Blood Pressure
Training Guide
Before We Get Started
Welcome to Blood Pressure Training: History, Physiology and Clinical Procedure. In this workbook we will cover Terminology of Blood Pressure; Functions of the Blood; Arteries and Veins; Hypo/Hypertension; Blood Pressure Measurement Technology; History; Noninvasive BPM Today; Auscultatory Method; Oscillometric Method; and Invasive Blood Pressure Measurement Today.

Measuring blood pressure is one of the most commonly performed diagnostic procedures. So it is important to have a clear understanding of what blood pressure is and how to measure it. The goal of this workbook is to provide you with a basic yet thorough understanding of noninvasive blood pressure measurement, and exercises throughout are designed to help you comprehend and retain this information.

Welch Allyn Blood Pressure Training Course Directory
Part I  Introduction
Part II  Anatomy and Physiology
Part III  Hypertension and Hypotension
Part IV  Evolution of BPM Technology
Part V  Invasive Blood Pressure Measurement
Blood Pressure Basics

- Blood pressure is the amount of blood pumped by the heart in relation to the size and condition of the arteries.
- Measured by force of blood on artery walls.
- Measured in millimetres of mercury (mmHg).
- Factors affecting blood pressure:
  - Volume of water in body.
  - Salt content of body.
  - Condition of kidneys, nervous system and blood vessels (arteries and veins).
  - Levels of various hormones in body.

Arterial vs. Venous Pressure

- Arteries take blood away from the heart.
- Arterial pressure is the force exerted by the blood upon the walls of the arteries.
- Veins bring blood to the heart.
- Venous pressure is the force exerted by the blood upon the walls of the veins.
- Blood pressure generally refers to arterial pressure.

Systole over Diastole

- Blood pressure measurement = systolic pressure over diastolic pressure.
- 120/80 mmHg (healthy measurement).
- Blood pressure is highest during systole.
- During systolic pressure, ventricles contract.
- During diastolic pressure, ventricles relax and refill.
- Blood pressure is lowest during diastole.

\[
\frac{120}{80} = \frac{\text{Systolic}}{\text{Diastolic}}
\]
Cardiac Cycle

• Complete cycle of heart events
• Beginning of the first heart beat to the beginning of the next

Systolic Pressure (SP)
• Highest recorded arterial pressure reading
• Occurs near the beginning of the cardiac cycle

Diastolic Pressure (DP)
• Lowest recorded arterial pressure reading
• Resting phase of cardiac cycle

The Cardiac cycle is broken down into four phases.

PHASE 1: Atrial systole
• It occurs when the atria are electrically stimulated and is denoted as the P-wave in an ECG
• This stimulation causes the atria to contract

PHASE 2: Ventricular systole
• It occurs when the ventricles are electrically stimulated and is denoted as the QRS-wave segment in an ECG reading
• This stimulation causes the ventricles to contract, and it is here that we get our systolic pressure reading

PHASE 3: Early diastole
• It is when the heart begins to relax after its stimulation and is denoted as the T-wave in an ECG
• Here the ventricles relax

PHASE 4: Diastole
• The heart finishes up its relaxation period; this moment is denoted as the TP-period in an ECG
• The diastolic pressure reading comes from the diastolic period of phases of the cardiac cycle

MAP and Pulse Pressure

• Mean Arterial Pressure (MAP)
  – Average pressure throughout cardiac cycle
  – ~ = DP + 1/3 (SP-DP)
• Pulse pressure
  – Difference between maximum and minimum pressures measured
  – = (SP-DP)
1. Give a brief but accurate definition of blood pressure in the space provided.

2. Circle the correct word in each bracketed section of the following statements.
   Arteries carry blood [to/from] the heart, while veins carry blood [to/from] the heart.
   When we refer to blood pressure, we generally refer to [arterial/venous] pressure.

