Can We Trust Ambulatory Blood Pressure Monitors? Approved Monitor Underestimates Diastolic Pressure & Misclassifies Patients

VP Lombardi, DR Taaffe, M Kaltenhauser, DL Pate
1. Health-care providers & clinicians urged to consider advantages of using 24-hr ABPM.

2. ABPMs theoretically appealing – up to 200 values ≤ 24 hr
   a. refine classification of suspected hypertensives,
   b. establish diurnal impact of treatments &
   c. tailor specific plans for optimizing BP.

3. Each step is entirely contingent upon obtaining data that is both accurate & reliable.

4. International (ESH, BHS) & US national (AAMI) approval protocols require testing only for subjects who are seated, yet ABPMs that achieve a passing grade are deemed accurate & reliable over 24-hr when patients assume multiple postures.
4579 articles with key words *ambulatory blood pressure*

91 (~ 2%) contained key word *validation*

17 (~ 0.4%) classified as true validation studies

3 studies measured all postures for all subjects

12 of 19 ABPMs currently available are recommended for use, yet only 2 have been tested for a variety of postures

1 ABPM is approved for multiple body positions

*www.dableducational.org*
KEY QUESTIONS

1. If ABPM accuracy & reliability differ based on posture, could this lead to errors in classifying patients & in comparing data?

2. How do two approved, identical ABPMs differ in assessing same arm BPs simultaneously in the lab & in the field?

3. How do ABPMs differ from clinicians using a Hg column when assessing subjects who assume multiple postures?
Dual Monitor Protocol (DMP): Lab + Field
Dual Monitor Protocol (DMP): Lab + Field

Valve: A1-A2 Sequential vs Simultaneous Testing
### Results Presented Today

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Gender</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 1 Labile HTN</td>
<td>♂</td>
<td>35 yr</td>
</tr>
<tr>
<td>2. 15 Normotensives</td>
<td>8 ♀</td>
<td>7 ♂</td>
</tr>
<tr>
<td>3. 14 Hypertensives</td>
<td>8 ♀</td>
<td>6 ♂</td>
</tr>
<tr>
<td>4. 11 1° ETOH</td>
<td>2 ♀</td>
<td>9 ♂</td>
</tr>
</tbody>
</table>
Original Dual Monitor Field Protocol, 10 hr Case Study, Labile Hypertensive, 35 yr O
151 Simultaneous, Same Arm BPs

<table>
<thead>
<tr>
<th></th>
<th>SBP (mm Hg)</th>
<th>Δ</th>
<th>DBP (mm Hg)</th>
<th>Δ</th>
<th>HR (bpm)</th>
<th>Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>134.3 ± 10.8</td>
<td></td>
<td>86.9 ± 8.8</td>
<td></td>
<td>69.2 ± 7.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.7 ± 4.3</td>
<td></td>
<td>1.7 ± 6.6</td>
<td></td>
<td>-0.6 ± 2.7</td>
<td></td>
</tr>
<tr>
<td>A2</td>
<td>131.6 ± 11.1</td>
<td></td>
<td>85.2 ± 8.8</td>
<td></td>
<td>69.8 ± 7.3</td>
<td></td>
</tr>
</tbody>
</table>

**P < 0.01, ***P < 0.001

NB: A1 & A2 accounted for 85% of SBP variance (R = 0.92) but only 52% of DBP variance (R = 0.72)
Auscultatory Gaps

+ 4-5 mm Hg

95% of t

+ 4-5 mm Hg

15 NTN
8 Q, 7 O
243 BPs

OBSERVER 1 vs OBSERVER 2
DIASTOLIC BLOOD PRESSURE (DBP)

Lab

$R^2 = 0.95$
ACCUTRACKER 1 vs ACCUTRACKER 2
DIASTOLIC BLOOD PRESSURE (DBP)

$R^2 = 0.69$

95% of t

$\pm 10-12$ mm Hg

15 NTN
8 Q, 7 O
243 BPs
OBSERVERS vs ACCUTRACKERS
DIASTOLIC BLOOD PRESSURE (DBP)

Within 16 mm Hg below & 7 mm Hg above
95% of tests

Average 5 mm Hg above!

Up to 15 mm Hg above!

Up to 23 mm Hg below!

