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ARIC

Atherosclerosis Risk in the Communities Study

ARIC cohort – Visit 5

Field Center Echocardiography Manual of Operations

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I. Introduction

The NHLBI Atherosclerosis Risk in the Communities (ARIC) study was initiated in 1985 and follows approximately 13,000 individuals in four U.S. communities for trends in incidence and mortality of coronary heart disease. Subjects are now in their seventh to ninth decade of life, a period of life during which the prevalence of heart failure and other cardiovascular morbid conditions increases dramatically. Over 9,000 participants expected in Visit 5 will undergo an echocardiographic examination. This represents a unique opportunity to investigate perturbations in cardiac structure and function across the spectrum of HF (stages A, B, and C) and their relationship to clinical outcomes.

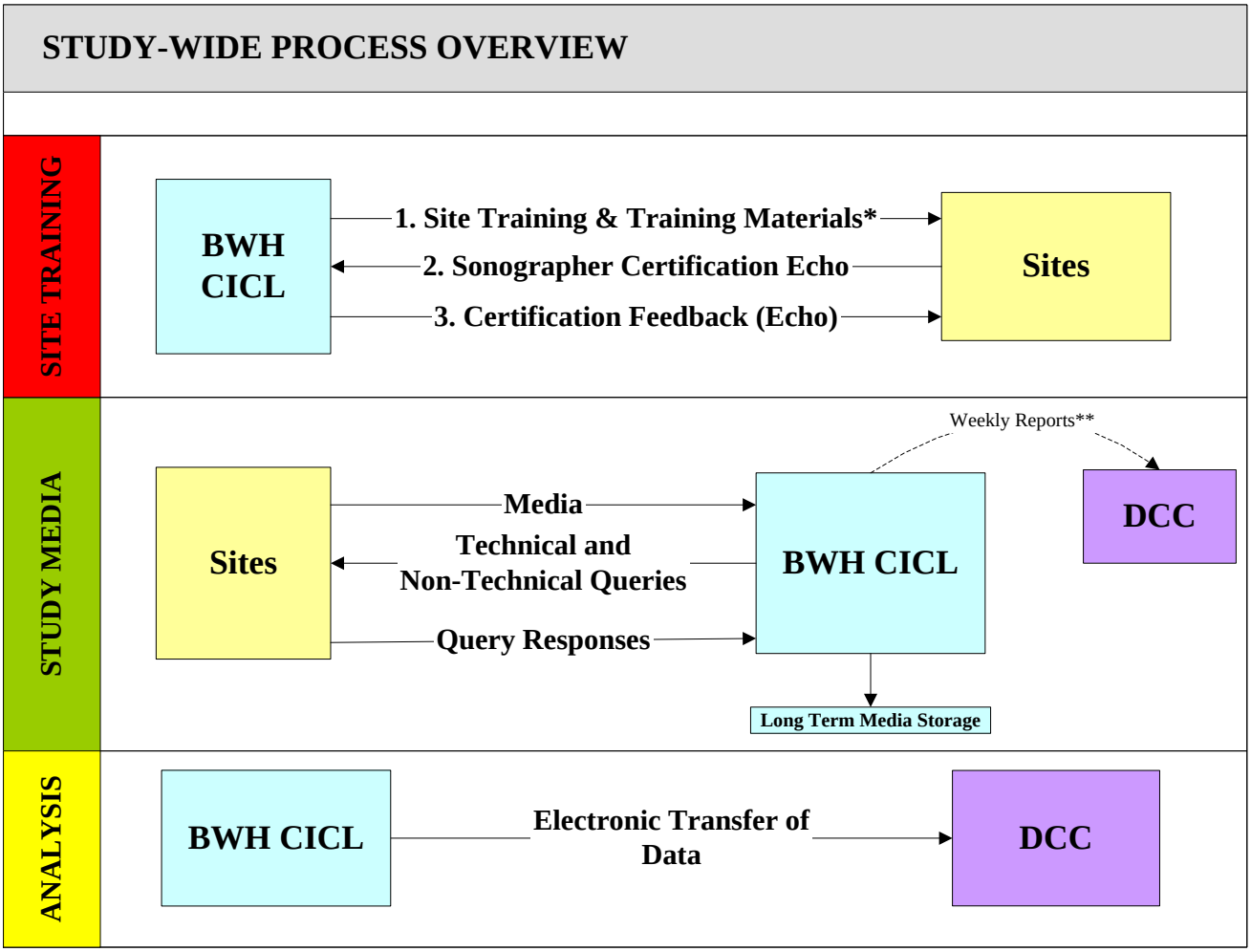
The Brigham & Women's Hospital Cardiac Imaging Core Laboratory (CICL) in Boston, Massachusetts will serve as the Echocardiography Reading Center for the ARIC Visit 5. This manual contains key information Field Centers need to perform high quality study echocardiograms.

OBJECTIVES	**Echocardiography**	• The objective of the ARIC Visit 5 Echocardiography study is to describe and quantify perturbations in cardiac size and function across the spectrum of heart failure stages in the ARIC cohort. • Echocardiographic examinations will be performed to estimate myocardial structure and performance including but not limited to: left and right ventricular systolic function, left ventricular end diastolic volume (LVEDV), left ventricular end systolic volume (LVESV), left ventricular mass, left atrial size, LV diastolic function, mitral inflow pulsed wave Doppler (E wave, A wave), isovolumic relaxation time (IVRT), tricuspid regurgitation (TR) velocity.
	Cardiac Imaging Core Lab	• To provide high quality reproducible quantitative analysis of study echocardiograms
	Site Instruction Manual	• To instruct field centers on how to perform and send study echos to the Cardiac Imaging Core Lab (CICL).

ROLES AND RESPONSIBILITIES	**Field Centers**	• Perform high-quality study echocardiograms per the protocol contained in this document
	ARIC Coordinatng Center	• Ensure that the CICL stays informed of study-wide changes and updates as the study progresses. • Serve as the primary liaison between the CICL and field centers for study deficiencies, chronic poor quality studies and other issues related to overall site performance. • Provide oversight and support, as required, for the entire process
	Cardiac Imaging Core Lab	• Receive, review and analyze study echos. • Train and certify each field center sonographer. • Provide field centers feedback on poor quality echos, and queries for technical/process improvement. • Serve as a resource for sites for all echo-related questions.

II. Study-Wide Process Overview

Field centers will electronically transmit echos directly to the Cardiac Imaging Core Lab (CICL). Below is a basic diagram to describe the study wide process that will occur.



III. Sonographer Certification

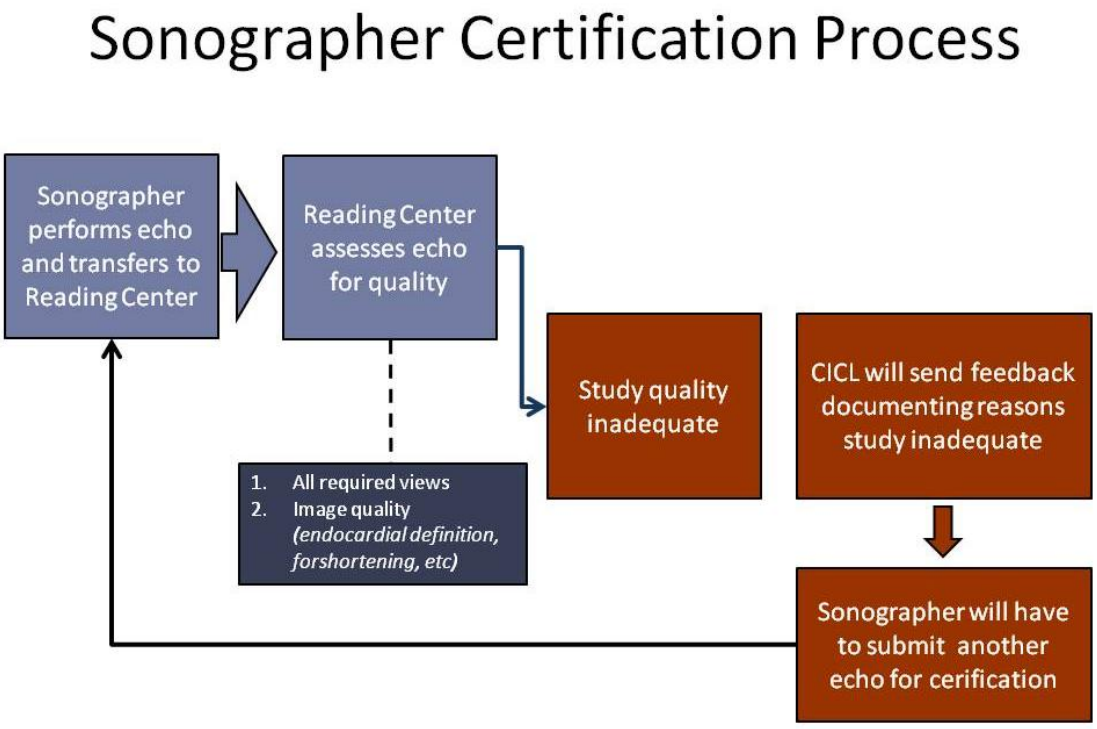
The purpose of certification is to ensure consistency in how echocardiograms are performed study-wide and to ensure performance of the highest quality echocardiograms. Any sonographer who will be performing study echocardiograms must first submit two certification studies performed in accordance with the protocol described in this manual and transferred electronically to the CICL for review and certification.

Studies will be scrutinized for adherence to protocol, acquisition of all required views, and image quality. Itemized direct written feedback and suggestions from the technical project manager will be provided for each study submitted. This is intended to address any individual equipment or operator dependent problems that may arise. Sonographers will have the opportunity to re-submit a sample protocol study should the initial submission be inadequate. Following submission of an adequate sample study, the sonographer will be officially certified and will receive feedback documenting this.

New Field Center sonographers starting during the study period will be required undergo the certification process outlined above by submitting 2 sample protocol studies in order to demonstrate the ability to perform a technically adequate protocol study and the knowledge to successfully transmit this data to the CICL.

A general outline of the process is outlined below. Prior to performing and submitting a sample study for certification, the following steps are recommended:

1. Read and review the Site Instruction Manual and Pocket Guide. The instructional video available on the ARIC Visit 5 Echocardiography Reading Center website is an additional resource. This is considered supplemental and is not a requirement to receive certification.
2. Contact the CICL for any questions before performing and submitting the certification echo to the CICL.
3. Send the certification echo to the CICL – per the instructions provided in this manual.



IV. Submission of Studies from the Field Center to the Reading Center

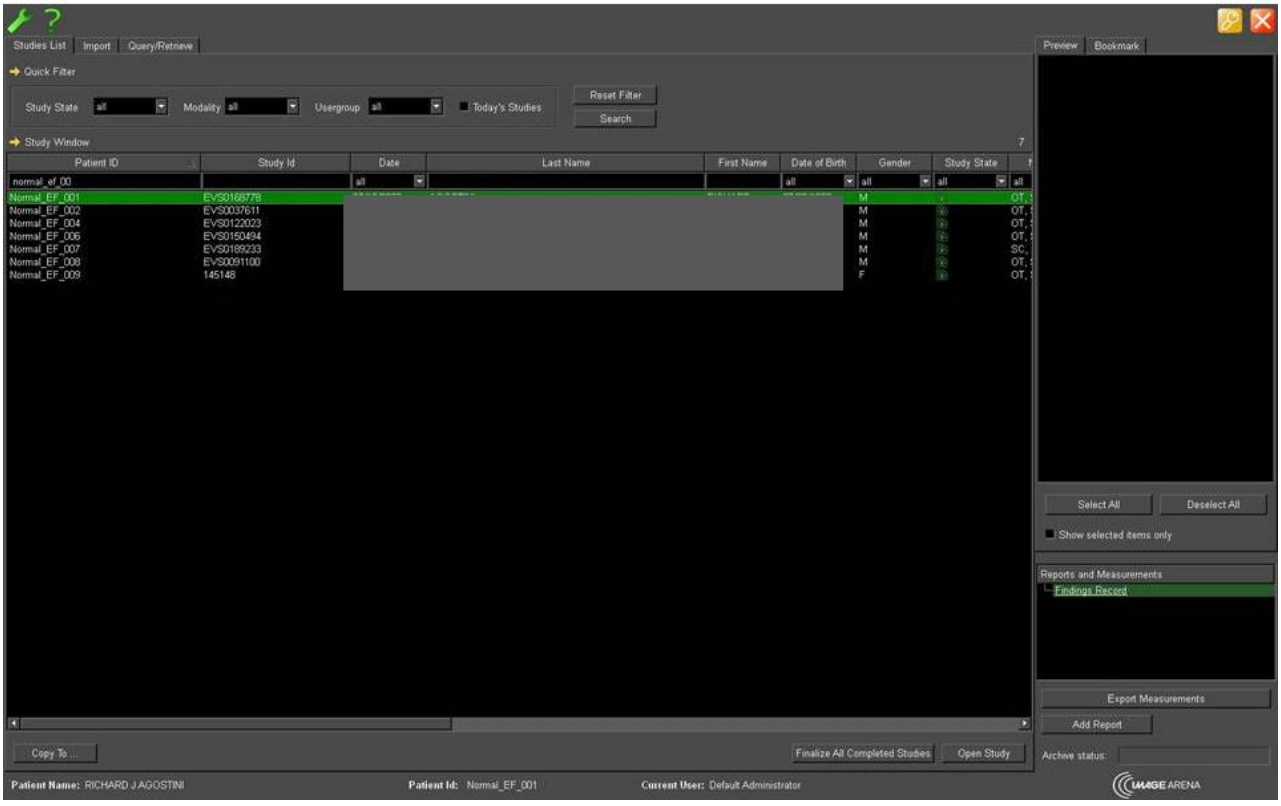
All ARIC Visit 5 echocardiograms will be transmitted electronically from Field Centers to the Echocardiography Reading Center via a secure web transfer system as detailed in Section V: Instructions for Electronic Transfer of Studies to the Reading Center. Field center staff will receive electronic confirmation (by email) upon successful receipt of each echocardiogram by the Reading Center.

Instructions for Electronic Transfer of Studies to the Reading Center

Echocardiograms will be transferred from Field Centers to the Reading Center electronically via direct VPN tunnel from the field center to the reading center server at the Brigham and Women's Hospital. A dedicated workstation at each Field Center with high-speed internet capability will be set up for study transfers.

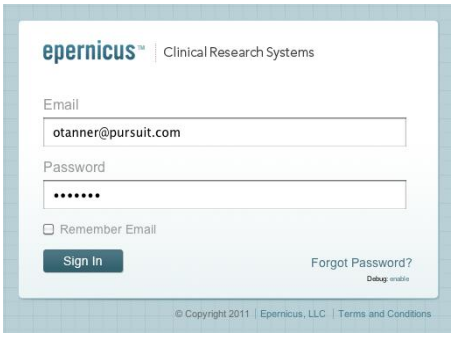
Transfer of completed studies to the Reading Center has 2 components:

(1) Upon finalizing and closing a study on the iE33 machine, studies will be automatically transferred to the Field Center PC which houses the Tomtec Image Arena software. This will act as a local temporary PACs for recent studies performed at the field center. Depending on local Field Center preference, studies will either automatically transfer or be manually selected for transfer by site sonographer from Image Arena to the BWH server. The user interface for the Tomtec Image Arena software is demonstrated in the figure below.



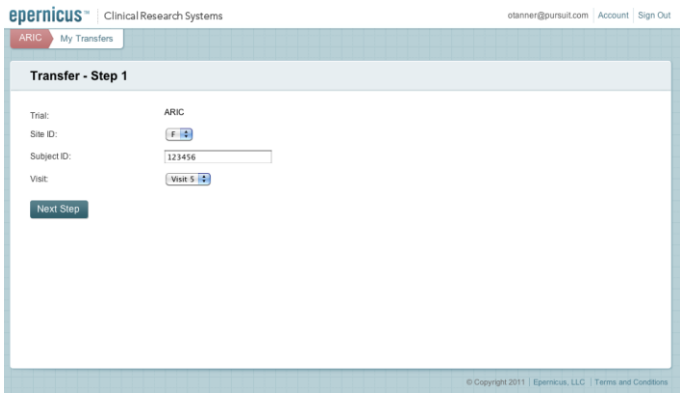
(2) For each Echocardiogram study performed and transmitted to the Reading Center, the sonographer must also ***separately*** submit an electronic Case Report Form (eCRF) to the Reading Center as outlined below. This form provides a notification for the Reading Center to expect the study images and provides important demongraphic and physiologic (heart rate, blood pressure) information necessary in analyzing the echo studies.

1. Sign in: Navigate to https://cicl.clinicalresearchsystems.com and sign in with your email address and password (provided to you by the Reading Center)

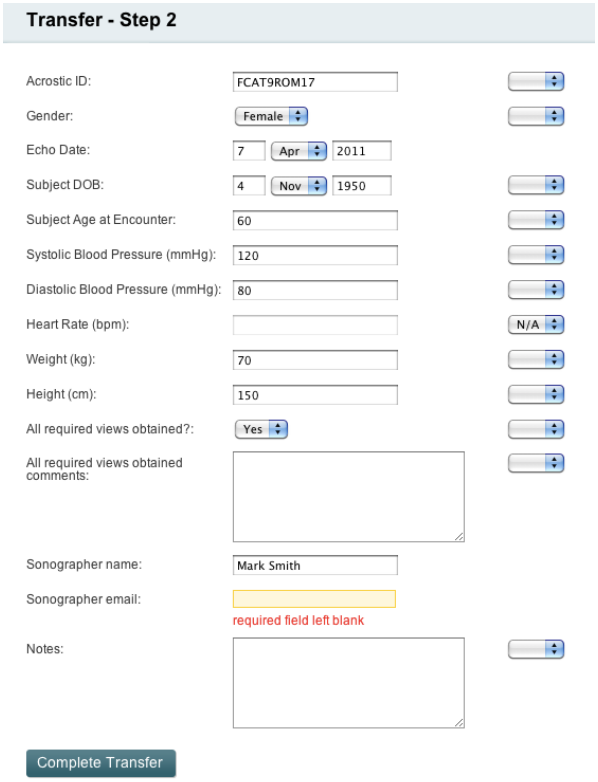


2. Initiate new eCRF: Click on “New Transfer” to begin process

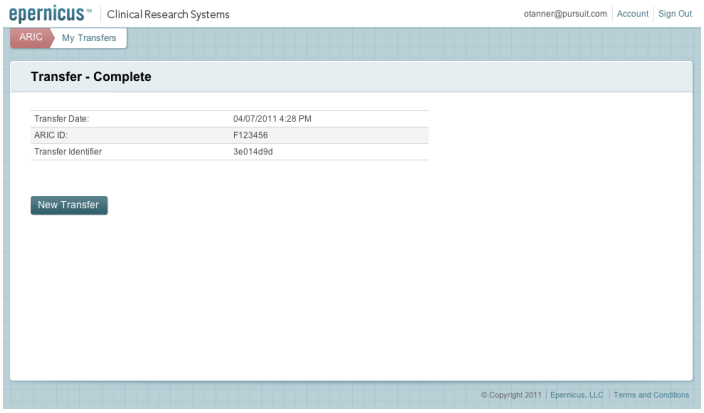
3. Enter participant ARIC ID
    - You will select your site identifier (one of ‘F’, ‘J’, ‘M’ and ‘W’) and enter the 6 digit Subject ID. Visit will default to the only available option (‘Visit 5’)



4. Enter required data
    - All fields are required, and are validated according to type. If certain fields are unavailable, you can select 'N/A' from the menu to the right side of that field to indicate that it is intentionally left blank.



5. Complete transfer by clicking the 'Complete Transfer' button
6. 'Transfer compete' confirmation screen
    - You can initiate another transfer, click on "My Transfers" to view your transfer history



For questions regarding either study performance or submission, the Reading Center has an established "hot line" channel of communication, which is listed within the Field Center Manual of Operations.

V. Reading Center Feedback to Field Centers

In situations where concerns arise regarding the quality of a study submitted by the Field Center, Field Centers, including the sonographer site supervisor, will receive CICL-Generated Poor Quality Feedback and Queries from the CICL via email to the Field Center Coordinator. The ARIC Coordinating Center and the performing sonographer will also receive a copy of this notification. This feedback will include technical instructions for quality improvement. Field Centers should respond to queries as soon as possible but latest within 10 business days; the query will contain easy to follow instructions for the Field Centers on how to resolve the query. Field Centers should contact the Reading Center with questions related to queries received.

VI. Instructions for Conducting Studies

A. Echocardiographic Equipment

All echocardiograms will be performed using dedicated Philips iE33 Ultrasound systems with Vision 2011. All echocardiogram examinations will be performed using the X5-1 xMatrix transducer, for 2D, Doppler, and 3D data acquisition. An acquisition default for the ARIC study will be programmed in each study echocardiography machine, incorporating the imaging parameters detailed in this section. All examinations should be performed using the 'ARIC' default for subjects in sinus rhythm and the 'ARIC AF' default for subjects in atrial fibrillation. All machines will also be programmed with an ARIC protocol to guide sonographers through the study protocol and ensure that all protocol required views are obtained.

Default settings for ARIC are as follows:

2D images	**Color Doppler**	**Spectral Doppler**
H pen Xres ON Elevation compounding ON Chroma 1 Gray scale 4 Persistence low Re-speed in the midline	Gain 65 Map 4 Smoothing 3 Persistence OFF	Compress 4 Reject 4 Speed 100 mm/sec

Default acquisition time will be 4 cardiac cycles. For patients in atrial fibrillation, select LOOP-TIME which will acquire for 5 seconds (automatic in protocol preset).

