REVIEW ARTICLE

# QUALITY CONTROL IN ECHOCARDIOGRAPHY REPORTING (PART A)

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For cardiac evaluation echocardiography is of immense importance. Easy availability, low cost, and portability lands it in the hands of novices at times. It has a learning curve and expertise must be obtained to keep the standard of reports high and reliable. The referring physician must be fully conversant with the indications of echocardiography. The echocardiographic machine should deliver images of high resolution and fully equipped with all the basic modalities. Availability of 3D (3-dimensional) imaging, tissue synchronization imaging and strain analysis are added advantages. Preliminary data of patient must be collected and the study should be recorded for off-line analysis. Finally, the findings should be narrated on a proforma in the form of a standardized report showing all the relevant features, especially directed to the query of referring physician, thus completing the loop.

**Keywords**: Transthoracic echocardiography, Echocardiography report and Quality control

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## INTRODUCTION

Quality control measures are of immense importance especially in fields like echocardiography where technical skill should be backed by latest scientific knowledge to produce excellent results.

To assure quality the first step is to have appropriate referral. For this 'appropriate use criteria (AUC)' have been forwarded by various agencies.[1,2]

For 'patient centered' quality control, Ingram TE et al., recommended a four-pronged system for every echocardiography laboratory.[3] They recommend scrutiny of a set number of recorded cases for: echo quality (acquisition and reporting), reproducibility (consistency and variability), education and customer satisfaction.

Kossaify A et al. recommended "patient selection, conformity to AUC, study performance, interpretation, reporting, competence assessment, CUDS (constructive unit direction and supervision), and QIP (quality improvement project) are essential ingredients to generate a high-quality echocardiographic product with beneficial clinical outcome".[4]

Steeds RP et al. emphasized appropriate use criteria to discourage its excessive use, although trans-thoracic echocardiography (TTE) has reduced diagnostic errors by 50 % in the last twenty years. They conclude, "TTE is operator dependent and it is vital that the test is performed by qualified individuals within proficient departments that monitor quality".[5]

Thus, it is quite clear that quality control in echocardiography is immensely important and is a multi-step process requiring vigilance at every step, Figure 1. In this document every step has been explained to ensure 'quality control in echocardiography reporting' by healthcare providers involved in this field.

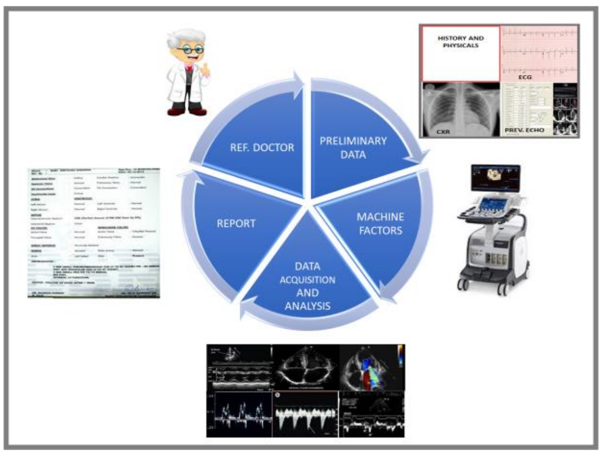


**Figure 1: Steps to assure quality control in Echocardiography reporting**

## MATERIAL AND METHODS:

Pub-med, Google scholar and Pakmedinet databases' search revealed 200 studies of which 44 were relevant.

**Referral for Echocardiography (ECHO):** Knowledge of the referring physician plays key role here. Al-Kaisey et al. reported 77% appropriate, 20.3% inappropriate, and 2.7% uncertain referrals.[6] Similarly, Patil et al. mentioned 82% appropriate, 12.3% inappropriate, 5.3% uncertain, and 0.4% non-fitting referrals in their study of 1825 subjects.[7]

Vanessa Rameh et al. in 501 patients referred for TTE found that according to 2011 AUC 74.6% had appropriate indication, whereas the rest were either inappropriate, uncertain or non-fitting.[8] Metulevicius et al. found 91.8% appropriate referrals while the rest were inappropriate or uncertain. However, no difference was noted for change of treatment in either group (p=0.29).[9]

