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1. Introduction

Although most of the pathological conditions associated with complicated pregnancies seem to resolve after delivery, there are differences during the postpartum period between women with normal pregnancies and those whose pregnancies were complicated with hypertensive disorders, gestational diabetes or fetal growth restriction. The highest risk for development of chronic hypertension is within the first few years after birth and these women have higher risk of early cardiac, cerebrovascular and peripheral arterial disease.

Since cardiovascular disease is the leading cause of death in women, it is important to identify those who should have screening for cardiovascular risk at a younger age. The postpartum period gives us the opportunity of not only assessing women’s cardiovascular risk but also for future pregnancy counselling about the importance of weight loss between pregnancies, and of routine exercise and a healthy lifestyle.

In a recent study (1), cardiovascular assessment was performed in postpartum women at 1 and 3 years postpartum. The risk of cardiovascular problems was not different between the 2 visits. Therefore, screening should take place within the first year postpartum because:

- Waiting does not seem to increase the chance of identifying a greater number of women with cardiovascular risk factors.
- Delaying intervention for those women potentially allows the disease process to progress and become more established, which may make it less likely to be reversible.
- Having a later visit increases the chance of loss to follow-up.
- It is a relatively short time postpartum, but enough for the normal physiologic changes of pregnancy to resolve.

At one year of postpartum, women with previous hypertensive disorders of pregnancy show:

- High blood pressure (mostly a rise in diastolic pressure), peripheral arterial resistance, heart rate and body mass index.
- Low cardiac output.

However in postpartum women with normal pregnancies, we should expect to see normal blood pressure, higher cardiac output, lower peripheral resistance and lower heart rate.


2. Introduction to the devices

In DYAD visit 2, we will carry out a cardiology assessment using two devices: Ultrasonic Cardiac Output Monitor (USCOM) and Arteriograph.

Using the Arteriograph, we will ask you to record the following information:

1. What is the woman’s pulse wave velocity?

PWV on the screen
2. What is the woman’s augmentation index?
   **Aix aortic** on the screen

Using the USCOM device, we will ask you to record the following information.

3. What is the woman’s heart rate?
   **HR** on the screen

4. What is the woman’s systemic vascular resistance index?
   **SVI** on the screen

5. What is the woman’s systemic vascular resistance?
   **SVR** on the screen

6. What is the woman’s Stroke Volume?
   **SV** on the screen

7. What is the woman’s Stroke Volume Index?
   **SVRI** on the screen

8. What is the woman’s Cardiac Output?
   **CO** on the screen

9. What is the woman’s Cardiac Index?
   **CI** on the screen

### 2.1 Arteriograph®

The Arteriograph® records maternal arterial stiffness and central pulse wave reflection. The Arteriograph® measures pressure fluctuations in the brachial artery by the cuff and the signals are transmitted wirelessly to a computer, which contains software for analysis.
2.1.1 Set up the Arteriograph®

1. Turn on the device by pressing the main button twice.

2. Start the Program by double-clicking the Arteriograph® icon on the desktop.

3. Log in to the software using your username.

4. The main program screen will display.

5. After login, you must create a new patient.

Create a new patient

1. Select the New patient command in the File menu or click on the New patient button on the toolbar at the top of the screen.

2. Enter the patient’s details in the New Patient screen. The fields in pale yellow (including date of birth, the height, and the upper arm circumference) are mandatory. The participant’s date of birth, height, weight and upper arm circumference are available on the data collection database (ODK-X), which you can access from the tablet.

3. The patient’s jugular – symphysis (JUG-SY) is automatically calculated by the arteriograph based on the patient height. To activate the automatic mode follow the steps on the screenshot:
2.1.2 Taking the measurement

1. Select **PW read** under **Tools** or press the **START** button on the toolbar.

2. When starting a measurement, a confirmation window will pop up with measurement information.
To achieve good measurement quality always use the cuff suggested by the software.

3. Wrap the cuff around the participant’s dominant upper arm.

4. Make sure that the cuff is tightened properly, without causing harm to the patient.

   The cuff should fit the patient’s arm evenly. Tightness is sufficient if your finger cannot or can only be inserted under the cuff with difficulty. Make sure that the patient’s skin is not pinched by the cuff.

5. Once the cuff has been fitted to the patient’s arm press Yes to start the measurement process. If these data need to be modified, press No and edit the patient’s characteristics.

6. The measurement process starts with the software connecting to the Arteriograph device. The progress can be tracked on the monitor and "CONNECT" will appear on the LCD of the Device.

7. After a short time, measurement will start automatically by performing a blood pressure measurement first. After this, the pulse wave recording is performed.

8. During the measurement there is a real-time data transfer enabling the user to see the recorded oscillatory waves on the screen. At the end of the examination the Device transmits the blood pressure values to the computer.
9. After the measurement is completed the automatically calculated blood pressure and arterial function data appear in the **Results** field, while the **recorded pulse wave** curves are displayed in the main window.