B. Subject Identification on Recorded Images

The CICL should receive no subject identifiers, such as the name, on actual echo recordings. **Record only the subject's study ID.**

C. Subject Preparation

The subject's blood pressure should be taken with 30 minutes of starting the echocardiogram and after the subject has been resting for 5 minutes. Be sure to record the blood pressure and initial heart rate on the Echo Tracking Form. Note: Although blood pressure is annotated on many of the images in this MOO, do NOT annotate the participant's blood pressure on the echo images for the ARIC exam.
Fill in *all* of the information on the Echo Tracking Form including heart rate, blood pressure, height, weight, and subject date of birth.

Electrocardiographic leads (3-lead) should be placed on the subject prior to imaging. An adequate ECG signal in which the QRS complex is clearly identifiable should be visible on the echocardiographic monitor must be present throughout the imaging exam duration.

The subject should be placed in the steep left lateral decubitus position unless this position is not possible.

Echocardiograms should be obtained in a manner that is most consistent with good subject care. Subject care issues, including subject comfort, should always supersede research interests. Indeed, subject cooperation and comfort are extraordinarily important in obtaining the highest quality echocardiographic examination.

VII. Guidelines for Image Optimization

Quantitative measurements entail manually tracing the endocardium and Doppler envelopes at various periods in the cardiac cycle. Even when images are of good quality, this can be extremely difficult, and it is therefore critically important that the best possible endocardial definition and Doppler signal are obtained. Guidelines for obtaining optimal quality 2D, color Doppler, Spectral Doppler, and Tissue Doppler acquisitions are outlined in this section.

A. General

For patients in sinus rhythm, at least three full cardiac cycles must be recorded for each protocol specified view. For subjects in atrial fibrillation, (at least 1) 5 second acquisition per view must be recorded. Recording should start when the view is optimized and end after the required number of cardiac cycles have been recorded per view.

The echocardiographic exam should be performed in the order listed in section VII: Echocardiogram Protocol: Required Views.

No measurements should be recorded on the images acquired at the Field Center. All measurements will be performed centrally at the Echocardiography Reading Center.

B. 2D Imaging

Throughout the course of the echo exam, both imaging depth and sector with should be continuously optimized to maintain a frame rate of 50-80 frames per second.

Ensure that the entire cardiac structure of interest is within the echo sector throughout both the systolic and diastolic periods. Optimal visualization of endocardial borders is essential for quantitative analysis. If necessary, increase 2D gain to optimally demonstrate left ventricular endocardial borders, particularly in the apical views. In general, tissue harmonic imaging should be used, except in the unusual situation where \this worsens endocardial border definition. Adjustment of sector width, imaging depth, 2D gain, and use of tissue harmonic imaging from the ARIC protocol defaults may be necessary to optimize image quality and will be at the discretion of the sonographer performing the examination.

Meticulous efforts to avoid foreshortening of imaging planes is essential to the integrity of the quantitative analysis performed on these studies. Utilize the landmarks detailed in the following sections to ensure on axis image acquisition.

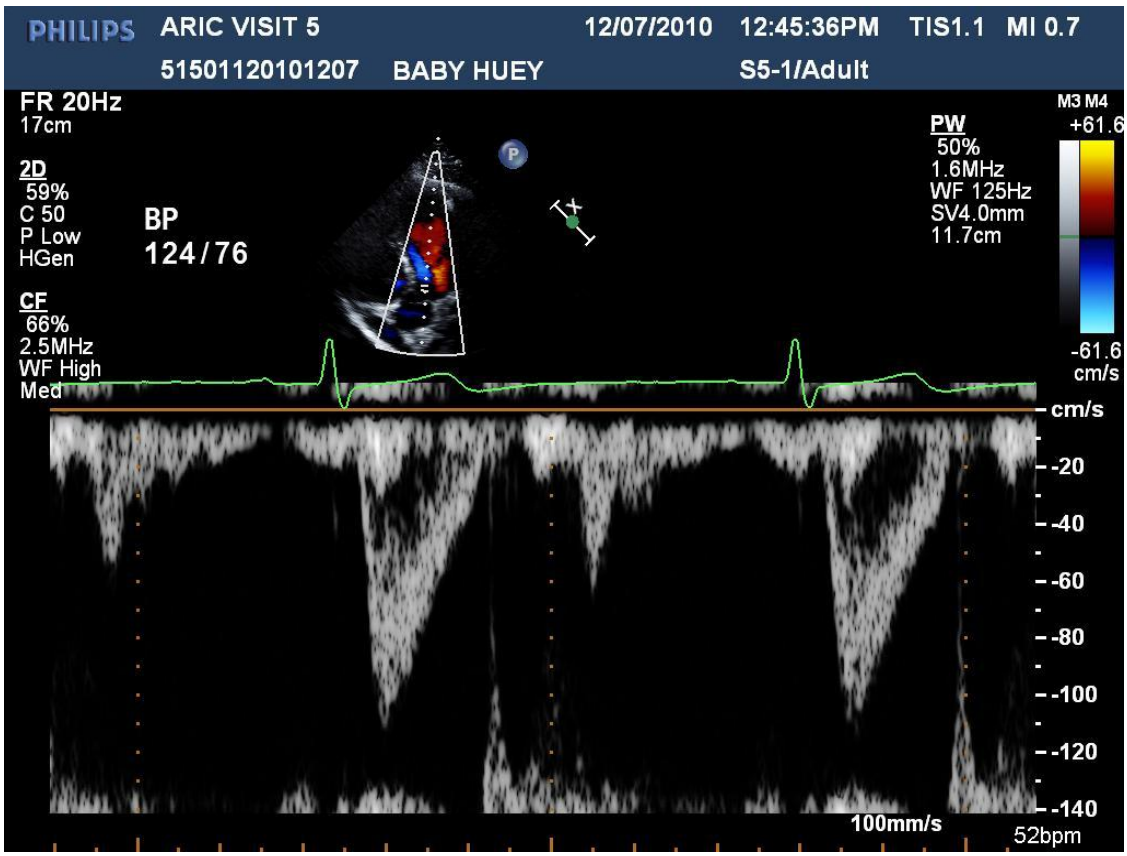
C. Color Doppler Imaging

For all color Doppler imaging, the color Doppler Nyquist limit should be at 64 cm/sec. Color Doppler gain should be set at a level just below the level at which random background noise is seen. Neither color Doppler gain nor the Nyquist limit should be adjusted by the sonographer from the ARIC protocol default. Color Doppler variance display will not be utilized in this examination.

For all color Doppler acquisitions, be sure to make the color Doppler sample window large enough to encompass the structure of interest, but no larger than necessary.

D. Spectral Doppler

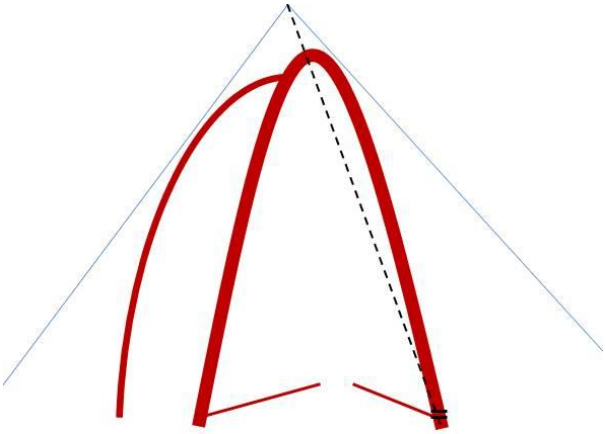
By the Doppler equation, velocity is inversely related to the cosine of the intercept angle between the ultrasound beam and the direction of blood flow. Therefore, the key principle in all spectral Doppler acquisitions (both pulsed wave and continuous wave) is to optimally align the ultrasound beam parallel to the direction of blood flow of interest. Good quality spectral Doppler tracings demonstrate clear onset and end of flow. For pulsed wave Doppler, gain should be optimized such that a well-defined envelop is visible, with a sharp peak and a lucent center. For both continuous and pulsed wave Doppler, sonographers will need to optimize the baseline shift and velocity range such that the spectral envelope occupies approximately three-fourths of display. The following ARIC protocol defaults will be set and should not be altered: (1) sweep speed 100 cm/sec, and (2) sample volume length 3mm [for pulsed wave Doppler].



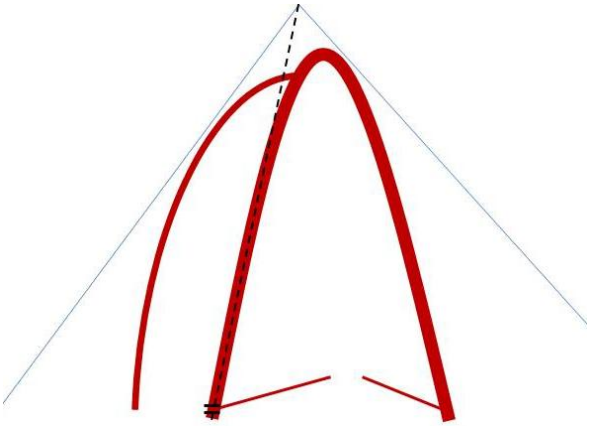
E. Tissue Doppler Imaging

Tissue Doppler imaging measures the velocity of myocardial tissue, which is low velocity and high amplitude. In contrast, the motion of blood is high velocity and low amplitude and these signals must be filtered. For this protocol, tissue Doppler imaging will be employed to measure annular velocities at both the mitral and tricuspid annulus (described in detail in the sections below). Like standard Doppler, the accuracy of tissue Doppler is dependent on a parallel angle of incidence of myocardial motion with the ultrasound beam. Optimally align the longitudinal motion of the ventricle with the ultrasound beam. Placement of the tissue Doppler sample volume appropriately at the level of annular (mitral or tricuspid depending on the view being obtained) is essential for high quality data and is reviewed in detail below. Sonographers will need to optimize the baseline shift and velocity range such that the spectral envelope occupies approximately three-fourths of display. The following ARIC protocol defaults will be set and should not be altered: (1) sweep speed 100 cm/sec, (2) sample volume length 5mm, and (3) filter setting of 100 Hz.

Proper positioning of sample volume for mitral annular TDI:



Lateral



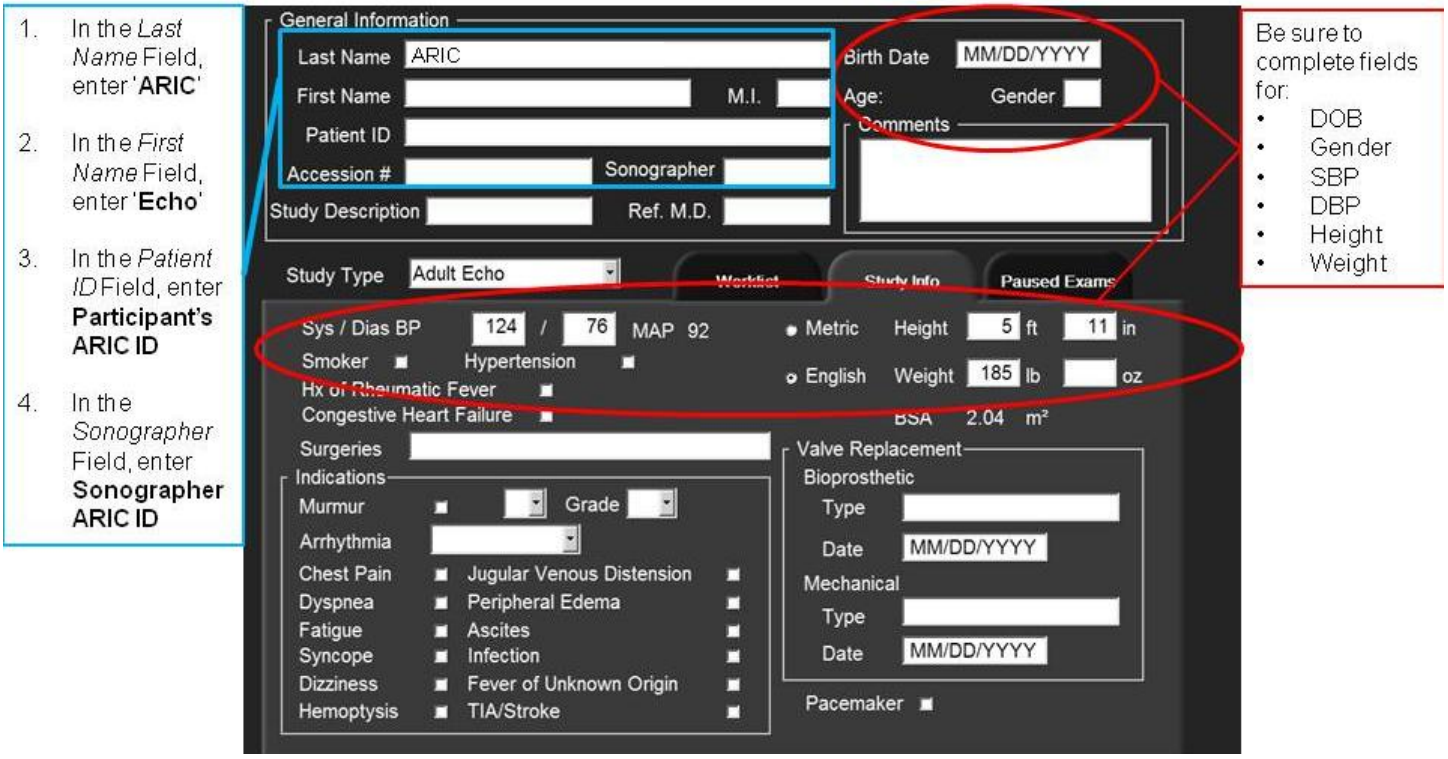
Septal

VIII. Echocardiogram Protocol: Required Views

A. Brachial Blood pressure	♦ Ensure that BP obtained within 30 min of the echo examination
B. Parasternal Position	
☑ *Parasternal long axis*	♦ 2D imaging (at deep depth) ♦ 2D imaging (at shallow depth) ♦ Color Doppler of the mitral and aortic valves
☑ *Parasternal short axis – Aortic valve level*	♦ 2D imaging of AV ♦ Color Doppler of AV ♦ 2D imaging of right ventricular outflow tract ♦ Color Doppler of right ventricular outflow tract ♦ PW and CW Doppler of the RVOT
☑ *Parasternal short axis – Mitral valve level*	♦ 2D imaging
☑ *Parasternal short axis – Papillary muscle level*	♦ 2D imaging ♦ M-mode
☑ *Parasternal short axis – LV apex*	♦ 2D imaging
C. Apical Position	
☑ *Apical 4 chamber view*	♦ 2D imaging ♦ 2D imaging, focused/zoomed on LV ♦ 2D imaging, focused on LA ♦ Color Doppler of mitral valve/LA ♦ PW Doppler of mitral flow ♦ TDI of septal and lateral mitral annulus ♦ iRotate to 2-chamber view (2D imaging) ♦ iRotate to 3-chamber view (2d imaging) ♦ 3D full volume acquisition of LV ♦ 3D full volume acquisition of RV
☑ *Apical 4 chamber – focused on the RV*	♦ 2D imaging ♦ Color Doppler of tricuspid valve/RA ♦ CW Doppler of tricuspid regurgitation ♦ TDI of lateral tricuspid annulus
☑ *Apical 5 chamber view*	♦ 2D imaging ♦ Color Doppler of left ventricular outflow tract ♦ Pulse wave of LVOT flow ♦ CW of transaortic flow
☑ *Apical 2 chamber view*	♦ 2D imaging focused/zoomed on LV ♦ 2D imaging focused on LA ♦ Color Doppler MV/LA
☑ *Apical 3 chamber view*	♦ 2D imaging
D. Subcostal View	
☑ *Inferior vena cava*	♦ 2D imaging (5 second acquisition)

IX. Detailed Review of Protocol Required Views

Beginning the Exam
Complete the subject information screen on the iE33 as detailed in the figure below:



Be sure to acquire an image of this screen.

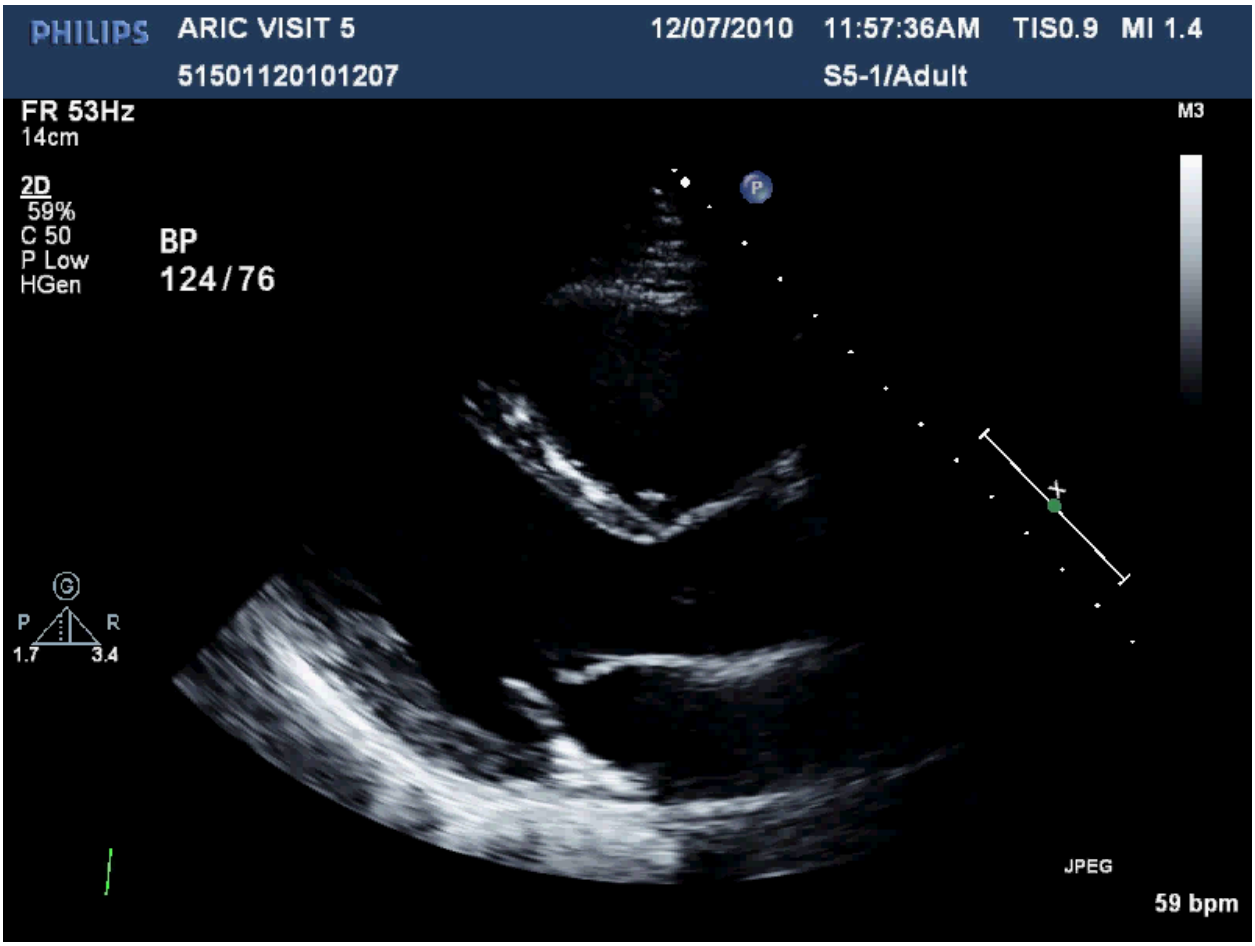
A. Brachial Blood Pressure
The participant's brachial blood pressure should be measured within 30 minutes of the start of the echo examination. The subject's blood pressure should be taken after the subject has been resting for 5 minutes. Blood pressure should be performed at baseline in both arms. The highest reading should be recorded and subsequent measure should be done on the arm with the highest reading. Be sure to record the blood pressure and initial heart rate on the Echo Tracking Form. Note: Although blood pressure is annotated on many of the images in this MOO, do NOT annotate the participant's blood pressure on the echo images for the ARIC exam.

B. Parasternal Views

Two parasternal views will be obtained:

- Parasternal long axis view
- Parasternal short axis view at 4 levels as detailed below (section B.2.)

