s)		**Peak gradient (mm Hg)**	
Mild	<3		<36	
Moderate	3-4		36-64	
Severe	>4		>64	

VALVE REGURGITATION ASSESSMENT:

While assessing regurgitation of any valve, the three components viz, flow convergence zone, vena contracta and jet area must be assessed. Regurgitation of any valve is classified as primary or secondary and assessment is done in an integrated way by incorporating:

A. Structural assessment for valve thickness, restriction of movement, coaptation defect, prolapse/flail, tenting, retraction, perforation and calcification etc.[12] Carpentier's classification for aortic (Figure 6),[13] and mitral regurgitation (Figure 7),[14] should be used. Chamber quantification should always be indexed.

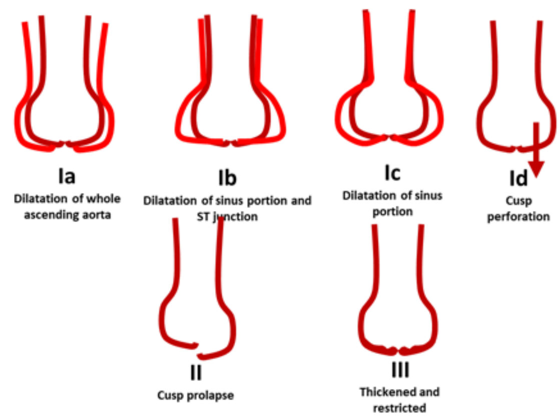

Figure 6: Carpentier's classification for the types of aortic regurgitation (casual).[13]

B. Qualitative assessment. Flow convergence zone should be noted for severity along with jet diameter, density (on CWD) and deceleration time (for AR and PR). Direction of jet should be clearly reported, either central or eccentric (likely severe regurgitation).

C. Semi-quantitative assessment involves Vena-Contracta size, jet diameter or area/ recipient chamber diameter or area ratio and in-flow velocities (AV valves) measurements. Mitral and Aortic regurgitation jets must be seen in two views, and minimal length in one view should be ≥ 2 cm for MR and ≥ 1 cm for AR with velocity of jet ≥ 3 m/s in one complete envelope.[15]

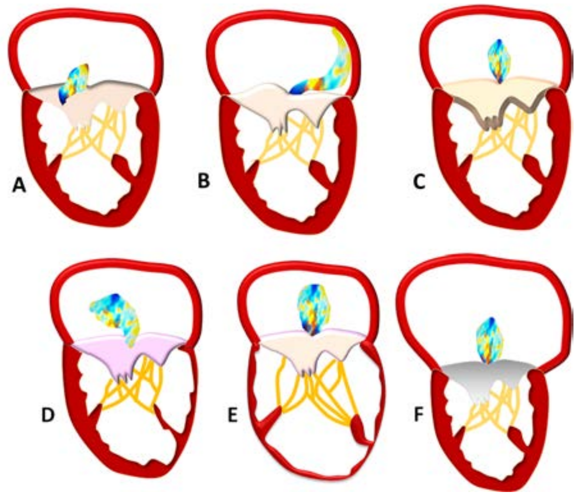

Figure 7: Carpentier classification for Mitral regurgitation. A- Type I (normal leaflet motion)- Cusp perforation, B- Type II (excess leaflet motion)- Leaflet prolapse and C- Type IIIa- (restricted leaflet motion) thickened (rheumatic) leaflets. D- ischemic (Type IIIb restricted leaflet motion in systole only), E- non-ischemic cardiomyopathy (type I) and F- atrial enlargement (type I)

D. Quantitative parameters like regurgitant volume, fraction and EROA should be applied if 50% or more of the parameters mentioned above are discordant. These parameters are calculated by PISA method and Continuity equation.

1. **PISA method**, usually employed (table 2C) for mitral and tricuspid regurgitation with following observations:[16]

   a. Timing of measurement: As MR is dynamic hence regurgitant peak velocity, antegrade flow velocity and antegrade flow should be measured in the same cardiac cycle.
   b. Duration of regurgitation varies and is holo-systolic only in cases of central orifice (mostly rheumatic), whereas in prolapse it could be late-systolic only and bi-modal in functional cases.
   c. Shape of PISA should be hemispheric, a little amount of conical shape can be adjusted by changing Va (aliasing velocity), however, this shouldn't be done too much. Tenting of leaflets will give a conical shape in which case angle correction (EROA X α/180) need be done.
   d. Shape of regurgitant orifice, usually circular but at times could be elliptical or crescentic (especially in secondary cases) which will make analysis difficult. Estimation by 3D is a better option or formula of hemi-ellipse may be used.
   e. Multiple jets entail evaluation of each orifice separately and then adding up all.
   f. Eccentric jets make PISA estimation extremely difficult.

2. **Continuity Equation method:** It helps in estimation of regurgitant volume, fraction and effective regurgitant orifice area. However, the method, (Table 2B) requires precision as some parameters measured, are squared which can raise the level of mistakes.

   LVOT is usually taken as one point of flow time and is compared with the point whose area or regurgitant parameters are to be assessed.

   Annuli of mitral and tricuspid valves are measured in A4C and RV directed A4C views respectively.

