Ease of use, feasibility and performance of ankle arm index measurement in patients with chronic leg ulcers: Study of 100 consecutive patients

Mesure de l’index de pression artérielle systolique à la cheville chez un patient porteur d’un ulcère de jambe. Faisabilité et performance chez 100 patients consécutifs hospitalisés dans un service spécialisé

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Summary

International guidelines on leg ulcers recommend measuring the ankle arm index (AAI) to diagnose and assess peripheral arterial occlusive disease (PAOD) of the lower limbs. These guidelines do not, however, describe the method which should be used to make the measurement: which artery should be measured – in the event of an open leg ulcer, what are the practical difficulties for positioning the cuff – how well do patients tolerate the procedure? We conducted a prospective study focusing on ease of use, tolerance and performance of AAI measurements in patients with leg ulcers. In compliance with recent French guidelines, we measured the AAI for both distal leg arteries and retained the lowest value for analysis. Within a six-month study period, 100 consecutive inpatients with leg ulcers of various etiologies were studied. Mean age was 75, female predominance 60%, body mass index 27. Etiologies of leg ulcers were pure venous (29%), mixed venous predominant (17%), pure arterial (9%), mixed arterial predominant (8%), mixed (6%), hypertensive ulcers (11%), rare cause (8%), multifactorial (12%). Pain was present in 92%, with aVAS above 3 for 73%. Measurement of AAI was possible in 98% of patients. It was too painful and thus considered unethical for two patients with hypertensive ulcers. For the 98 patients measured, the ulcer had to be protected during the measurement in 76%. The measurement procedure only took five minutes for one leg, and was judged easy to perform by 93% of the operators. For the majority (76%) of patients, the measurement was not painful. We determined the diagnostic performance of AAI by comparing...
Introduction

Leg ulcer is a common condition with an estimated overall prevalence of 0.63% [1], 3% for persons aged over 80 years [2].

A vascular mechanism is involved in 90% of cases. Venous disorders predominate among the vascular causes, accounting for 70% of patients. But 30% of the vascular causes result from peripheral arterial occlusive disease (PAOD) of the lower limbs, either exclusively in which case the ulcers are termed arterial, or associated with venous disease, in which case the term mixed ulcers is used. The prevalence of PAOD of the lower limbs increases with age; it is estimated to affect 50% of patients aged over 80 years with a leg ulcer [3].

Screening for PAOD in patients with leg ulcers is highly recommended both by international guidelines concerning leg ulcers [4–6] and the French national guidelines proposed in November 2006 by the Superior health authority (Haute Autorité de santé [HAS]) [7]. The HAS conducted a systematic review of the literature to establish a level-of-evidence grade for PAOD of the lower limbs increases with age; it is estimated to affect 50% of patients aged over 80 years with a leg ulcer [3].

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Despite the strong recommendations of the HAS, it is not routine practice to measure the AAI in patients with leg ulcers. An epidemiology survey conducted in Portugal in 2005 was a cross-section study of the Lisbon region [10]; the AAI was measured in only 9% of the patients with a leg ulcer. In our own unit in the Saint-Joseph Paris Hospital Group where more than 200 hospital stays in 2006 concerned patients with leg ulcers, the AAI was measured in only 50%. The reasons for not performing the measure were: difficult technique related to the size of the ulcer, fluid discharge, conflict with the dressing, pain provoked by the ankle cuff, lack of time, and belief that palpation of the distal pulses was sufficient to diagnose PAOD of the lower limbs.

In this context, we decided to conduct a prospective study on the ease-of-use, feasibility and usefulness of measuring the ankle pressure. This study was conducted in 100 consecutive patients with leg ulcers hospitalized from January to July 2007 in the vascular medicine department of the Saint-Joseph Paris Hospital Group.

Material and methods

This was a prospective study conducted in 100 consecutive patients attending a single center for leg ulcers and hospitalized in the vascular medicine department of the Saint-Joseph Paris Hospital Group from January 2007.

Inclusion criteria

Patients with leg ulcers, irrespective of the cause or size of the ulceration, hospitalized in the vascular medicine department (day care or acute care unit) were included consecutively starting in January 2007.

Measurement of the arm-ankle index

The HAS recommendations were applied. The AAI was taken as the lower of the two values obtained on the ankle of the leg with the ulceration.

Factors studied

A standard worksheet was used for data collection.

Important clinical information

- Demographic data: name, age, gender, presence of diabetes, body mass index (BMI).
- Clinical data: presence or absence of distal pulses (with indication of which pulse was absent). Pain assessment using a 10-point visual analogue scale (VAS). Mean VAS, peak VAS, VAS at analgesic intake, and reason for taking an analgesic (ulcer or other reason).
- Aspect of the ulceration: site of the ulcer, size determined as the greatest horizontal diameter times the greatest vertical diameter and noted as less than 10 cm², 10–20 cm², 30–40 cm², or greater than 40 cm².
- Presence of edema and/or fluid discharge, assessed by inspection and considering bandage soiling.

AAI measurement

Values

- Arteries were considered incompressible if the AAI was greater than 1.3.
- The normal range of AAI was defined as 0.9 to 1.3. AAI < 0.9 was considered pathological.
- The AAI was used to define the ulcer as mixed or not: for AAI = 0.7 to 0.9, the ulcer was considered mixed predominantly venous; for AAI < 0.5, the ulcer was considered mixed predominantly arterial; for AAI = 0.5 to 0.7, the ulcer was considered mixed without venous or arterial predominance.