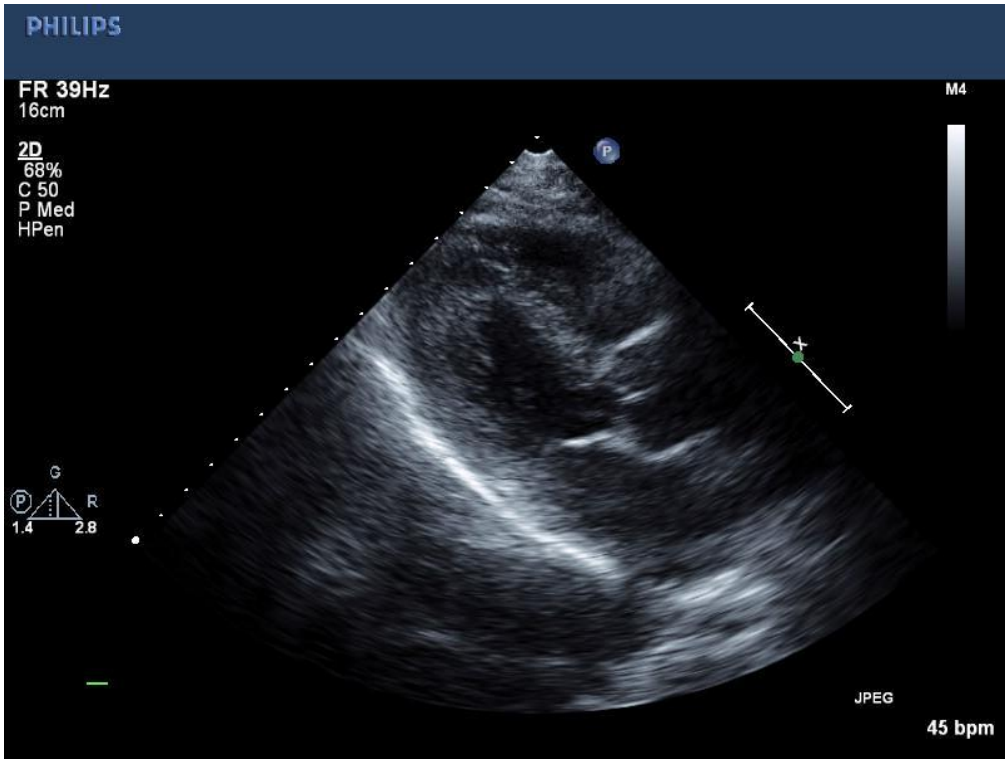
B.1. Parasternal Long Axis View



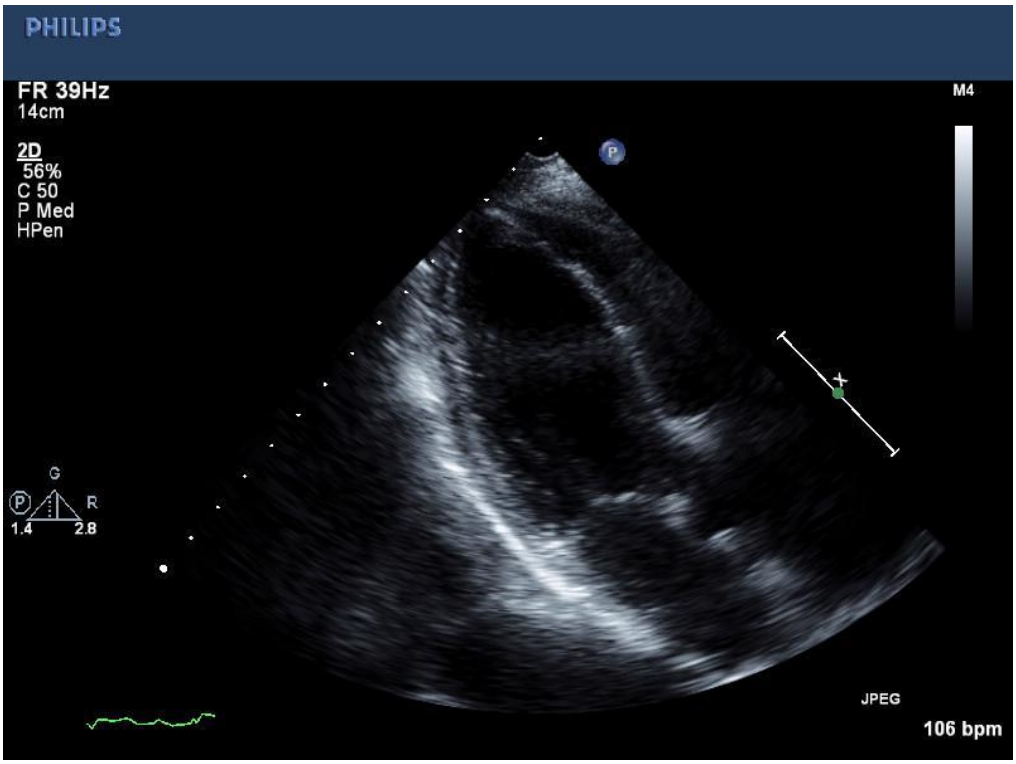
In the ideal echocardiographic "window" for the long axis:

- The LV endocardium at the septum and the posterior wall are well delineated.
- The proximal interventricular septum is horizontal and continuous with the aortic root.
- The anterior and the posterior mitral valve leaflets, and the right and noncoronary aortic valve leaflets are visible.
- The left ventricular apex is not visualized.

Avoid obtaining shortened or low parasternal views:

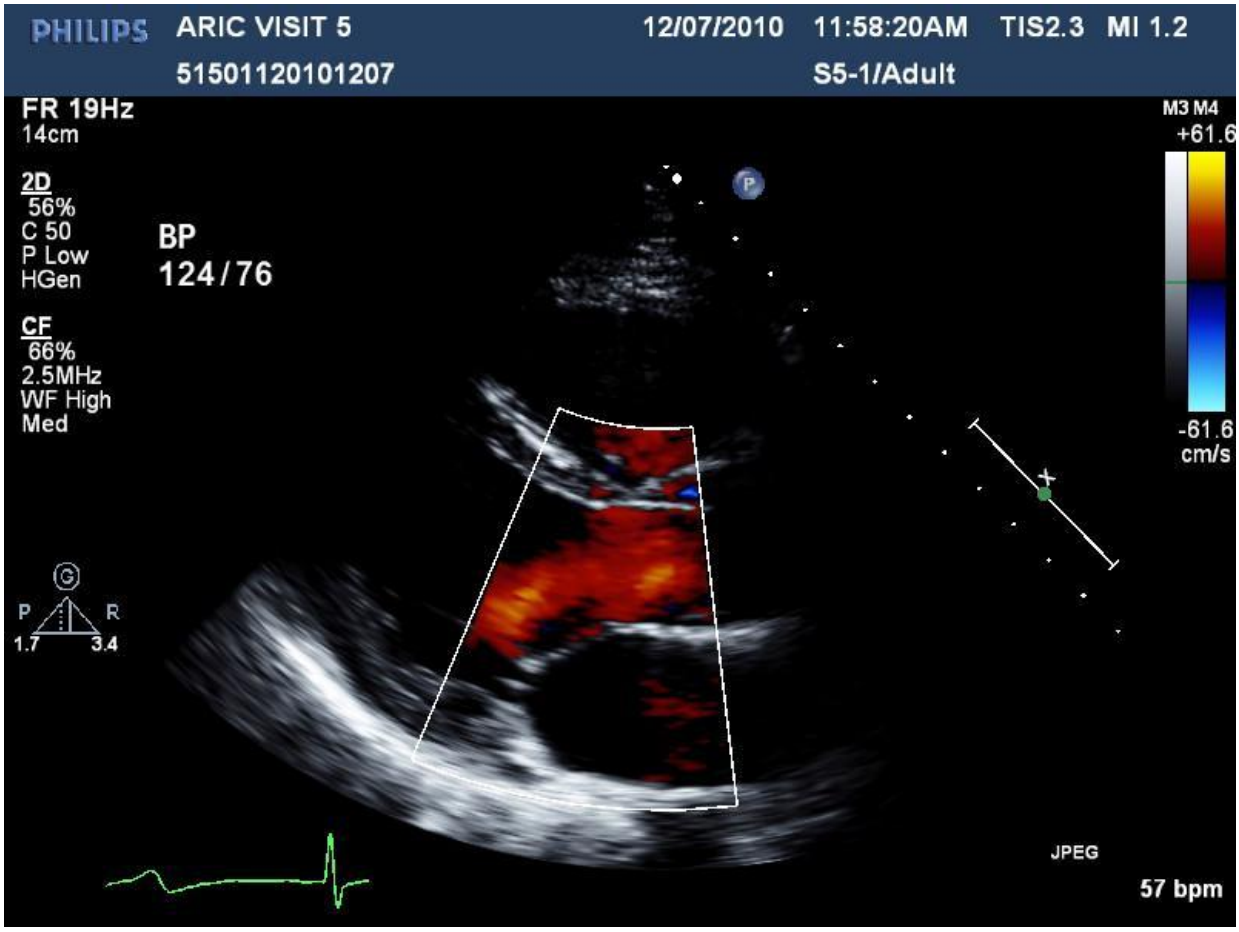


Grossly forshortened PLAX View



Low PLAX View

Parasternal Long Axis View with color Doppler

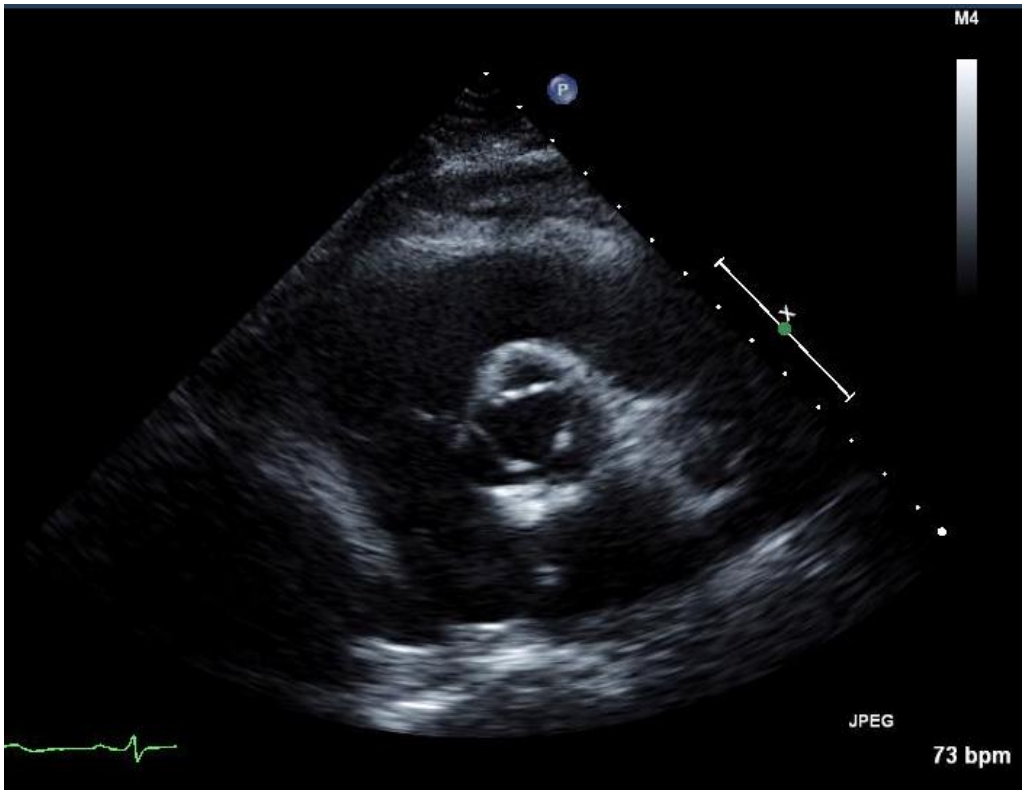


2. Parasternal Short Axis View

Parasternal short axis view will be obtained at four levels:

1. At the aortic valve level with the RVOT and pulmonic valve visible.
2. At mitral valve when both anterior and posterior mitral valve leaflets are visualized.
3. At the mid-papillary muscle level with the papillary muscles visible.
4. At the left ventricular apex.

B.2.i. Aortic Valve Level



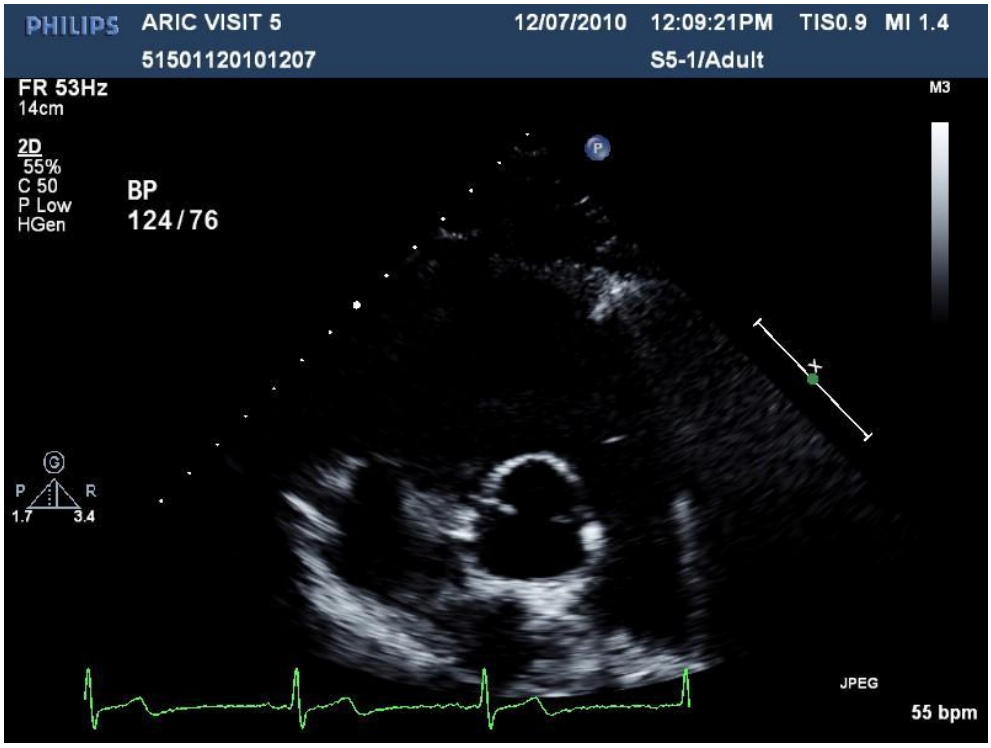
Acquire both 2D imaging and color Doppler of this view.

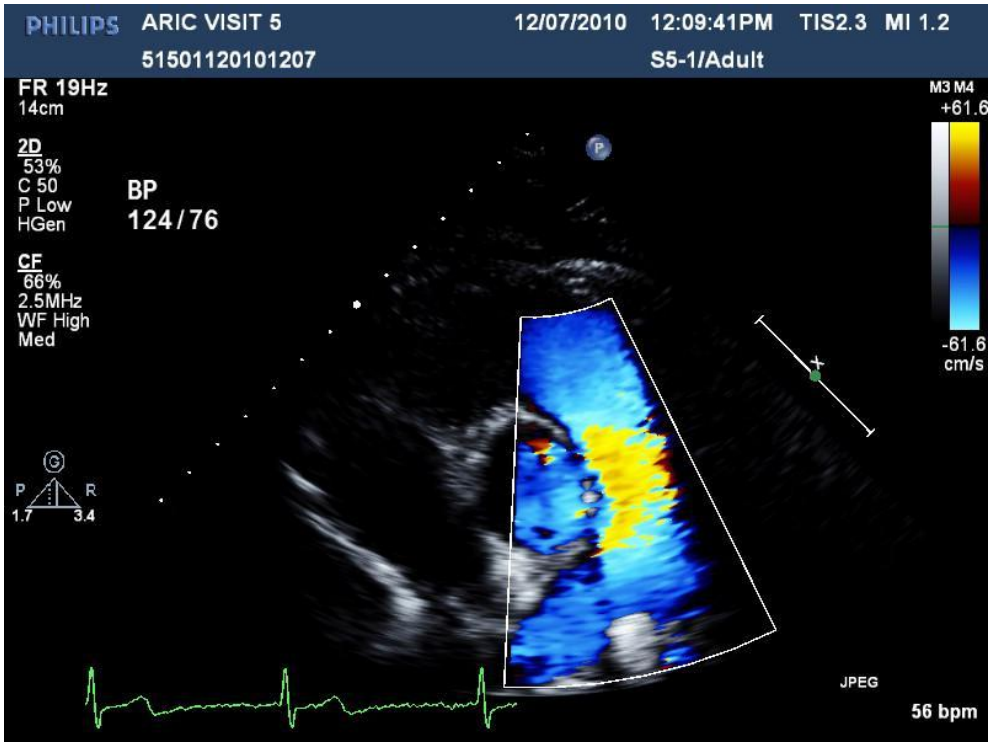
In the ideal echocardiographic "window" for the short axis at the aortic valve level:

- All 3 cusps of the aortic valve are visible, with a clear upside down triangle pattern during systole.
- The tricuspid valve and interatrial septum are visible.

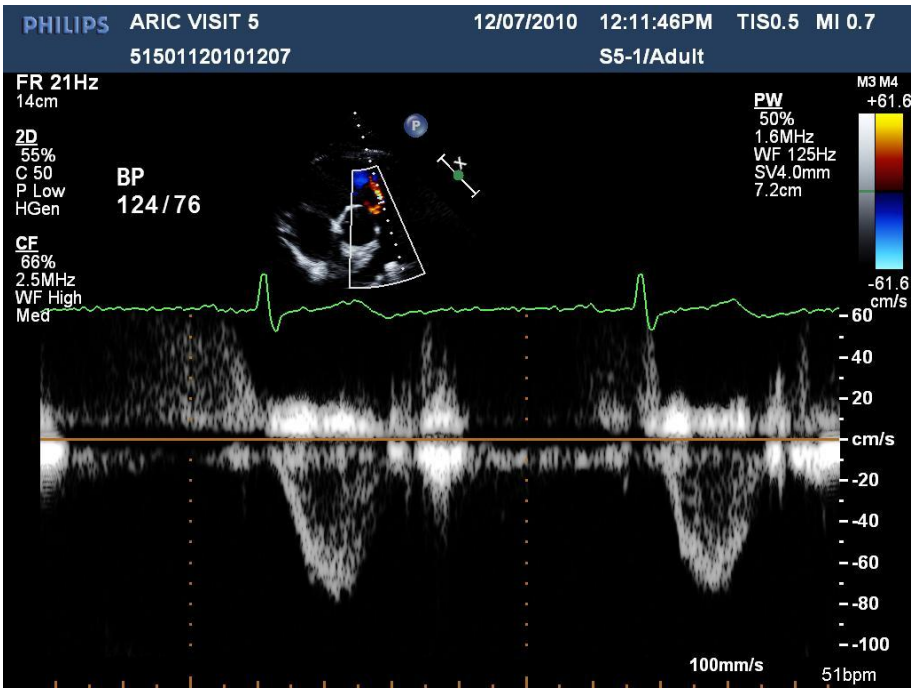
From the parasternal short axis view at the aortic valve level, the following additional images will also be obtained:

- **PSAX view focused on the right ventricular outflow tract and pulmonic valve**



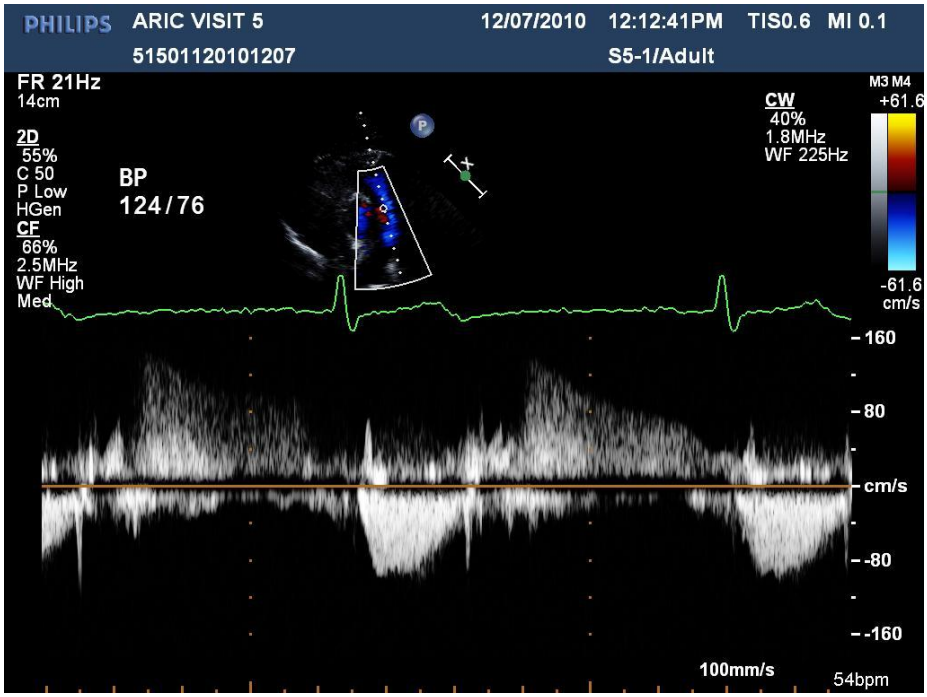


- **Continuous and pulsed wave spectral Doppler of RVOT and trans-pulmonic flow**



Pulse Wave Doppler in RVOT

  - For pulse wave acquisition, ensure that the sample is in the right ventricular outflow tract (RVOT) approaching the pulmonic valve, just prior to the level of flow acceleration and spectral broadening. Record a minimum of 3 cardiac cycles (10 for subjects in atrial fibrillation) at a sweep speed of 100 mm/sec.



