Pulse wave assessment

Daniel Hackett

University of Sydney, Australia

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Pulse Wave Assessment

**Contributed by:** Daniel Hackett, University of Sydney

**Projects:** Physique traits, muscle performance, and health status of natural bodybuilders and powerlifter
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1 Introduction/Background

Pulse wave assessment (PWA) is used to evaluate systemic arterial stiffness using pressure wave forms obtained from peripheral arteries and transforming them into aortic stiffness (Hirata et al., 2006). These measures can assist with providing evidence of vascular damage (Cohn et al., 1999; van Popele et al., 2001) and also be used as a prognostic predictor (Laurent et al., 2001; Guerin et al., 2001). PWA involves the use of a Sphygmocor (tonometric device) which will be placed at the brachial and posterior tibial sites.

1.1 Terminology and abbreviations

- PWA = Pulse wave analysis
- PWV = Pulse wave velocity
- HRV = Heart rate variability

2 Key papers / theoretical basis for the method

2.1 Theoretical basis

Increased aortic wave reflections have been shown to independently predict cardiovascular disease and mortality (Wang et al., 2010; Weber et al., 2010), therefore providing evidence for the validity of pulse wave assessments. Intraclass correlation coefficient values for repeated pulse wave assessment measurements taken at hourly or weekly intervals have been reported to be 0.72–0.90 (Papaioannou et al., 2007; Crilly et al., 2007).

2.2 References


### 3 Ethical considerations

Please see the following documents:


### 4 Facility and equipment

This section should include a list of the laboratory equipment, smaller equipment, and consumables required for this method. Where possible, please also include photographs or images of the equipment and/or space. Please add additional rows or delete unnecessary rows in tables.

#### 4.1 Testing facility

The room requires an examination plinth to allow the assessor easier access to the sites where the pulse assessments will be taken.
### 4.2 Equipment

#### 4.2.1 Laboratory-based equipment

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Photo/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SphygmoCor unit</td>
<td><img src="image" alt="SphygmoCor unit" /></td>
</tr>
<tr>
<td>Notebook computer with SphygmoCor software installed</td>
<td><img src="image" alt="Notebook computer" /></td>
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#### 4.2.2 Smaller equipment/instruments

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<td>Large bone calliper</td>
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<td>Stopwatch or timer</td>
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### 4.2.3 Consumables

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<td><img src="image1" alt="Alcohol swabs" /></td>
</tr>
<tr>
<td>Surgical razor</td>
<td><img src="image2" alt="Surgical razor" /></td>
</tr>
<tr>
<td>ECG electrodes and leads</td>
<td><img src="image3" alt="ECG electrodes and leads" /></td>
</tr>
<tr>
<td>Fine tip marker</td>
<td><img src="image4" alt="Fine tip marker" /></td>
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</tbody>
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### 4.2.4 Personal Protective Equipment (PPE)

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<tbody>
<tr>
<td>Lab coat</td>
<td><img src="image5" alt="Lab coat" /></td>
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5 Training/qualifications/competencies

This section should provide details of any training and inductions that must be completed prior to undertaking this method.

Please indicate (check the box) to indicate which of the following is required prior to undertaking this method:

<table>
<thead>
<tr>
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<th>No</th>
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<td>☒</td>
<td></td>
</tr>
</tbody>
</table>

If yes, please provide details: In-house training.

| ☐  | ☒  | Formal qualification required |
| ☒  |    | Other specific requirements |

6 Restricted access

The use of this method is restricted to individuals who have undergone training under someone who has experience with using the Sphygmocor device.

7 Health and safety / Risk Assessment

There are no apparent risks with using this device, nor the assessment procedure using this device.
8 Workflow

8.1 Equipment set-up

- Connect the SphygmoCor unit to the laptop via USB (use the bottom port, on the right of the laptop)
- Connect the ECG leads and footswitch to the SphygmoCor unit
- Connect the Laptop to the power and switch on.
- Log-in; open the SphygmoCor software.
- Enter patient details (see below)
- Enter study details (see below)

8.2 Initial measures

- Check the patient is fasting, and has consumed no caffeine.
- Remove shoes and measure height of sternal notch on the stadiometer.
- Palpate and locate the right brachial artery, use a fine tip pen to mark the location.
- Using the stadiometer, measure the height of the brachial artery indicated by the marked location.

