The measurement of blood pressure and hypertension

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III. Department of Medicine
Recommendations for Blood Pressure Measurement in Humans and Experimental Animals

Part 1: Blood Pressure Measurement in Humans

A Statement for Professionals From the Subcommittee of Professional and Public Education of the American Heart Association Council on High Blood Pressure Research

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(Hypertension. 2005;45:142-161.)
History of the blood pressure measurement

**direct**
Stephen HALE 1726 horse carotid

**indirect**
Riva-Rocci Scipione 1896 inflatable bladder

Korotkoff 1905 auscultation

Коротковъ Николай Сергеевич
Experiment III
Tube in the carotid artery
a modern artist’s conception
The Korotkoff phases

I. Appearance of the first tapping sound

II. Murmur is heard

III. The sounds are crisper and increase in intensity

IV. Distinct, definite muffling of the sound

V. Disappearance of the sound
Technique of measurement

systolic bp : the first phase
diastolic bp : the fifth phase

it used to be a matter of debate

the equipment

sphygmomanometer
rubber bladder and covering cuff
( mercury, aneroid, electronic)

width 40-50 % of arm circumference
if too narrow overestimates
if too wide underestimates

length 80% of arm circumference
1. quiet environment, 5 minute rest
2. Arm at heart level
3. Manometer at eye level
4. Locate brachial artery by palpation
5. Center the bladder over brachial artery, the lower margin 2.5 cm above antecubital space
6. Inflate the bladder and determine the disappearance of the radial pulse
7. Rapidly deflate
8. Position the stethoscope over the palpated brachial artery
9. Inflate rapidly 30 mmHg above determined level
10. Release the cuff at 2-3 mmHg/s speed
11. Note the systolic BP at the onset of two consecutive beats (Korotkoff I)
12. Note muffling : Korotkoff IV disappearance : Korotkoff V as diastolic pressure
repeat after 2 minutes!!
measure by even digits (note the scale!)
right down before you forget !!!!
Recording the pressure and the auscultatory gap: range of Korotkoff sounds

- First of at least two regular sounds (systolic pressure)
- Sound stops—read as false high diastolic pressure 202 if observer stops listening
- Auscultatory gap (no sounds)
- K sounds begin again; may be read as a false low systolic pressure of 192 mm Hg if observer does not inflate high enough
- mm Hg on manometer
- True diastolic pressure—the absence of sound (K5) 144 mm Hg. This is operationally defined as the last regular sound heard.
- Muffling 154 mm Hg
- K phase 4
  The sounds muffle. Record if sounds are heard to zero
Determining the palpated systolic pressure and the maximum inflation level
Blood pressure cuff placement and pulse detection

Figures from: www.images.med
The blood pressure cuff and arm circumference
### Blood pressure cuff sizes, arm circumference ranges, and bladder widths and lengths

<table>
<thead>
<tr>
<th>CUFF SIZES</th>
<th>ARM CIRCUMFERENCE RANGE AT MIDPOINT, cm</th>
<th>BLADDER WIDTH, cm</th>
<th>BLADDER LENGTH, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newborn</td>
<td>&gt;6</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Infant</td>
<td>6-15</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Child</td>
<td>16-21</td>
<td>8</td>
<td>21</td>
</tr>
<tr>
<td>Small adult</td>
<td>22-26</td>
<td>10</td>
<td>24</td>
</tr>
<tr>
<td>Adult</td>
<td>27-34</td>
<td>13</td>
<td>30</td>
</tr>
<tr>
<td>Large adult</td>
<td>35-44</td>
<td>16</td>
<td>38</td>
</tr>
<tr>
<td>Adult thigh</td>
<td>45-52</td>
<td>20</td>
<td>42</td>
</tr>
</tbody>
</table>
Calibrating the manometer

Pump air into the system until the mercury manometer reads standard say 180. Then record the pressure that the aneroid reads. Do this throughout the range to be tested. Aneroid should be ±3 mm Hg.