Gurzun MM and Ionescu A did a remarkable study in Wales assessing all echo referrals and reports (n=1070), done in the entire country in one week for AUC application, type of center, health care worker, referrals from in/out-patients and the result of abnormal reports found.[10] They noted that, "major indications were assessment of: cardiac structure and function (45.7%), valvular function (25%), and hypertension, heart failure, or cardiomyopathy (13.9%). In-patient requests were more often appropriate than out-patients. The most common inappropriate indication was initial evaluation for a murmur/click, without symptoms/signs of structural heart disease (2.7%). The proportions of appropriate requests by specialty was 89% for medical, 87% for GPs, 85.3% for cardiologists, 80.8% for surgical, and 60% for cardiac surgeons (P<0.05 for cardiac surgeons); 47.8% of requests were generated by cardiologists, and abnormalities were detected in 82% of all scans (37% minor findings and 45% major findings), least often in those requested by GPS".

**PRELIMINARY DATA:** The performing and reporting person for echocardiography must have pre-study knowledge with regard to demographics, clinical findings, ECG and Chest X-ray (CXR).[11] Review of previous study will greatly facilitate about the progress of disease and making informed decisions. Echocardiography laboratory requirements are:

a) Room should be 12-20 $m^2$, with enough darkness to ensure good image visualization and minimal sound so as to hear doppler signals clearly. Reporting area should be separate.[12]
b) Echo couch should be of adjustable height with space cut-out to make apical views easily.
c) Emergency cart, defibrillator, provision of oxygen supply and suction facility.
d) A single machine should be used at the most for 2500 cases per annum.[12] Images and clips should be digitally stored in DICOM format.[13]
e) All probes must be cleaned with anti-septic after every study.
f) Ideally a technical staff to record images and a cardiologist for interpretation are needed. It has been proposed that the head of unit should not examine more than 1800 cases per annum.[12] The recommended level of training (exclusively for TTE) according to COCTAS FORCE require a duration of 9 months with a total of 300 exams performed and 750 interpreted in three levels of three months each.[14] Dedicated recommendations for echocardiography in ICU have also been forwarded.[15] Furthermore, for complete training in echocardiography including all modalities have been forwarded by AHA/ACC.[16]
g) Patient should wear loose flexible clothes and an attendant be allowed especially for female patients. ECG gating is a must and provision of respiration monitoring is advisable.[17] Patient is usually examined in left lateral position.
h) 40 to 45 minutes are required for a study.

**MACHINE FACTORS:** Echocardiographic machines have evolved with regard to technology immensely, in the last few decades making them more compact, advanced in features and improved in resolution. These are now available in pocket size as well, but all of them don't have the capability for a comprehensive echo exam. A standard machine must have the capability of M-mode, 2-D, color, pulsed wave (PW), continuous wave (CW) and tissue doppler (TD) along with harmonic imaging (HI).

Multi-frequency probe (1-5 MHz) or dedicated probes of low (2-2.5 MHz) and high frequency (3 and greater) should be available.[18] Pedoff probe availability is a recommended enhanced provision. The foot prints of the probe should be as small as possible (10-13mm) so as to fit into the intercostal spaces easily.

Echocardiographic machines must be kept in highest order of working with annual maintenance and no machine older than ten years should be in use. Sound knowledge of the operator to optimize the image from patients of various body habitus and echogenicity is mandatory.

**DATA ACQUISITION:** Good quality data is acquired by convex phased array transducers for the following modalities.

**A. M-mode imaging:** It still retains value due to high sampling rate and good temporal resolution. 2D directed M-mode images are utilized for measurements. The alignment during recording of chamber dimensions should be perpendicular to the structure measured otherwise off axis cuts produce errors. During acquisition of Mitral annular plane systolic excursion (MAPSE) and Tricuspid annular plane systolic excursion (TAPSE) the cursor should remain parallel to RV free wall and LV lateral wall respectively and on axis with movement of respective annuli.