8.3 Patient set-up

- Patient should be in a gown.
- Once the patient lies down for the first test of the morning (BIA), a stopwatch or timer should be used to ensure they are in the supine position for 10 minutes before commencing data collection.
- Place ECG electrodes and connect the leads in a II lead configuration (see below)

8.4 Data collection and data handling

- Enter the diastolic and systolic blood pressure values that have been obtained from the cuff sphygmomanometer. Use the mean of two measures taken 1 min apart in the supine position.
- Wait 2 minutes.
- During the PWA data capture, use the tonometer to identify the brachial and posterior tibialis (PT) sites to be used in PWV – a site where a clear waveform can be observed should be selected.
- Mark the brachial and PT sites using a fine tip marker.

**Comparison and correction of the brachial site**

1. Compare the brachial site located using the tonometer to the measured brachial site identified earlier by palpation.
2. The second measure (i.e. the brachial location measured with the tonometer) is the correct location to be used; therefore the measured distance must reflect this location.

3. If there is a difference between the two marks, measure the distance (cm) between both brachial sites marked. If the correct site is superior, the measured difference must be added to the brachial distance measured earlier on the stadiometer. If the correct site is inferior, the measured difference must be subtracted from the brachial distance measured.

4. This corrected brachial distance measurement (cm), is the number that will be entered into the computer for PWV data collection.

- Conduct PWA (see below)
- Check quality and repeat if necessary (see below)
- Remove the patient’s pillow
- Measure the distances for PWV (see below)
- Conduct PWV (see below)
- Check quality and repeat if necessary (see below)
- Replace the patient’s pillow
- Conduct HRV (see below)
- Remove ECG leads, close down the software and continue with the next assessment

8.4.1 Selecting a database

It is important to select the correct database before creating a new patient. Subjects cannot be moved from one database to another.

To select the appropriate database, select ‘Database manager’ from the ‘System’ menu.

Highlight the database you want to use and click the ‘Select’ button. Click ‘Ok’.

8.4.2 Patient entry – select or enter a new patient

Open the ‘Patient’ screen by clicking on the ‘Patient’ button. This screen will allow you to create a new patient entry or select a patient that is already present in the database.

To create a new patient entry, select the ‘Create New’ button and enter the patient details.

Once you have finished entering the patient details, click on the ‘Update’ button to add the details of the patient to the database.

To select an existing patient from the database, you may choose the patient by one of the following means:

- Scroll down the list of patients and click on the row to select that patient. If you click on the heading ‘Family name’ at the top of the browser this will place the patients in alphabetical order. When the patient is selected the patient name is highlighted.

OR
• Place the cursor in the ‘Patient Search’ field and enter the patient’s family name. Click the ‘Search’ button or press ‘Enter’ and the system will select the patient whose family name is the closest match. Ensure the patient you wish to select has been highlighted.

**Note:** Before creating a new patient entry, please check that the patient does not already exist in the database, as separate patient entries cannot be merged.

### 8.4.3 Pulse wave analysis

#### 8.4.3.1 Entering study details

**While still in the ‘Patient Screen’;** select ‘PWA’ mode by clicking on the ‘PWA’ button on the left-hand side of the screen.

**Open the Study Screen** by clicking on the “Study”. This screen will allow you to enter the study details and to proceed to ‘Capture data’.

For measurements taken at the radial artery:

- Click the ‘radial’ check box.
- Enter the diastolic and systolic blood pressure values that have been obtained from the cuff sphygmomanometer. Use the mean of two measures taken 1 min apart in the supine position.
- The Medication, Notes, Operator and Anthropometric fields are optional.

At least 2 minutes should elapse between taking the blood pressure and performing the tonometry reading.

#### 8.4.3.2 Performing the data capture

**To proceed to the capture data** screen, click on the ‘Capture Data’.
8.4.3.3 Placement of the tonometer

- **Figure 1**
- Feel for the location of the strongest pulse at the radial artery of the patient’s **right** wrist, and place the tonometer on the skin at this point. The best results are obtained if the patient’s wrist is bent slightly downwards, in the ‘dorsiflex’ position. You may wish to support the patient’s wrist in your hand or place a small pillow or rolled towel under the patient’s wrist for support.
- Gently press the tonometer into the skin until a waveform signal appears on the screen. If the trace is off the screen, a straight line will be drawn across the horizontal axis of either the top or bottom of the signal screen, indicating that either too much or not enough pressure is being applied, respectively.
- The tonometer should be perpendicular to the wrist and adjustments to the position should be made until a strong, accurate and reproducible waveform is displayed in the ‘Signal detail’ window. This signal will be automatically re-scaled and zoomed to fit the waveform within the signal detail window every 5 seconds.

