TIPS AND TRICKS FOR FACILITATING TEACHING OF DOPPLER WAVEFORMS AND ANKLE-BRACHIAL-INDEX IN UNDERGRADUATE LEVEL: A PRACTICAL GUIDE

Efstratios Georgakarakos, MD, MSc, PhD
Assistant Professor of Vascular Surgery
University Hospital of Alexandroupolis, Greece
Introduction

• Measurement of Ankle-Brachial Index (ABI) is considered a basic skill for the diagnosis and assessment of peripheral arterial disease and a predictive tool for cardiovascular events.

• However, real-world practice shows that current teaching and practice is far from ideal.

• Moreover, the value of ABI is undeappreciated if its measurement is restricted only to physicians working in the vascular field.

• Deficiencies of education have led to the placement of ABI among the “Top-10 forgotten diagnostic procedures,” (Vasa 2016; 45:5-6)
ABI measurement and vascular teaching are underappreciated in undergraduate medical curricula

- There is marked discrepancy in the teaching of Angiology and ABI skills among the Greek medical schools...

- ...while practical training in ABI was reported to be implemented during the 2\textsuperscript{nd} and 3\textsuperscript{rd} cycle of 20\% and 60\% of French Medical Schools, respectively.

Bafitis et al, Int Angiol 2017; 36:386-391

Mahé G, J Mal Vasc 2015; 40:165-72
ABI measurement and vascular teaching are underappreciated in undergraduate medical curricula

- Wyatt et al. documented a poor level of knowledge of ABI calculation and interpretation among internal medicine residents irrespective of the year of residency

<table>
<thead>
<tr>
<th>Measurement error</th>
<th>N [%]</th>
<th>Baseline (n = 29)</th>
<th>Post-educa (n = 24)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure to use Doppler to assess brachial pressures</td>
<td>25 [86]</td>
<td>1 [4]</td>
<td></td>
</tr>
<tr>
<td>Failure to assess both pedal vessels (i.e. DP and PT)</td>
<td>24 [83]</td>
<td>0 [0]</td>
<td></td>
</tr>
<tr>
<td>Failure to assess both brachial pressures</td>
<td>23 [79]</td>
<td>0 [0]</td>
<td></td>
</tr>
<tr>
<td>Failure to accurately record Doppler signal from brachial or pedal artery</td>
<td>12 [60]*</td>
<td>12 [50]</td>
<td></td>
</tr>
<tr>
<td>Use of small arm cuff to assess pedal pressures</td>
<td>15 [52]</td>
<td>1 [4]</td>
<td></td>
</tr>
<tr>
<td>Incorrect placement of ankle cuff over body of calf muscles</td>
<td>14 [48]</td>
<td>2 [8]</td>
<td></td>
</tr>
<tr>
<td>Failure to use Doppler to assess pedal pressures</td>
<td>9 [31]</td>
<td>0 [0]</td>
<td></td>
</tr>
<tr>
<td>Assessment of radial artery pressure instead of brachial pressure</td>
<td>1 [4]</td>
<td>0 [0]</td>
<td></td>
</tr>
</tbody>
</table>

Wyatt et al, Vasc Med; 2010:15:99-105

- Chaudru et al. showed that experienced residents perform better than inexperienced ones, but not faultlessly

Chaudru et al, Vasa 2016; 45:37-41
ABl training: a challenging task for dedicated tutors

**Summary:** Background: Ankle-brachial index (ABI) at rest is the main clinical tool to diagnose the presence of lower extremity peripheral artery disease (PAD). The method for ABI procedure (i.e., measurement, calculation and interpretation) is standardised and guidelines were published in 2012. This study sought to: 1) assess knowledge about the three major steps of the ABI procedure (i.e., measurement, calculation and interpretation) among residents from different medical schools, 2) compare the ABI knowledge of experienced residents (i.e., who have already performed ABI procedure more than 20 times) with the knowledge of inexperienced residents, and 3) describe the most common errors by residents.

Methods: Residents from six medical schools were invited to complete a questionnaire about the ABI procedure. Results: Sixty-eight residents completed the questionnaire. None of them knew how to perform the entire ABI procedure. Overall, 22%, 13% and 41% of residents correctly answered questions about ABI measurement, ABI calculation and ABI interpretation, respectively. Score comparisons underlined the fact that experienced residents (n = 26) answered ABI measurement questions to a significantly better level and had a significantly higher total score than inexperienced residents (n = 42) (P = 0.0485 and P = 0.0332, respectively). Errors were similar for most of the residents. Conclusions: Our study confirms that experienced residents have significantly better ABI procedure knowledge than inexperienced residents. However, none of them are able to perform the entire ABI procedure without any mistake with regard to current guidelines. It is important that training be given to residents in medical schools in order to improve their ABI procedure knowledge.

