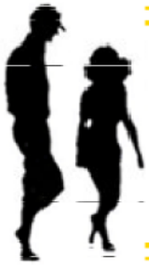


CARDIA

Coronary Artery Risk Development in Young Adults

Carotid Ultrasound

Sonographer Manual Version 1.1

Ultrasound Reading Center

New England Medical Center

Table of Contents

1. Overview of the Carotid Artery Ultrasound Scanning Protocol

1.0 Summary

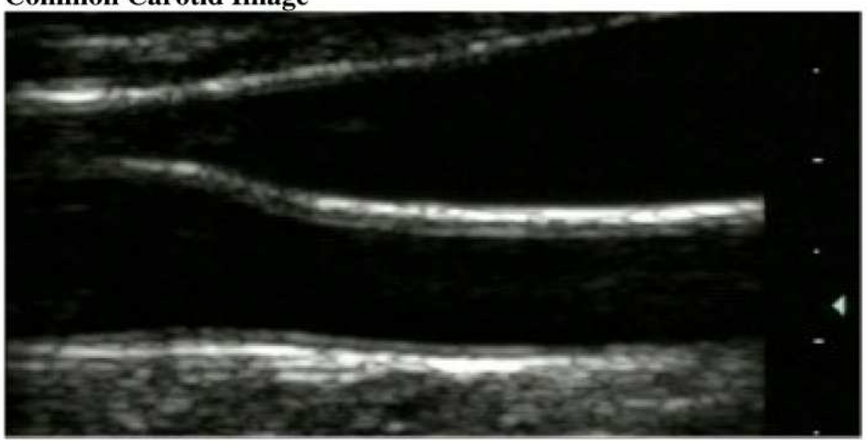
Magnified, single, gray scale images of the carotid artery at three levels on the right and left sides of each participant will be obtained. The segments to be imaged are the distal common carotid artery, the carotid bulb, and the proximal internal carotid artery. Images will be acquired with the participant's head rotated 45 degrees away from the side of study. A single image will be captured at the common carotid level of the artery and two images each from a different angle will be captured of both the carotid bulb and the internal carotid artery. A video stream of the right common carotid artery will be recorded. In addition, the common carotid, the carotid bulb and internal carotid segments will be captured as a single or static image and will be accompanied by a 3 to 5 second real-time cine loop demonstrating at least two complete cardiac cycles. All static images will be captured at end-diastole. Captured images will show optimal visualization the intima-media complex of the far and near wall of each segment studied over a 1-cm length of the artery. Quantitative analysis will be performed on the far and near wall interfaces for each segment. Qualitative analysis including image quality will be performed on all static images.

1.1 Background

Wall boundaries can be demonstrated with high-resolution ultrasound imaging. They appear as two parallel echogenic lines separated by a hypoechoic space in longitudinal views of the carotid arteries. The artery walls are usually best observed in the common carotid artery where the vessel course is parallel to the skin surface and is located at a right angle to the ultrasound beam.

The first echo along the far wall is derived from the lumen-intima interface and the second, normally brighter, echo along the far wall originates from the media-adventitia interface. Between these interfaces lies the media, which appears as an echolucent zone. The distance between the first two lines corresponds to the combined thickness of the intima and media. Because of its collagen content the adventitia is quite echogenic and appears as a bright zone highlighted along its inner margin by the media. However the periadventia, depending on location, is composed of loose areolar tissue and in most instances is echolucent.

Common Carotid Image



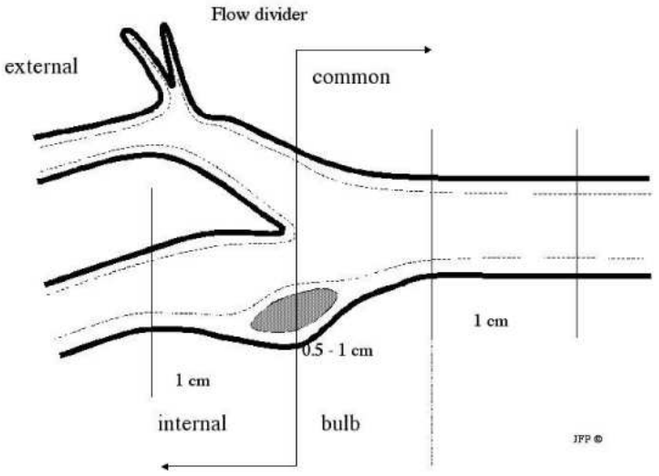
Internal Carotid Image

It is more difficult to image the interfaces when the near and far walls of the vessels are curvilinear and not at right angles to the ultrasound beam. In the carotid bulb, where the walls flare, only short wall segments may be seen on any single frame. This same phenomenon is observed in the proximal portion of the internal carotid artery when the walls are not parallel and hence sub-optimally visualized. Other causes for loss of wall interfaces that are not related to scanning technique are the presence of plaques and the presence of fat in the arterial wall. The interfaces can also be seen along the near wall but the lines may be disrupted and the echoes weaker because the ultrasound beam is passing from tissue to fluid. At times, it is impossible to maximize both the near wall and far wall interfaces on the same image. On such occasions the priorities are to first optimize the far wall, and second the near wall. Plaque refers to a focal protrusion into the lumen from the wall of 50% or greater than the thickness of the adjacent wall. Images are magnified to clarify the display of the arterial interfaces.

1.2 Introduction to the Carotid Ultrasound Scanning Protocol

The extracranial carotid arteries are the largest arteries in the neck. The right common carotid artery originates from the innominate artery on the right and the left common carotid artery originates directly from the aortic arch. Each common carotid artery ascends in the neck lateral to and posterior to the trachea. At the approximate level of thyroid cartilage, slightly below the angle of the mandible, the common carotid artery bifurcates into the external and internal carotid arteries.

The common carotid artery (CCA) dilates to form the carotid bulb proximal to the bifurcation into the internal and external carotid arteries. The origin of the bulb can be recognized in most, though not all, subjects. The carotid artery bulb is defined as the site where the artery begins to dilate slightly and the vessel walls curve out, i.e.: they are no longer parallel to each other. The bulb is elliptically shaped and geometrically complex in the longitudinal view. The tip of the flow divider defines the bulb's upper limit. The tip of the flow divider also marks the origin of the internal and external carotid arteries. It is usually situated at the midpoint or upper two-thirds of the carotid bulb.