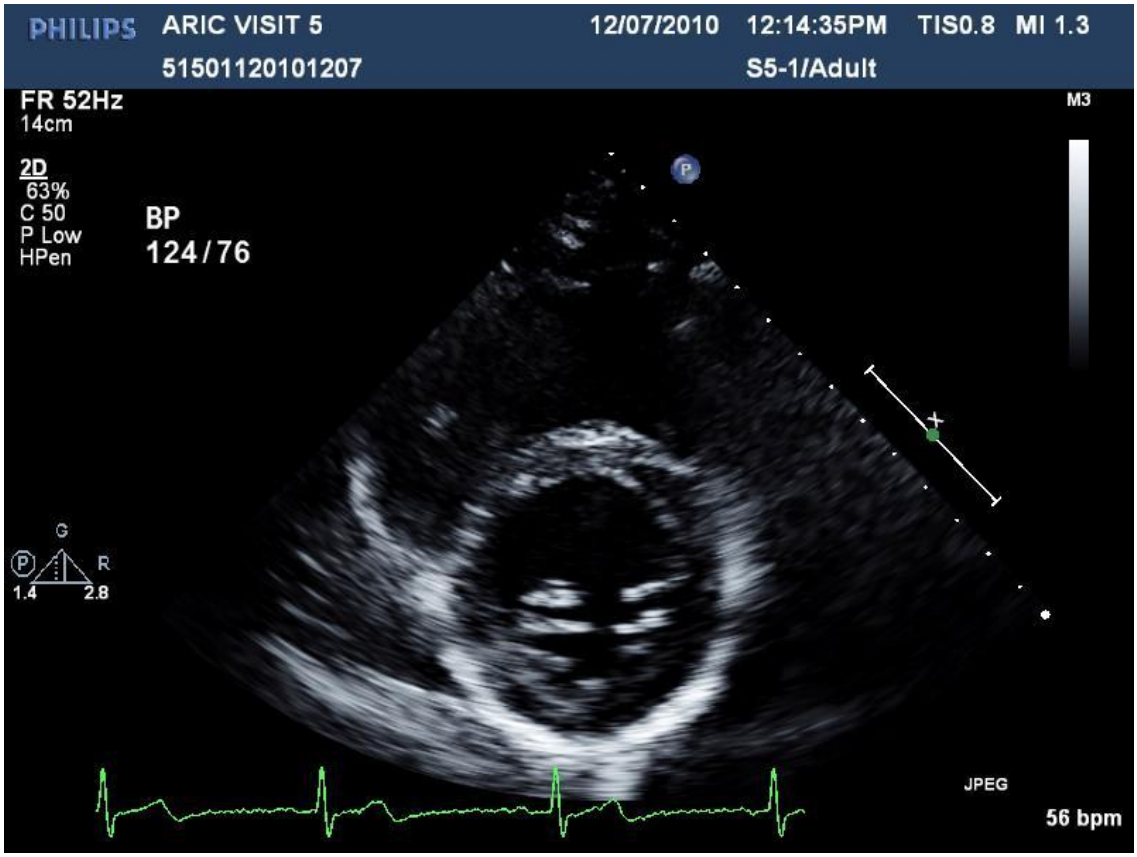
Continuous Wave Doppler through Pulmonic Valve

B.2.ii. Mitral valve level, mid-papillary level, and apical level

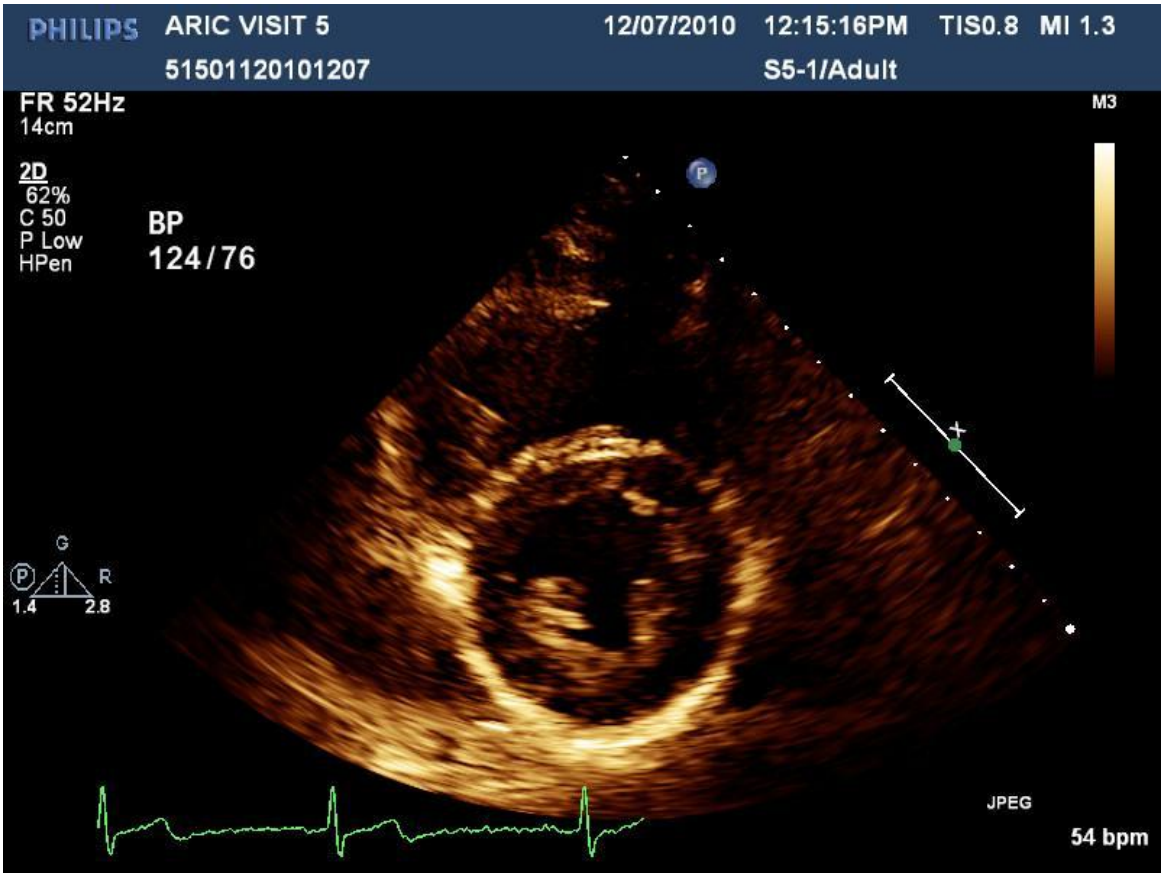
In the ideal echocardiographic "window" for the short axis:

- In the absence of prior infarction, the left ventricle should have a circular shape in the short axis – an elliptical shape suggests off-axis/tangential cut through the ventricle.
- Use internal LV landmarks to ensure imaging at consistent planes in the short axis: visualization of the anterior and posterior mitral leaflets for the mitral valve leaflets; visualization of both papillary muscles for the mid-papillary level
- For all short axis images, adjust sector width and imaging depth to ensure acquisition frame rate of 50 to 70 frames per second.

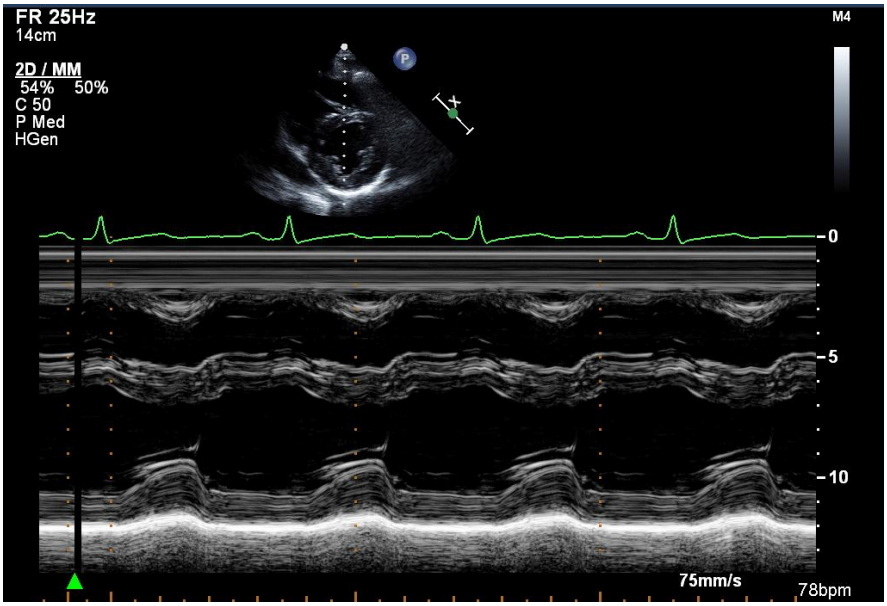
Mitral Valve Level



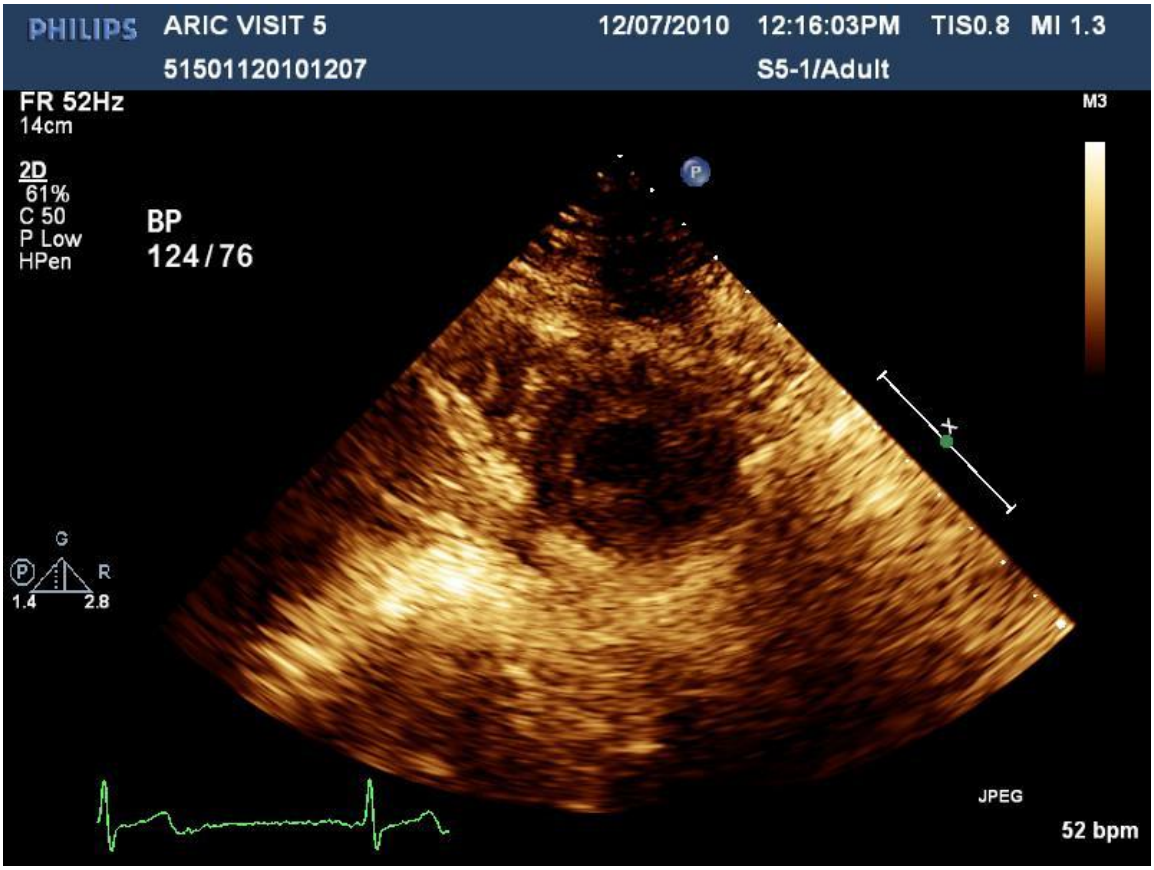
Mid-papillary Level



- For the quantification of left ventricular mass, M-mode recordings of the left ventricle should be obtained with the ultrasound beam at or just below the tips of the mitral valve leaflets in the parasternal short-axis view, for the required number of cardiac cycles. Minimal valvular apparatus should be visible in the image:



Apical Level



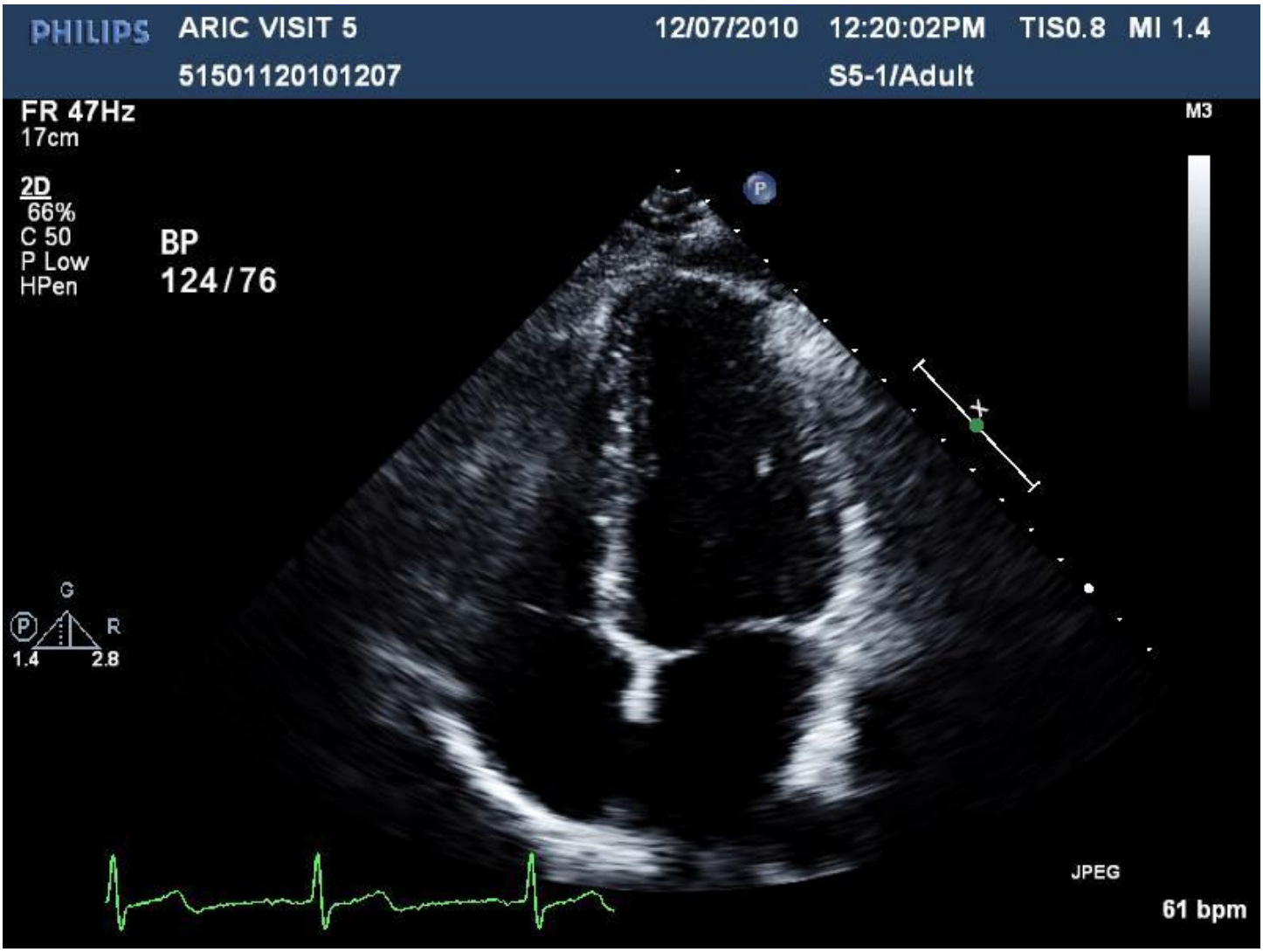
C. Apical Views

Five apical views will be obtained:

- The standard apical four-chamber focused on the LV
- The apical four-chamber dedicated to optimal imaging of the RV
- The five-chamber view
- The two-chamber view
- The three-chamber view

At the Reading center, left ventricular and atrial areas and volumes will be measured from these views (i.e. using Simpson's method). Therefore, in all apical views, special attention should be paid to properly align the image and capture the left ventricle and atrium in full. Avoid either foreshortening or elongating the chambers by transducer angulation.

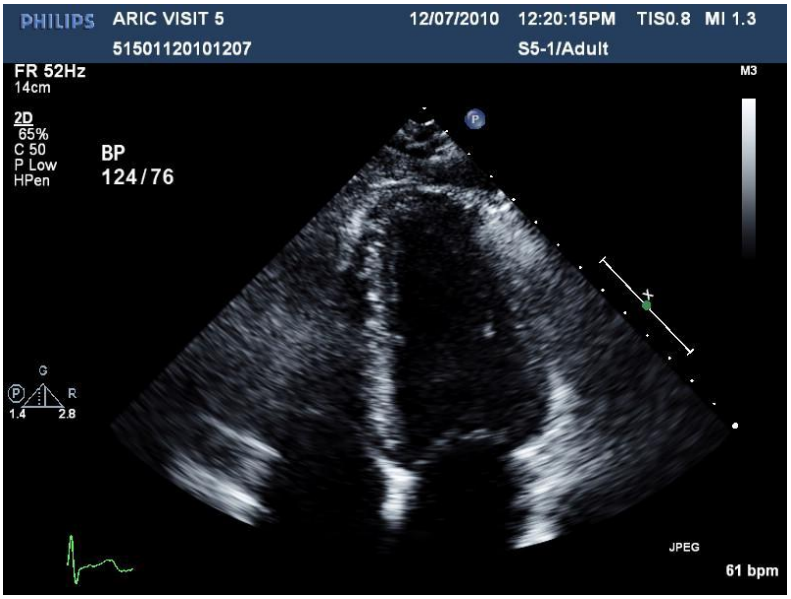
C.1. Apical 4-Chamber View



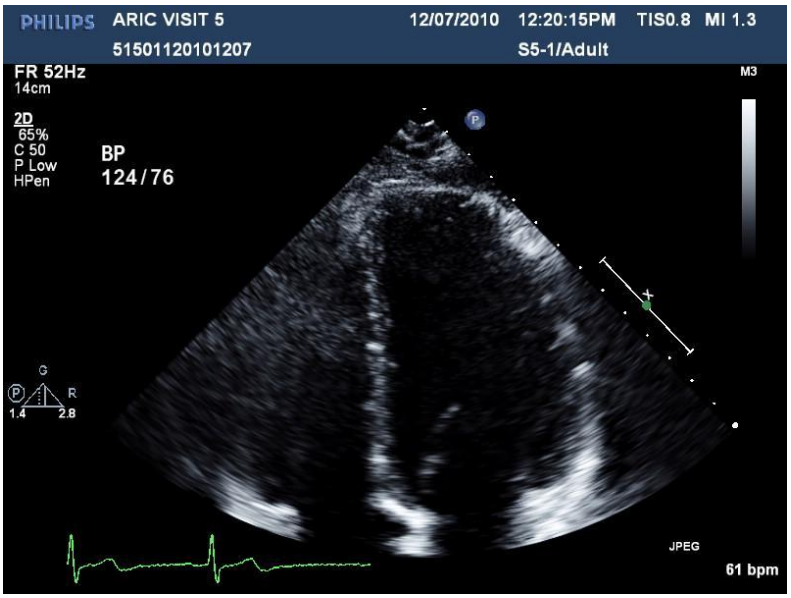
Apical 4-Chamber

C.1.i. ***Focus on LV***

- Obtain 1 clip optimizing visualization of the left ventricle during systole and diastole. Obtain a second clip optimizing visualization of the left atrium thoughout systole and diastole.
    - Maximize LV length and be careful not truncate the true long axis.
    - The entire LV endocardium must be within the imaging sector in both end-diastole and end-systole. Pay special attention to the apex and the lateral LV free wall, which are often the most difficult areas to visualize.
    - Adjust sector width and imaging depth to ensure acquisition frame rate of 50 to 70 frames per second.



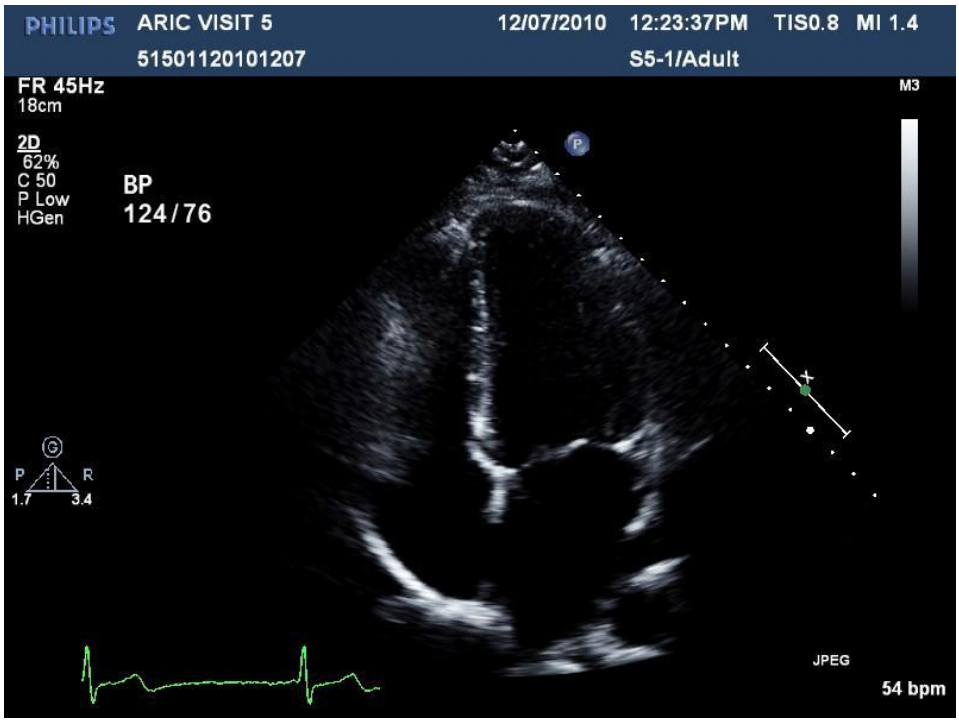
Apical 4 Chamber view, end-systole



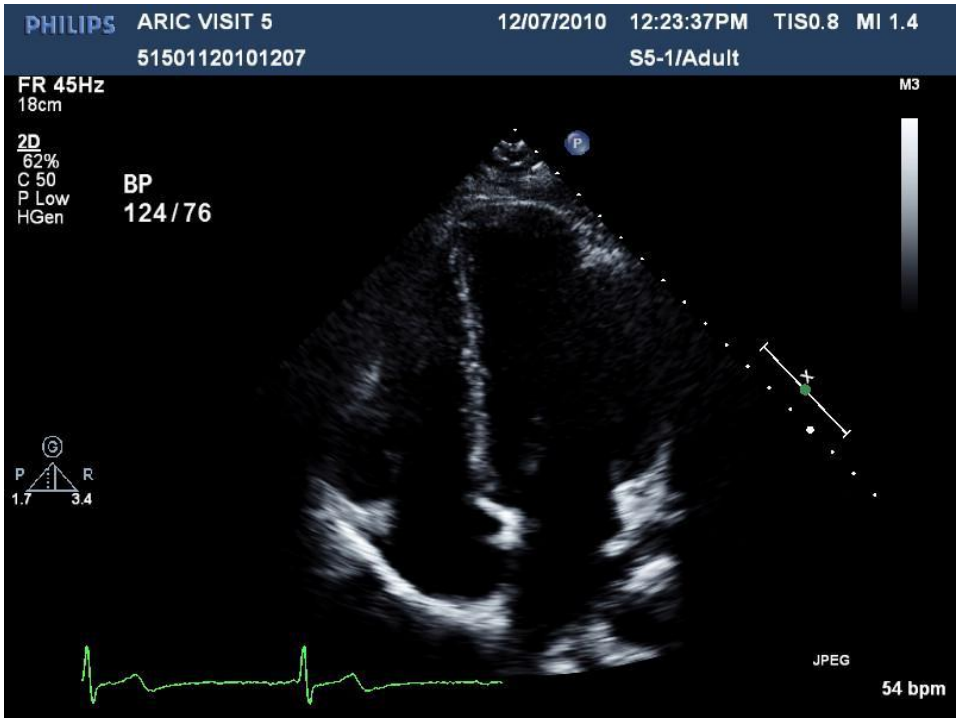
Apical 4 Chamber view, end-diastole

C.1.ii. ***Focus on LA***

- Obtain 1 clip optimizing visualization of the left ventricle during systole and diastole. Obtain a second clip optimizing visualization of the left atrium thoughout systole and diastole.
    - Properly align the image and capture the left atrium in full. Avoid any foreshortening of the chamber.



