

**Wisconsin Sleep Cohort Study - UW AIRP Protocols**  
**Arterial Tonometry, Echocardiography and Carotid Intima Media Thickness**

[Pulse Wave Database](#)    [Echo Database](#)    [CIMT Database](#)

**Study Setup**

***Before Subject arrives***

1. Prior to starting, complete study CRF with subject's ID, initials, and date of study. The operator's initials should be on the study form. This information should also be recorded in the SphygmoCor system prior to starting
2. In the SphygmoCor system, select "System → Database Manager"
3. Highlight "SCS-2" and click the select button
4. When SCS-2 appears as selected database, click OK
5. Click "Create New" to add a new patient
6. Enter the study running total (1,2,3,4....) in the Patient ID field
7. Enter subject's study ID under the LAST NAME field, enter initials in FIRST NAME, enter DATE OF BIRTH, and SEX. Click UPDATE to save patient demographics

***General Information***

1. When patient arrives record Height, Weight, Gender, Race, on CRF
2. Have subject change into gown leaving undergarments on.
3. Place subject in supine position prior to recording for at least 10 minutes, record room temperature and insure comfort of the subject
4. While patient is supine measure distances and record on CRF (mm)
  - a. Distance from suprasternal notch to strongest carotid pulse
    - i. This measurement should be taken with the subjects head turned to the left and chin extended
  - b. Distance from suprasternal notch to strongest femoral pulse
    - i. Measurement should be taken as a straight line from the sternal notch to the strongest pulse point.
    - ii. Preserve patient modesty by offering an extra gown or a sheet.
5. Attach Ultrasound and tonometry systems ECG leads to chest
6. Measure and record blood pressure once on right arm and twice on left arm. Leave cuff on left arm on and print results. Use the most recent left arm BP's and corroborate that it does not differ from the paired measurement by more than 5 mmHg or opposite arm by more than 10 mmHg. Entered values are recorded on CRF
  - c. If necessary, continue performing BP measurements until a consistent steady state is reached
  - d. Critikon - Dinamap 400 series (oscillometric) system with appropriate selection of cuff size and correct placement

**Radial PWA**

1. Select PWA (pulse wave analysis) from the patient menu
2. In the study screen, make sure RADIAL is checked, enter the most recent left brachial blood pressure reading (MAP, DP)
3. Type in height, weight, and operator's initials.
4. If possible synchronize to acquire tonometry data and LVOT PW Doppler velocities to capture data simultaneously.

- Obtain at least 12 seconds of high quality tracings. The system will analyze the last 10 seconds of the recording and process the data. If the “operator index” (OI, weighted equation using the information of systolic height, diastolic variation and pulse pressure differences between all the beats selected) is more than 85%, the data can be accepted. If OI is below that threshold, another set of tracings should be obtained. The average of 2 good quality sets with an acceptable OI is used for analysis.
- Record central PP(pulse pressure), central Alx (central Augmentation index), Alx-HR75 (Al corrected for a heart rate of 75), OI on CRF

**Central PWV**

- Select PWV from patient menu. In the study screen, select Site A as Carotid and Select Site B as Femoral
- Enter Mean and Diastolic brachial blood pressure used for PWA. Enter distances previously measured (Distal=femoral, Proximal=Carotid)
- Type in height, weight, and operator’s initials
- Capture carotid and femoral data (12 seconds of uniformly spaced and shaped pulse tracings)
- Record PWV (SD) on CRF. If either tracing is colored red (weak upstroke or significant HR variability), repeat the acquisition of the paired pulses (carotid and femoral tonometry).
- End the study before starting a new subject**

***PWA/PWV parameters reported:***

- PP (aortic pulse pressure),
- Alx (central Augmentation index)
- Alx-HR75 (Al corrected for a heart rate of 75)
- OI (a QA measure)
- PWV (central pulse wave velocity)