Average 5 mm Hg below

15 NTN 8♀️, 7 ♂️
243 BPs

DBP DIFFERENCE, mm Hg

DBP MEAN, mm Hg
OBSERVERS vs ABPMs in NORMOTENSIVES
POSTURAL DIFFERENCES

BP DIFFERENCE (MM Hg)

*** P < 0.001, DBP Supine vs Standing
*** P = 0.006, DBP Seated vs Standing
*** P < 0.001, DBP Standing vs Supine & Seated
OBSERVERS vs ABPMs in 10 ETOH-DEPENDENTS

POSTURAL DIFFERENCES

**P = 0.01, DBP Supine vs Standing

**P = 0.02, DBP Standing vs Supine & Seated
OBSERVERS vs ABPMs IN NORMOTENSIVES
ARM POSITION DIFFERENCES

***P = 0.002

***P = 0.002, DBP Relaxed vs Phlebostatic
OBSERVERS vs ABPMs IN HYPERTENSIVES
ARM POSITION DIFFERENCES

**P = 0.04, DBP Relaxed vs Phlebostatic
OBSERVER CORRECTED VS 24-HR ABPM DIASTOLIC BLOOD PRESSURE (DBP) IN A MEDICATED HYPERTENSIVE (HF-8)

**ABPM**
- DBP = 83 mm Hg
- Normotension

**Observer Corrected**
- DBP = 93 mm Hg
- Stage I Hypertension

**LAB TEST**

**TIME (hr)**
0 2 4 6 8 10 12 14 16 18 20 22 24

**ABPM**
- S = ONSET OF SLEEP
- A = AWAKE
- M = MEDICATION
- C = CIGARETTE
OBSERVER CORRECTED VS 24-HR ABPM DIASTOLIC BLOOD PRESSURE (DBP) IN A PRIMARY ALCOHOL DEPENDENT (ABPSL-4)

**ABPSL-4**

**DBP = 94 mm Hg**
Stage I Hypertension

Observer Corrected

**DBP = 87 mm Hg**
Pre-Hypertension

**S = ONSET OF SLEEP**

**A = AWAKE**

**C = CIGARETTE**

**ABPM**

**LAB TEST**

**TIME (hr)**

0 2 4 6 8 10 12 14 16 18 20 22 24

**DIASTOLIC BLOOD PRESSURE (mm Hg)**

50 60 70 80 90 100 110 120

Observer Corrected
CLINICALLY SIGNIFICANT DIFFERENCES IN ABPM & OBSERVER-CORRECTED NHLBI (1997, 2003) CLASSIFICATIONS OF 1275 ABPM FIELD SYSTOLIC (SBP) & DIASTOLIC (DBP) PRESSURES IN 11 PRIMARY ALCOHOL-DEPENDENTS