To test the electronic device connect the pressure sensing input to the Y tube to the Mercury primary standard. Raise and lower pressure in system with the bulb.
Measurement of blood pressure in the clinic
## Interpretation of ABI

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 1.30</td>
<td>noncompressible</td>
</tr>
<tr>
<td>0.95-1.30</td>
<td>normal</td>
</tr>
<tr>
<td>0.41-0.90</td>
<td>mild-to-moderate peripheral arterial disease</td>
</tr>
<tr>
<td>0.00-0.40</td>
<td>severe peripheral arterial disease</td>
</tr>
</tbody>
</table>
Skills a good blood pressure observer must have

4. The brain must be programmed to follow the proper guidelines every time the pressure is measured.

3. Must be able to store the systolic and diastolic pressure and recall them accurately.

1. Be able to see manometer.

5. Must be able to hear the Korotkoff sounds and know how to interpret them.

2. Must be able to find and feel the pulses needed for blood pressure measurement.

6. Must be able to recall and write down correctly and legibly the sounds heard.
The measurement is subjective

1. the observer: hand-eye-ear differences
2. the patient: environment, time of the day
3. Interaction: “white-coat hypertension"
4. Equipment: calibration, random zero etc
5. ABPM: 24 hours monitoring

Special pitfalls: absent phase V, auscultatory gap, arrhythmias, obesity
Measure on both arms and leg supine and standing
How to measure ABI

- Patient resting supine for 5-10 minutes
- Measure Systolic BP in both arms
  - Higher value is denominator of ABI
- Measure Systolic BP in DP and PT
  - Higher value is numerator of ABI
My results mean of 41 measurements

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>9 &lt; 1</td>
<td>104/70</td>
<td>105</td>
<td>70</td>
</tr>
<tr>
<td>12 &lt; 2</td>
<td>142/84</td>
<td>-143</td>
<td>71</td>
</tr>
<tr>
<td>7 &lt; 3</td>
<td>152/114</td>
<td>153</td>
<td>104</td>
</tr>
<tr>
<td>13 &lt; 4</td>
<td>216/110</td>
<td>219</td>
<td>109</td>
</tr>
<tr>
<td>11 &lt; 5</td>
<td>178/70</td>
<td>178</td>
<td>71</td>
</tr>
<tr>
<td>9 &lt; 6</td>
<td>116/78</td>
<td>115</td>
<td>77</td>
</tr>
<tr>
<td>7 &lt; 8</td>
<td>150/108</td>
<td>150</td>
<td>97</td>
</tr>
<tr>
<td>8 &lt; 9</td>
<td>114/78</td>
<td>116</td>
<td>78</td>
</tr>
<tr>
<td>100/68</td>
<td>101</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>14 &lt; 10</td>
<td>266/200</td>
<td>264</td>
<td>189</td>
</tr>
<tr>
<td>11</td>
<td>174/70</td>
<td>176</td>
<td>71</td>
</tr>
<tr>
<td>12</td>
<td>136/74</td>
<td>138</td>
<td>62</td>
</tr>
<tr>
<td>13</td>
<td>212/104</td>
<td>215</td>
<td>103</td>
</tr>
<tr>
<td>14</td>
<td>264/198</td>
<td>265</td>
<td>189</td>
</tr>
</tbody>
</table>

Which was the right measurement?
No answer!! Such is the method.
Special pitfalls

absent phase V: aortic insufficiency
auscultatory gap
arrhythmias,
obesity
Measure on both arms and one leg
supine and standing
In outpatients: sitting, on the right arm
## Classification of Hypertension by JNCVI (1997)