3. How is a blood pressure measurement written? Circle the correct phrase.
   A. Diastole over Systole
   B. Systole over Diastole

4. Name 4 phases of the cardiac cycle.
Functions of the Blood

- Transports oxygen from lungs to all body cells
- Transports all nourishment to cells, including monosaccharides, amino acids, fatty acids, glycerol, vitamins, mineral salts and water
- Removes all waste products from tissues and cells and takes to appropriate organ for excretion or to the liver in preparation for excretion
- Transports hormones and enzymes to target organs
- Defends body by transporting white blood cells, antibodies and antitoxins
- Prevents excessive loss of body fluid and cells by clotting
- Maintains body temperature

Blood and Plasma

Blood
- Highly specialized tissue
- Consists of several types of cells
- Cells are suspended in a fluid medium called plasma

Plasma
- Faintly yellow transparent fluid
- 90% water
- Floating in plasma are different types of cells
- Plasma transports various dissolved substances from one part of the body to another
Floating in Plasma

Nutrient Materials
- Amino acids, glucose, fatty acids, glycerol and vitamins
- Absorbed from digestive tract

Organic Waste Products
- Urea, uric acid and creatinine
- Produced by protein metabolism (formed in the liver and conveyed to the kidneys)

Hormones
- Chemical substances formed by glands
- Pass directly into blood and are transported to target organ

Enzymes
- Proteins act as catalysts to chemical reactions without being used up themselves

Antibodies and Antitoxins
- Protective substances made of complex proteins
- Produced by plasma cells in lymph glands and spleen

Gases
- Oxygen, carbon dioxide and nitrogen
- Dissolve in plasma and are transported via erythrocytes (in plasma)

Cellular Content of Blood
- Erythrocytes (red blood cells) — 45%
- Leucocytes (white blood cells) — 1%
- Thrombocytes (platelets) — <1%
- Remaining 55% is plasma

Erythrocytes
- Erythrocytes give blood colour
- Erythropoiesis is the process of forming red blood cells
  - Form in red bone marrow in extremities of long bones
  - Form in layers of compact bone like sternum and vertebrae
- Two lines of development to a mature erythrocyte
  - Erythrocyte itself
  - Haemoglobin, which transports oxygen
- Survive for 120 days after maturity
- Seven days to mature
- Women usually have a lower normal erythrocyte count
Leucocytes
• Function is to fight disease
• Larger than erythrocytes
• Fewer in number than erythrocytes
• Divided into two main groups
  – Granular (75% of white blood cells)
    • Neutrophils
    • Eosinophils
    • Basophils
  – Nongranular
    • Lymphocytes
    • Monocytes

Thrombocytes
• Small cells
• 300,000 thrombocytes per millilitre of blood
• Involved in blood clotting
• Several factors activate platelets
• Can deplete rapidly
• Aspirin causes dysfunction

Blood Groups
Four Main Blood Groups
• Group A 42%
• Group B 8%
• Group AB 4%
• Group O 46%
All figures above for Caucasians

Circulatory System/Cardiovascular System
Two Main Parts
• Blood circulatory system
  – Heart and blood vessels
• Lymphatic system
  – Lymph nodes and lymph vessels

Blood Vessels
• Arteries (blood from heart)
  – Arterioles
  – Capillaries
  – Destination
  – Venules
• Veins (blood to heart)
Arteries
- Transport blood away from heart
- Arteries vary in size but all have same structure
- Consist of three tissue layers
  - Tunica adventitia—fibrous outer layer
  - Tunica media—smooth, elastic muscular middle layer
  - Tunica intima—epithelium and lumen (inner layer)
  - In large arteries tunica media—more elastic tissue and less muscle
  - In smaller arterioles tunica media—almost all smooth muscle

Veins
- Transport blood to heart
- Consist of three tissue layers
  - Tunica adventitia
  - Tunica media
  - Tunica intima
- Venous walls are thinner than arterial walls (with less muscle and elastic tissue)
- Valves stop backflow of blood
- Valves diminish hydrostatic pressure below heart
Arteries and Veins

Arteries
- High-pressure blood
- Blood flow away from heart
- Mainly oxygenated blood
- Thick walls
- No valves

Veins
- Low-pressure blood
- Blood flow towards heart
- Mainly de-oxygenated blood
- Thin walls
- Valves

Nervous Control
- Veins and arteries are powered by nerves from the autonomic nervous system
- Nerves change the calibre of the vessels, controlling amount of blood circulating
- Changes in calibre result from contraction or relaxation of the blood vessel’s muscular wall
- Small and medium vessels are easier to control (they have more muscle than elastic tissue)
- Larger vessels (e.g., the aorta) are more difficult to control (they are more elastic and have less muscle tissue)

Cell Respiration
- Internal/cell respiration—the interchange of gases between the blood and the cells of the body
- Oxygen from the arteries diffuses through the arterial end of the capillary wall into the tissue fluid, then into the cell through its semipermeable wall
- Carbon dioxide, a waste product of cell metabolism, diffuses into the blood towards the venous end of the capillary
What is Normal Blood Pressure?
- Impossible to precisely categorize
- 120/80 considered normal for healthy adults
- Systolic pressure 140 mmHg or below
- Diastolic pressure 90 mmHg or below