10. Collect the following information in the database:
   - Augmentation index: **Aix aortic**
   - Pulse wave velocity: **PWV**

11. Every examination is saved automatically
12. The Device can be turned off by pressing the **main button** twice.

2.1.3 Best Practice using the Arteriograph®:

- Ask the participant to lay down on her back. Before taking the measurement, the patient should remain still and at mental rest for 5 minutes.
- Put the cuff on the dominant arm.
- Connect the hose of the cuff to the air connector of the Device. Push the plug on the hose into the air connector of the device and twist the plug slightly until it securely clicks.
• Inform the woman that there will be two or more puffs during measurements
• Explain what the patient will experience
  o Tight feeling
  o Minor discomfort perhaps
  o Pins and needles in fingers
• Ask the participant not to talk or move during the measurement.

2.1.4 Common Errors
If the cuff is too large or loose the results field will appear empty. The error message “Small amplitudes!” may also appear on the screen.

The cuff should not contact the patient’s chest during the measurement because the respiratory movements may cause pressure alterations and artefacts in the cuff.

2.1.5 Quality Control

Standard deviations are automatically calculated by the software. Large standard deviation of the measured data indicates some disturbance in the measurement.

Repeat measurements if:

• Standard deviation (SD PWVao) is greater than 1.1 or if there is no SD.
  The SD appears in red colour in the Results field to warn the user.
• There are no numbers in the results field except BP
• Bluetooth connection between the Arteriograph® and the computer was disrupted during processing
• Error Messages

Error codes will appear in the LCD screen, their explanation is specified below. Please note that errors can occur due to patient movement.
2.1.6 Care and Maintenance of the Arteriograph®

<table>
<thead>
<tr>
<th>Error Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>“low battery” Measuring was disrupted because of low battery.</td>
</tr>
<tr>
<td>31</td>
<td>“cuff missing” The cuff is not connected to the Device.</td>
</tr>
<tr>
<td>32</td>
<td>“cuff clogged” The rubber hose of the cuff is blocked or something is choking the hose.</td>
</tr>
<tr>
<td>33</td>
<td>“air leakage” The cuff (or the Device) leaks.</td>
</tr>
<tr>
<td>34</td>
<td>“the cuff is not on the arm” While connected to the Device, the cuff is not put on the patient.</td>
</tr>
<tr>
<td>35</td>
<td>“measuring disrupted” For some reason (e.g. the user presses the button) measuring is disrupted.</td>
</tr>
<tr>
<td>37</td>
<td>“the cuff pressure is exceeded 300mmHg” During the blood pressure measurement the cuff pressure has reached or exceeded the maximum allowable pressure of 300mmHg’s value.</td>
</tr>
<tr>
<td>90-99</td>
<td>“Device error” Blood pressure measuring failed for some Device error or the battery is low.</td>
</tr>
<tr>
<td>100</td>
<td>“Faulty measuring result” The calculated results cannot be considered as a real blood pressure value or the patient is having arrhythmia.</td>
</tr>
<tr>
<td>101</td>
<td>“motion” The measuring conditions, e.g. the patient’s movement, interfere with the process of measuring.</td>
</tr>
<tr>
<td>102</td>
<td>“no pulse detected” For some reason the Device does not detect the cardiac pulses.</td>
</tr>
<tr>
<td>110</td>
<td>“Faulty measuring result” The signals are insufficient for blood pressure calculation. (Artifacts, arrhythmia.)</td>
</tr>
<tr>
<td>111</td>
<td>“Faulty measuring result” The calculated results cannot be considered as a real blood pressure value. (The most likely reason is noisy measurement signals.)</td>
</tr>
<tr>
<td>115</td>
<td>“Faulty measuring result” The pulse rate cannot be calculated or cannot be considered as a real value.</td>
</tr>
</tbody>
</table>
a) Cleaning
• Clean/disinfect the cuff sleeve as and when needed. A light shirt can be worn under the cuff.
• For disinfecting the cuff sleeve, it is recommended to use alcohol-based disinfectant or isopropanol (70%)
• Please leave the solution to dry completely before storing or reusing the cuff.
• Take the bladder and the tube carefully out of the cuff sleeve before disinfection. The bladder and tube may be damaged by disinfectants.

b) Charging
• Arteriograph® is a battery-operated device (4 durable alkaline AA batteries).
• If the voltage drops below 4.4V, the batteries must be replaced. A warning symbol of low battery appears on the LCD.