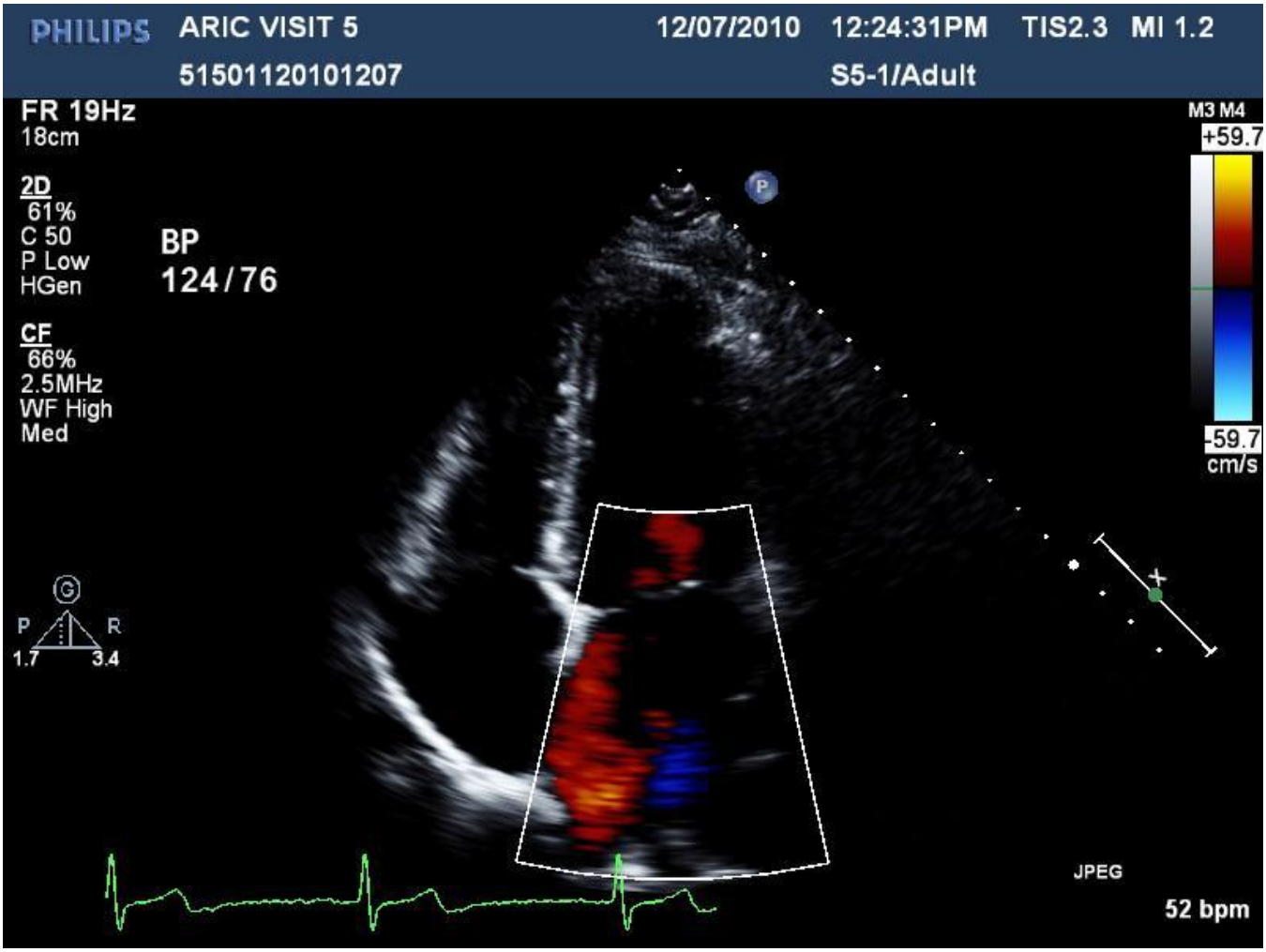
End-systole



End-diastole

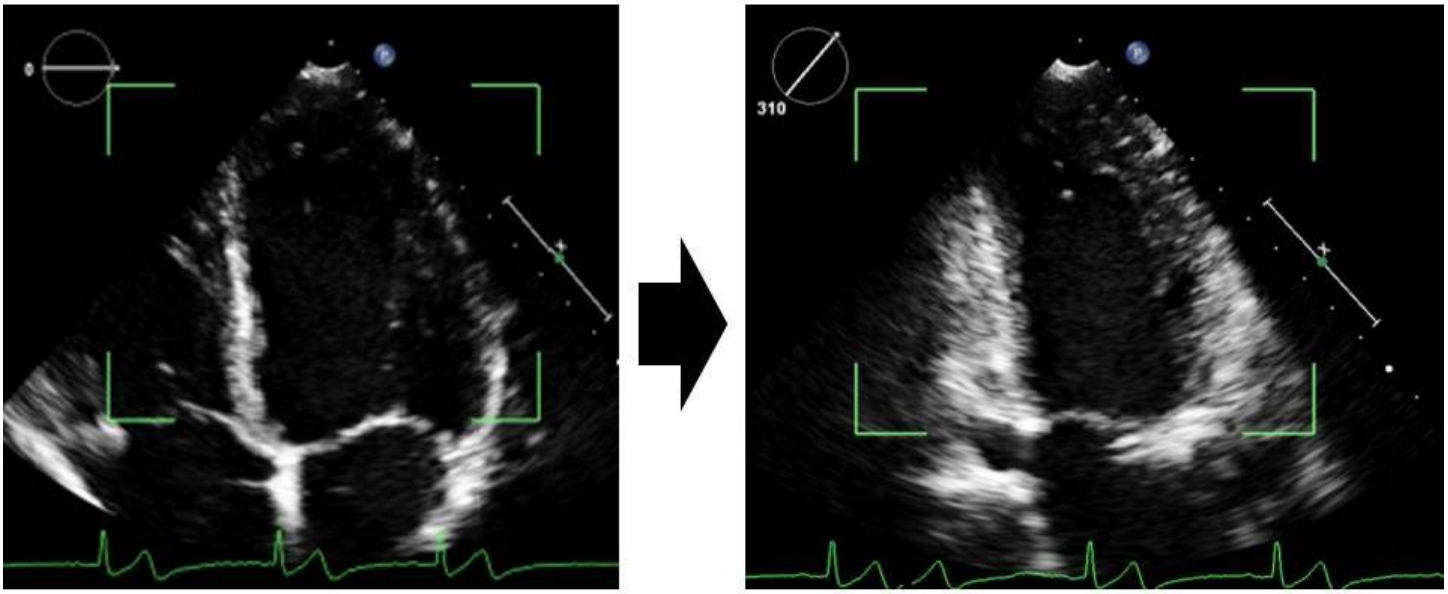
C.1.iii. ***Color Flow Doppler for Mitral Regurgitation***

- Adjust color Doppler sample sector over the mitral valve and include the entire LA cavity. To optimize frame rate, keep the color sector scan as narrow as possible, while including the entire LA. The color Nyquist limit is set at 64 cm/s in the ARIC protocol and should not be altered.



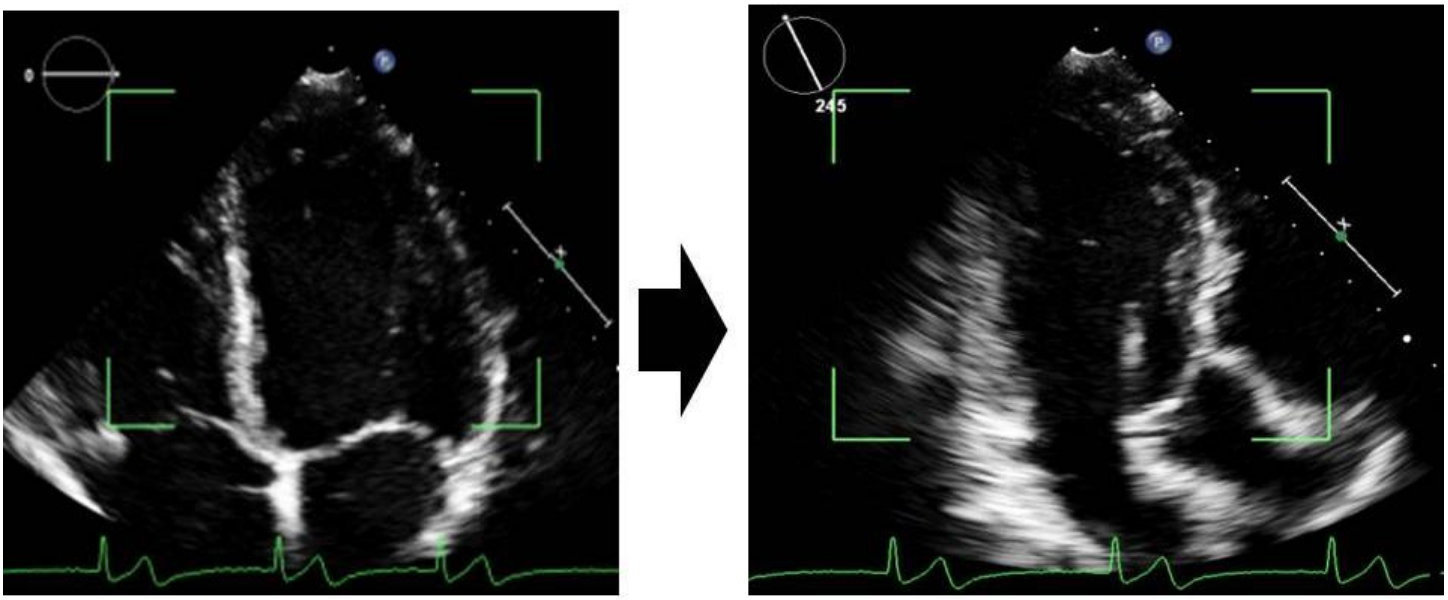
C.1.iv. Omniplane imaging of A2C and A3C using iRotate function

- Keeping the transducer in position to optimize A4C acquisition, adjust the iE33 iRotate knob first to obtain a 2-chamber view, then a 3-chamber view. Acquire each view. Note that the optimal iRotate angle to acquire the 2- and 3-chamber view from the A4C transducer position will vary by subject.



Apical 4 Chamber View

2 Chamber View
(acquired with iRotate at 310° in this subject)

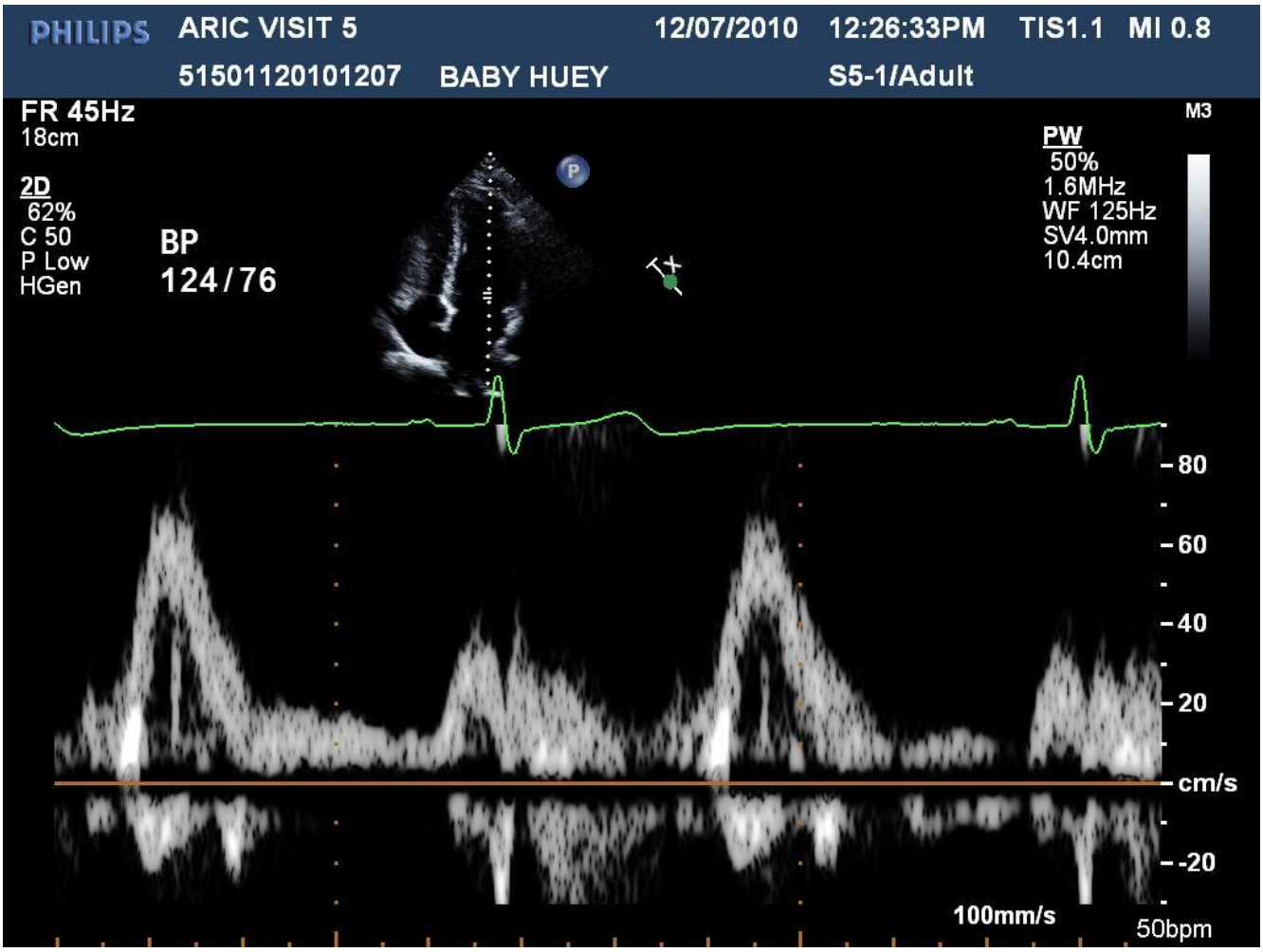


Apical 4 Chamber View

3 Chamber View
(acquired with iRotate at 245° in this subject)

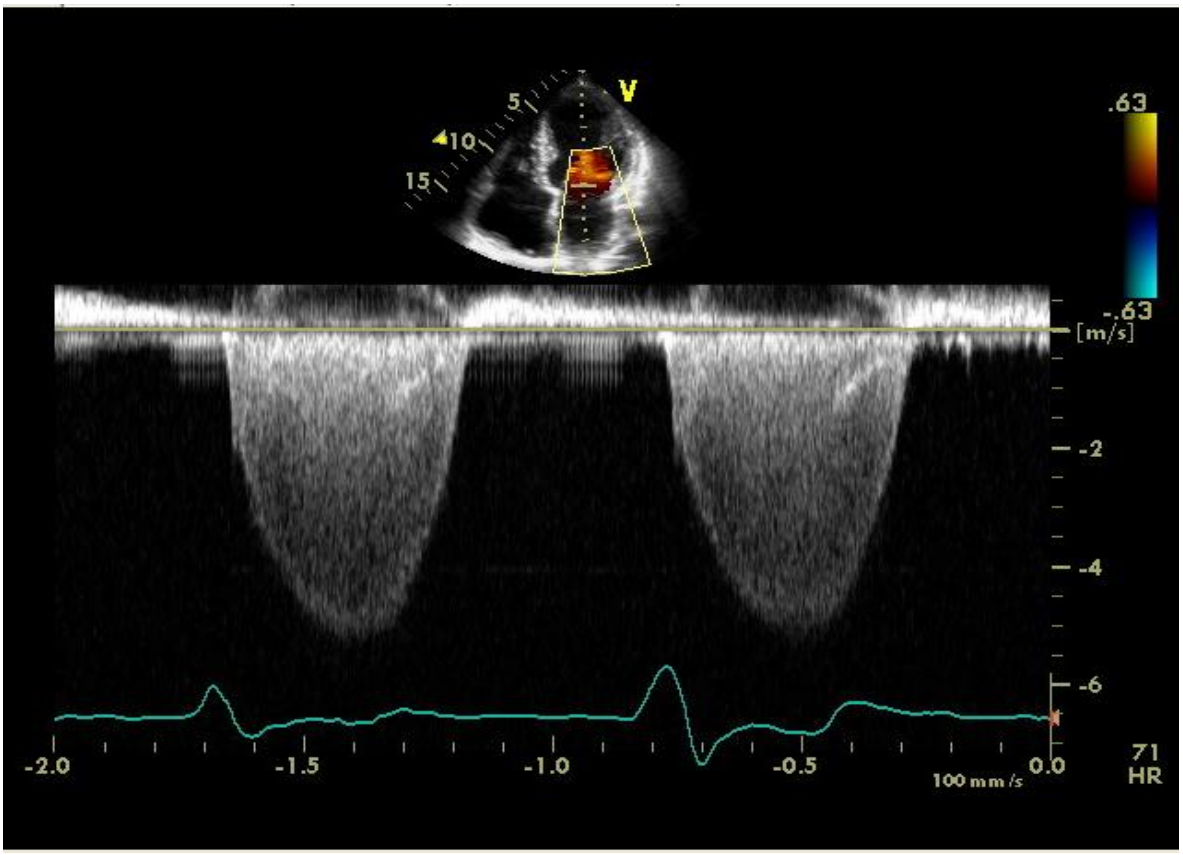
C.1.v. Spectral Doppler of Mitral Inflow

- From the apical four chamber view record the mitral inflow velocity curve with the pulsed-wave Doppler sample volume positioned at the tips of the mitral leaflets during quiet respiration for 30 seconds (or at least five cardiac cycles). Adjust the baseline and Doppler scale to visualize the peak E and A wave velocities. Record a minimum of 3 cardiac cycles (10 for subjects in atrial fibrillation) at a sweep speed of 100 mm/sec.



C.1.vi. CW Doppler of the Mitral Regurgitation

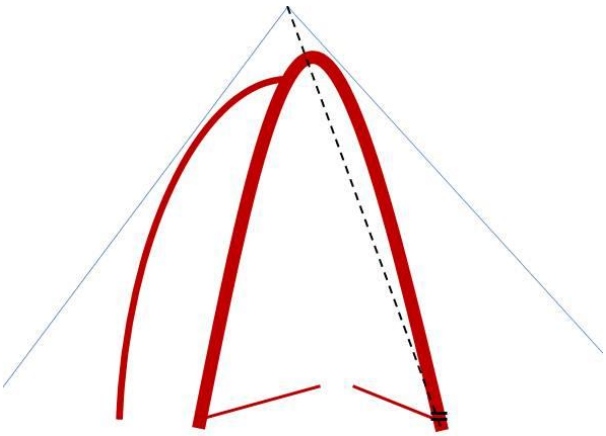
- Position the interrogation line as parallel to the flow as possible. Adjust the baseline and scale to capture the peak MR velocity. Record a minimum of 3 cardiac cycles (10 for subjects in atrial fibrillation) at a sweep speed of 100 mm/sec.