The external carotid artery lies anterior and slightly medially to the internal carotid artery in 90% of individuals. In the remaining 10%, the orientation is reversed. The external carotid artery is usually smaller than the internal and it has branches that supply the neck and face. The internal carotid artery has no branches in the neck and ascends into the calvarium to supply the brain.

The carotid ultrasound protocol requires the capture of static grayscale images and real-time sequences or cine loops from the common carotid, bulb, and internal carotid arteries according to a standard protocol on the right and left side. The real-time sequences are intended to help the image analyst in his/her task. Occasional artifacts can be more readily recognized with the aid of the dynamic sequences.

1.3 Scan Identification – Media Labels and Log Sheets

The Ultrasound Reading Center will provide videotape labels and log sheets to the field centers. Study specific numbered labels for the videotapes enable the long-term organization of CARDIA data. A log sheet is completed for each videotape. Before beginning the first scan on a tape, matching pairs of labels are applied to the videotape and log sheet. Labels are put on the spine and the face of the videotape and the matching label is put in the specified area of the log sheet. The log sheet is Attachment 1 of this document.

When completing the log sheet, take the time to write legibly and double check the participant's Subject ID's. ID errors can be difficult and time consuming to trace. The CARDIA Subject ID is a twelve digit number. The first two digits indicate the field center.

1.4 Procedure Form: CARDIA Form 77 Carotid Ultrasound

A procedure form, *Form 77 Carotid Ultrasound*, will be completed for every participant by the sonographer. The data from *Form 77 Carotid Ultrasound* forms are entered into the CARDIA

database. The form and a detailed description of how to complete it are Attachments 2 and 3 of this document.

1.5 Machine Set-up, Probe Frequency and Magnification

Pre-sets have been defined for the GE Logiq 700 device. The settings will be set at the start of the study and should not be altered. Each machine will have only one probe. The probe that will be used for CARDIA is an M12L. The probe frequency is set to 13 MHz for scanning the common carotid artery and reduced to 9 MHz when scanning the bulb and the internal carotid artery.

GE Logiq 700 Carotid Ultrasound Pre-sets

Frequency: 13 MHz
66 Dyn Range
Res
Edge 3
Map G
Ave. 2
Number focal zones: 2 *(position of focal zones: mid artery)*

Longitudinal images of the common carotid, carotid bulb and the internal carotid artery are magnified.

To turn the magnification “ON”

- Press the "ZOOM" key
- Use the trackball to center the region of interest
- Press the "SET" key

To turn the magnification “OFF”

- Press the “Exit” key

1.6 Subject Demographics

Participant information is entered on the ultrasound machine’s demographic information screen to identify the scan as a CARDIA scan. The information on this page identifies the scan data with the proper participant. Videotape the demographic information page for five seconds. Demographics should follow standard laboratory protocol for patients.

To enter subject information to GE Logiq 700 demographic information screen

The participant ID number is entered

Press "New patient"
Hit "return" until you reach the new patient question (Y/N); type "Y" and then return
Keep hitting return until the Last Name field is active: Type “CARDIA”
In the First Name field: type “Carotid IMT Baseline”
In the Middle Name field type: enter the participant’s Alphacode
Keep hitting return until the ID# field: enter the participant ID number

Hit return for gender (M or F)
Hit return and enter your Sonographer ID
Videotape screen for 5 seconds
Hit the "Exit" key to exit to begin scanning

1.7 Participant Position

The carotid ultrasound procedures are performed with the subject in the supine position. The subject is made comfortable in a position that allows head rotation to either side. The sonographer stands or is seated at the end of the exam table near the participant's head. The top of the head is about three inches from the end of the exam table and the head is rotated 45 degrees away from the side being scanned.

1.8 Anatomical Sites of Interest

The extracranial carotid arteries are divided into four anatomically defined segments: the distal common carotid artery, carotid bulb, the internal carotid artery, and the external carotid artery. The lateral extent of each segment is defined relative to the tip of the flow divider, which is typically the most clearly defined anatomical reference in the carotid system. The three segments of interest are the distal common carotid artery, the carotid bulb, and the internal carotid artery. No external carotid images will be recorded.

Anatomical Definitions

1. Distal common carotid: the 1 cm segment of the common carotid artery proximal to the origin of the carotid bulb, where the near and far walls of the artery are parallel to one another. The end of the distal common carotid artery is marked by the dilatation of the vessel walls, which is the carotid bulb.

2. Carotid bulb: for study purposes this arterial segment is defined as the inferior extent of the bulb between the common carotid dilatation and the tip of the flow divider. Anatomically, the dilatation associated with the bulb usually extends above the tip of the flow divider extending into the proximal internal carotid artery. It ends when the walls of the artery lose their curvature and become parallel.

3. Internal carotid artery: anatomically, the caudal, or inferior, extent is defined by the tip of the flow divider. The vessel then ascends in the neck and enters the base of the skull. For the purposes of this protocol, the ultrasound study will be limited to the initial 10 mm of the internal carotid artery distal to the flow divider.

4. External carotid artery: originates at the carotid bulb is more superficial and nearer the mid-line than the internal carotid. No images of the external are recorded.

5. Internal jugular vein: the internal jugular vein lies superficial and somewhat lateral to the common carotid artery. If in the plane of imaging, it serves as an acoustic imaging window.

1.9 Imaging Sequence

Scanning Procedure

To obtain the images described below, a real-time imaging sequence or a cine loop of each arterial segment will be captured. Magnification is turned "ON" with the "Zoom" button when capturing images of the common carotid, bulb and internal carotid artery. Magnification is "OFF" during the transverse sweep and pulse-wave Doppler measurement. The probe frequency is set to 13 MHz when capturing common carotid images and to 9 MHz when capturing buld or internal carotid images. Cine loops are captured by selecting the cine-loop button and are "frozen" using the freeze button. The sonographer then cycles through the cine loop images to select the one image that best displays the intimal walls. It is important that this image is always obtained in the latter part of the cardiac cycle as close to end diastole as possible. End diastole is the portion of the cardiac cycle when the carotid lumen is smallest and the vessel shows the least movement. Arterial walls are typically more clearly displayed on this image. The static images are videotaped for five seconds. The cine loop is then set in motion and it is videotaped in its entirety.