At this point you should **identify the brachial and posterior tibial sites and lightly mark them in preparation for PWV testing**. A sharp initial upstroke on each wave is most important for these sites rather than a large consistent waveform. The right side should be used for all measures – if the left side needs to be used due to physical/medical reasons then this should be indicated on the data sheet and the left side must be used on that patient for all timepoints.

8.4.3.4 Capturing the waveforms

- **Once you have achieved a consistent radial pressure waveform**, hold steady for at least 12 seconds (equal to approximately 3 screen sweeps of waveforms) press the ‘Space Bar’ on your keyboard or press the foot switch.

*Examples of typical, good quality radial waveforms*

Each waveform should have a sharp initial upstroke. The series of waveforms should have consistent peaks and troughs, and the contour of the waveform; in particular the peak pressure and shoulder, should be identical.
Examples of poor raw radial waveform data

8.4.3.5 Examine the report for quality control

After you have completed the data capture, the ‘Report Screen’ will be automatically displayed. This can also be recalled at any time by selecting the patient in the ‘Patient Screen’ and pressing the ‘Report’ button.

Operator Index

- The main quality control parameter is the Operator Index. This is displayed on both the Clinical and Detailed Screen. The Operator Index is a number that is calculated from a weighting equation using four quality indices.
- The Operator Index range is 0-100. As a general guide, if the Operator Index is ≥ 80 it is considered acceptable. If the Operator Index is ≤ 79 the recording is unacceptable and should be repeated.

8.4.4 Pulse wave velocity

8.4.4.1 Entering study details

While in the ‘Patient Screen’; select PWV mode by clicking on the ‘PWV’ button on the left-hand side of the screen.

Open the Study Screen by clicking on the ‘Study’. This screen will allow you to enter the study details and to proceed to ‘Capture data’.

Mandatory fields to be selected or entered:

- Select the box corresponding to the site where the measurement is to be taken.
  - Site A is the brachial site at which the first measurement is to be taken and;
  - Site B refers to the PT/DP site at which the second measurement will be taken.
• **Enter the blood pressure** (systolic and diastolic) that has been obtained from the cuff sphygmomanometer before PWA.
• The Capture Time is set to a default of 10 seconds for both the Site A and Site B measurements.

### 8.4.4.2 Measuring the Sites

- The distance should be measured on the right side and entered as the **distance to the nearest 1 millimetre directly between each artery location and the suprasternal notch** are entered in the proximal and distal boxes.
- Palpate for the supra-sternal notch and identify the point immediately superior to the sternum.
- With the patient standing upright in the anatomical position with the head facing straight, using a stadiometer:
  - Measure and record the distance from the sternal notch to the floor (Figure 2).
  - Measure and record the distance from the marked brachial site to the floor (Figure 3).

**IMPORTANT:** It is essential that you check the brachial location using the tonometer, when the patient is lying down and adjust and correct for any differences once the actual brachial location has been marked. Please refer to Order of Testing, 4 Data Collection, Comparison and correction of the brachial site.

- Using a large bone caliper, measure and record the distance from the base of the foot to the marked posterior tibial site while the patient is lying supine – ensure that the blade of the calliper runs along the length of the foot and that the foot is dorsi flexed to 90° (Figure 4).

**Figure 2**
Rest corner of stadiometer on sternal notch

**Figure 3**
Bottom edge of stadiometer in-line with marked site

**Figure 4**
Distance from the base of the foot to the marker posterior tibial site
8.4.4.3 Placement of ECG leads

- To ensure a stable, artefact free ECG, the skin should be properly prepared (hair removed at electrode site and skin cleaned with an alcohol wipe), and the electrodes positioned correctly. The ECG leads should be positioned as shown in the diagram.

- This is a Lead II configuration. The leads can be placed either on the limbs or on the chest area if required for stronger QRS levels.

8.4.4.4 Performing the data capture

- **To proceed to the capture data screen**, click on the ‘Capture Data’.

- Once the ECG trace is visible on the screen and is steady, proceed as follows:
  - Check that the R wave on the ECG trace is the tallest part of each ECG waveform, noting that this may require adjustment of the ECG cables or ECG electrodes.
  - **The tonometer should be placed at the artery defined for Site A (brachial).** A strong, accurate and reproducible waveform should have already been identified during PWA at the marked site. This signal will be automatically re-scaled and zoomed to fit the waveform within the signal detail window every 5 seconds.
  - **When you are satisfied that you have a good reading**, press the ‘Space Bar’ on your keyboard or click the footswitch.
  - A prompt window will appear confirming that the signals have been captured successfully.
• When you are ready to proceed to take the reading at Site B, click the OK button or press the footswitch. If you wish to take the reading again, click No and repeat the reading at Site A.