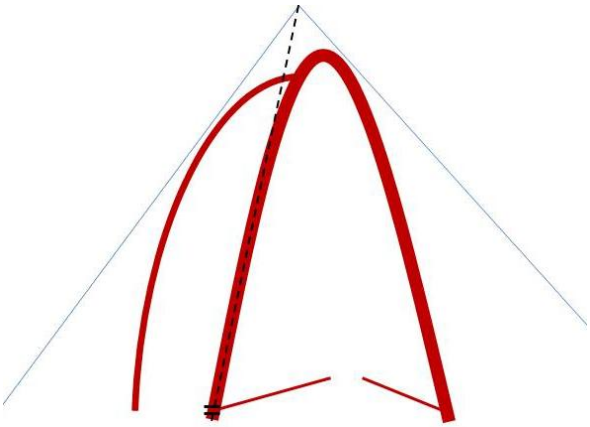
C.1.iv. Tissue Doppler Imaging (TDI) of Mitral Annulus (lateral and septal)

1. Decrease image depth (to include the LV and a small part of the LA, ideal depth approximately 16 cm) and optimize the 2D image for the LV, focusing on the lateral wall and the mitral annular region.
2. Adjust the image to orient the motion of the lateral wall parallel to the cursor. Both gains and filter settings should be set low (100 Hz or less) to obtain the best images.
3. Initiate 2D color DTI and position the sample volume on the ventricular side of the lateral mitral annulus at the junction of the LV wall with the mitral annulus of the lateral myocardial segment; the myocardium should stay within the sample volume for as much of the cardiac cycle as possible.
4. Before the data is acquired, check that only the region to be sampled is moving through the sample volume.
5. Switch to PW spectral DTI and set the scale to 20 cm/sec with a sweep speed of 100 mm/sec.
6. Before collecting data, set the Pulsed Doppler velocity range to avoid velocity aliasing (a velocity range of +/- 24 cm/sec is normal though subjects with high heart rates may require a higher setting).
7. Once a clear pattern is obtained, record at least 10-20 beats during quiet respiration (or preferably during breath holding at end-expiration).
8. Record a minimum of 3 cardiac cycles (10 for subjects in atrial fibrillation) at a sweep speed of 100 mm/sec.
9. Repeat this process for the septal mitral annulus

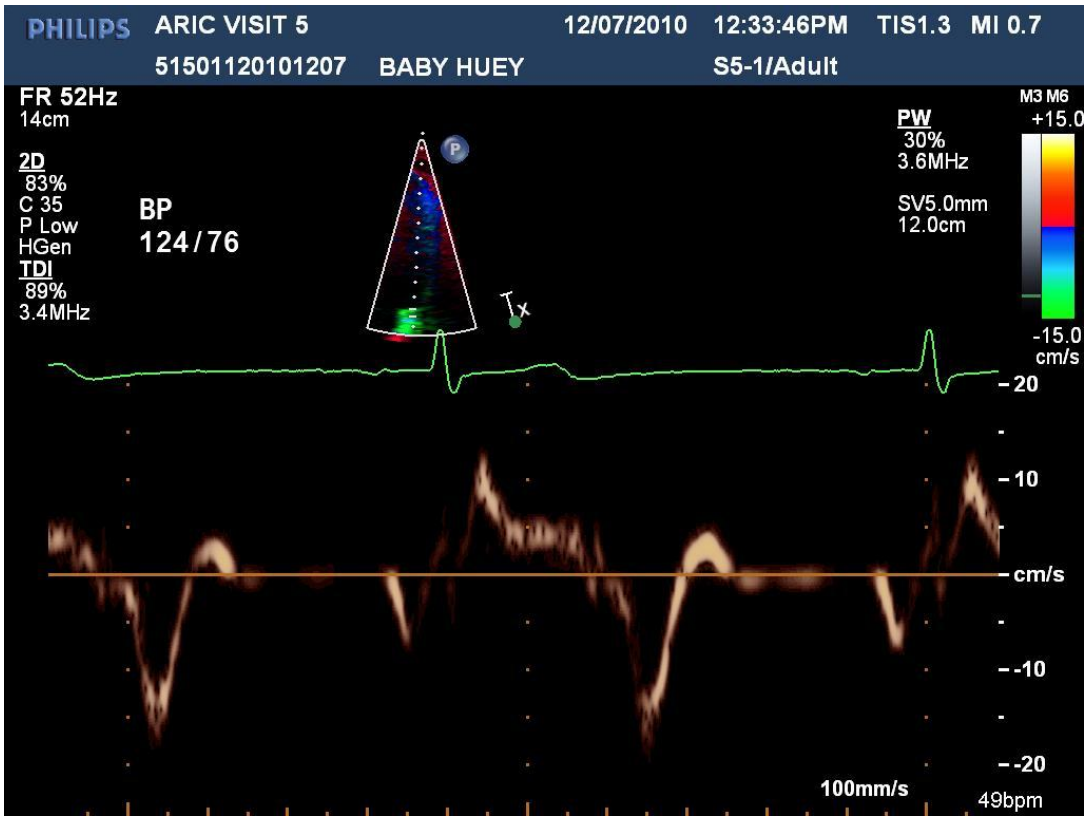
Proper positioning of sample volume for mitral annular TDI:



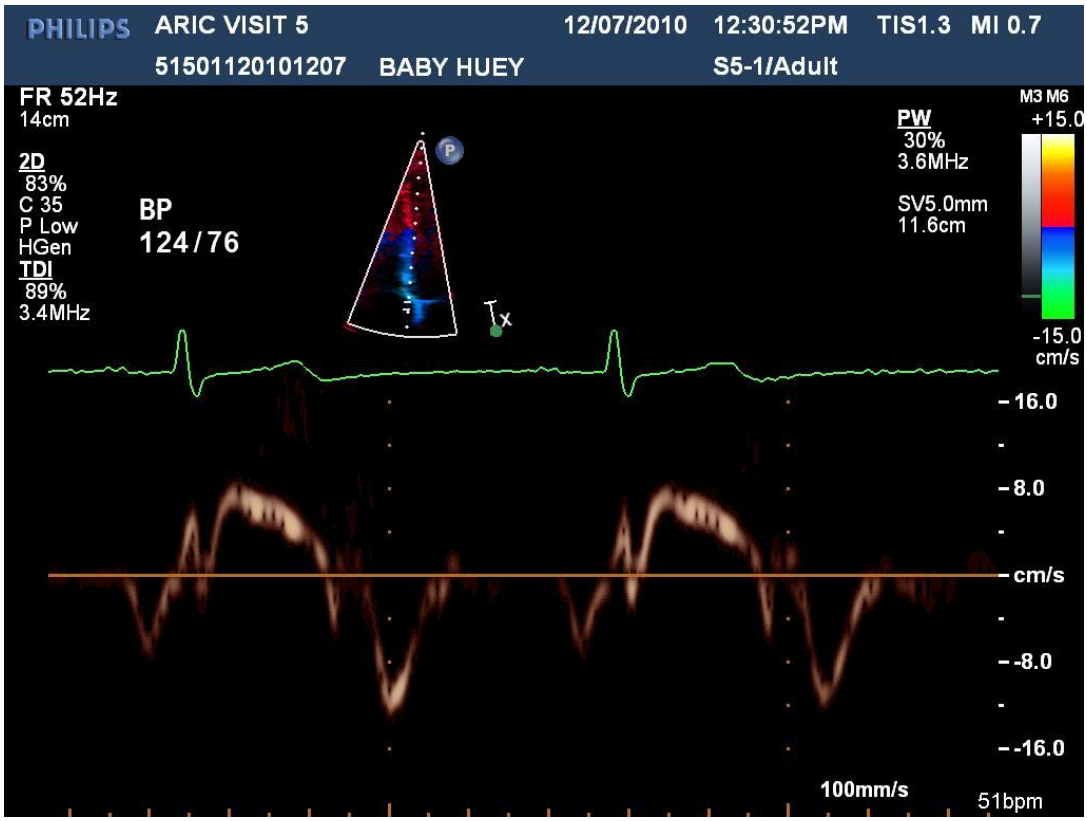
Lateral



Septal



Tissue Doppler imaging at the lateral mitral annulus

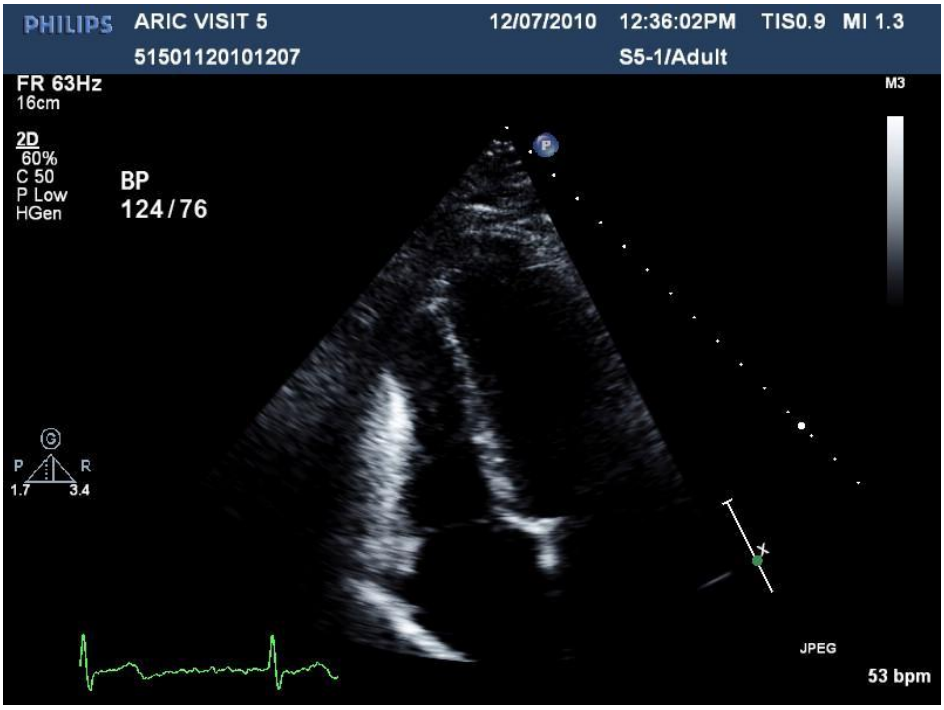


Tissue Doppler imaging at the septal mitral annulus

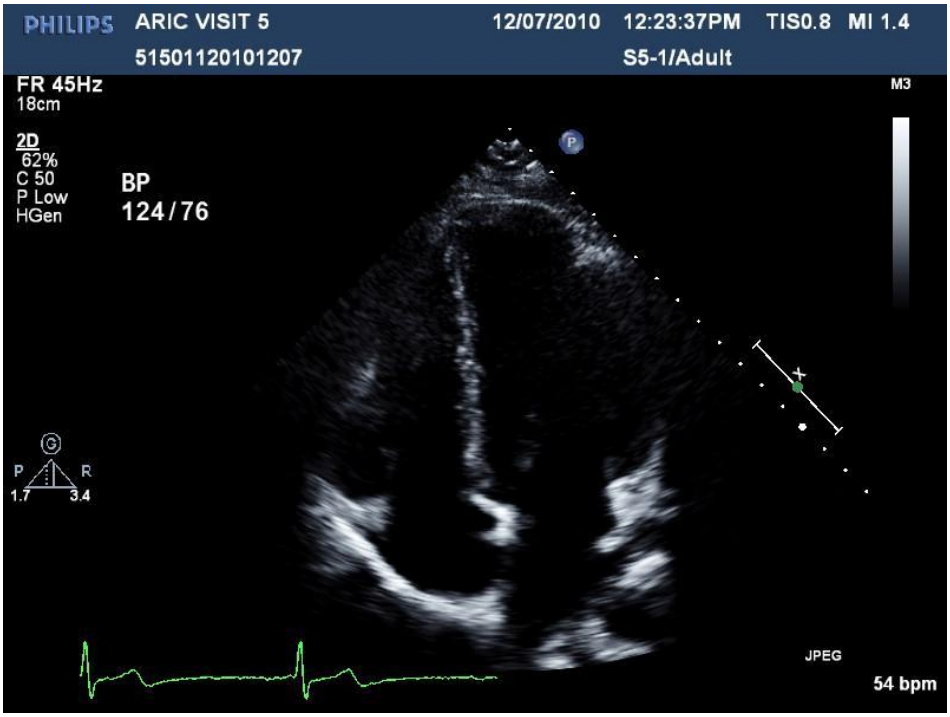
C.2. Apical 4-Chamber View (Focused on the Right Ventricle)

In the ideal echocardiographic "window" for the Apical 4-Chamber View focused on the right ventricle:

- The right ventricular length is maximized and the right ventricular apex is clearly visualized. The entire RV endocardium must be within the sector scan in both end-diastole and end-systole.



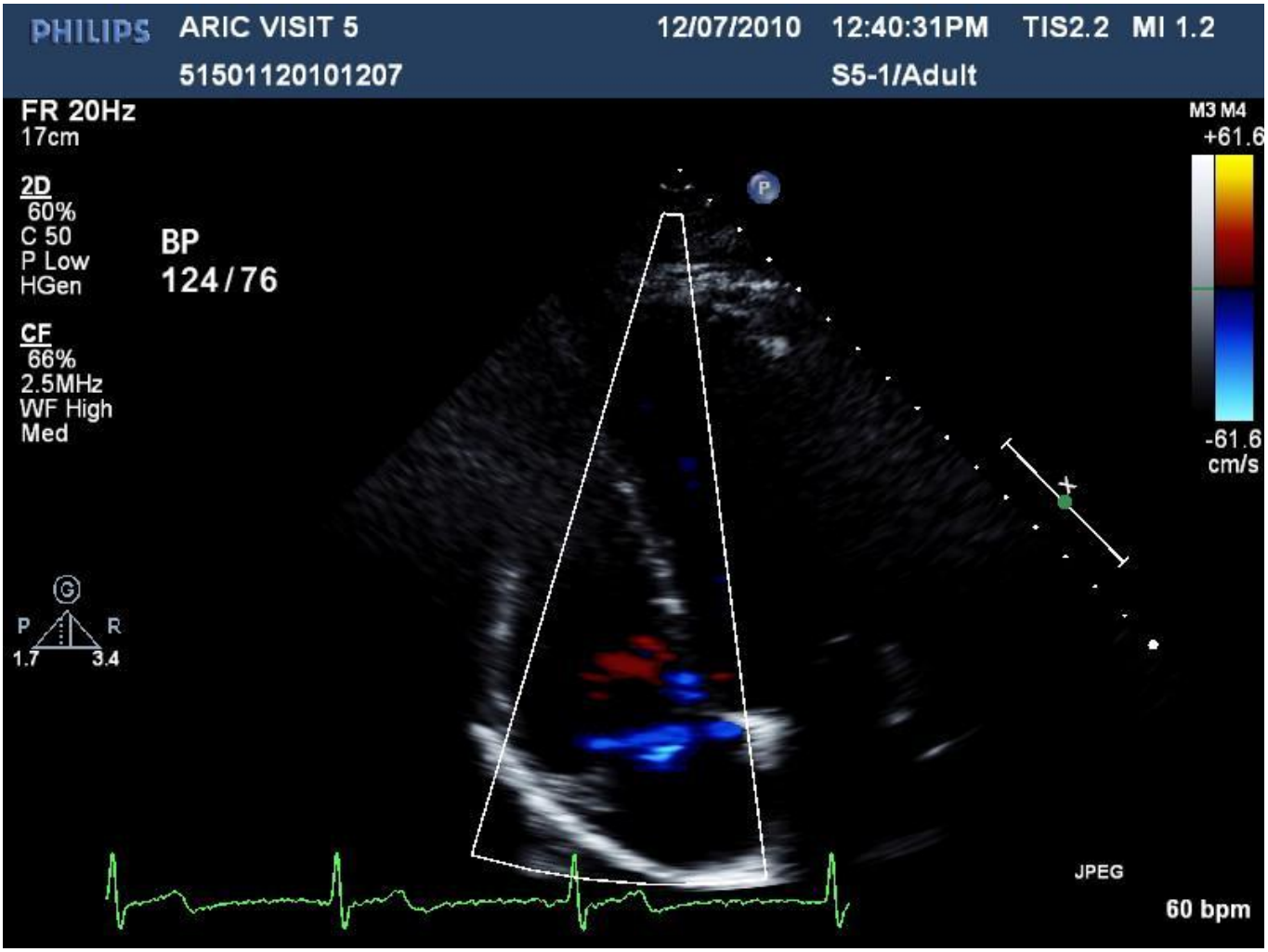
End-systole



End-diastole

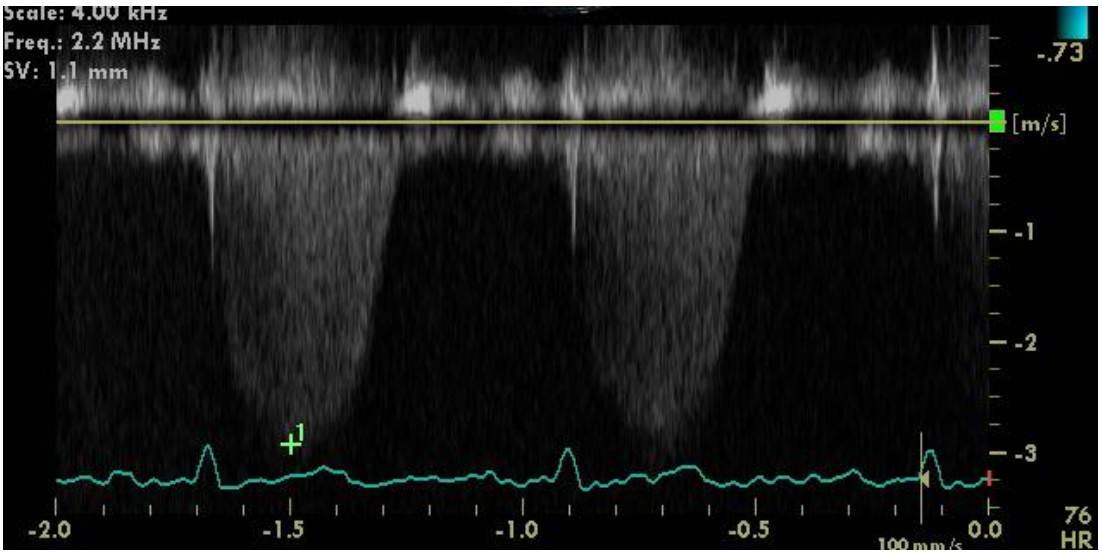
C.2.i. Color Doppler of tricuspid inflow

- Adjust color Doppler sample sector over the tricuspid valve and include the entire RA cavity. The color Nyquist limit is set at 64 cm/s in the ARIC protocol and should not be altered.



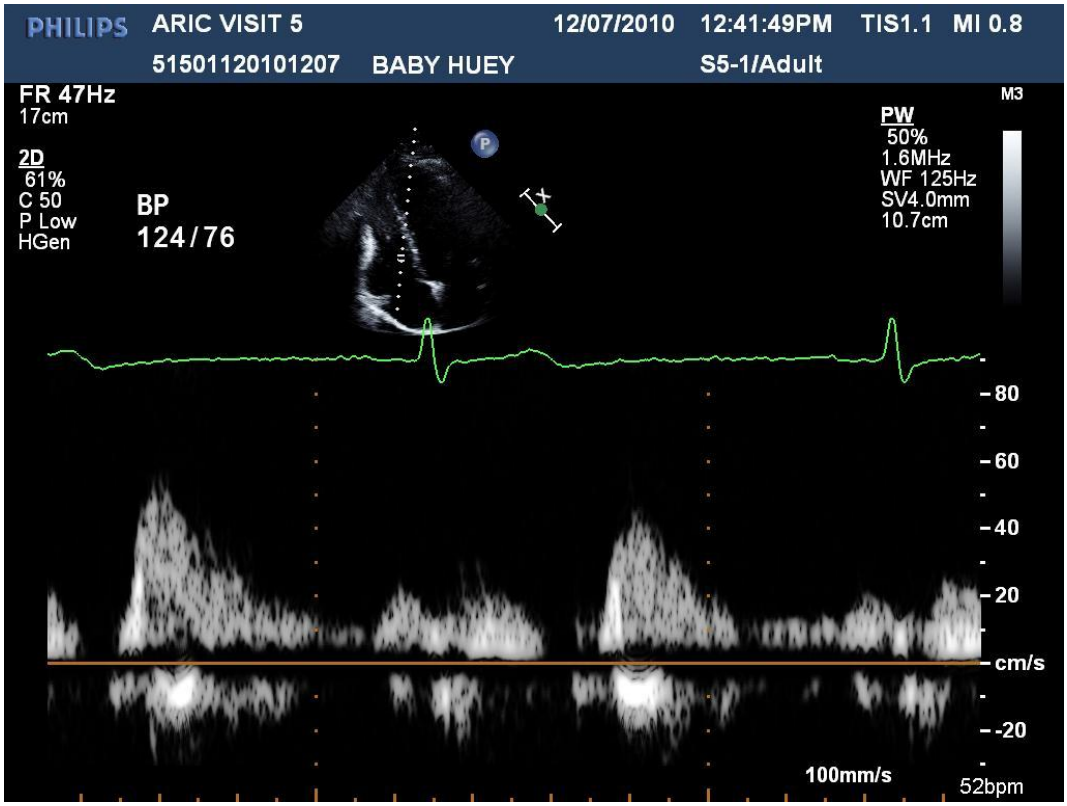
C.2.ii. CW Doppler of Tricuspid Regurgitation

- Position the interrogation line down the right ventricle and atrium as parallel to tricuspid regurgitant flow as possible. Adjust the baseline and scale to capture the peak TR velocity. Record at least 3 (10 for subjects in atrial fibrillation) full representative systoles at sweep speed of 100 mm/sec.