**B. 2D imaging:** This is the cornerstone of echocardiography. By adopting following measures, good quality 2D images can be obtained:

1. The area of interest should form the center of image and never off axis.
2. Sector width and image depth should ensure a frame rate of 50 to 70/sec.
3. For ventricular assessment the endocardium should be clearly visible in all the segments during the entire cardiac cycle especially apex and anterior wall as these require additional manipulation for proper visualization. Foreshortening should be avoided. Chordae and papillary muscles are counted as part of ventricular cavity. Contrast should be used if two or more segments for wall motion are not properly visualized. Apical views are taken so that the entire length of LV remains visible along with one third of left atrium. Apex should lie in the angle of the image sector (as ellipsoid and not rounded in normal hearts) and the chambers appear vertical, not slanting. Length of views shouldn't differ by more than 0.5 cm. In apical 2C view no part of RV should be visible.
4. Right ventricle should always be assessed in RV focused apical view with entire length of RV visible and no fore-shortening noted.
5. Atrial assessment needs complete visualization and no fore-shortening.
6. Inferior vena cava should be visualized in its maximum diameter.
7. All the views may not be recorded in every patient. Apical (93-99%) and PS LAX (97%) are obtained in majority of cases.[20]

**C. Color Doppler:** Very important, especially with regard to valvular regurgitation and shunt assessment. Measures for good quality color doppler images are:

1. Nyquist limit set around 64 cm/s (50-70 cm/s).
2. Region of interest (ROI) is kept minimum, enclosing the area of interest. Aortic valve needs smaller ROI whereas Mitral and Tricuspid valves need larger.
3. The formula of BART (blue away red towards) is used.
4. Factors affecting regurgitant jet size are:
   a. Regurgitant jet momentum, impingement on wall and entrainment.
   b. Nyquist limit and pulse repetition frequency.
   c. Color gain, ultrasound frequency and attenuation in far field.
   d. Angle of interrogation and orifice geometry.[21]
5. While recording PISA (proximal Isovelocity surface area) for estimation of valve regurgitation the following precautions are needed:
   a. Apical 5 chamber (aortic), 4 chamber (mitral and tricuspid), 3 chamber (mitral) or parasternal short axis (PS SAX) (pulmonary) views should be chosen.
   b. Valve of interest should be in the center of image, in zoomed view.
   c. All the three components of regurgitation i.e., Flow convergence zone, Vena contracta and regurgitation jet should be clearly visible, Figure 2.
   d. Baseline is shifted towards regurgitant jet so that a Nyquist limit of 35-40 cm/s may be obtained to keep the shape of PISA hemispheric.
   e. Color variance is turned off.
   f. PISA radius should be taken from the zone of color aliasing (i.e., junction of blue and yellow color) till Vena contracta, Figure 2.

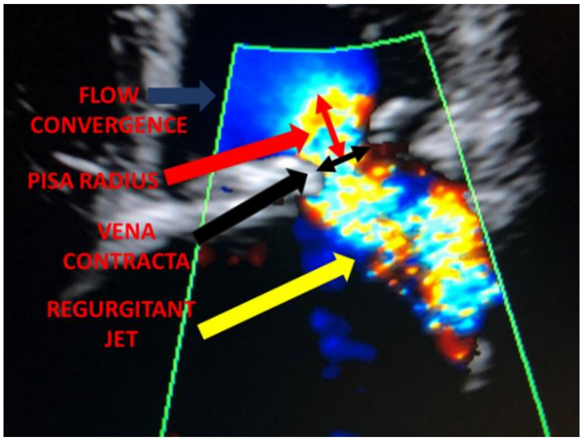


**Figure 2: The zones of regurgitation jet through mitral valve**

**D. Pulsed wave doppler:** A good quality PW recording must satisfy:

1. Ultrasound beam aligned parallel to the blood flow.
2. The onset and offset of blood flow should be clear, by using wall filters.
3. A clear spectrum is recorded with sharp peaks or outer rim and clear center, with no feathering or spikes, Figure 3.
4. Sweep speed should be 100 cm/s however, for recording respiratory variation in cardiac tamponade or constrictive pericarditis this should be 25 cm/s. Sample volume should be 1-2mm in size for mitral valve and left ventricular outflow tract (LVOT) with low wall filters and signal gain (100-200Hz).