**Table 1. Results of Questionnaire by Category**

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage Correct</th>
<th>Range (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevalence</td>
<td>48.9</td>
<td>0-100</td>
</tr>
<tr>
<td>Screening</td>
<td>33.8</td>
<td>0-80</td>
</tr>
<tr>
<td>Treatment</td>
<td>45.0</td>
<td>0-87.5</td>
</tr>
<tr>
<td>Outcomes</td>
<td>42.5</td>
<td>0-100</td>
</tr>
<tr>
<td>Overall</td>
<td>41.7</td>
<td>10.5-73.7</td>
</tr>
</tbody>
</table>

Schwartz et al, Angiology; 2012:63:597-602

Chaudru et al, Vasa 2016; 45:37-41
Training of students in ABI measurement requires time-commitment to achieve comparable results with professionals.

**Summary:** Background: Ankle brachial index (ABI) is a first-line non-invasive screening tool for peripheral arterial disease (PAD) in at-risk populations. The need to extend ABI use in large population screening has urged its use by professionals other than vascular physicians. As advocated by the American Heart Association, ABI teaching is part of medical curriculum in several countries. We determined accuracy in ABI measurement by trained medical students compared with an experienced angiologist. Methods: Twelve 5th-year medical students underwent 9 days of training at Lausanne University Hospital. Students and an experienced angiologist, blinded to students' results, screened consecutive hospitalised patients aged ≥65 or ≥50 with at least one cardiovascular risk factor during a 6-week period. Results: A total of 243 patients were screened of whom 39 (23.7%) met the inclusion criteria. Median age was 80. 45.5% were women, and 6.8% were symptomatic. In total, 116 ABIs were available for analysis. Agreement between students and angiologist was moderate with a k value of 0.498 (95% confidence interval: 0.389–0.608). Overall accuracy and precision of PAD screening performed by students showed sensitivity of 73.2% and specificity of 88.0%. Positive and negative predictive values were 76.9% and 95.7%, respectively. Positive and negative likelihood ratios were 6.3 and 3, respectively. Conclusions: A nine-day training program on ABI measurement is not sufficient for inexperienced medical students to achieve an acceptable diagnostic accuracy in detecting PAD in at-risk populations.

Monti et al, Vasa 2016; 45:43-48
Aim of this presentation is to present certain tips that facilitate the estimation and interpretation of ankle brachial index

The following tips reflect our experience from ABI bed-side teaching in our University Hospital, Medical School, Democritus University of Thrace (DUTH), where “Vascular Surgery” is core subject

<table>
<thead>
<tr>
<th>Medical School</th>
<th>Year</th>
<th>Estimated hours of lectures*</th>
<th>Estimated hours of clinical practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>NKUA</td>
<td>4th (2 semesters)</td>
<td>15 (5+10)</td>
<td>10 (5+5)</td>
</tr>
<tr>
<td></td>
<td>6th</td>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td>AUTH</td>
<td>3rd</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>4th</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>6th</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>UOP</td>
<td>5th</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>UOI</td>
<td>4th</td>
<td>20</td>
<td>–</td>
</tr>
<tr>
<td>UTH</td>
<td>4th (2 semesters)</td>
<td>4 (2+2)</td>
<td>–</td>
</tr>
<tr>
<td>UOC</td>
<td>4th</td>
<td>14</td>
<td>–</td>
</tr>
<tr>
<td>DUTH</td>
<td>4th</td>
<td>13</td>
<td>13</td>
</tr>
</tbody>
</table>

NKUA: National and Kapodistriat University of Athens; AUTH: Aristotle University of Thessaloniki; UOP: University of Patras; UOI: University of Ioannina; UTH: University of Thessaly; UOC: University of Crete; DUTH: Democritus University of Thrace.

*The teaching hours refer to vascular surgery either as a core subject or as part of other core subjects (mainly general surgery).

Bafitis et al, Int Angiol 2017; 36:386-391
How to measure ABI

**Conditions:**
- Room with comfortable temperature (19°C–22°C).
- Patient at rest for 5 to 10 min in supine position, relaxed, head and feet supported.

**Calculation**

For peripheral artery disease (PAD) diagnosis:

\[
\text{ABI}_{\text{right}} = \frac{\text{Higher of the PT or DP systolic pressure in right ankle}}{\text{Higher of the left or right brachial systolic pressure}^*}
\]

For cardiovascular risk assessment:

The lower of the ABIs of the left and right leg should be used.