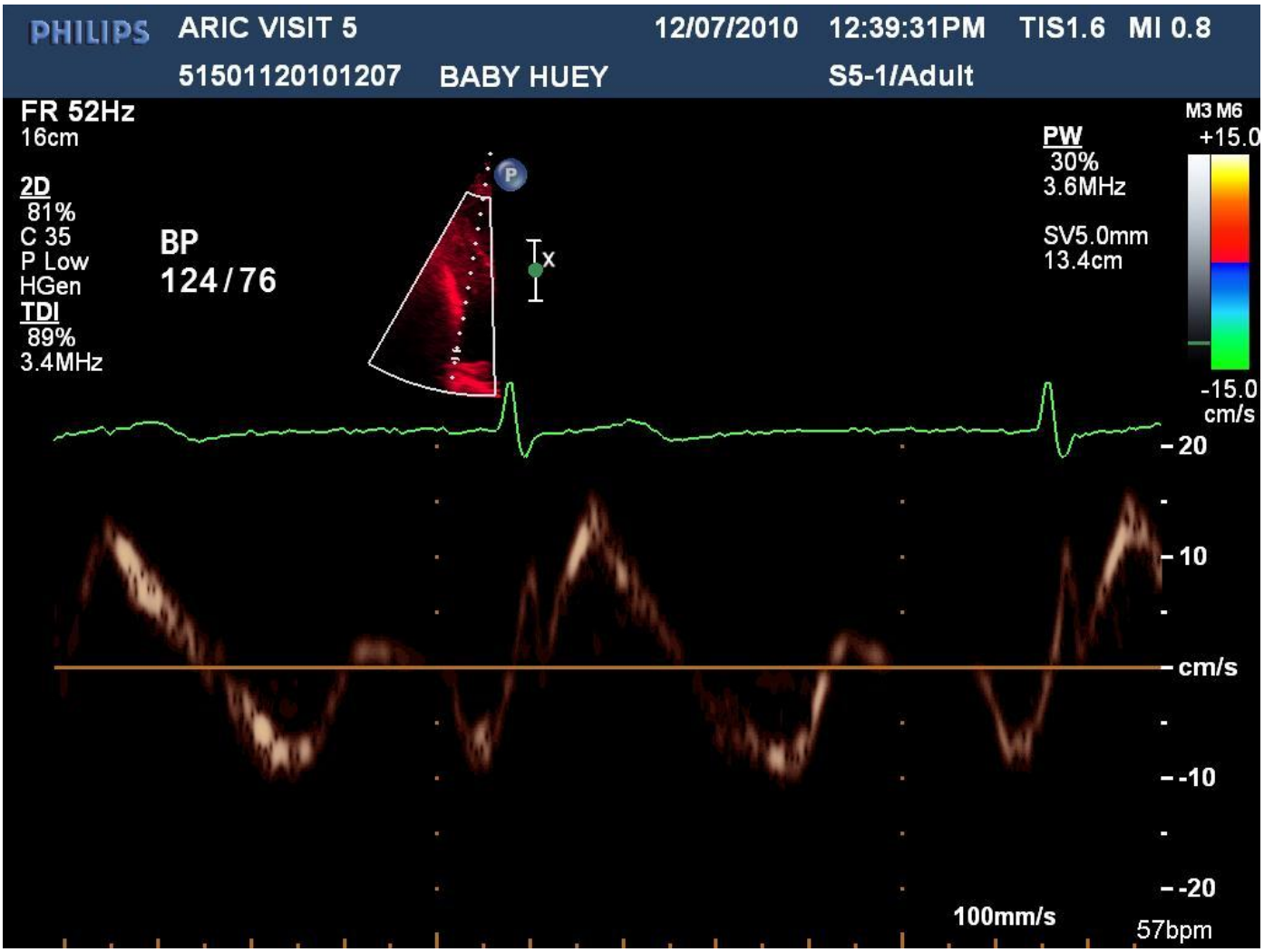
C.2.iii. Pulse Wave Doppler of tricuspid inflow

- Record the tricuspid inflow velocity curve with the pulsed-wave Doppler sample volume positioned at the tips of the tricuspid leaflets during quiet respiration for 30 seconds (or at least five cardiac cycles). Adjust the baseline and Doppler scale to visualize the peak E and A wave velocities. Record a minimum of 3 cardiac cycles (10 for subjects in atrial fibrillation) at a sweep speed of 100 mm/sec.



C.2. v. Tissue Doppler imaging at the lateral tricuspid annulus

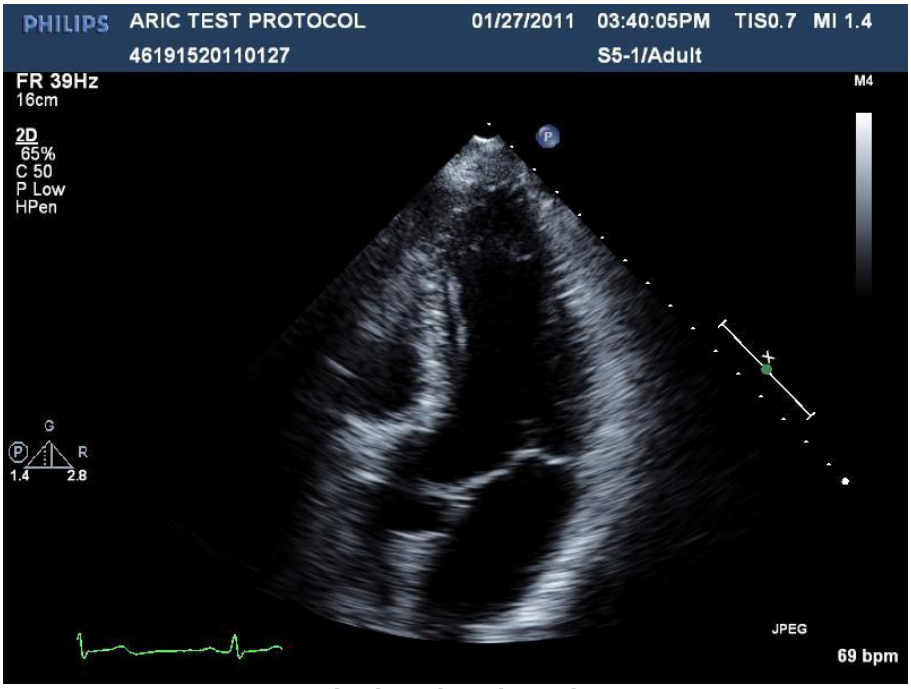
- Decrease image depth to include the RV and a small part of the RA (optimal depth approximately 16 cm) and optimize the 2D image for the RV, focusing on the tricuspid annular region.
- Adjust the image to orient the motion of the anterior tricuspid annulus parallel to the cursor. Both gains and filter settings should be set low to obtain the best images.
- Initiate 2D color DTI and position the sample volume on the ventricular side of the lateral tricuspid annulus at the junction of the RV wall with the tricuspid annulus: the myocardium should stay within the sample volume for as much of the cardiac cycle as possible.
- Switch to PW spectral DTI and set the scale to 20 cm/sec with a sweep speed of 100 mm/sec. Once a clear pattern is obtained, record at least 10-20 beats during quiet respiration (or preferably during breath holding at end-expiration).
- Record a minimum of 3 cardiac cycles (10 for subjects in atrial fibrillation) at a sweep speed of 100 mm/sec.



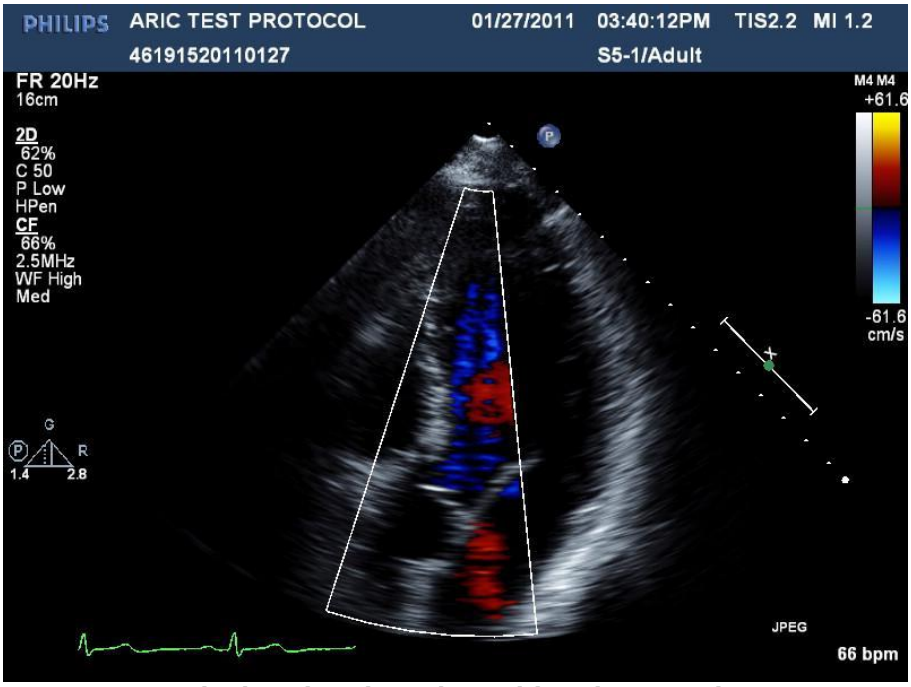
C.3. Apical 5-Chamber View

In the ideal echocardiographic "window" for the Apical 5-Chamber View:

- Maximize LV length, making sure not to truncate the true long axis.



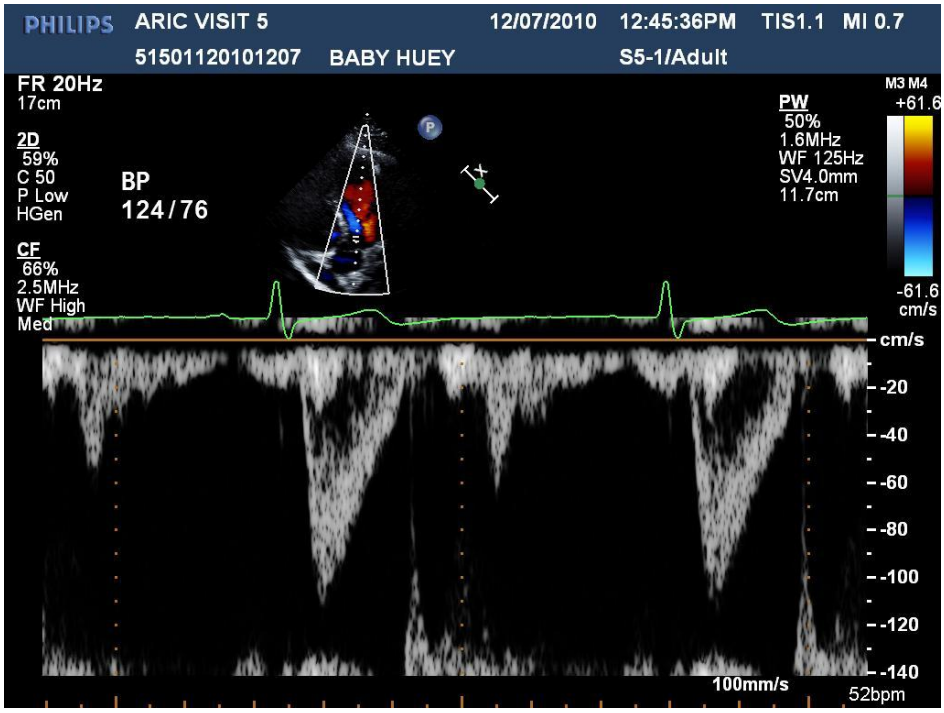
Apical 5 Chamber View



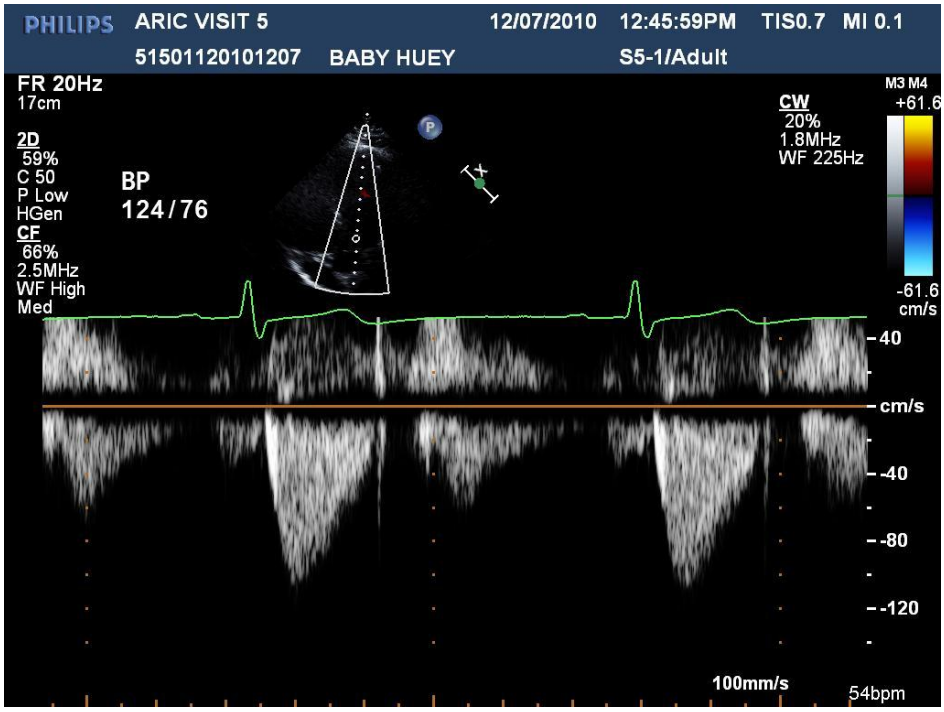
Apical 5 Chamber View with color Doppler

C.3.i. Pulsed wave Doppler at the left ventricular outflow tract

- For pulse wave acquisition, ensure that the sample is in the left ventricular outflow tract (LVOT) approaching the aortic valve, just prior to the level of flow acceleration and spectral broadening. Record a minimum of 3 cardiac cycles (10 for subjects in atrial fibrillation) at a sweep speed of 100 mm/sec.
-

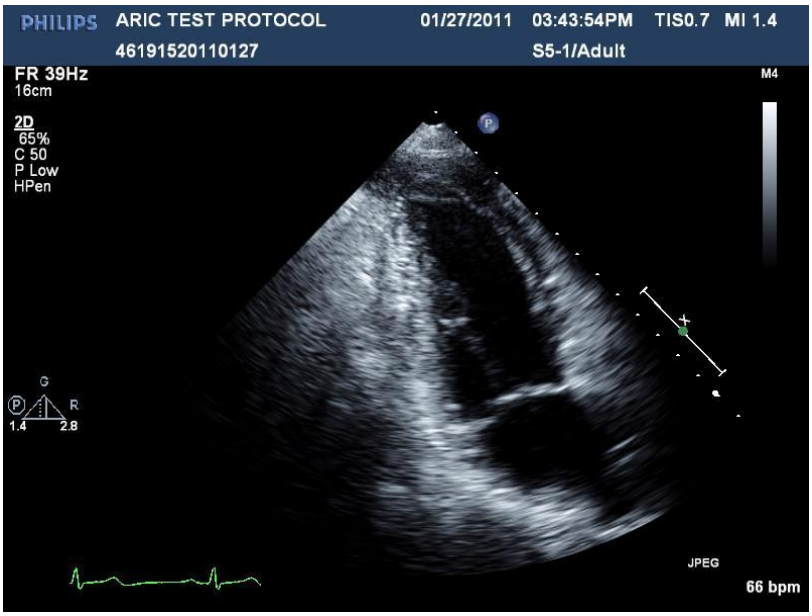


C.3.ii. Continuous wave Doppler across the aortic valve

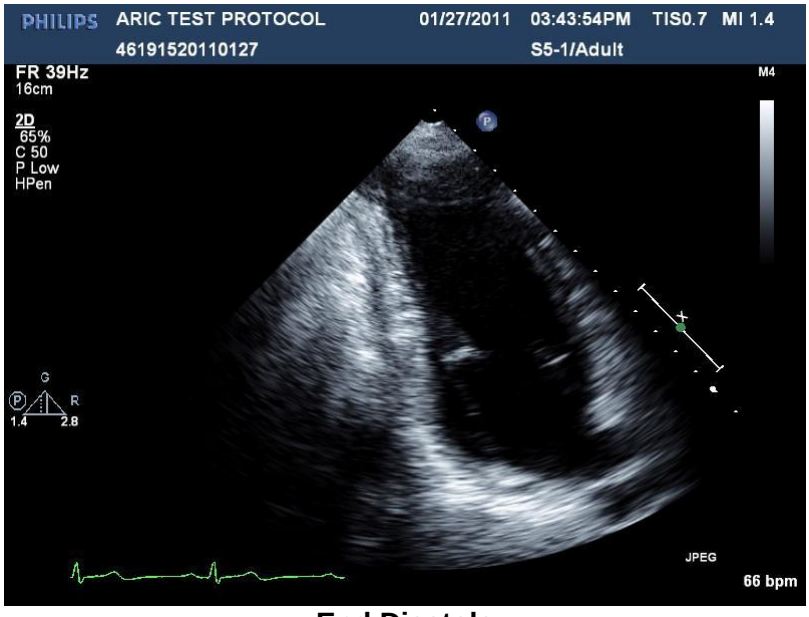


C.4. Apical 2-Chamber View

- Obtain 1 clip optimizing visualization of the left ventricle during systole and diastole.
  - Maximize LV length and be careful not truncate the true long axis.
  - The scan plane transects the anterior and inferior LV walls, with neither the RV nor the LV outflow tract visualized.
  - The most difficult areas in which to visualize the endocardium are usually the anterior LV wall and the apex; pay particular attention to these walls**.** Visualization of both anterior and inferior wall endocardium will be essential to accurately calculate left ventricular volume by Simpson's formula.
  - Adjust sector width and imaging depth to ensure acquisition frame rate of 50 to 70 frames per second.

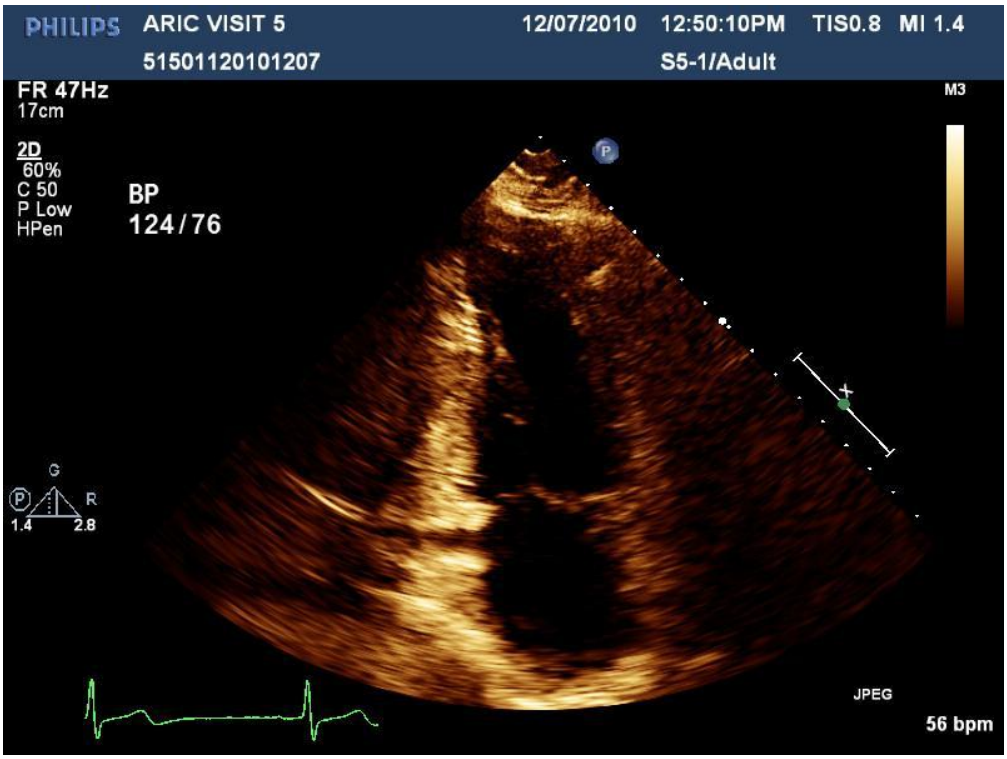


End Systole

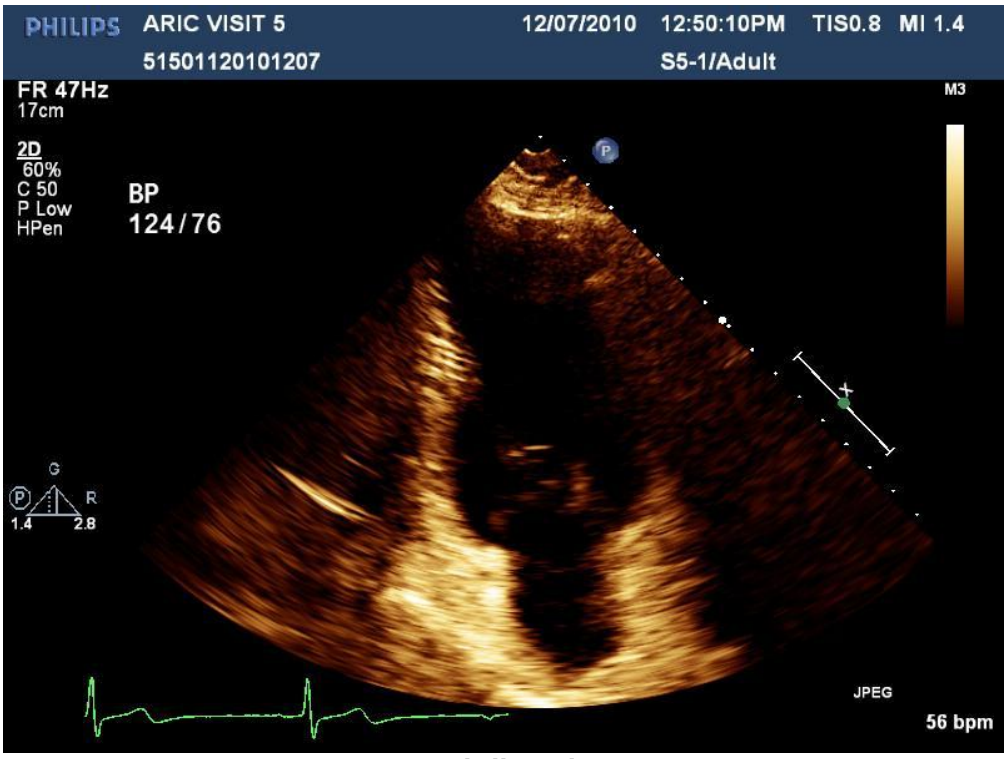


End Diastole

- Obtain a second clip optimizing visualization of the left atrium thoughout systole and diastole.
  - Special attention should be paid to properly aligning the image and capturing the left atrium in full. Avoid any foreshortening of the chamber.