5. For mitral and tricuspid valve, the sample volume should be placed between the tips of leaflets whereas for LV and RV outflow it should be placed just proximal to the valves.
6. For pulmonary vein the sample volume (size 3-4mm) should be placed 1-2 cm inside the vein interrogated
7. Isovolumic relaxation time (IVRT) is recorded in apical 5C view with Mitral inflow and LV out flow recorded simultaneously.
8. Valsalva records must be obtained for 10 seconds.
9. In sinus rhythm 3 beats and in atrial fibrillation 5 beats are recorded and averaged.

**E. Continuous wave doppler:** Same quality control measures are adopted as for PW doppler, but here all the velocities are recorded hence the envelope would be homogenous, Figure 3.

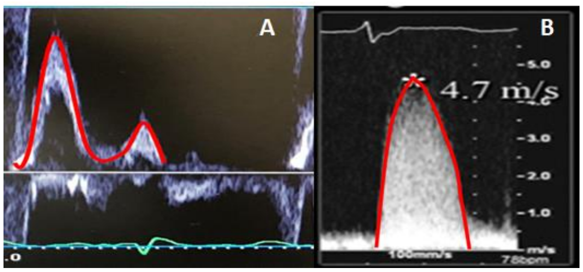


**Figure 3: A. PW record shows clear centre and sharp peaks traced from modal velocity. B. CW doppler spectrum, homogenous and uniform with tracing done from the outer border to include all velocities**

In aortic stenosis PEDOFF probe should always be used, recording gradients from all the windows and not just from apical position. In 100 patients of aortic stenosis recording gradient from various windows, Jeremy J et al showed that in 61% of patients, maximum gradient was recorded from right parasternal window (due to angulation) and 23% of patients were mis- classified if non-apical windows were not recorded.[22] In cases with peak velocity less than 3m/s a combined imaging and doppler probe can be used.

**F. Tissue Doppler:** As tissue movement is of low velocity (< 20 cm/s.) and high amplitude, this modality suits best. The basic pre-requisites are the same as for PW doppler, additional points for quality control are:

1. The ultrasound beam aligns parallel to the ventricular wall.
2. Sample volume size ranges from 5-10 mm in axial direction.
3. Sampling should start from the junction of myocardium and the respective annulus.
4. Depth should be set to include only a small part of atrium along with the whole ventricle.
5. Gain and filter should be set low.
6. Graphic records are obtained during quite breathing or held expiration.

For a complete TTE study the recommended number of clips and images are 53 and 52 respectively.[23]

**STUDY ANALYSIS:** This is the job of an experienced and well-trained cardiologist. After acquainting with the preliminary data, the first task is to assess the technical quality of record. The measurements of the structures have been well outlined in the appendix of their recommendations for a standardized report in adult echocardiography by Gardin JM et al.[24]

A recorded study can be analyzed in the following way.

**CHAMBER QUANTIFICATION:** Should be done according to the guidelines of established authorities. Dimensions are taken either directly from 2D images (preferred) or from 2D directed M-mode tracings. Measurements in M-mode are done by leading edge to leading edge method and in 2D inner edge to inner edge method. Volumes are measured by Bi-plane Simpson's method. Ventricular functions are also assessed by various parameters as detailed below.

**1-Left Ventricle:** In M-mode distances are measured just below the tips of Mitral valve leaflets, for LV end-diastolic and end-systolic dimensions, Figure 4.

LV mass should be measured according to Devereaux formula, having prognostic value and wealth of clinical evidence.[25]

**LV mass = 0.8 (1.04 ([LVIDD + PWTD + IVSTD]$^3$-[LVIDD]$^3$) + 0.6 g**

Difference of 15 g can occur if there is an error of 1 mm in measurement of LV wall thickness.[26] 2D formulae can also be used. Relative wall thickness is measured either by dividing the sum of septum and posterior wall by LV end diastolic diameter or using the formula 2X LVPW/LVEDD to avoid problems of sigmoid and paradoxic septum.[27] Based on LV mass and RWT four patterns of LV hypertrophy are reported By Ganau A et al in hypertensive subjects.[28]

LV volume measurements are done by biplane Simpson's method, figure 4B. These are especially useful for small and large body sized subjects particularly in females for valvular regurgitation. Endocardial border is traced between the compact myocardium and blood pool with trabeculae and papillary muscles, counted as part of the volume of cavity, Figure 4C.