**Sequence of pressure measurements (from 1 to 7):**

1. Sphygmomanometer (the cuff should have a width at least 40% of the limb circumference). Ankle cuff is placed just above the malleolus.
2. 8 to 10 MHz Doppler probe with Doppler gel applied over the probe. Probe is placed in the area of the pulse at 45° to 60° angle to the surface of the skin.
3. Inflate the cuff up to 20 mmHg above flow signal disappearance and then deflate slowly to detect the pressure level of flow signal reappearance.
4. The cuff should not be applied over a distal bypass or over ulcers.

**Interpretation**

\[
\begin{align*}
\leq 0.40 & \quad \text{Severe PAD} \\
0.41 - 0.50 & \quad \text{Mild to moderate PAD} \\
0.91 - 1.00 & \quad \text{Borderline} \\
1.01 - 1.40 & \quad \text{Normal} \\
>1.40 & \quad \text{Incompressible artery}
\end{align*}
\]

Chaudru et al, EJVES 2016; 51:240-247
1. Hold hand steady over patient’s dorsal foot to estimate dorsalis pedis artery

2. Support your hand on the firm surface of the dorsal foot to avoid subtle trembling movements (pendulum)

3. Pendulum movements are exacerbated once the sphygmomanometer is inflated leading to loss of arterial signal and underestimation of the segmental pressure
4. Likewise, support the examiner’s hand against the bed surface to estimate posterior tibial artery.

5. Avoid venous interference when estimating arterial sign often perceived as attenuated, barely audible arterial sign.

6. Apply gentle squeezing maneuvers distally to the examined area to augment venous return and delineate non-arterial origin.
7. Recruit the Pole test to assess ischemia and evaluate “high” ABI

Results. Measurements obtained by cuff-manometry were significantly higher to those obtained by pole test (mean pressure difference: 40 mmHg, *p* < 0.001). The difference between the two methods remained statistically significant for both diabetics (50.73, *p* < 0.001) and non-diabetics (31.46, *p* < 0.001). Mean TcPO₂ value was 15.51 mmHg and there was no important difference between patients with and without diabetes. Overall, there was a correlation between sphygmomanometry and pole test (r = 0.481). The correlation persisted for patients without diabetes (r = 0.581), but was not evident in patients with diabetes. Correlation between pole test and TcPO₂ was observed only for patients with diabetes (r = 0.444). There was no correlation between cuff-manometry and TcPO₂. The pole test offered an accuracy of 88% for the detection of CLI. The sensitivity of this test was 95% and the specificity 73%.
Getting familiar with the arterial waveforms

Statement for Doppler waveforms analysis

Guillaume Mahé, Carine Boulon, Ileana Desormais, Philippe Lacroix, Luc Bressollette, Jean-Louis Guitot, Claire Le Hello, Marie-Antoinette Sevestre, Gilles Feron, Joel Constans, Christian Boissier, and Alessandra Bura-Riviere

Vasa (2017), 46 (5), 337–345
High ABI with monophasic Doppler sign: questionable

Flow through multiple & smaller collaterals (when main road is closed) results in monophasic, slow, attenuated waveforms

Flow through open unobstructed “highway” results in triphasic waveforms

Normal waveform

Pathologic waveform
Discriminate the normal- from the monophasic post-obstructive arterial signals

8. Getting familiar with the triphasic signal
Combining audible signs with visual recordings

Chaudru et al, Int J Cardiol, 2015
Ahn et al, J Ultrasound Med, 2015

Use portable color Duplex in the bedside teaching

9. Comprehension of bi- and triphasic flow
10. Discriminate from venous continuous flow
11. Check ABI in cases of incompressible crural vessels
12. Ultrasound stimulates students’ attention and enhances skills
Underline the significance of ABI presentation with practical examples

- Trauma in Lower limb
- External fixation
- Inability to apply sphygmomanometer to estimate ABI
- A triphasic Doppler signal can remote serious arterial damage although ABI >0.9 remains the task
Repetition is the mother of learning and the father of action!

13. Perform at least 20 measurements of ABI

Improvement of students’ performance in ABI after practice even for critical limb ischemia

Take home messages

• Teaching basic principles of vascular examination can be an intriguing task
• Acquaintance of ABI-practical skills is a demanding process and needs commitment, repetition and combination of theory and practice
• Understanding of Doppler waveforms completes ABI interpretation and helps avoiding misinterpretations in vascular examinations
Questions to Vascupedians

• How often do you perform ABI estimation pre- and post-operatively in your patients?
• How do you perform peripheral vascular evaluation in patients with incompressible crural vessels (e.g., diabetics and dialysis patients)?
• Is ABI measurement considered a basic practical skill in your medical school?
• What is the commonest difficulty you encounter when measuring ABI?
• Do referral letters from general practitioners or family doctors in your country report an ABI estimation?
• Are you familiar with basic arterial waveforms?
• Would you consider the basic knowledge of arterial waveforms as necessary when estimating ABI and/or differentiating “arterial” symptoms?