<table>
<thead>
<tr>
<th>Class</th>
<th>Systolic</th>
<th>Diastolic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Optimal</strong></td>
<td>&lt;120</td>
<td>&lt;80</td>
</tr>
<tr>
<td><strong>Normal</strong></td>
<td>&lt;130</td>
<td>&lt;85</td>
</tr>
<tr>
<td><strong>High Normal</strong></td>
<td>130-139</td>
<td>85-89</td>
</tr>
<tr>
<td><strong>Hypertension</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 stage</td>
<td>140-159</td>
<td>90-99</td>
</tr>
<tr>
<td>2 stage</td>
<td>160-179</td>
<td>100-109</td>
</tr>
<tr>
<td>3 stage</td>
<td>≥ 180</td>
<td>≥ 110</td>
</tr>
</tbody>
</table>

This is the presently accepted classification.
<table>
<thead>
<tr>
<th>Category</th>
<th>Systolic</th>
<th>Diastolic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal</td>
<td>&lt;120</td>
<td>and</td>
</tr>
<tr>
<td>Normal</td>
<td>120–129</td>
<td>and/or</td>
</tr>
<tr>
<td>High normal</td>
<td>130–139</td>
<td>and/or</td>
</tr>
<tr>
<td>Grade 1 hypertension</td>
<td>140–159</td>
<td>and/or</td>
</tr>
<tr>
<td>Grade 2 hypertension</td>
<td>160–179</td>
<td>and/or</td>
</tr>
<tr>
<td>Grade 3 hypertension</td>
<td>≥180</td>
<td>and/or</td>
</tr>
<tr>
<td>Isolated systolic hypertension</td>
<td>≥140</td>
<td>and</td>
</tr>
</tbody>
</table>

Isolated systolic hypertension should be graded (1, 2, 3) according to systolic blood pressure values in the ranges indicated, provided that diastolic values are <90 mmHg. Grades 1, 2 and 3 correspond to classification in mild, moderate and severe hypertension, respectively. These terms have been now omitted to avoid confusion with quantification of total cardiovascular risk.
Finally, the mercury sphygmomanometer should probably be abandoned for ecological reasons (ie, the toxicity of mercury). Replacement of office BP measurement with physician-independent methods (ambulatory BP monitoring and home BP self-measurement) is advocated by many guidelines.
Conclusions  The automated device performed as well as an anaeroid manometer operated by well trained, experienced observers. The two alternative devices to the mercury sphygmomanometer examined in this study may be potential replacement devices for blood pressure measurement. *Blood Press Monit* 12:23–28 © 2007 Lippincott Williams & Wilkins.
JNC 7 Express
The Seventh Report of the Joint National Committee on
Prevention, Detection, Evaluation, and Treatment of High Blood Pressure
2003
diastolic blood pressures; shaded vertical areas indicate night-time. (a) Normal ABPM pattern. This ABPM suggests normal 24-h systolic and diastolic blood pressures (128/78 mmHg daytime, 110/62 mmHg night-time). (b) White-coat hypertension. This ABPM suggests white-coat hypertension (175/95 mmHg) with otherwise normal 24-h systolic and diastolic blood pressures (133/71 mmHg daytime, 119/59 mmHg night-time). (c) White-coat effect. This ABPM suggests mild daytime systolic hypertension (149 mmHg), borderline daytime diastolic hypertension (87 mmHg), borderline night-time systolic hypertension (121 mmHg) and normal night-time diastolic blood pressures (67 mmHg) with white-coat effect (187/104 mmHg). (d) Systolic and diastolic hypertension. This ABPM suggests mild daytime systolic and diastolic hypertension (147/
(d) Systolic and diastolic hypertension. This ABPM suggests mild daytime systolic and diastolic hypertension (147/93 mmHg), but normal nighttime systolic and diastolic blood pressures (111/66 mmHg). (e) Isolated systolic hypertension. This ABPM suggests severe 24-h isolated systolic hypertension (176/68 mmHg daytime, 169/70 mmHg nighttime). (f) Hypertensive dipper. This ABPM suggests severe daytime systolic hypertension (181 mmHg), moderate daytime diastolic hypertension (117 mmHg) and normal nighttime systolic and diastolic blood pressures (111/68 mmHg). (g) Hypertensive non-dipper. This ABPM suggests severe 24-h systolic and diastolic hypertension (210/134 mmHg daytime, 205/130 mmHg nighttime).
### TABLE 3. Suggested Values for the Upper Limit of Normal Ambulatory Pressure