• Repeat the process by placing the tonometer on the artery defined for Site B (posterior tibial) and proceed with the capture when you have obtained a signal of satisfactory quality. A prompt box will appear to confirm that the signal was captured successfully. If you are satisfied with the reading at Site B and wish to proceed to the report, click OK. If you wish to repeat the reading at Site B, click No and repeat the reading at Site B.

8.4.4.5 Examine the report for quality control

After you have completed the data capture, the Report Screen will automatically be displayed. This can also be recalled at any time by selecting the patient in the Patient Screen and pressing the ‘Report’ button.

Check that information was entered correctly on the Study Screen. If the patient data is incorrect, click the patient tool-bar button to return to the Patient Screen and update patient details. If the study data is incorrect, click the ‘Recalculate’ tool-bar button to open the SphygmoCor Recalculate Report window.

8.4.4.6 Quality Control Checks

• The tonometry waveforms should be clear and smooth and it is important that the foot of the waveform is easily identified. The quality control parameters used in PWA may assist in assessing the quality of the tonometry waveform and are displayed to the right of the waveforms.

• The green dots on the waveforms indicate the marker for calculating timing from the waveform to the ECG (onset points) and it is important that these are in a similar location on each waveform.

• The R wave on the ECG should be the tallest part of the ECG trace and the green dots should be located at the top of the R wave and not on any other part of the ECG trace.

• The SD(ms) in the statistical table (i.e. for each of the site A and B measures) should be below 6% of the mean time. If the SD is above 6% it will appear in red. Repeat the reading.

Note: Do not relate to the patient your impression of their PWV/arterial stiffness based on the clinical norms on the report screen. These norms relate to carotid-femoral measures and are different from this novel brachial-ankle method.
8.4.5 Additional comments on performing brachial and posterior tibial measurements

**Brachial Measurement:**

The operator should feel for the position for the strongest pulse at or above the bicipital aponeurosis, medial to the biceps tendon, and place the tonometer directly on the top of the skin at this point. The operator can be standing or seated to one side. A pillow may be placed next to the patient to allow the operator to rest their forearm to ensure that the tonometer and wrist remain steady during the measurement. On leaner subjects a clearer pulse wave may be observed at a slightly more proximal site.

![Brachial Measurement Image]

**Posterior Tibial Measurement:**

The operator should feel for the position for the strongest pulse. The posterior tibial artery pulse can be palpated posterior and inferior to the medial malleolus. The pulse wave can generally be obtained with the foot resting at a natural angle, but on certain individuals a better wave form may be obtained with either the foot in neutral (perpendicular to the bed), or with slight external rotation and passive dorsi flexion provided by the operator.

![Posterior Tibial Measurement Image]

**If a reading at the posterior tibial site cannot be obtained:**

Take a reading (and new distance measure) from the left leg, or from the dorsal pedis artery of the right foot. Make a note of this on the data collection sheet so any follow-up assessment can be done at the same site.
8.5 Cleaning and equipment maintenance

The tester must first unplug the SphygmoCor from the electronics module from the computer. Then, using a damp cloth with mild detergent, the equipment is gently wiped after each use. Use a 70% Isopropyl Alcohol (IPA) impregnated wipe or spray for low-level disinfection. Allow a contact time of at least 5 minutes. Ensure excess liquids or cleaning agents are wiped immediately from the equipment.

8.6 Reporting of information

Verbal feedback of the findings is reported to the participants.
9 Supplier and ordering information

Complete the table with the list of items, the manufacturer, reference/order numbers, suppliers, alternative items, other notes to assist in re-ordering or sourcing items.

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<th>Item description</th>
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<th>Supplier</th>
<th>Alternative supplier (if applicable)</th>
<th>Notes</th>
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</table>
| SphygmoCor unit and software      |              | **Company name:** AtCor Medical –West Ryde Corporate Centre  
**Name of contact:** Service department  
**Contact details:** Suite 11, 1059-1063 Victoria Rd, West Ryde (Sydney) NSW 2114 Australia  
**Email:** inquiry@atcormedical.com  
**Web:** www.atcormedical.com  
**Phone:** 02 9874 8761 | NA           |                                 |                                      |       |
10 Appendices