Table 4: Parameters for valve regurgitation severity assessment (green = mild, blue = moderate and red = severe lesions)[12]

	Mitral Regurgitation	Aortic Regurgitation	Tricuspid Regurgitation	Pulmonary Regurgitation
SEMI QUANTITATIVE				
VCW width (cm)	<0.3			NA
	0.3-0.69	0.3-0.6	0.3-0.69	
	≥0.7 (0.8 for biplane)	>0.6	0.7-0.89 0.9-1.1 >1.1	
Diastolic inflow pattern	A wave dominant	NA	A wave dominant	NA
	Intermediate		Intermediate	
	E wave dominant (> 1.2 m/s)		E wave dominant (> 1 m/s)	
Jet /Outflow width ratio (%)	NA	<25	NA	
		25-49		

		50-64		
		≥6		>0.7
AR jet CSA/LVOT CSA (%)	**NA**	<5	**NA**	**NA**
		5-60		
		≥60		
QUANTITATIVE				
Regurgitant volume (cc)	<30			NA
	30-44 45-59		30-44	
	≥60		≥45	
Regurgitant fraction (%)	<30			<20
	30-39 40-49		NA	20-39
	≥50			≥40
EROA (cm)	<0.2	<0.1	<0.2	
	0.2-0.29 0.3-0.39	0.1-0.19 0.2-0.29	0.2-0.39	
	≥0.4	≥0.3	≥0.4	

ASSESSMENT OF PULMONARY ARTERY PRESSURE

Pulmonary artery systolic pressure is estimated from Tricuspid regurgitation jet velocity as shown in Table 2D.

ECHO REPORT PROTOCOL: Image quality must be reported in every case as good/fair/bad with reason mentioned for bad quality.[17,18] Any off-axis views and measurements taken must be duly reported. Most of the reports should be delivered at the time of study completion and this should always be done within 24 hours of study. The report protocol must show the features as mentioned in appendix A.

COMMUNICATION WITH REFERRING PHYSICIAN: This is the last part to ensure quality in echo reporting and the performing and analyzing doctor must be in intimate contact with the clinician to ensure effective treatment decisions.

CONCLUSION: Thus, it is clear that for quality control in echocardiography diligent attention should be paid at every step. This will result not only in a good quality standardized report, but the adoption of these principles by every laboratory and health care worker will ensure uniformity in reporting.

APPENDIX A

A sample of echo report proforma

TRANS-THORACIC ECHOCARDIOGRAPHY REPORT **Date:**

Name:	Age:	Gender:	MR No.
Demographics	Height m	Weight Kgs	BSA m^2
Heart rate bpm	B.P. mmHg	Machine used:	**Image quality:**
Ref. by:	**Sonographer:**	**Reporting Cardiologist:**	

2D AND M-MODE MEASUREMENTS

AORTA (Annulus)		**RV (Base)**		**IVS**		**EF%**	
M:2.3-2.9, **F:**2.1-25		2.5 – 4.1		**M:**0.6 – 1.0, **F:**0.6 – 0.9			
AORTA (Sinus)		**RV (Mid)**		**LVPW**		**RWT**	
M:3.1 - 3.7, **F:**2.7 - 3.3		1.9 -3.5		**M:**0.6 – 1.0, **F:**0.6 – 0.9		<0.42	
AORTA (STJ)		**RV (Length)**		**LVEDD**		**LV Mass Indexed**	
M:2.6 - 3.2, 2.3 -2.9		5.9 – 8.3		**M:**4.2 – 5.8, **F:**3.8 – 5.2		**M:** < 115, **F:** < 95	
LA Diameter		**MPA**		**LVESD**		**MV Area**	
M:3.0 – 4.0, **F:**2.7 - 3.8		1.7 – 2.5		**M:**2.5 – 4.0, **F:**2.2 – 3.5			
LA Volume		**RA Diameter**		**LV VOL (D)**		**IVC (size)**	
M:18 -58, **F:**22 - 52		**M:**2.9 – 4.5, **F:**2.9-4.5		**M:**62 - 15, **F:**46 - 106		1.2 – 1.7	
LA Volume (indexed)		**RA Area**		**LV VOL (S)**		**IVC (collapse)**	
< 34 ml/m^2		**M:** 16.2, **F:** 15.2		**M:**21 - 61 **F:**14 – 42		>50%	

RIGHT VENTRICULAR SYSTOLIC FUNCTION PARAMETERS

TAPSE		**FAC**		**RVS'**		**RIMP**		**TRV**		**PAP**	
>1.6cm		>35%		>10.5%		>0.54		<2.8		<38	

LV DIASTOLIC FUNCTION PARAMETERS

E		**A**		**E/A**		**DT**		**E'**		**E/E'**	
M:0.58-0.90		**M:**0.42 – 0.76		**M:** 0.87 – 1.85		**M:** 119 - 240		**M:** 9.5- 17.5		**M:**4.6 – 8.8	
F: 0.61-0.93		**F:** 0.45 – 0.77		**F :** 0.85 – 1.91		**F:** 119 - 240		**F:** 9.4 – 17.6		**F:** 4.9 – 9.1	

Units of measurement:	Dimension- cm; Area-cm.sq, Volume-ml, Blood velocity-m/s, Tissue velocity –cm/s, mass-grams, EF-%, Time- msc, Pressure - mmHg

INTERPRETATION:

COLOR DOPPLER:

DOPPLER STUDY (PW & CW):

CONCLUSION:

CARDIOLOGIST:

AUTHORS' CONTRIBUTION

IH: Concept and design, data acquisition, interpretation, drafting, final approval, and agree to be accountable for all aspects of the work.

Conflict of interest: Authors declared no conflict of interest.

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