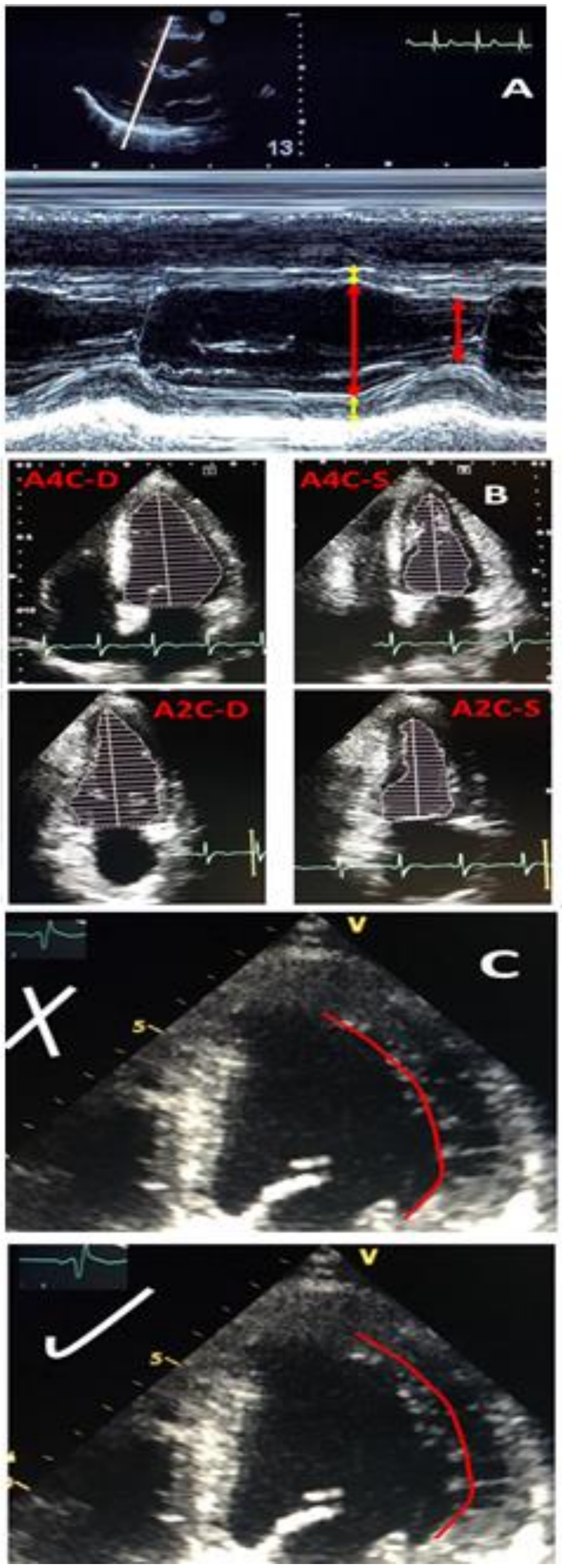


**Figure 4: A. M-mode directed 2D method for measurement of ventricular septum, left ventricle posterior wall (yellow arrows), diastolic and systolic dimensions (red arrows). B. LV volume measurement by bi-plane Simpson's method. C. Tracing of endocardial border between blood pool and compacted myocardium**

**2-Right ventricle:** Measurements are taken in RV focused apical view with maximal expansion of RV cavity and no fore-shortening of length. Apical trabeculum should be included in area measurement. Basal and mid diameter along with the length are measured, Figure 5. TAPSE and TDI measurements need precautions as previously explained.