Variability of Blood Pressure
BP Influenced by:
- Physical activity
- Anxiety
- Pain
- Environmental factors (temperature)
- Psychological factors (mood)
- Can vary between right and left arm

Hydrostatic Effect
- Hydrostatic pressure—static pressure of liquid
- Affected by gravity
- Heart level (mid-right atrium) a reference point for clinical pressure measurements

Pathological Variability of Arterial Pressure
- Cardiac dysrhythmias produce beat-to-beat variation in pulse pressure
- Marked respiratory variation (up to 50 mmHg) restricts normal cardiac filling (pulsus paradoxus)
- Mechanical ventilation causes cyclic changes of systolic arterial and pulse pressure in hypovolaemic patients
Summary Quiz on Part II

1. Give a breakdown by percentage of the cellular content of blood.
   Erythrocytes  ___ %
   Leucocytes    ___ %
   Thrombocytes  ___ %
   Plasma        ___ %

2. Finish filling in the letters and circles to represent the compatibility of the four blood groups.

   A

3. What three tissue layers comprise both arteries and veins?
   __________________________________________________________
   __________________________________________________________

4. Why do some veins have valves?
   __________________________________________________________
   __________________________________________________________

5. Define cellular respiration.
   __________________________________________________________
   __________________________________________________________

6. What is considered a normal BP for healthy adults? ______ / _______
Hypertension
• SP consistently > 140 mmHg
• DP consistently > 90 mmHg
• Caused by genetics, environment, diet, etc.

Pre-Hypertension
• Systolic between 120–139 mmHg
• Diastolic between 80–89 mmHg
• On multiple readings
• Pre-Hypertension is not a disease but a description used to identify people at high risk of developing hypertension

Secondary Hypertension
• Adrenal gland tumors
• Cushing’s syndrome
• Renal disorders
• Medications, drugs or other chemicals
• Haemolytic-uraemic syndrome
• Schönlein-Henoch purpura

Symptoms of Hypertension
• Headache
• Tiredness
• Confusion
• Vision changes
• Angina-like pain
• Heart failure
• Haematuria
• Epistaxis
• Tinnitus
• Irregular heart beat

Complications of Hypertension
• Hypertensive heart disease
• Heart attacks
• Congestive heart failure
• Arteriosclerosis
• Aortic dissection
• Renal failure
• Stroke
• Brain damage
• Blindness

<table>
<thead>
<tr>
<th>Blood Pressure Classification</th>
<th>SBP mmHg</th>
<th>DBP mmHg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>&lt;120</td>
<td>and &lt;80</td>
</tr>
<tr>
<td>Prehypertension</td>
<td>120–139</td>
<td>or 80–89</td>
</tr>
<tr>
<td>Stage 1 Hypertension</td>
<td>140–159</td>
<td>or 90–99</td>
</tr>
<tr>
<td>Stage 2 Hypertension</td>
<td>≥160</td>
<td>or ≥100</td>
</tr>
</tbody>
</table>
Treatment of Hypertension

Medications
- Diuretics
- Beta-blockers
- Calcium channel blockers
- Angiotensin-Converting Enzymes (ACE) inhibitors
- Others

Lifestyle changes including
- Weight loss
- Exercise

Hypotension
- SP consistently < 90 mmHg
- DP consistently < 60 mmHg

Three main types
- Orthostatic hypotension—sudden change in body position, usually from lying down to standing up
- Neurally mediated hypotension (NMH)—when standing for long time (usually in children and young adults)
- Severe hypotension—brought on by shock

Other Causes of Hypotension
- Medications, drugs, alcohol
- Dehydration
- Heart failure, heart attack
- Arrhythmias
- Syncope (fainting)
- Advanced diabetes
- Shock including anaphylaxis, hypovolaemia, MI, sepsis, etc.