<table>
<thead>
<tr>
<th>ABPM vs Observer NHLBI Classification</th>
<th>%SBP Values</th>
<th>%DBP Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>+1 <strong>ABPM 1 Category Above Observers</strong> (eg ABPM indicates Prehypertension, Observers Normotension)</td>
<td>3%</td>
<td>1%</td>
</tr>
<tr>
<td>+0 <strong>ABPM Identical Category as Observers</strong> (eg Both ABPM &amp; Observers indicate Normotension)</td>
<td>85%</td>
<td>44%</td>
</tr>
<tr>
<td>-1 <strong>ABPM 1 Category Below Observers</strong> (eg ABPM indicates Normotension, Observers Prehypertension)</td>
<td>12%</td>
<td>~40%</td>
</tr>
<tr>
<td>-2 <strong>ABPM 2 Categories Below Observers</strong> (eg ABPM indicates Normotension, Observers STAGE I Hypertension)</td>
<td>0%</td>
<td>15%</td>
</tr>
<tr>
<td>-3 <strong>ABPM 3 Categories Below Observers</strong> (eg ABPM indicates Normotension, Observers STAGE II Hypertension)</td>
<td>0%</td>
<td>~1%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Patient</th>
<th>BP Source</th>
<th>SBP</th>
<th>NHLBI Class</th>
<th>DBP</th>
<th>NHLBI Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ᵃ 37 yr</td>
<td>ABPM</td>
<td>129.7</td>
<td>Normal</td>
<td>87.5</td>
<td>Pre HTN</td>
</tr>
<tr>
<td></td>
<td>Δ</td>
<td>127.7</td>
<td>Normal</td>
<td>80.8</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>Δ</td>
<td>2.0</td>
<td>Normal</td>
<td>6.7</td>
<td></td>
</tr>
<tr>
<td>2 ᵃ 37 yr</td>
<td>ABPM</td>
<td>128.4</td>
<td>Normal</td>
<td>89.1</td>
<td>Pre HTN</td>
</tr>
<tr>
<td></td>
<td>Δ</td>
<td>124.5</td>
<td>Normal</td>
<td>80.6</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>Δ</td>
<td>3.9</td>
<td>Normal</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>3 ᵃ 49 yr</td>
<td>ABPM</td>
<td>155.7</td>
<td>Stage I HTN</td>
<td>92.9</td>
<td>Stage I HTN</td>
</tr>
<tr>
<td></td>
<td>Δ</td>
<td>151.2</td>
<td>Stage I HTN</td>
<td>88.4</td>
<td>Pre HTN</td>
</tr>
<tr>
<td></td>
<td>Δ</td>
<td>4.5</td>
<td>Stage I HTN</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>4 ᵃ 32 yr</td>
<td>ABPM</td>
<td>121.8</td>
<td>Normal</td>
<td>86.6</td>
<td>Pre HTN</td>
</tr>
<tr>
<td></td>
<td>Δ</td>
<td>120.2</td>
<td>Normal</td>
<td>79.9</td>
<td>Opt Normal</td>
</tr>
<tr>
<td></td>
<td>Δ</td>
<td>1.6</td>
<td>Normal</td>
<td>6.7</td>
<td></td>
</tr>
<tr>
<td>5 ♀ 29 yr</td>
<td>ABPM</td>
<td>104.5</td>
<td>Optimal BP</td>
<td>80.3</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td>Δ</td>
<td>103.8</td>
<td>Optimal BP</td>
<td>71.2</td>
<td>Optimal BP</td>
</tr>
<tr>
<td></td>
<td>Δ</td>
<td>0.7</td>
<td>Optimal BP</td>
<td>9.1</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>Gender</td>
<td>Observers</td>
<td>ABPM</td>
<td>Δ</td>
<td>BP Status</td>
</tr>
<tr>
<td>-----</td>
<td>--------</td>
<td>-----------</td>
<td>------</td>
<td>-----</td>
<td>----------------</td>
</tr>
<tr>
<td>6</td>
<td>男</td>
<td>31 yr</td>
<td>119.3</td>
<td>1.4</td>
<td>Optimal BP 87.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>117.9</td>
<td></td>
<td>Optimal BP 79.9</td>
</tr>
<tr>
<td>7</td>
<td>男</td>
<td>39 yr</td>
<td>138.7</td>
<td>0.5</td>
<td>Pre HTN 91.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>138.2</td>
<td></td>
<td>Pre HTN</td>
</tr>
<tr>
<td>8</td>
<td>女</td>
<td>35 yr</td>
<td>114.3</td>
<td>4.3</td>
<td>Optimal BP 80.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>110.0</td>
<td></td>
<td>Optimal BP 80.4</td>
</tr>
<tr>
<td>9</td>
<td>男</td>
<td>30 yr</td>
<td>112.5</td>
<td>2.7</td>
<td>Optimal BP 81.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>109.8</td>
<td></td>
<td>Optimal BP 81.9</td>
</tr>
<tr>
<td>10</td>
<td>男</td>
<td>43 yr</td>
<td>120.8</td>
<td>0.4</td>
<td>Normal 92.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>120.4</td>
<td></td>
<td>Normal</td>
</tr>
<tr>
<td>11</td>
<td>男</td>
<td>59 yr</td>
<td>165.1</td>
<td>0.0</td>
<td>Stage II HTN 98.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>165.1</td>
<td></td>
<td>Stage II HTN 98.8</td>
</tr>
</tbody>
</table>
SUMMARY & CONCLUSIONS

1. An approved ABPM significantly underestimates DBP. Two identical model ABPMs have a lower level of agreement than two clinicians using a Hg column.

2. The magnitude of ABPM underestimation is statistically & clinically significant & varies according to posture.

3. Diastolic pressure underestimations are greatest when subjects are awake & standing with the arm relaxed.

4. Variable underestimations may lead to misdiagnosis & mismanagement of patients & to errors in interpreting research results.