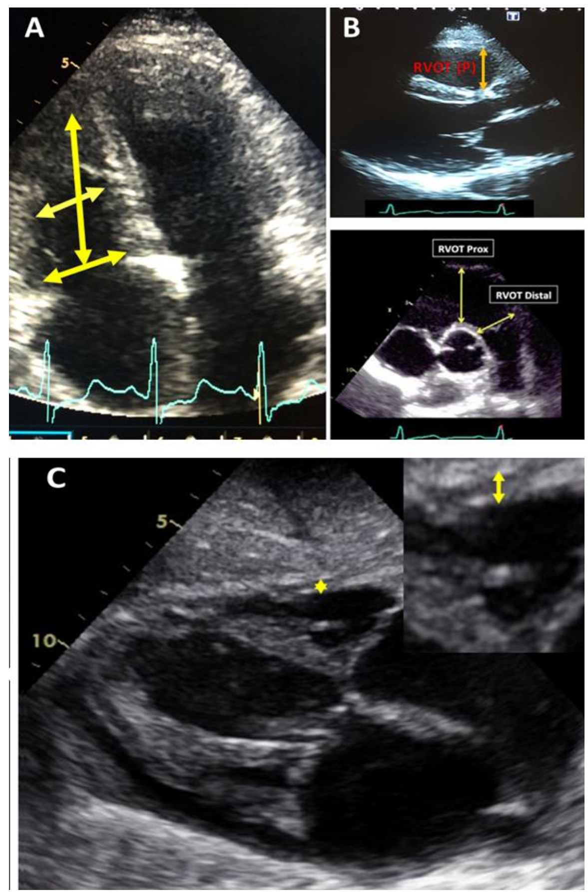


**Figure 5: Right ventricle measurements. A-A4C RV directed view showing the three RV measurements, B-PS long and short axis views showing RVOT measurement proximal and distal and C- sub-costal view showing RV free wall measurement (yellow arrow)**

**3-Left atrium:** Dimension should be measured in 2D parasternal long axis (PS LAX) view from aorta to left atrial posterior wall (at aortic sinus level), preferred method or in M mode. For volume measurements apical 4 and 2 chamber views are utilized, tracing the endocardial border and excluding the confluence of pulmonary veins and LA appendage, Figure 6.

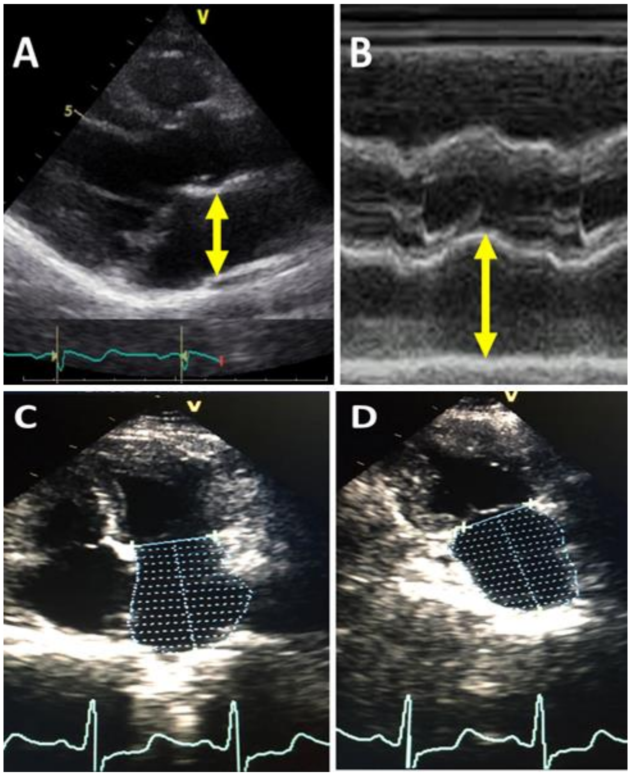


**Figure 6: Left atrium. A and B; Diameter C; Volume measurement**

**4-Aorta:** Measured in 2D PS LAX view either by 2D or M mode in zoom mode. Annulus is measured in mid-systole (at hinge points of right coronary sinus and the junction of left and non-coronary sinus) whereas, sinu-tubular (ST) junction and ascending aorta measured at end diastole, Figure 7.