Initial Scan
The purpose of the initial scan is to orient the sonographer to the subject's carotid anatomy. The sonographer should locate the bifurcation and distinguish which vessel is the internal and which is the external carotid artery. The site of maximal wall thickening in the near or far wall, in the bulb or internal carotid artery should also be identified. Color and pulse-wave Doppler can be used as identification aids. The initial scan is not recorded.

Part One – CCA Video (Right Common Carotid Artery Only)

Video of Right Common Carotid Artery

Real-time gray scale imaging of the right common carotid artery is done in the lateral projection with the jugular vein lying immediately above the common carotid (or at 45 degrees if the internal jugular vein is not present). The probe frequency is set to 13 MHz. The image is centered on a 10 mm segment of the right common carotid artery at least 10-mm below (caudad to) the right common carotid artery bulb. The carotid bulb may be displayed on the left side of the monitor (when facing the screen). If the bulb cannot be identified, but the tip of the flow divider can, this may substitute as the internal landmark on this view. After locating the tip of the flow divider on the transverse image, the transducer is slowly moved down the neck approximately 2 to 3 cm. Rotate the transducer into the lateral plane keeping the jugular vein in the same imaging plane. The probe is then centered on the upper 2 cm of the common carotid. The sonographer magnifies the longitudinal image (jugular vein above common carotid artery) and videotapes for a minimum of 20 seconds so that the video sequence captures at least 20 cardiac cycles. The far and near wall interfaces of the common carotid artery walls in are clearly depicted during this recording.

Part 2 – Carotid IMT

1. Transverse (Short-Axis) Sweep

The purpose of this imaging sequence is to orient the sonographer and the image analyst to the subject's carotid anatomy. The sonographer should turn "OFF" the magnification and locate the bifurcation and distinguish the internal and external carotid artery. A transverse sweep begins at the base of the neck in the low common carotid and smoothly travels up through the bulb, into the internal and external bifurcation, and the probe is then brought back down to the proximal common carotid. The full sweep is captured, up from the common, into the internal and back, for 3 to 5 seconds. The transverse scan is done with the field of view set at a depth of 4 cm. This can be modified in cases of variant anatomy and deeper lying arteries

2. Pulse-wave Doppler

The critical pulse-wave Doppler information is the peak velocity in the internal carotid artery. The peak velocity is measured at peak systole at the point of maximum flow acceleration. Probe frequency is set to 9 MHz. To locate the peak velocity a 2-mm Doppler sample gate is placed in the center of the distal common carotid artery. The sample gate is then moved from the common through the bulb to the proximal internal. If there is no site of disturbed or turbulent flow, the Doppler measurement should be taken from the first centimeter of the internal carotid artery. The audible signal can be used to facilitate placement of the Doppler sample gate. Angle correction must not exceed 60 degrees. The frozen image of the measurement is videotaped for approximately five seconds. The pulse-wave Doppler measurement is done with the ultrasound machine in standard zoom mode at a depth of 4 cm. Record the PW Doppler measurement on the procedure form.

3. Common Carotid Artery

The common carotid artery image captures the distal 10 mm of the common carotid artery immediately proximal to the carotid bulb. Probe frequency is set to 13 MHz. Magnification is turned "ON." The carotid bulb is displayed on the left side of the monitor (when facing the screen). The probe should be manipulated to obtain the best view of the common carotid arterial wall and hence depict the lumen-intima and media-adventia interfaces over a 1-cm length of the vessel wall. From this image, the IMT of the common carotid (CCA IMT) is obtained. For reproducibility purposes, both the double-line patterns of the near and the far wall interfaces need to be optimally displayed. The primary imaging target and hence the transmit zone (acoustical focus) is always the far wall intima-media complex. However, simultaneous display of the near and far wall interfaces of the artery ensures that the probe is placed exactly over the center of the vessel along its horizontal plane. Display of both near and far walls is always preferable. In instances when both cannot be imaged simultaneously, maximizing display of the far wall intima-media interfaces is the first priority. Simultaneous display of near and far wall interfaces is necessary for performing diameter measurements. The image should be captured as close to a 45 degrees as possible while maintaining optimal display of wall interfaces.

4. Carotid Bulb

The carotid bulb image captures the carotid artery from the beginning of the dilation to a point just above the flow divider. Magnification is “ON.” Probe frequency is set to 9 MHz. The bulb is often the most difficult segment to image over a length of 1 cm. The probe should be adjusted so as to show a segment displaying both far and near wall intima-media interfaces. When it is not possible to do so, the target becomes optimal display of the far wall interfaces. Two images of the carotid bulb are captured. The first image is taken with the probe held at a 45 degree angle and the second with the probe rotated towards the top of the head to an angle as nearly vertical as possible while displaying far and near wall interfaces.

5. Internal Carotid Artery

The internal carotid artery image will be centered on the initial 10 mm distal to the flow divider. Magnification is “ON.” Probe frequency is set to 9 MHz. Two images of the internal carotid artery are captured. The first image is taken with the probe held at a 45 degree angle and the second with the probe rotated towards the top of the head to an angle as nearly vertical as possible while displaying far and near wall interfaces.

1.10 Scanning Summary

The scanning protocol is presented in two parts. Part 1 – CCA Video is the capture of a video stream of the right common carotid artery. Part 2 – Carotid IMT is performed on first on the right and then on the left side. On each side Part 2 – Carotid IMT scanning begins with a transverse sweep from the base of the common carotid up through the internal carotid. The transverse sweep is followed by a pulse-wave Doppler measurement in the ICA and then grayscale images of the common carotid, the carotid bulb, and the internal carotid arteries.