**Transthoracic Echocardiogram**

- Start new study in the ultrasound system (Acuson, Sequoia 512c), enter study name-subject ID- and initials in the study heathers. Include the sonographer’s initials, subject height, weight, DOB and sex.
- Insure good ECG signal/noise ratio before starting
- All loops are 3-5 beats long (medium to low compression) and Doppler velocities recorded at 100 cm/s unless indicated
- The 4V1c transducer is used and the highest harmonic imaging setting selected while penetration preserved.
- Connect nasal thermistor to the nostril and adjust gain for display
- The protocol views are listed below

Window	View	Concentration	Acquisition	Measurements
PLAX	LAX	LVOT diameter	3-5 beat loop zoomed	
			2 frames measured at peak systole	LVOT Diameter (cm)
		MR color Doppler	3-5 beat loop	Grade MR severity
		2D LV function	3-5 beat loop	Might be used for %SF
	SAX mid papillary muscles level	2D image for LV mass	3-5 beat loop Adjust gains and focus to show epi and endocardium.	ED epicardial area ED endocardial area
		ED frames for LV mass measurement	Traced end diastolic area for AL-mass (don't include PAPs), average 2-3	Same as above

		LV M-Mode for SF% and Mass (cubed)	100 cm/s sweep speed	LVedd, LVesd, IVSh and PWh, SF%
		LV M-Mode with respirometer for R/L interaction	50 cm/s sweep speed	Presence or absence of significant respiratory variation
	<b>SAX base</b>	PA diameter	Improve image definition	RVOT/PA end-diastolic diameter
		PA annulus diameter for flow	Measure the annulus during early ejection (2 to 3 frames after the R wave) from the anterior corner to the junction of the posterior pulmonic leaflet with the aortic root	Perform in triplicate
		PW Doppler at the PV level	Align with flow; adjust filter, scale, and gain. Speed 100 cm/s	Acceleration time (<90msec is abnormal) Presence of systolic notch (Y/N)
		PW or CW of PI if present	Full PI envelope	End diastolic PI velocity for dPAP
		TV Views (SAX and LAX)	Color Doppler to access TR severity and jet direction	Grade TR severity
		TV CW Doppler	Adjust filter, gain, angle of interrogation for complete TR velocity envelope	Report Peak TR velocity and PG, add RA pressure for RV/PA peak systolic pressure
<b>AP4</b>	<b>LV view</b>	2D Acoustic capture loop for auto EF	True apex, adjust focal zone and gain	Use auto EF and edit as needed, save systolic and diastolic traced images Use length for AL-LVMass calculation
		Color Doppler across Mitral Valve (+ AP2 plane)	Adjust alignment, color gain and scale 60-70 cm/s	Grade MR severity
		Color Doppler across TV Valve	Adjust alignment, color gain and scale 60-70 cm/s	Grade AI severity
		Repeat TV CW Doppler	Adjust filter, gain, angle of interrogation for complete TR velocity envelope	Report Peak TR velocity and PG, add RA pressure for RV/PA peak systolic pressure
	<b>RV free wall</b>	2D loop for function with respirometer	End expiration measurements	Trace end diastolic and end systolic for delta area and measure annulus to apex shortening
		TDI RV lateral wall		Right s' and right e' velocities
	<b>LA volume</b>	2D loop	3-5 beat loop	
		2D frame	end expiration-end systole	MOD for LA volume biplane
	<b>Diastolic function assessment</b>	MV PW Doppler	Tips of MV leaflets	E, A waves velocities and ratio
		MV PW Doppler during Valsalva maneuver	To unmask pseudo-normalized pattern,	E, A waves velocities and ratio

			record several Doppler panels with respirometer	
		Pulmonary Vein Doppler	Align, guide with color Doppler, zoom and adjust gains	S/D ratios, Ar duration
		TDI lateral wall	Use TDI preset	s',e',a'
	<b>RA volume</b>	2D loop	3-5 beat loop	
		2D frame	end expiration-end systole	MOD for RA volume
<b>AP5</b>	<b>LVOT velocity</b>	PW Doppler frame	At least 3 good beats	LVOT VTI and HR
<b>AP2</b>	<b>LV view</b>	2D Acoustic capture loop for auto EF	True apex, adjust focal zone and gain	Use auto EF and edit as needed, save systolic and diastolic traced images
	<b>LA volume</b>	2D loop	3-5 beat loop	
		2D frame	end expiration-end systole	MOD for LA volume biplane
<b>Subcostal</b>	<b>IVC diameter</b>	Perpendicular view, at largest		1cm from junction
	<b>IVC diameter (sniff)</b>	Perform sniff test if at rest the diameter was >2cm	Measure the smallest diameter during sniff	Obtain after having practiced with subject
	<b>RV free wall</b>	Improve wall definition	3-5 beat loop	RV thickness
<i>Close study</i>	<i>Save on labeled CD</i>	<i>Transfer to Siemens reading workstation</i>	<i>Generate echo report</i>	<i>Screen Capture all offline measurements and save</i>