5. International (ESH, BHS) & US National (AAMI) approval protocols should be revised to require testing for a variety of postures. Without more comprehensive, postural & activity testing, ABPMs cannot be claimed as approved for truly ambulatory conditions.
DISCUSSION
Are ABPMs truly superior to Clinic BPs in predicting cardiovascular mortality?

Difficulty in Determining Diastolic Endpoint

GRASS MODEL 7P8

TACHOGRAPH

HR RANGE = 68-80 B/MIN, X = 73.3 B/MIN

SPHYGMOMANOMETER

BP = 130/75? MM Hg

Where is DBP?
Standing posture
Elbow relaxed @ side

**Chart Speed = 100 mm/min**

**Sensitivity = 20 mV/cm**

**Deflation Rate = 2.8 mm Hg/s**

**Blood Pressure = 135/85**

Standing posture, Elbow @ Phlebostatic Axis or ♥ level

**Chart Speed = 100 mm/min**

**Sensitivity = 20 mV/cm**

**Deflation Rate = 2.9 mm Hg/s**

**Diastolic??**

**Blood Pressure = 125/50**

**20 mV**
K-Sound Intensity Changes with Activity

- Pre-exercise, Standing, Relaxed Arm
- Post-exercise, Standing, Relaxed Arm

> 2.5 to 3-fold increase in K-sound intensity

15 squat repetitions
Oscillometry Flashlight-Nomogram Effect

Assume PP = C

Auscultatory BP (K-sounds)

Oscillometric BP (Pulses in cuff)

Difficult to determine cut points, especially Diastolic BP
Oscillometry Flashlight Effect

Underestimate DBP
Oscillometry Flashlight Effect

Overestimate SBP
1. Use Dual Monitor Protocol with postural challenges to verify accuracy & reliability

2. Use Correction Factors for 24-hr ABPM values

3. Develop postural & activity adjusting ABPMs

4. Modify AAMI, BHS, & ESH/IP criteria to require postural & activity challenges

5. Reflect back & return to basic physiology
AVERAGE 24-HR DIASTOLIC BLOOD PRESSURE (DBP) vs. LABORATORY STANDING RELAXED ARM DBP IN SUSPECTED HYPERTENSIVES

\[ R = .914, \quad P = .001, \quad R^2 = .835 \]

\[ 24\text{-}hr \text{ DBP} = .61 \times \text{Lab DBP} + 33.0 \]
AVERAGE 24-HR SYSTOLIC BLOOD PRESSURE (SBP) vs. LABORATORY SUPINE PHLEBOSTATIC ARM SBP IN PRIMARY ALCOHOL DEPENDENTS ($1^0$ ETOH)

$R = 0.941$, $P < 0.001$, $R^2 = 0.886$

$$24\text{-hr SBP} = 0.65 \times \text{Lab SBP} + 49.6$$
Comparing Posture & Arm Position for Lab Measurements with 24-hr, Awake & Sleep Systolic (SBP) and Diastolic (DBP) Blood Pressures Obtained by Ambulatory Blood Pressure Monitoring (ABPM) In Medicated & Non-Medicated Hypertensives