Scanning summary for GE Logiq 700 With Image Labels and Magnification Notes

The carotid ultrasound images are collected and videotaped in this order:

IMAGE DESCRIPTION	IMAGE LABEL	TO BE VIDEOTAPED
PATIENT INFORMATION PAGE Complete the demographic information page with Study and Subject Identifiers		5 seconds
PART 1 – CCA VIDEO **RIGHT SIDE ONLY**		
Magnification "ON"		
Video – Right CCA Probe: 13 MHz	RCC	20 seconds of real time
Magnification "OFF"		
PART 2 – CAROTID IMT		
RIGHT SIDE		
Standard Zoom – Depth = 4cm		
1. Transverse (short-axis) sweep Probe: 13 MHz	R Trans	15 second real-time scanning sweep
2. Pulse-Wave Doppler from ICA Probe: 9 MHz	RPW	5 seconds of static, measured image
Magnification "ON" to display a 2cm by 2cm field-of-view		
3. 1 view of Common Carotid Artery Probe 13 MHz	RCC	5 seconds of frozen image then the cine loop
4. 2 views of Bulb Probe: 9 MHz	RB 1 RB 2	For each view: 5 seconds of frozen image then the cine loop
5. 2 views of Internal Carotid Artery Probe: 9 MHz	RICA 1 RICA 2	For each view: 5 seconds of frozen image then the cine loop
Magnification "OFF"		
LEFT SIDE		
Standard Zoom – Depth = 4cm		
1. Transverse (short-axis) sweep Probe: 13 MHz	L Trans	15 second real-time scanning sweep
2. Pulse-Wave Doppler from ICA Probe: 9 MHz	LPW	5 seconds of static, measured image
Magnification "ON" to display a 2cm by 2cm field-of-view		
3. 1 view of Common Carotid Artery Probe: 13 MHz	LCC	5 seconds of frozen image then the cine loop
4. 2 views of Bulb Probe: 9 MHz	LB 1 LB 2	For each view: 5 seconds of frozen image then the cine loop
5. 2 views of Internal Carotid Artery Probe: 9 MHz	LICA 1 LICA 2	For each view: 5 seconds of frozen image then the cine loop

1.11 Sonographer Response to a Significant Stenosis – ALERT

Some participants will have significant carotid stenoses, which are discovered, perhaps for the first time, during this examination. An ALERT is defined as a 70% or greater stenosis in the common carotid, the bulb or internal carotid artery. The only criteria used to estimate stenosis is the peak systolic pulse-wave Doppler. A 70% or greater stenosis is indicated by a pulse-wave Doppler measurement of **250 cm/s in the common carotid, bulb or internal carotid**. Imaging data should **not** be used in arriving at this conclusion; its role is limited to determining the site of the abnormality.

If a sonographer believes a significant vascular abnormality is present, he should double-check this finding by repeating the Doppler measurement. Under no circumstances should any concern be conveyed either directly or indirectly to the participant by the sonographer. **The clinic coordinator should be told immediately after the participant has left the scanning area.** An inquiry is thereby triggered at the field center regarding the presence of relevant symptoms in the participant. It will be determined whether he is under care for the vascular abnormality. If necessary, appropriate referrals will be provided by the clinical center medical personnel.

The field center holds the responsibility for the participant's health care. When a participant presents with what is suspected to be a problem, this finding is to be communicated immediately to the field center medical personnel. **Do not wait for confirmation from the Ultrasound Reading Center.** The scan will not likely be reviewed for several weeks. Moreover, the readers and the project manager are not qualified to provide any sort of diagnostic report.

1.12 Criteria for Satisfactory Images

The criteria for optimal B-mode ultrasound image of the carotid arteries is defined as the clear visualization on long axis views of arterial interfaces, internal arterial landmarks, and lesions.

1. Far wall - arterial wall furthest from probe
   a) lumen - intimal boundary
   b) medial - adventitial boundary
2. Near wall - arterial wall nearest the probe
   a) adventitial - medial boundary
   b) intima - lumen boundary

The area of interest will be centered in the middle of the image and the probe will be aligned to show as much of the vessel cephalad and caudad as possible. The sonographer should optimize the visualization of the interfaces by adjusting the gain settings, beam steering and probe placement.

It is expected that the lumen of a good carotid artery IMT ultrasound study image will contain a significant amount of artifact. To clearly visualize the intimal linings the gain setting must be set considerably higher than it is for a typical clinical study.

Satisfactory images are properly magnified and the magnification level is the same for all longitudinal views. If a sonographer mistakenly uses an incorrect magnification level or changes it mid-scan, he/she should make a note of the problem in the "Comments" section of the

videotape log sheet. Without a note from the sonographer, the reader will assume the magnification is the same for all of the images. Thus, the image will be calibrated incorrectly, resulting in erroneous measurements.

1.13 Imaging Priorities

Some participants will not have easily visible intima-media interfaces. For these cases, the sonographer will prioritize the far wall intima-media interfaces over the near wall intima-media interfaces. For the more difficult cases, where there is some disease, the top priority is optimal imaging of the segment under study at a fixed angle rather than optimizing plaque, this being defined as a focal protrusion from the vessel wall exceeding 50% of the adjacent "normal" segment.

In summary, the imaging priorities are:

1. Far wall interfaces (clear visualization of far wall is more important than that of the near wall)
2. Near wall interfaces

2. Overview of Carotid Ultrasound Analysis Protocol

2.0 Preview and Digitization of a Carotid Ultrasound Study

Upon receipt of the CARDIA videotape, log sheet and procedure forms, the scans are assigned to a reader for review and analysis. The reader reviews the videotape log sheet and the procedure form for scan specific information. This is how the reader becomes aware of scan specific situations, such as images captured out of order, errors in labeling, or other technical difficulties encountered during the scanning procedure. Carotid system structures are identified: the common carotid artery, the carotid bulb, the internal carotid artery, and if visible the external carotid artery. The site where the interfaces are most clearly imaged is identified. In addition, the pulse-wave Doppler measurements are assessed.

After previewing the videotape, the video sequences and images are digitized. The computer-based ultrasound image analysis system combines the digitization and analysis functions. The program is designed to permit the user to immediately proceed from digitization to analysis.

2.1 Calibration

The first step in carotid ultrasound analysis is calibration. It is necessary to calibrate each ultrasound video sequence and image in order to convert the computer unit, pixels, to centimeters. To calibrate an image the reader positions the calibration tool such that it demarcates the 1-cm distance between calibration marks on the image.

Readers assume that the magnification level does not change from one image to the next within a carotid ultrasound scan. If the magnification level is changed within a scan for any reason, please communicate this to the readers by making note of the change on the log sheet.

2.2 The Interfaces

The goal of the reader is to identify the leading edges of the far wall interfaces and "draw" the lines needed to calculate IMT.