Symptoms of Hypotension
- Blurry vision
- Confusion
- Dizziness
- Syncope
- Light-headedness
- Sleepiness
- Weakness

Treatment of Hypotension
- Severe hypotension
  - Emergency treatment
- Orthostatic hypotension
  - Medication review
- NMH
  - Avoid triggers
  - Add extra fluids or salt to diet
Summary Quiz on Part III

1. What does a patient have if:
   SP is consistently greater than 140 mmHg
   DP is consistently greater than 90 mmHg
   (circle correct answer)
   A. Hypotension
   B. Hypertension
   C. Pre-hypertension

2. What does a patient have if:
   SP is consistently lower than 90 mmHg
   DP is consistently lower than 60 mmHg
   (circle correct answer)
   A. Hypotension
   B. Hypertension
   C. Pre-hypertension

3. What are three causes of secondary hypertension?

4. Draw lines to connect the three main types of hypotension with the appropriate treatment.
   - Severe hypotension: Avoid appropriate triggers
   - Neuromediating Hypotension (NMH): Emergency treatment
   - Orthostatic hypotension: Medication review
Part IV
Evolution of BPM Technology

NONINVASIVE VS. INVASIVE
2 NIBP METHODS

- AUSCULTATORY METHOD
  - IMPORTANCE OF CUFF SIZE
- OSCILLOMETRIC METHOD
  - IBP—DIRECT ARTERIAL PRESSURE
**History of Blood Pressure Measurement**

1733
- Reverend Stephen Hales inserts long glass tube upright into horse’s artery
- Pumping action of heart generates pressure, raising blood level in tube

1847
- Carl Ludwig records human blood pressure with kymograph (“wave writer” in Greek)
  - Inserts catheter directly into artery using U-shaped manometer tube with ivory float, rod and quill attached

1855
- Karl Vierordt uses inflatable cuff around arm to pressurize arterial pulse

1860
- Etienne Jules Mary invents sphygmograph
  - Accurate for pulse, not blood pressure
  - Provides first clinical device yielding successful pulse measurement

1881
- Samuel Siegfried Karl Ritter von Basch invents sphygmomanometer
  - Water-filled bag connected to manometer
  - Feels pulse on skin above artery

1896
- Scipione Riva-Rocci develops mercury sphygmomanometer (inflatable cuff over upper arm)

1901
- Harvey Cushing brings Riva-Rocci’s design of the mercury sphygmomanometer to U.S.
  - Today mercury devices are still perceived as most accurate in the manual market

1905
- Nikolai Korotkoff distinguishes systolic blood pressures with sounds at different phases of cuff inflation and deflation
  - Use of stethoscope for Korotkoff sounds makes auscultatory method standard practice

**Blood Pressure Measurement Today**

- Noninvasive measurement
  - Measure occlusion of brachial artery
    - Auscultatory method
    - Oscillometric method
  - Invasive measurement
    - Direct measurement of arterial pressure
      - Placing cannula needle in artery

**Noninvasive Vs. Invasive**

**Noninvasive**
- Routine examinations and monitoring
- Indirect method (external)
- Requires less expertise
- Less accurate than invasive measure
- Simple and quick

**Invasive**
- Restricted to hospitals
- Direct method (internal)
- Generally performed by anaesthesiologist or surgeon
- More accurate than noninvasive
- Requires close supervision
Noninvasive Blood Pressure (NIBP) Uses
- Oldest monitoring parameter (along with temperature and pulse)
- Evaluates general well-being of patient
- Standard monitoring parameter
  - Patients under local, regional or general anaesthesia
  - Operating room (OR)
  - Recovery rooms and post-anaesthesia care unit
- When invasive arterial pressure monitoring is not required
- To compare with invasive pressure readings

Arterial Pressure
Brachial Artery (BA)
- Major blood vessel
- Upper arm (both arms)
- Bifurcates just past elbow
- When occluded, pulse of BA can be felt and measured

Auscultation Vs. Oscillation Methods
Auscultation
(aw-skūl-tay-shōn)

*n.* the process of listening, usually with a stethoscope, to sounds produced by movement of gas or liquid within the body, as an aid to diagnosis

Oscillation
(oss-I-lay-shōn)

*n.* a regular side-to-side movement; vibration
Auscultatory Technique

• Manual method
• Uses microphone (stethoscope) to detect Korotkoff or “K” sounds
• Gauge measures pressure changes in cuff
• Measures SP and DP
• Estimates MAP
• Less convenient than oscillometric technique
• Sensitive to microphone placement and human hearing

Auscultatory Equipment

Auscultation BPM Steps

1. Select cuff size appropriate for the patient’s arm circumference. The applicable range, in centimetres, is printed on each cuff.

2. Wrap the cuff around the arm with the artery index marker located over the brachial artery and with the lower edge of the cuff 2.5 cm above the bend in the elbow.