<table>
<thead>
<tr>
<th>Lab Position</th>
<th>24-hr R</th>
<th>Awake R^2</th>
<th>Sleep R^2</th>
<th>24-hr R</th>
<th>Awake R^2</th>
<th>Sleep R^2</th>
<th>24-hr R</th>
<th>Awake R^2</th>
<th>Sleep R^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supine</td>
<td>.671*</td>
<td>.516</td>
<td>.555</td>
<td>.762*</td>
<td>.652</td>
<td>.694*</td>
<td>.762*</td>
<td>.652</td>
<td>.694*</td>
</tr>
<tr>
<td>Phlebostatic</td>
<td>P=.048</td>
<td>P=.155 NS</td>
<td>P=.121 NS</td>
<td>P=.017</td>
<td>P=.057 NS</td>
<td>P=.038</td>
<td>P=.017</td>
<td>P=.057 NS</td>
<td>P=.038</td>
</tr>
<tr>
<td>Seated</td>
<td>.680*</td>
<td>.426</td>
<td>.625</td>
<td>.695*</td>
<td>.542</td>
<td>.681*</td>
<td>.695*</td>
<td>.542</td>
<td>.681*</td>
</tr>
<tr>
<td>Phlebostatic</td>
<td>P=.044</td>
<td>P=.253 NS</td>
<td>P=.072 NS</td>
<td>P=.038</td>
<td>P=.132 NS</td>
<td>P=.043</td>
<td>P=.038</td>
<td>P=.132 NS</td>
<td>P=.043</td>
</tr>
<tr>
<td>Seated</td>
<td>.752*</td>
<td>.578</td>
<td>.520</td>
<td>.667*</td>
<td>.760*</td>
<td>.403</td>
<td>.667*</td>
<td>.760*</td>
<td>.403</td>
</tr>
<tr>
<td>Relaxed</td>
<td>P=.019</td>
<td>P=.103 NS</td>
<td>P=.151 NS</td>
<td>P=.050</td>
<td>P=.017</td>
<td>P=.282 NS</td>
<td>P=.050</td>
<td>P=.017</td>
<td>P=.282 NS</td>
</tr>
<tr>
<td>Standing</td>
<td>.327</td>
<td>.174</td>
<td>.400</td>
<td>.800*</td>
<td>.724*</td>
<td>.734*</td>
<td>.800*</td>
<td>.724*</td>
<td>.734*</td>
</tr>
<tr>
<td>Phlebostatic</td>
<td>P=.390 NS</td>
<td>P=.655 NS</td>
<td>P=.286 NS</td>
<td>P=.010</td>
<td>P=.027</td>
<td>P=.024</td>
<td>P=.010</td>
<td>P=.027</td>
<td>P=.024</td>
</tr>
<tr>
<td>Standing</td>
<td>.489</td>
<td>.257</td>
<td>.582</td>
<td>.914*</td>
<td>.828*</td>
<td>.761*</td>
<td>.914*</td>
<td>.828*</td>
<td>.761*</td>
</tr>
<tr>
<td>Relaxed</td>
<td>P=.181 NS</td>
<td>P=.505 NS</td>
<td>P=.100 NS</td>
<td>P=.001</td>
<td>P=.006</td>
<td>P=.017</td>
<td>P=.001</td>
<td>P=.006</td>
<td>P=.017</td>
</tr>
<tr>
<td>Overall</td>
<td>.581</td>
<td>.584</td>
<td>.418</td>
<td>.866*</td>
<td>.768*</td>
<td>.762*</td>
<td>.866*</td>
<td>.768*</td>
<td>.762*</td>
</tr>
<tr>
<td></td>
<td>P=.101 NS</td>
<td>P=.099 NS</td>
<td>P=.263 NS</td>
<td>P=.003</td>
<td>P=.016</td>
<td>P=.017</td>
<td>P=.003</td>
<td>P=.016</td>
<td>P=.017</td>
</tr>
</tbody>
</table>
# Best Lab/Clinic Postures, Arm Positions & Equations for Predicting ABPM 24-hr, Awake & Sleep Blood Pressures in Primary Alcohol-Dependents (1<sup>0</sup> ETOH) & Hypertensives (HTN)

<table>
<thead>
<tr>
<th>Group</th>
<th>Pressure</th>
<th>24-hr</th>
<th>Awake</th>
<th>Sleep</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1&lt;sup&gt;0&lt;/sup&gt; ETOH</td>
<td>SBP</td>
<td>Supine Phlebostatic</td>
<td>Seated Relaxed*</td>
<td>Supine Phlebostatic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$R = 0.941$, $P &lt; 0.001$, $R^2 = 0.886$</td>
<td>$R = 0.921$, $P &lt; 0.001$, $R^2 = 0.848$</td>
<td>$R = 0.864$, $P = 0.001$, $R^2 = 0.746$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24-hrBP = 0.65LabBP + 49.6</td>
<td>AwakeBP = 0.85LabBP + 30.1</td>
<td>SleepBP = 0.79LabBP + 12.7</td>
</tr>
<tr>
<td></td>
<td>DBP</td>
<td>Supine Phlebostatic</td>
<td>Supine Phlebostatic</td>
<td>Supine Phlebostatic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$R = 0.732$, $P = 0.010$, $R^2 = 0.536$</td>
<td>$R = 0.670$, $P = 0.024$, $R^2 = 0.449$</td>
<td>$R = 0.672$, $P = 0.023$, $R^2 = 0.452$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24-hrBP = 0.49LabBP + 45.5</td>
<td>AwakeBP = 0.39LabBP + 57.1</td>
<td>SleepBP = 0.94LabBP - 7.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HTN</td>
<td>SBP</td>
<td>Seated Relaxed</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$R = 0.752$, $P = 0.019$, $R^2 = 0.566$</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24-hrBP = 0.47LabBP + 73.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DBP</td>
<td>Standing Relaxed</td>
<td>Standing Relaxed</td>
<td>Standing Relaxed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$R = 0.914$, $P = 0.001$, $R^2 = 0.835$</td>
<td>$R = 0.828$, $P = 0.006$, $R^2 = 0.686$</td>
<td>$R = 0.761$, $P = 0.017$, $R^2 = 0.579$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24-hrBP = 0.61LabBP + 33.0</td>
<td>AwakeBP = 0.50LabBP + 48.7</td>
<td>SleepBP = 0.51LabBP + 25.3</td>
</tr>
</tbody>
</table>