The following line numbers correspond to specific anatomic interfaces as defined below:

Wall	Line Number	Interface
Near Wall	Line 1	Periadventitia-Adventitia
	Line 2	Adventitia-Media
	Line 3	Intima-Lumen
Far Wall	Line 4	Lumen – Intima
	Line 5	Media – Adventitia
	Line 6	Adventitia – Periadventitia

Measurements from carotid study images are made from pairs of lines (i.e., lines 4-5) drawn on the image. The lines are drawn with the stylus pen and are approximately 1-cm in length. On the common carotid view, the lines are drawn in the 1-cm segment proximal to the bulb and on the bulb and internal carotid views the lines are drawn in the middle of the image where the interfaces are most clearly displayed.

The measurements that are made are of the near wall, far wall, vessel width and lumen. The measurement algorithm calculates the distance between pairs of lines and reports the minimum, maximum and average (and standard deviation) values. The vessel structures are defined by the lines pairs as follows:

Vessel Structure	Line Pair
Near Wall	2 – 3
Far Wall	4 – 5
Vessel Width	1 – 6
Lumen	3 – 4

2.3 Image Quality Scores

An image quality score is assigned to every analyzed image. This score is based on the quality of the image and the reader's confidence that the lines drawn represent the true interfaces. Although the score is subjective, the following is a loose guideline for scoring the common and non-diseased internal carotid arteries. Note that the criterion used to assign a quality score to a diseased vessel differs slightly from that of a healthy vessel.

Common & Healthy Internal Arteries

1. Unacceptable: only one or no lines drawn.
2. Poor: only two lines, one pair, drawn, giving a lumen measurement (lines 3 & 4, or 2 & 5) or vessel width (lines 1 & 6)

3. Acceptable: only two or three lines on either near or far wall with an opposing line (lumen measurement).
4. Very Good: all six lines drawn, all measurements made.
5. Excellent: all six lines clearly visualized and easily drawn, with good gain and positioning.

Atherosclerotic Carotid Arteries

1. Unacceptable: only one or no lines drawn.
2. Poor: only two lines, one pair, drawn, yielding a lumen measurement (i.e., 3&4, or 2&5) or vessel width (i.e., 1&6) or can draw lines on wall opposing the lesion but no lesion measurement can be made.
3. Acceptable: four to five lines drawn, lesion traceable but not clearly defined, with at least one posing line.
4. Very good: all six lines drawn, lesion clearly defined, with opposing line.
5. Excellent: lesion clearly defined, with opposing wall measurement, lines are easily drawn and the image has good gain and positioning.

2.4 Subjective Assessment

Qualitative assessments are made of the carotid bulb and internal carotid artery. Lesions in the common carotid artery are not characterized by this protocol. Lesion surface, morphology, the percent stenosis, location and density are the characteristics assessed.

2.4.1 Surface

The surface of the artery or lesion is categorized as one of the following:

1. Smooth - no lesion is present in the artery and the lumen-intima surfaces (lines 3 & 4) are free of irregularities. If there is a lesion present then this category is applicable when the lumen-intima surface (lines 3 & or 4) of the lesion is smooth and free of irregularities.
2. Mildly irregular - the lesion has minute surface irregularities.
3. Markedly irregular - the lesion has noticeable surface irregularities. This can be best described by saying that the surface is “bumpy” but without a prominent pit or crater.
4. Ulcerated - the lesion surface has prominent ulceration, pit(s)or crater(s) that is at least 1mm in depth and is at least 1mm in width. The “back wall” of the lesion, defined as the media-adventitia interface, can be clearly seen at the point of ulceration.
5. Can’t tell - the surface characteristics of the artery/plaque cannot be determined due to insufficient information (images are unclear or missing).

2.4.2 Morphology

The morphology, the form and structural characteristics, of the lesion are categorized as:

1. No lesion - no lesion present in either the internal or bulb
2. Homogeneous - a lesion that demonstrates an echogenicity that does not vary across its width and thickness.
3. Heterogeneous - a lesion with have a mixture of lucent and echogenic zones.
4. Can't tell - the morphology of the plaque cannot be determined due to insufficient information (images are unclear or missing).

2.4.3 Percent Stenosis

All available information is used to determine the percent stenosis. Information sources include digitized images, real time sequences or cine loops and Doppler values. The degree of stenosis is crudely estimated from the images and real time sequence or cine loop as a ratio of artery width. The Doppler value (velocity) which is known to be a more reliable measure is incorporated to refine the estimate.

It may not be evident from the images the images that there is a 100% occlusion. In some cases, there may not be a Doppler value because the sonographer was unable to produce a Doppler signal. When Doppler values are nonexistent and the images are unclear, the reader must rely on comments from the sonographer to determine the degree of stenosis.

In all instances where the PW Doppler is greater than 150 cm/s, it is used to categorize the percent stenosis according to the following table.

Percent Stenosis – PW Doppler Categorization

% Stenosis	Doppler Values
0-49%	<150 cm/sec
50-74%	> 150 cm/sec but < 250 cm/sec
75% -99%	**250 cm/sec ALERT**
100% (occlusion)	0.0 cm/sec

The categories from which the percent stenosis must be chosen are more specific:

1. Normal - no focal lesion present in either the internal or bulb.
2. 1-24% - Doppler values that are <150 cm/sec and reader's estimate based on the three images of the internal showing that the lesion occupies 1-24% of the vessel width.

3. 24-49% - Doppler values that are <150 cm/sec and reader's estimate based on the three images of the internal showing that the lesion occupies 25-49% of the vessel width.
4. 50-74% - Doppler values that are ≥ 150 cm/sec but <250 cm/sec.
5. 75-99% - Doppler values that are ≥ 250 cm/sec.
6. 100% - Doppler values that are 0.0 cm/sec.
7. Bad image/Nl (normal) Doppler - the images are so unclear that % stenosis can't be estimated by looking at them but Doppler values fall within normal range, < 150 cm/sec.
8. Can't tell – the percent stenosis cannot be determined due to insufficient information (images are unclear or missing).

2.4.4 Location

The plaque location describes the site of the lesion. The categories are:

1. No lesion - no lesion is present in either the internal or bulb
2. Can't tell - cannot determine the location of the plaque cannot be determined due to insufficient information (images are unclear or missing).
3. Internal - the lesion is located in the internal carotid
4. Bulb - the lesion is located in the bulb
5. Can't tell - cannot determine the location of the plaque cannot be determined due to insufficient information (images are unclear or missing).