### ***Echocardiographic parameters reported***

#### A. LV Mass:

- M-Mode Cubed LV Mass =  $\{0.8 \times \{1.04[(LVIDd + PWTd + SWTd)^3 - (LVIDd)^3]\} + 0.6 \text{ g}$
- LV Mass (AL) =  $1.05 \{ [5/6 A_1 (l+t)] - [5/6 A_2 (l)] \}$

where,  $A_1$ =Total LV area and  $A_2$ = LV cavity area from SAX tracings

l = major axis from mitral annulus to apex, and t = wall thickness derived from the short axis epicardial and cavity areas

#### B. LV Systolic function:

- M-mode derived SF% and LV chamber dimension and wall thickness
- 2D derived EF% from a biplane approach, 4CH+2CH
- End-systolic and diastolic volumes

#### C. LV Diastolic function:

- E/A ratio, E/e' ratio, s' velocity, pulmonary vein S/D ratio
- LA volume biplane MOD, (ml)
- The report will classify as normal, abnormal relaxation, pseudo-normal, or restrictive pattern

#### D. RV Thickness:

- Measured from the sub-costal plane (mm)

#### E. RV Systolic function

- Tricuspid annulus to apex fractional shortening, %
- Tissue Doppler Derived longitudinal Strain and Strain Rate

#### F. RV Diastolic function

- RA volume from AP4 window (ml)

#### G. RV/PA pressures

- RV/PA peak systolic pressure calculated from=  $[4 \times (\text{TR peak velocity})^2] + \text{RA pressure}$ , in mmHg
- Mean PA pressure =  $[4 \times (\text{Peak PI velocity})^2] + \text{RA pressure}$ , in mmHg
- Pulmonary Vascular Resistance =  $[(\text{ratio of TR velocity} / \text{VTI}_{\text{RVOT}}) \times 10] + 0.16 = \text{Woods units (WU)}$

#### H. Cardiac Output/Cardiac Index

- LVOT stroke volume (ml) and HR (bpm)
- Cardiac output (L/min)
- Cardiac Index (L/min/m<sup>2</sup>)

#### I. Systemic Vascular Resistance

- Calculated as:  $80 \times [(\text{Mean BP} - \text{estimated RA pressure}) / \text{CO}] = \text{expressed in (dyne} \times \text{sec)/cm}^5$

### **CIMT protocol**

1. Review previous study for return subjects using Access Point software. Review angles used, detected plaques, and their location.
2. Place the Meijer arc around the subject's neck. Turn on CIMT preset, enter data again to generate a separate scanning file for CIMT.
3. Start with the Right side. Record a slow transverse loops from clavicle to bifurcation.
4. Record 3 longitudinal loops screening for plaques. Obtain extra loops if necessary.
5. PW Doppler of ICA and ECA. Save still frame of each.
6. Save 3 digital frames at the time of the R-wave of the distal CCA at the OAI, ant and posterior angles respectively. Adjust focal zone and gains as needed to improve double line visualization. Maintain a cursor at the level of the tip of the flow divider for reference.
7. Repeat scanning protocol for the left side.
8. Close the study and save.

### ***CIMT parameters reported***

- A. Right CCA mean and max CIMT
- B. Left CCA mean and max IMT
- C. Mean of mean R and L CCA CIMT
- D. Mean of max R and L CCA CIMT

(note: will use original protocol for any subjects undergoing their first CIMT study)