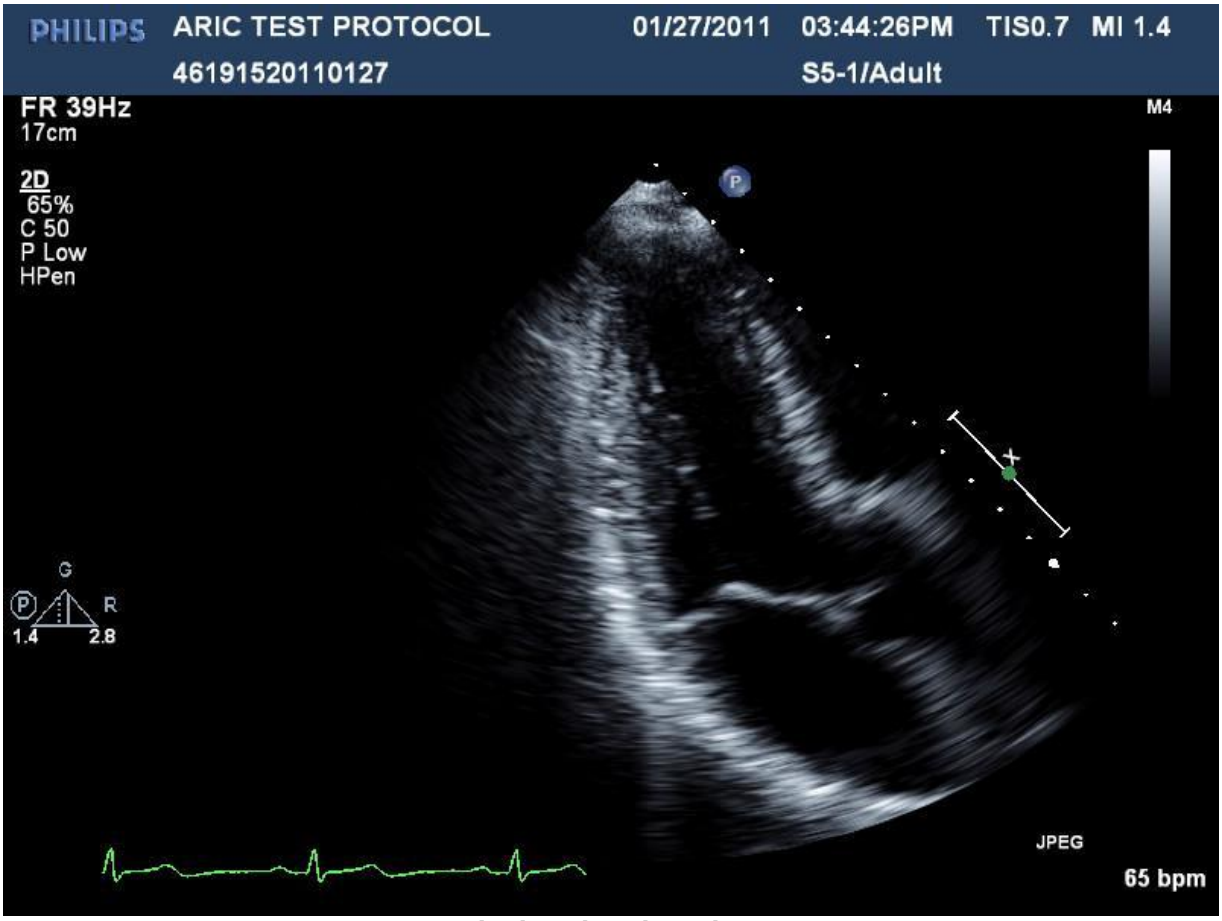
End-systole



End-diastole

C.5. Apical Three Chamber View:

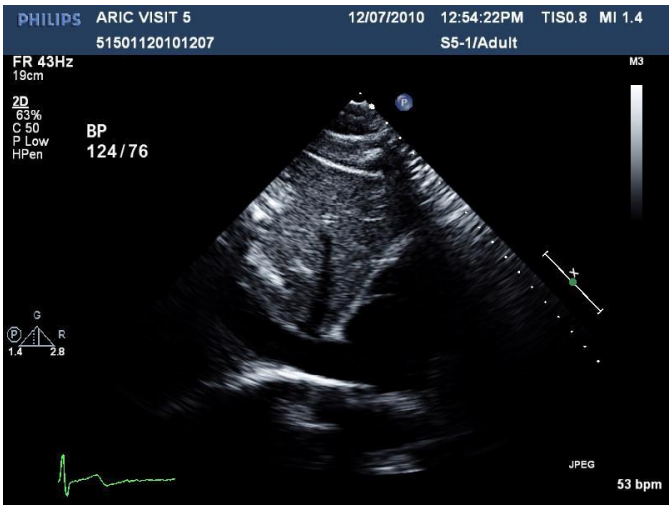
- Obtain a 2D image, including the entire LA and LV and mitral valve

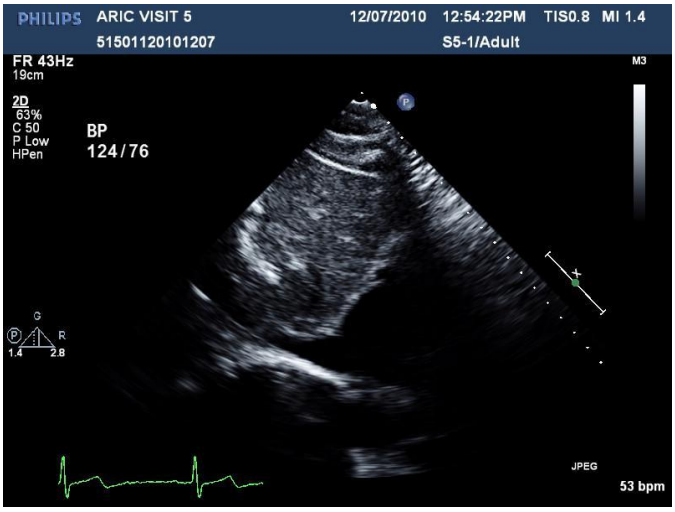


Apical 3 Chamber view

D. Sub-costal View

This view is obtained from the sub-xiphoid position with the transducer manipulated to visualize the proximal inferior vena cava where it meets the right atrium. Approximately 5-10 beats should be acquired in this view to allow for assessment of both IVC size and compressibility with respiration.



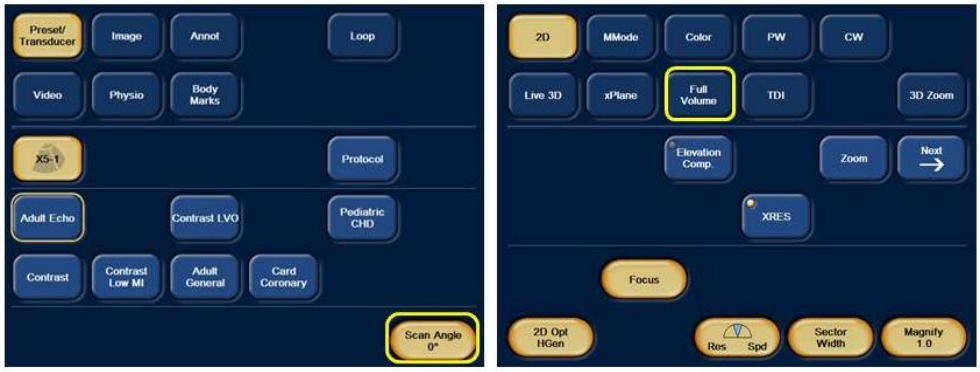


E. 3D Acquisition

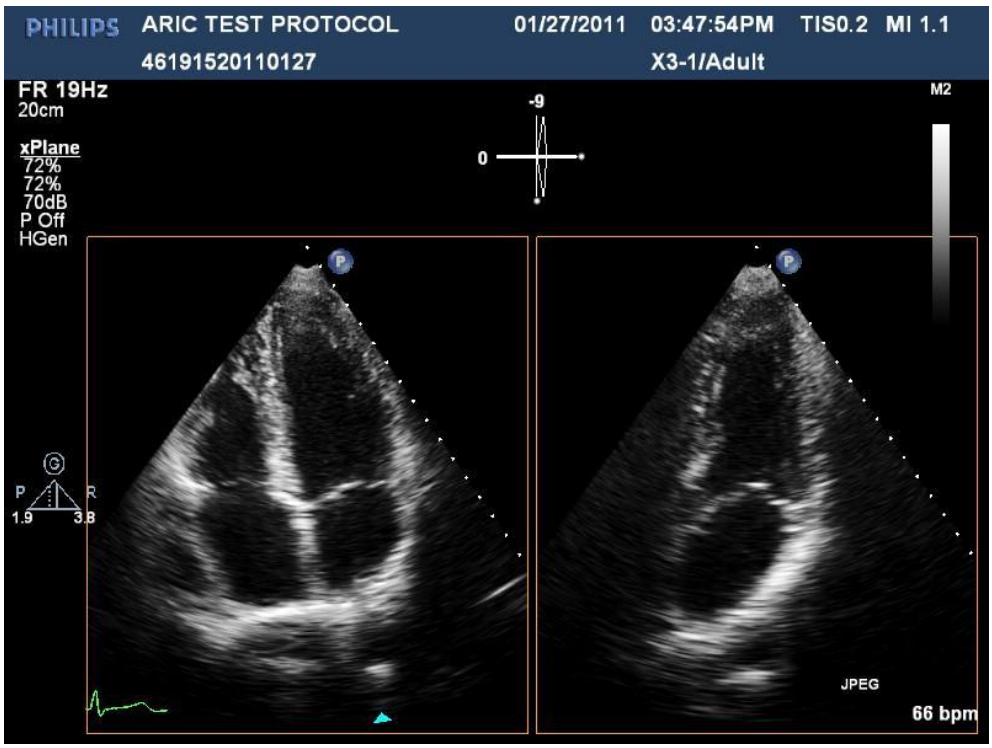
All 3D acquisitions are full volume acquisition. Note that the 3D controls are only available in the right touch panel when the Scan Angle control is set to 0°.

E.1. 3D full volume acquisition of the Left Ventricle

1. Optimize the apical 4 chamber view 2D image, including the entire LV and LA in the image.
2. Ask the subject to hold their breath in order to minimize motion of the chest. If the subject is unable to hold their breath, then ask him/her to take very shallow breaths. Be sure to hold the image steady for the same reason.
3. Activate "FULL VOLUME" on the right touch screen



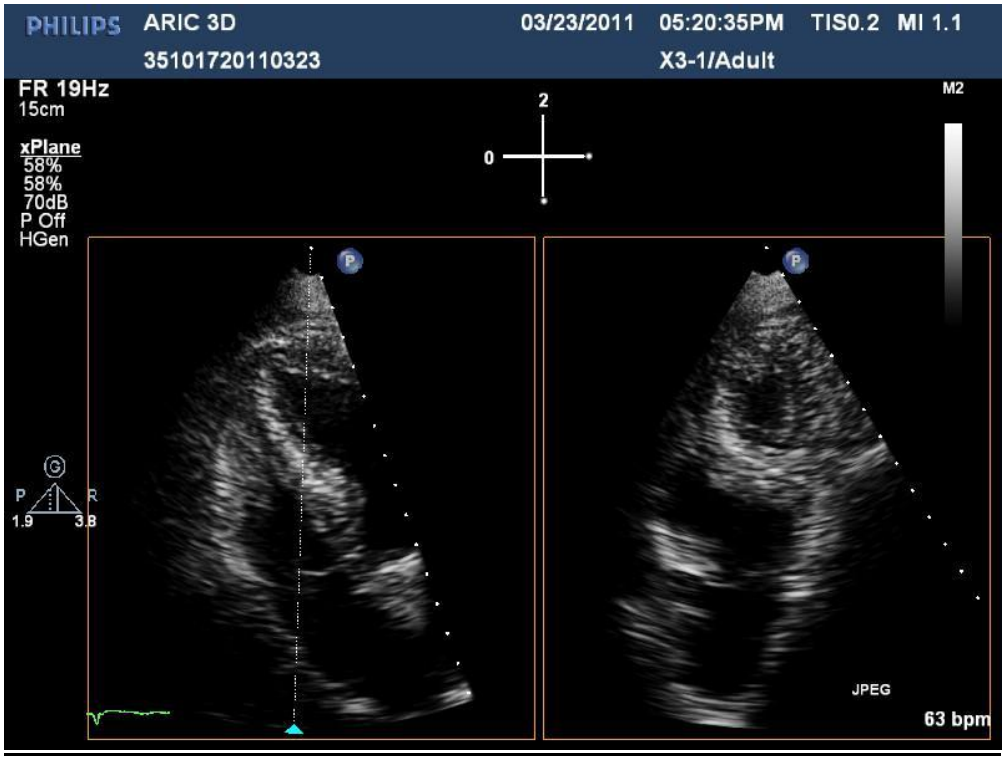
4. Select “4 BEAT FULL VOLUME” on the bottom of the right touch screen
5. Touch “IMAGE” on the left touch screen and select “REFERENCE IMAGES”
6. Ensure that the reference 2D images demonstrate centered, on axis A4C and A2C images



7. Wait for the reference 2D images to "settle" prior to acquiring the 3D volume, in order to avoid any stitch artifact
8. Press “ACQUIRE”

E.2. 3D full volume acquisition of the Right Ventricle

Follow the steps outlined above, focusing on the right ventricle. The ideal reference 2D image when acquiring the 3D full volume acquisition of the right ventricle is demonstrated below.



X. ARIC iE33 Acquisition Protocol

(1) In the PATIENT ID screen:

1. Enter ‘ARIC’ in the LAST NAME field
2. Enter ‘ECHO’ in the FIRST NAME field (for abdominal aortic studies, enter ‘AORTA’)
3. Enter the participant ARIC specific identification in the PATIENT ID field
4. Drop down the arrow in STUDY TYPE, select “ADULT ECHO”
5. Enter participant’s systolic blood pressure, diastolic blood pressure, height (in cm), weight (in kg) in the appropriate fields
6. ACQUIRE that screen

(2) Under Presents, select “ARIC” (if the participant is in atrial fibrillation or had a significantly irregular rhythm, select the “ARIC AF” preset)

(3) Attach ECG leads and cycle the PHYSIO/ECG LEAD selection until a clear ECG signal with an upright R wave is displayed.

(4) If the participant is in atrial fibrillation, under LOOP you must select “TIME” (will default to 5 seconds)

Once the ARIC preset is selected, the gains, depth, and color settings are going to default to the following settings:

2D
Gain 50
Compress 48
H pen
Xres ON
Elevation compounding ON
Chroma 1
Gray scale 4
Persistence low
Re-speed in the midline

COLOR
Gain 65
Map 4
Smoothing 3
Persistence OFF

PW/CW
Compress 4
Reject 4
Speed 100

MMODE

Map 1
Speed 75

Other settings
Acquisition _ Prospective
accept prior to store ON
DICOM DSGF selected for format
transfer acquisition rate
DO NOT select Native data even on MEDIA
only 3D activated

(5) The ARIC protocol will prompt and advance the sonographer through the following protocol views:

1. PLAX deep 2D 18 cm
2. PLAX shallow 2D 13-14 cm
3. PLAX COLOR MV/AV
4. SAX AV 2D
5. SAX AV COLOR
6. SAX RVOT 2D
7. SAX PV COLOR
8. SAX PV PW 1(FRAME)
9. SAX PV PW 2(FRAME)
10. SAX PV CW 1(FRAME)
11. SAX PV CW 2(FRAME)
12. SAX MV 2D
13. SAX PAP 2D
14. SAX PAP MMODE 1(FRAME)
15. SAX PAP MMODE 2(FRAME)
16. SAX APEX 2D
17. AP4 2D 17-18 cm
18. AP 4 FOCUS LV (no zoom)
19. AP 4 FOCUS LA (no zoom)
20. AP 4 COLOR MV/LA
21. AP 4 MV PW 1(FRAME)
22. AP 4 MV PW2 (FRAME)
23. AP 4 TDI SEPTAL PW 1(FRAME)
24. AP 4 TDI SEPTAL PW 2(FRAME)
25. AP 4 TDI LATERAL PW 1(FRAME)
26. AP 4 TDI LATERAL PW2 (FRAME)
27. AP4 RV/RA NARROW SECTOR 2D
28. RV/RA COLOR TV/RA
29. TV CW 1 (FRAME)
30. TV CW 2 (FRAME)
31. TV ANNULUS TDI PW 1 (FRAME)
32. TV ANNULUS TDI PW 2 (FRAME)

33. AP 5 2D
34. AP 5 COLOR LVOT
35. LVOT PW 1 (FRAME)
36. LVOT PW 2 (FRAME)
37. AV CW 1 (FRAME)
38. AV CW 2 (FRAME)
39. AP 2 IROTE (scan angle knob, turn counterclock)
40. AP 3 IROTATE (continue counterclock rotation from previous)
41. AP 2 CONVENTIONAL 2D FOCUS LV
42. AP 2 CONVENTIONAL 2D FOCUS LA
43. AP 2 COLOR
44. AP 3 CONVENTIONAL 2D
45. SUB X WITH IVC OPEN 2D 5 sec

For 3D acquisition (can be performed either with apical views or at end of conventional exam at the sonographer's discretion):

PAUSE PROTOCOL (LEFT TOUCH SCREEN)
MUST change LOOP length to "1 BEAT"

1. FULL VOLUME LV/LA 4 BEATS (bottom right touch screen)
   3D instructions: obtain the optimal 2D, touch Full Volume (right touch panel)
   On the bottom of the right touch panel turn the knob to 4 beats. Under LOOP select "BEATS" and "1".
   On the Left touch panel under IMAGE select the reference images ("helpers"), wait for the "helpers" to settle, then ACQUIRE image, then ENTER to save.
2. FULL VOLUME RV/RA 4 BEATS (bottom right touch screen)
   Same as for LV/LA, but bring the RV/RA to the middle of the sector, optimize.

UNPAUSE PROTOCOL

(6) END the protocol

(7) ACCEPT the protocol

(8) END the exam to transfer studies to TOMTEC ImageArena

For ARIC AFIB preset/protocol:
All the views are the same, the difference is:

1. At the beginning of the exam, MUST change LOOP setting manually from "BEATS" to "TIME" (automatically defaults to 5sec)

2. Every PW and CW is 3 screens as opposed to 2 screens for sinus rhythm patients (to accommodate sufficient spectral envelopes at the set sweep speed)

   MMODE is still 2 screens on the speed of 75

XI. Reporting of Critical Results

Sonographers performing echocardiographic studies will occasionally identify abnormalities that they consider important and will alert site investigators directly. These findings will include, but are not limited to, tamponade, aortic dissection, thrombosed or frankly dysfunctional prosthetic valve, pseudoaneurysm, intracardiac abscess or obvious vegetation, and intracardiac thrombus. The Echocardiography Reading Center will also be informed via a free text field in the electronic Echocardiography Transmittal Form (ETF) to facilitate an expedited analysis of the study. Site investigators will be responsible for handling alert findings (either as alerts requiring emergency/immediate referral, urgent referral, or routine referral as they deem appropriate), including relaying findings to study participant and, where consent has been provided, to the participant's treating provider.

Overreading cardiologists at the Echocardiography Reading Center may identify critical abnormalities that would require emergent notification and arrangements for care. Such findings will be reported within 24 hours of review by the Reading Center to the Data Coordinating Center and will be communicated to the field centers as an Immediate Alert Notification. Abnormalities that would trigger a critical result include, but are not limited to a) tamponade, b) aortic dissection, c) thrombosed or frankly dysfunctional prosthetic valve, d) pseudoaneurysm, e) intracardiac abscess or obvious vegetation, f) intracardiac thrombus. Each field center should have a plan for handling these types of alerts, including relaying findings to study participant and, where consent has been provided, to the participant's treating provider.

Overreading cardiologists at the Echocardiography Reading Center may identify specific non-critical abnormalities that would be important for a patient and physician to be aware of, but that don't necessarily require emergent care. These findings will be incorporated into the routine data transfers from the Echocardiography Reading Center directly to the Data Coordinating Center. Such findings include: a) moderate or greater mitral regurgitation, b) moderate or greater mitral stenosis, c) moderate or greater obstructive lesions of left ventricular outflow, including aortic stenosis and dynamic left ventricular outflow tract obstruction, d) moderate or greater aortic regurgitation, e) moderate to severe pulmonary hypertension, f) severe right ventricular enlargement.

Limited quantitative data will be included in the routine reporting letter generated by the data coordinating center for all participants. This will include three commonly used measures of cardiac structure and function: a) left ventricular ejection fraction, b) left ventricular diastolic diameter, c) left ventricular wall thickness. These data will be presented in a table with reference values (see example below). Values that exceed the reference thresholds would represent routine referrals as defined in section X. (Study Results Reporting Schedule) of this document. Reference values are based on practice guidelines published by the American Society of Echocardiography.[1]

[1] Lang RM, Bierig M, Devereux RB, Flachskampf FA, Foster E, Pellikka PA, Picard MH, Roman MJ, Seward J, Shanewise JS, Solomon SD, Spencer KT, Sutton MS, Stewart WJ. Recommendations for chamber quantification: a report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. J Am Soc Echocardiogr. 2005;18(12):1440-63.

XII. Contact Information

For technical echo-related questions, please direct all questions and inquiries to the Brigham and Women's Hospital Cardiac Imaging Core Lab:

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