*NB: For 1<sup>0</sup> ETOH, in predicting Awake ABPM, Supine Phlebostatic ($R = 0.920$, $P < 0.001$, $R^2 = 0.846$; AwakeBP = 0.61LabBP + 58.3) was a close second behind the Seated Relaxed position.
SpaceLabs 90207 Problems with Variability
Underestimation & Special Populations

In pregnancy
In pregnancy
In pre-eclampsia**
In pre-eclampsia
In children
In elderly, supine over all pressures
During hemodialysis

NB:  **SBP Underestimation 10 ± 10 mm Hg
**DBP Underestimation  8 ±  7 mm Hg

See www.dableducational.org for detailed references.
### SpaceLabs 90207 BP Success (S), Error (E) & Movement Artifact (M), Dual Monitor Field Protocol

<table>
<thead>
<tr>
<th>Overall, Limited Motion</th>
<th>Stair Ascent/Descent Only</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S</strong> 81% 81%</td>
<td><strong>E</strong> 19% 19%</td>
</tr>
<tr>
<td><strong>M</strong> (14%) (11%)</td>
<td>(13%) (20%)</td>
</tr>
</tbody>
</table>

**NB:** Both SL1 & SL2 exhibited “run-away” inflations on stair ascent, likely incorrectly perceiving motion artifact as inability to exceed SBP. Both devices largely motion & vibration intolerant.
TWO 24-HR ABPM SPACELABS 90207 UNITS
DUAL-MONITOR FIELD PROTOCOL, LABILE HYPERTENSIVE

Valid Cases SL1 = 137
Valid Cases SL2 = 142
SPACELABS 1 vs SPACELABS 2
DIASTOLIC BLOOD PRESSURE (DBP)
LABILE HYPERTENSIVE (52 yr ♂) FIELD TEST
SIMULTANEOUS, SAME ARM, N = 57 TRIALS

![Graph showing DBP mean vs DBP difference]
AO-pABPM Prototype Model

O = Oscillometric Transducer *
  detects pulse Δs in BP cuff

C = Cone-shaped, velcro cuff **
  5 sizes: large adult, adult, small adult, pediatric, neonatal

A = Auscultatory Transducer **
  piezo-electric curved crystal microphone detects K-sounds

p = pump

MedSmartt ***
AO-pABPM

\[ \begin{align*}
  \text{d} & = \text{distance between components} \\
  \text{i} & = \text{interference potential} \\
  a_1, a_2 & = \text{accelerometers 1 & 2 detect static acceleration, tilt = body position}
\end{align*} \]

*1979, **1992, ***2005-2006
Inclinometers/Posture Sensors

Potential pump types: (1) Piezo-electric pump enables silent pumping & consumes little power, but currently has too low a flow rate, (2) CO2 gas canister which has near-silent pumping but with potential safety issues, & (3) Conventional diaphragm pump which is noisier and has higher power consumption.

NB: Inverted from Anterior view so technical staff can view during baseline calibration and subjects during subsequent testing. The AO pABPM will have an option for blocking column display output, so that subjects may view only Time, Measurement #, Posture, and EC/_Error Codes for 1 min after each field test measurement.