LOW BATT

c) Security and Care of Devices
• If you do not intend to use the device for a longer period, remove the batteries and store them in a dry and cool place out.
• The manager of each area should allocate a safe designated place for the devices to be stored when not in use.
• Devices are portable and where possible should be attached to firmer objects such as trolleys or tables.
• Never attempt to open the devices, keep them out of direct sunlight and away from moisture.
2.2 Ultrasound Cardiac Output Monitor (USCOM®)

The Ultrasound Cardiac Output Monitor (USCOM®) records maternal cardiac output and systemic vascular resistance using a small Doppler probe positioned in the suprasternal notch with the ultrasound beam directed towards the aortic outflow tract.

2.2.1 Set up the USCOM for a patient examination

1. Place the USCOM unit on a firm stable base within one metre of the patient.

2. Plug the USCOM power supply into a mains power outlet and connect the power supply to the connector on the rear of the USCOM unit (the USCOM unit can run on battery for up to two hours provided that the battery is adequately charged).

3. Press the ON/OFF button on the front of the unit. The unit will perform internal diagnostics, set defaults and launch the USCOM application.

4. Plug the Transducer into the rear of the USCOM unit.

5. The WELCOME screen is displayed. Press the LOG IN button.
6. After login, the WELCOME screen will reappear. You must create a new patient before taking the measurements.
Create a new patient

1. From the **WELCOME** screen touch **NEW PATIENT**

2. The **PATIENT DETAILS** screen will appear. Enter the participant’s details including
   - Name, date of birth, weight, height, sex
   - and patient ID.
   - Set reading to “**AORTIC**”
   - Press **OK**.

3. The **EXAMINATION** screen will be displayed.

2.2.2 Taking the measurement

1. Ask the participant to lay down on her back.

2. Apply ultrasound gel to the underside of the transducer.

3. Place the USCOM probe in the suprasternal notch (dip in the neck, between the clavicles above the sternum.)

4. From the Examination screen, touch **START (4)** to commence sampling. Once **START** has been selected, the button legend changes to **FREEZE**.
5. Slowly increase the pressure and rotate probe upwards until at 90° to the clavicle.

6. Remain in this position and slowly rotate probe left and right until the strongest sound and highest peaks are recorded in the **Doppler Spectral Display**.

7. Maintain the probe in the position where the strongest sound and highest peaks are recorded and allow the USCOM to collect data until at least 20 seconds of stable trace has been observed. Touch **FREEZE** to stop acquiring data, the last 20 seconds of data will be available.

8. Quality control: check the shape of the waves using the arrows under the blue waves.

To obtain a good quality wave you must:

a. Be able to see the tip of the wave. If you cannot see it, you need to modify the scale (so the whole triangle is seen).

b. Intensity of the Doppler signal can be affected by attenuation due to air, fat, bone, calcium or scar tissue. The best Doppler signal is not always well filled or dark.

c. When you see 2 different waveforms, the one from aortic valve is the higher and thinner. The other one is usually shorter and wider. You should focus on the first one.

Bad quality wave:

a. If you cannot see the whole wave, if they have different shapes among them (one is shorter than the other, you cannot find 4-5 similar shape waveforms). In that case, you should continue “recording” until you can see several similar waves to obtain a better evaluation.
Once you press freeze, take the participant BP. Touch the screen anywhere on the value and enter the systolic (BP sys) and diastolic (BP dia) blood pressure then press OK.

9. Touch the screen anywhere on the value a new box should open containing all information.

10. Collect the following data on the database (number in RED):

   Heart Rate: **HR**
   Systemic vascular resistance index: **SVRI**
   Systemic vascular resistance: **SVR**
   Stroke Volume: **SV**
   Stroke volumen index: **SVI**
   Cardiac output: **CO**
   Cardiac index: **CI**
11. Touch **CANCEL** then **SAVE** to store the measurements.

12. Press the **USCOM logo** to return to homepage.

### 2.2.3 Care and Maintenance of the USCOM

#### Cleaning
- The USCOM unit must be turned off and unplugged from the power supply.
- Do not spill or spray water on the display or transducer connector.
- Wipe display, and cables with a cloth moistened with mild liquid soap and water. Do not use harsh or abrasive detergents or solvents.
- Do not clean with abrasive pads.
- Do not wet or immerse.

#### Battery

The USCOM unit can operate from a battery for up to 2 hours. The battery provides information such as battery time remaining.

Battery status is displayed on the Examination, History and Trend screens in the top right hand corner.

- When the Battery is charging the following icon is shown
- When the Battery is draining the following icon is shown
• When the Battery is not fitted the following icon is shown

• Touching the Battery icon displays additional information about the Battery. Touch the icon again to remove the information.

Security and Care of Devices

• Do not operate the unit if the transducer is cracked or damaged.
• Handle transducer carefully. Dropping or banging can damage the transducer and reduce signal quality.
• The manager of each area should allocate a safe designated place for the devices to be stored when not in use.
• Devices are portable and where possible should be attached to firmer objects such as trolleys or tables.
• Never attempt to open the devices, keep them out of direct sunlight and away from moisture.