2.4.5 Density

The lesion density qualifies the compactness of the plaque. The categories are:

1. No lesion - no lesion is present in either the internal or bulb
2. Hypodense - a plaque that appears darker than the surrounding tissue.
3. Isodense - a plaque that has same level of brightness as the surrounding tissue.
4. Hyperdense - the plaque appears brighter than the surrounding tissue and some of the tissue beneath the plaque is shadowed.
5. Calcified - the plaque appears much brighter than the surrounding tissue and all of the tissue beneath the plaque is shadowed.
6. Can't tell - cannot determine the density of the plaque cannot be determined due to insufficient information (images are unclear or missing).

3. Data Transmission

3.0 Data Media: Videotape

Carotid ultrasound images are transmitted to the Ultrasound Reading Center recorded on videotape. Media is **not** returned to the field center to be re-used. Scans can be recorded to videotape by Super VHS videocassette recorders. **Super VHS tape must be used.** It can be purchased at Radio Shack, B & H Photo Video (www.bhphotovideo.com, or 800.947.5525) or through the field center's vascular lab or radiology department. Standard, non-Super VHS, tape is not acceptable.

When using the VCR, it is important to wait for the mechanical delay of the VCR mechanism to engage when timing recordings. A few seconds of over-recording is infinitely more desirable than a non-recording. If at any time during an examination a better image than that previously recorded is obtained, **do not** erase or tape over the previous recording. Add the new images to the videotape and make a note in the *Comments* section of the log sheet to inform the reader.

At the Ultrasound Reading Center the readers digitize (computerize) and analyze the images from the carotid ultrasound videotapes. The computer-based system to accomplish these tasks was developed by the Ultrasound Reading Center.

3.1 Study Procedure Form

There is a procedure form to be completed by the sonographer for each participant who is scheduled to be scanned. This form includes field center and scan identifiers, as well as pulse-wave Doppler values, completeness and quality assessments. This information is entered to the study database and facilitates data tracking. The procedure form for CARDIA and detailed description of how to complete it are Attachments 2 and 3 of this document.

3.2 Labels and Log Sheets

The Ultrasound Reading Center will provide labels and master copies of the log sheet. These items make it possible to track and organize the numerous scans that arrive at the Ultrasound Reading Center. It is very important that the sonographers carefully label the videotapes and the corresponding log sheets. The labels contain the study name, field center name, exam number and tape number. The log sheet enables the reader to quickly locate each study on the individual videotapes and to obtain pertinent information regarding particular cases.

The sonographer completes the appropriate sections of the log sheet for each subject he scans. The items recorded on the log sheet are:

- **Scan Date** – the date of the carotid scan
- **Subject ID** – the ID number assigned to the participant (no names please)
- **Sonographer ID** – the CARDIA technician ID assigned to the sonographer

- **VCR Start** – if videotape is used, the VCR counter/timer that indicates where the particular study is located on the tape

- **Plaque** – if there is a plaque(s) circle the location(s). *RB = right bulb, RICA = right internal carotid, LB = left bulb, LICA = left internal carotid*

- **Comments** – communication from the sonographer to the reader

Sample Log Sheet Entries

	Scan Date	Subject ID	Sonog ID	VCR Start Time	Plaque	Comments
1.	4/20/2004	300115811991	325	0:00	RB RICA LB LICA	*no plaques, easy scan*
2.	4/21/2004	304587157452	387	4:33	**RB** RICA LB LICA	*RB plaque*

The value of sonographer-reader communication cannot be overstated. Use the Comment section of the logsheet to communicate any deviations from the norm. Include notes about the protocol, plaques, problems or difficulties encountered. For example, if a scan is cancelled, images are recorded out of order, **write it down**. The readers base their decisions on the information the sonographer provides. It is not easy for the readers, who are not medically trained, to distinguish plaque from artifact. Efforts by the sonographer reduce the guesswork and to assist the reader in the analysis process results in better outcome data and is greatly appreciated.

3.3 Shipping Scan Media, Log Sheets and Procedure Forms to the URC

The CARDIA ultrasound scans are recorded to Super VHS videotapes and are shipped to the Ultrasound Reading Center every week. The scan videotape is packaged with the log sheet and copies of the procedure forms. A copy of the log sheet should be made and kept on file at the clinical center. A delivery service with package tracking capabilities must be used such as United Parcel Service and FedEx.

The mailing address is:

Daniel H O'Leary
Ultrasound Reading Center
25 Stuart Street, 2nd Floor
Boston, MA 02116

Shipping Telephone: 617.636.0036

URC Contact	Name	E-mail	Telephone
Project Manager	Laurie Funk	lrcfunk@comcast.net	717.228.3750
Image Analysis Coordinator	Julie Santacroce-Burt	jsantacroce@tufts-nemc.org	617.636.0036

3.4 Data Transmission to the Coordinating Center

The carotid ultrasound analysis program output is an MS Access database that contains the calculated measurements and subjective scores for each analyzed participant study. The calculated measurements include values for the far wall, near wall, vessel width, and lumen. The subjective scores that characterize the surface of the artery or lesion include assessments of the morphology, the percent stenosis, the location of the lesion, and the morphology. Also included with each participant data record are the sonographer ID, scan date, reader ID, read date and pulse-wave Doppler measurements. Data files are periodically transmitted to the Coordinating Center.

4. Clinical Center Sonographers

4.0 Sonographer Certification

Certification Requirements

1. Sonographer attends Sonographer Training Session at Ultrasound Reading Center. Training session attendance is mandatory. Training sessions begin at 9:00 AM and end at 3:30 PM. The training session consists of a lecture, scanning practice, demonstration of the analysis process, and a review of administrative procedures

2. Sonographer submits Certification Tape, Log Sheet, and Procedure Forms.
   The Certification tape contains recording of five (5) scans on five volunteers. It demonstrates sonographer's knowledge of protocol and ability to acquire high quality images.

3. Ultrasound Reading Center reviews the Certification Tape.
   A subjective critique is prepared and based upon the quality of the images and adherence to the protocol and determines whether or not to certify sonographer.

4. Sonographer is Certified or Certification is Pending

   A. If the sonographer is certified, the Coordinating Center assigns a Sonographer ID and the sonographer can begin scanning study participants.