3. Apply the cuff snugly, allowing room for no more than two fingers.

4. Inflate cuff rapidly to a level 30 mmHg above estimated (or palpatory) systolic pressure.

5. Partially open the valve to allow deflation at a rate of 2 to 3 mmHg per second. As the pressure falls, note systolic pressure and diastolic pressure detected with your stethoscope.

6. Rapidly release the remaining pressure and record measurements immediately. After a minimum of 30 seconds, repeat the above steps for a second reading.
**Korotkoff Sounds**

- Phase I — Sharp thud start of SP
- Phase II — Blowing or swishing sound
- Phase III — Softer thud
- Phase IV — Softer blowing sound that disappears
- Phase V — Silence
- Debate on whether phase IV, phase V or combination best represents DP

**Korotkoff Sounds—Phase IV vs. Phase V**

- Some paediatricians and paediatric cardiologists recommend using Phase IV to describe diastolic pressure
- Phase IV sounds are muffled, less distinct, and softer
- Phase IV should also be recorded in all populations when sounds are heard nearly to a level of 0 mmHg

**Ensuring Accuracy (auscultatory method)**

- Use correct cuff size
- Expel air from cuff before measurement
- Do not place cuff on same extremity as infusion line (impedes IV flow)
- Apply cuff snugly around upper arm (2.5 cm above elbow joint)
- Test by inserting two fingers under cuff
- Place artery marker on cuff over brachial artery
- Arm must be supported and level with heart
- Ensure no tight clothing constricts arm
- Check hose connections to cuff and monitor (sphygmomanometer)
- Movement impedes NIBP readings
- Instruct patient to lie/sit still during measurement
Oscillometric Technique

- Oscillations caused by arterial pressure pulse
- Automatic method
- Senses pressure changes in cuff
- Uses algorithm to calculate systolic and diastolic values
- Not direct measurement of BP
- Measures MAP
- Estimates SP and DP
- Easy to use

Oscillometric Equipment

Oscillometric Method

- Position patient
- Apply cuff (upper arm)
- Inflate cuff (occludes brachial artery)
- As cuff deflates, pressure data is recorded (automatically)
- Over time pressure data looks like waveform
1. Who initially distinguished systolic and diastolic blood pressures by identifying sounds at different phases of cuff inflation and deflation?

2. Correctly complete the sentences below by drawing lines from the words on the left to the corresponding words on the right.

- Noninvasive blood pressure measures
- Arterial pressure directly with a cannula needle
- Invasive blood pressure measures
- Pressure in the brachial artery by its occlusion with an inflatable cuff

3. What is the name of the artery shown in the diagram below?
4. The auscultatory method, or manual NIBP method, requires attention to accuracy. Put the steps involved in taking blood pressure, using the auscultatory method, in the correct order by writing the appropriate number (1–5) next to each statement below.

___ Record results.
___ Place a stethoscope over the patient’s brachial artery (distal to the cuff).
___ Inflate the cuff to occlude the brachial artery.
___ Wrap the cuff around the patient’s upper arm.
___ Listen for the Korotkoff sounds as the cuff deflates.

5. Circle True or False

Using the correct cuff size helps ensure accuracy of blood pressure measurement.

6. The statements below describe the auscultatory method or oscillometric method of NIBP. (circle one)

• Automatic method of measuring blood pressure
• Senses pressure changes in cuff
• Uses algorithm to calculate systolic and diastolic values
• Measures mean arterial pressure
• Estimates systolic and diastolic pressure
• Easy to use
Advantages of Direct Arterial Pressure
- BPM continuously available (patient in critical condition)
- Hemodynamic consequences of arrhythmias readily observed (fast atrial fibrillation, multiple premature beats)
- Arterial tracing is an irreplaceable guide for fluid transfusion therapy in major surgeries
- Repeated blood samples readily obtained (blood gas analysis)

Invasive Blood Pressure Measurement Setup

Part V Invasive Blood Pressure Measurement

1. Monitor
2. Fluid Back
3. Fluid Back
4. Flushing Set and Transducer
5. Specific Cable

Diagram showing cannula needle insertion into different veins.
1. List two advantages of taking direct arterial blood pressure.

2. Write the terms below that correctly name numbers 1–5 in the diagram.

1. __________
2. __________
3. __________
4. __________
5. __________
Congratulations!
You’ve Successfully Completed Blood Pressure Training

NOTES:

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