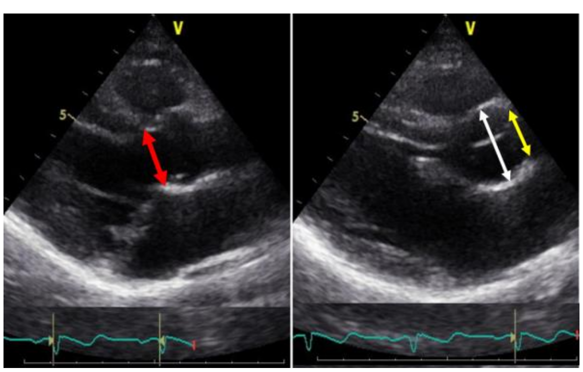

**Figure 7: Aortic measurements, annulus (red arrow), sinus portion (white arrow) and ST junction (yellow arrow)**

**5-Right atrium:** Measured in RV focused view with no foreshortening and base maximally expanded at end systole from mid interatrial septum to lateral wall. Area is traced along inner lining excluding area under TV annulus and RA appendage, Figure 8A.

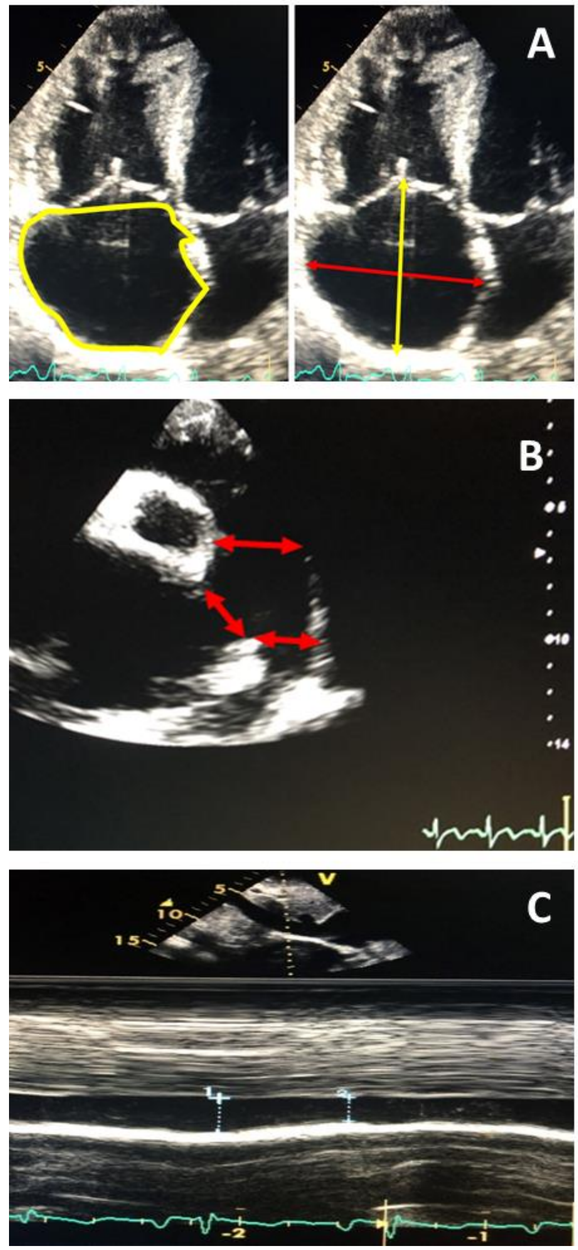


**Figure 8: A: Right atrial dimensions and area. B: Main and branched pulmonary arteries. C: Inferior vena cava**

**6-Inferior vena cava:** Measured 1-2 cm distal to opening in right atrium, collapsibility with respiration also noted, figure 8C.

**7-Pulmonary artery:** Main Pulmonary artery is measured at end diastole at mid- point in PS SAX view and branches are measured at ostia, figure 8B.

**8-Pulmonary Vein:** Recorded in A4C view and also in Supra-sternal SAX view (Crab's view), especially for flow velocities.

For functional assessment of ventricles, valvular disease, pulmonary artery pressure assessment and conclusion reader is referred to part B of the article under same head.

## 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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