<table>
<thead>
<tr>
<th></th>
<th>Optimal</th>
<th>Normal</th>
<th>Abnormal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daytime</td>
<td>&lt;130/80</td>
<td>&lt;135/85</td>
<td>&gt;140/90</td>
</tr>
<tr>
<td>Nighttime</td>
<td>&lt;115/65</td>
<td>&lt;120/70</td>
<td>&gt;125/75</td>
</tr>
<tr>
<td>24-Hour</td>
<td>&lt;125/75</td>
<td>&lt;130/80</td>
<td>&gt;135/85</td>
</tr>
</tbody>
</table>
Blood pressure thresholds (mmHg) for definition of hypertension with different types of measurement

<table>
<thead>
<tr>
<th>Type</th>
<th>SBP</th>
<th>DBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office or clinic</td>
<td>140</td>
<td>90</td>
</tr>
<tr>
<td>24-hour</td>
<td>125–130</td>
<td>80</td>
</tr>
<tr>
<td>Day</td>
<td>130–135</td>
<td>85</td>
</tr>
<tr>
<td>Night</td>
<td>120</td>
<td>70</td>
</tr>
<tr>
<td>Home</td>
<td>130–135</td>
<td>85</td>
</tr>
</tbody>
</table>
Aetiological classification of hypertension

A. Essential hypertension >90%
   prevalence 10-20%
B. Renal hypertension
   1. parenchymal: acute glomerulonephritis,
       chronic nephritis, pyelonephritis
   2. renovascular fibromuscular, atherosclerosis
   3. trauma: perirenal hematoma,
       arterial renal thrombosis, dissection
C. Endocrine
   1. thyroid: hyperthyreosis
   2. adrenal gland: phaeo, primary hyperaldo, congen hyperplasia, Cushing sy
D. Neurogenic: brain tumor, resp acidosis, encephalitis
E. Mechanical: coarctation of aorta, AI
F. gravidity
G. mixed: polycythaemia vera, carcinoid sy burning
A hypertension as a risk factor

**Cardiac**
- hypertrophy, coronary disease, infarction

**Vascular:**
- aortic sclerosis, aneurysm, dissection
- peripheral arteries, carotid !!!

**Kidney:**
- decrease of GFR, renal failure

**Neurological:** encephalopathy, stroke !!!

**Retinal:** retinopathy
Prevalence of isolated systolic and diastolic blood pressure by age and gender
Rate and proportion of cardiovascular disease events by systolic blood pressure level
Risk of myocardial infarction with isolated systolic hypertension in men
Impact of pulse pressure at specified levels of systolic blood pressure

![Graph showing the impact of pulse pressure on CHD hazard ratio.](image-url)
Stroke probability in mildly hypertensive men according to associated risk factors
Risk of peripheral arterial disease by systolic blood pressure and diabetic status

![Graph](image)
A: Systolic blood pressure

Age at risk:
- 80–89 years
- 70–79 years
- 60–69 years
- 50–59 years
- 40–49 years

IHD mortality (floating absolute risk and 95% CI)

Usual systolic blood pressure (mm Hg)
Fig. 1 Ten year risk of fatal CVD in high risk regions of Europe by gender, age, systolic blood pressure, total cholesterol and smoking status.
A most serious epidemic. Unresolved problems

Estimated No. of hypertensives in the USA: **41,9 M**

- unaware of: **31%** **13,1 M**
- aware but not treated: **17%** **7,0 M**
- inefficiently treated: **29%** **12,0 M**
- well treated: **23%** **9,7 M**

19% of population ≥ 65 years, still 45% of all patients who are unaware, are in this age group.

(NEJM 2001;345:479-486)
Association of heart rate with mortality in hypertensive men
Cardiovascular disease rates in women according to echocardiogram-left ventricular hypertrophy and hypertensive status