   B. If certification is pending, the sonographer must submit another certification tape. If, after the second set of certification scans, the Ultrasound Reading Center is still unsatisfied and does not think the sonographer can rise to the necessary standard, the clinic coordinator and investigator will be notified by the Ultrasound Reading Center project manager and advised to identify a new sonographer.

4.1 Sonographer Quality Control

Following initial certification sonographer performance will be evaluated to monitor and assure quality control. The Ultrasound Reading Center has found it best to minimize the number of sonographers and readers thereby limiting problems prospectively rather than retrospectively adjusting data. If possible, two sonographers should perform all examinations at each field

center. Ideally, these individuals would be experienced vascular sonographers, preferably RVT certified or equivalent. If not RVT certified, the sonographers should have experience in an ICAVL accredited laboratory. The Ultrasound Reading Center protocol is such that it can be quickly taught to someone who routinely performs high quality clinical ultrasound examinations.

4.2 Ultrasound Reading Center – Sonographer Communication

Experience with other studies has demonstrated the need for rapid and possibly frequent communication between the Ultrasound Reading Center and the sonographers. Examples of the kind of problems that required immediate attention in the past include the apparent non-recording of images on videotape and discordance between Doppler and imaging data. Sonographers are asked to keep notes and to use the Reader Comments field on the log sheet so that they may provide direction to the Ultrasound Reading Center when necessary. Sonographers are encouraged to e-mail or call the project manager to discuss problems or questions as they arise. If necessary, a member of the Ultrasound Reading Center staff will visit field centers.

If a sonographer submits unacceptable or un-analyzable studies, the reader will alert the image analysis coordinator and project manager. An unacceptable study is one from which very little or no data can be obtained. Unusable studies can be the result of poor images or failure to follow the protocol (incorrect images). Continued poor performance by a sonographer will result in a telephone call to the sonographer and the clinic coordinator. Severe cases will warrant a memo to the field center and Ultrasound Reading Center Director documenting the persistent poor quality. If necessary the Ultrasound Reading Center will request that the sonographer discontinue scanning for the study.

Throughout the exam period, the sonographer will receive sets of *Reader Comments.* The reader writes *Reader Comments to the Sonographer* at the time of study analysis. These comments come to the sonographers in the form of a periodic feedback report. Typically, the comments contain constructive criticisms and suggestions for improving the study images, i.e., gain adjustments, check the Doppler gate angle or position adjust focal zones.

4.3 Ultrasound Reading Center Report on Sonographer Performance

In addition to the *Reader Comments,* sonographers will receive feedback from the Ultrasound Reading Center in the form of a sonographer performance quality control report. The reports quantitatively track each sonographer's performance and will include the number of studies and average image quality scores tabulated for all of the field centers, and then by each individual field center, by sonographer and reader. Copies of the reports will be distributed to the field centers, the Ultrasound Reading Center PI and the coordinating center. Cumulative summaries will be published periodically to serve as an ongoing benchmark against which to judge individual results.

4.4 Sonographer Performance Standards

A baseline quality control score, derived from the score assigned to each image and the number of lines drawn for each image will be established after analysis of pilot and pre-pilot data, below which sonographer performance will be considered unacceptable if maintained for consecutive weeks. The readers will be monitored to ensure uniform scoring throughout the exam period.

Additional training may be required of sonographers and/or readers in the event of any significant temporal drift in accuracy or precision of sonographer performance and/or reading. In terms of the analysis of the actual measurements produced, we will subscribe to those suggested by echocardiography - namely, a goal of mean variability of 10%, with a cut-off point of 15% acceptable variability.

4.5 Replacement or Retraining of a Sonographer

If a sonographer resigns or is replaced due to poor performance, a replacement must be trained and certified prior to performing scans on research subjects. Consistently poor performance by a sonographer will initiate a call of encouragement and investigation by the project manager. Continued poor performance will result in the sonographer being re-trained or replaced. A new sonographer can be introduced to the protocol by a certified sonographer, but the new sonographer will not be certified to conduct participant exams until he attends an Ultrasound Reading Center training session. Contact the Ultrasound Reading Center immediately when the need to train a new sonographer becomes apparent.

4.6 With-in Sonographer Variability Assessment

Intra-sonographer variability during the examination period will be assessed from the data obtained by repeating complete carotid ultrasound studies on a number of subjects. Each sonographer will complete two scans on a subset of approximately twenty participants distributed throughout the exam time period. The videotapes will be sent to the Ultrasound Reading Center for analysis coded with random number subject identifiers assigned by the Coordinating Center. The reader be blinded – he will not know that a scan he is analyzing is a standard scan or a sonographer intra-variability quality control scan. Subjects for the replicate studies will be recruited during the exit interview. The sonographer will not recruit replicate study volunteers. The repeat scan should be scheduled to occur no sooner than one week and no later than one month after the initial scan. On the return visits, each volunteer will be scanned once by each sonographer.

4.7 Achieving and Maintaining Quality Ultrasound Data

Quality carotid ultrasound data begins with the sonographer. The sonographer produces the images on which the readers draw the lines from which the IMT calculations are made. A poor set of images results in a poor and sometimes incomplete set of data. The readers are entirely dependent upon the sonographers to provide clear images and to explain any conditions, anatomical or procedural that vary from the norm.

To maintain high quality ultrasound data:

A. Acquire clean images that clearly display the intimal linings and the lesions. The intimal linings and the lesions are the top priority; they are what are measured by the reader. It is expected that in order to clearly display the intimal linings the lumen will contain more artifact than the typical clinical study.

B. Videotape the images in the order stated by the protocol. A scan that is videotaped out of order is not as easy for the readers to analyze.

Part 1 – *CCA Video*

Right common carotid video stream

Part 2 - *Carotid IMT*

Right Side

1. Right transverse sweep of common and internal
2. Right common carotid pulse-wave Doppler
3. Right common carotid
4. Right bulb view 1
5. Right bulb view 2
6. Right internal carotid view 1
7. Right internal carotid view 2

Left Side

8. Left transverse sweep of common and internal
9. Left pulse-wave Doppler measurement
10. Left common carotid
11. Left bulb view 1
12. Left bulb view 2
13. Left internal carotid view 1
14. Left internal carotid view 2

C. Annotate the images with the following information:

1. CARDIA
2. Subject Alphacode
3. Subject ID
4. Sonographer ID
5. Image Labels:
   R CCA Video
   R Trans, RICA PW, RCC, R bulb 1, R bulb 2, RICA 1, RICA 2;
   L Trans, LICA PW, LCC, L bulb 1, L bulb 2, LICA 1, LICA 2

D. **Magnify** the longitudinal views of the CCA, bulb and ICA. Keep the magnification level constant throughout the scan.

E. Use the **correct probe frequency**: 13 MHz for CCA's and 9 MHz for images of the carotid bulbs and ICA's.

F. Annotate the images and use arrows to distinguish the vessels when the images are atypical. Don't force the reader to guess which vessel is the internal and which is the external carotid.

G. **Use the Comment section of the log sheet to communicate** any abnormalities, problems or difficulties encountered. For example, if a scan is canceled or if there are images missing or

out-of-order, **write it down**. The importance of this communication cannot be stressed enough. The readers are not medically trained and base all of their decisions on the information the sonographer provides.

H. Record the frozen images for 5-10 seconds. Any less than 5 seconds makes the image difficult to capture and any longer than 10 seconds reduces the reader's efficiency.

I. Record real time image sequences or cine loops to enable the reader to discriminate between true anatomy and artifact.

J. Take the time to verify subject ID's. Check the ID typed into the ultrasound machine and written on the log sheet. If an incorrect ID is videotaped because the wrong ID was typed into the ultrasound machine, tell the Ultrasound Reading Center about it with a note in the Comments section of the log sheet. After the videotape leaves the field center sorting out erroneous ID's can be a very difficult, if not impossible task. Watch for transpositions.

K. Complete the log sheet and the procedure form while you are scanning.

	Scan Date	Subject ID	Sonog. ID	VCR Start Time	Plaque ε	Comments
1.					RB RICA LB LICA	
2.					RB RICA LB LICA	
3.					RB RICA LB LICA	
4.					RB RICA LB LICA	
5.					RB RICA LB LICA	
6.					RB RICA LB LICA	
7.					RB RICA LB LICA	
8.					RB RICA LB LICA	
9.					RB RICA LB LICA	
10.					RB RICA LB LICA	

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Y20 - CARDIA VII
CAROTID ULTRASOUND

exam date ☐☐ / ☐☐ / ☐☐☐☐ Alphacode ☐☐☐☐☐
Month Day Year

☐☐☐ 1. Tape#

2. VCR Start ☐☐ ☐☐ ☐☐ Time
Hr Min Sec

3. Results of Part 1 – CCA Video Scan (20 seconds of right common carotid dynamic acquisition):

1 ☐ Done – ***Skip to Q5***
2 ☐ Incomplete
3 ☐ Not Done – ***Complete Q4 and skip to Sonographer ID***

4. Reason Part 1 – CCA Video Scan was incomplete or not done:

1 ☐ Equipment malfunction
2 ☐ Time/staff/room constraints
3 ☐ Examinee refused/uncooperative
4 ☐ Examinee physically unable
5 ☐ Other, specify: ☐

5. Results of Part 2 - Carotid IMT Scan:

1 ☐ Done – ***Skip to Q7***
2 ☐ Incomplete – complete Q6 and rest of questions if possible
3 ☐ Not Done – ***Complete Q6 and skip to Sonographer ID***

6. Reason Part 2 - Carotid IMT Scan was incomplete or not done:

1 ☐ Equipment malfunction
2 ☐ Time/staff/room constraints
3 ☐ Examinee refused/uncooperative
4 ☐ Examinee physically unable
5 ☐ Other, specify: ☐

7. Were ICA Doppler blood flow signals detectable?

Right side: 1 ☐ No 2 ☐ Yes
Left side: 1 ☐ No 2 ☐ Yes

8. Pulse wave Doppler measurements (cm/s)

Right ICA/Bulb ☐☐☐ . ☐ cm/s

Left ICA/Bulb ☐☐☐ . ☐ cm/s

9. Quality of this scan:

1 ☐ Good
2 ☐ Fair
3 ☐ Poor

Sonographer ID# ☐☐☐ Reviewer ID# ☐☐☐

Data Entry ID# ☐☐☐

PROCEDURE FORM DOCUMENTATION

Protocol Name: Carotid Ultrasound
Form Name: Form 77, Y20 CARDIA VII, Carotid Ultrasound

Form Item	Response Options	Explanation
Form Header Section Exam Date Alphacode	Participant ID Barcode Label Date of Procedure Alphacode	Scan identifiers: subject identifiers and procedure date
1. Tape #	3 digit number	Number on videotape label and videotape logsheet, no letters
2. VCR Start Time	Hour: Minutes: Seconds	VCR counter time, not the time of day
3. Results of Part 1 – CCA Video Scan	○ Done – Skip to Q5 ○ Incomplete ○ Not Done – Complete Q4 and skip to Sonographer ID at end of form	Indicate whether or not the scan was successfully completed.
4. Reason Part 1 – CCA Video was incomplete or not done:	○ Equipment malfunction ○ Time/Staff/Room constraints ○ Examinee refused/uncooperative ○ Examinee physically unable ○ Other	If scan is "Incomplete" or "Not Done" indicate why
5. Results of Part 2 – Carotid IMT Scan	○ Done – Skip to Q7 ○ Incomplete – Complete Q6, others as possible ○ Not Done – Complete Q6 and skip to Sonographer ID	Indicate whether or not the scan was successfully completed.
6. Reason Part 2 – Carotid IMT Scan was incomplete or not done:	○ Equipment malfunction ○ Time/Staff/Room constraints ○ Examinee refused/uncooperative ○ Examinee physically unable ○ Other	If scan is "Incomplete" or "Not Done" indicate why
7. Were ICA Doppler blood flow signals detectable?	Right Side: ○ Yes ○ No Left Side ○ Yes	Indicate whether or not the PW Doppler blood flow signals were detectable in Right and Left ICA's

	○ No	
8. PW Doppler measurements	3 digits, plus 1 decimal place for the measurement from both the Right and Left ICA's Units: cm/s	Enter peak flow velocity measurement taken from ultrasound display screen
9. Quality of this examination	○ Good ○ Fair ○ Poor	Sonographer's quality assessment: is this scan good, fair or poor?
Sonographer ID#	3 digit ID#	Sonographer ID#
Reviewer ID#	3 digit ID#	Reviewer ID#
Data Entry ID#	3 digit ID#	Data Entry ID#