Ease of measurement

The following items were used to determine the ease of measurement:

- the need or not to protect the ulcer with compresses to install the cuff;
- the duration of the measurement process, timed with a stopwatch;
- opinion of the physician performing the measurement.

Patient’s assessment of the painfulness of the measurement process

A simple verbal scale was used (0 = not painful; 1 = slightly painful; 2 = painful; 3 = very painful).

Arterial ultrasound of the lower limbs

An arterial duplex Doppler exploration was performed in all patients to study the correlation between the results of palpation of the distal pulses, the AAI measurement, and the real presence of PAOD. A PAOD of the lower limbs was considered to be present when the ultrasound exploration identified tight narrowing or obstruction of an artery.

Etiology of the ulcers

- Ulcers associated with reflux or obstruction of the superficial and/or deep veins in a subject with a normal arterial ultrasound were considered to be pure venous ulcers.
- Ulcers associated with severe PAOD and AAI ≤ 0.5 were considered to be pure arterial ulcers.
- Both venous and arterial etiologies contributed to mixed ulcers. Using the Nelzen classification [11], ulcers were considered venous with venous predominance for AAI ≤ 5 and mixed without predominance for AAI 0.5 to 0.7.
- Martorell’s ulcer was identified in hypertensive patients with superficial, extensive, necrotic, and very painful ulcerations with no other identifiable cause of ischemic ulceration (gammapathy, antiphospholipid antibodies, cryoglobulinemia).
- Rare causes of leg ulcers were vasculitis, cancer, pyoderma, or primary atrophie blanche.
- Multifactorial ulcers associated at least three etiologies or potentially favoring factors. Episodes of heart failure, presence of rheumatoid polyarthritis, and "cortisone
skin” caused by long-term corticosteroid therapy were considered to be favoring factors.

Statistical analysis

The sensitivity and specificity of two items, palpation of the peripheral pulses and AAI, to identify PAOD of the lower limbs were determined taking the results of the arterial duplex Doppler exploration as the gold standard.

Results

One hundred consecutive patients were studied in a period of six months, January 13, 2007 to June 30, 2007. This was a routine recruitment for the vascular medicine department. Eighty-one were inpatients and 19 were day care patients. Inpatients were hospitalized for an etiological work up and for therapeutic management (venous surgery, revascularization by arterial surgery or angioplasty, skin grafts).

General characteristics of the study population

The study population presented the usual characteristics of patients hospitalized for leg ulcers: age > 70 years, female predominance, elevated BMI (Table 1).

Pain

Pain was recorded in 92% of patients (VAS > 0) and 73% had a VAS ≥ 3. Seventy-five percent of patients were taking level 2 or 3 analgesics, reflecting the severity of the pain symptoms (Table 2).

Table 2 Incidence and intensity of pain and use of analgesics.  
Fréquence et intensité de la douleur, prise d’antalgiques.

| Pain, present | 92% |
| Mean VAS ≥ 3 | 73% |
| Mean VAS | 3.85 (0–10) |
| Peak VAS | 7.65 (2–10) |
| Use of analgesics | 82 (82%) |
| Use of analgesics solely for ulcer | 72 (72%) |
| Level 1 analgesics | 24.4% |
| Level 2 analgesics | 59.7% |
| Level 3 analgesics | 15.8% |

Characteristics of the ulcer

Edema and fluid discharge were common, recorded for more than two thirds of the ulcers. A small proportion of the ulcers were small (slightly more than one third measured < 10 cm²). One third of the ulcers were large (> 40 cm²), some were semi-circumferential others circumferential. The preferential localization was the medial malleolus (55%) reflecting the predominant venous etiology.

Distal pulses

Both pulses could be palpated in less than a quarter of patients and neither pulse could be palpated in more than 40%. For those with only one perceptible distal pulse, the posterior tibial pulse was missing for 97%. Considering pulse perception alone and taking the absence of one distal pulse as diagnostic for PAOD of the lower limbs, 77% of the patients would have been considered to have PAOD of the lower limbs and only 23% considered not to have PAOD of the lower limbs (Table 3).

Arm-ankle index: practical aspects

The AAI could be measured in 98% of patients. The cuff pressure was so painful for two patients it was considered unethical to pursue the measurement. Both of these patients had Martorell’s ulcer. The ulcer had to be protected with a compress in more than three-quarters of patients although this did not prolong the duration of the measurement which was on average five minutes (time to make the measurement on one leg with an ulcer). Taking the pressure measurement was considered easy for 93% of patients, difficult for 5% (difficulty in perceiving the flow in very pathological arteries) and impossible in 2% because of the pain (Table 4).

Table 3 Pulse palpation in 100 patients.  
Palpation des pouls des 100 patients.

| Both pulses palpated | 24 (24%) |
| One pulse absent | 34 (34%) |
| Both pulses absent | 42 (42%) |
| Absence of posterior tibial pulse alone | 33 |
| Absence of anterior tibial pulse alone | 1 |

Table 4 Practical aspects of the AAI measurement in 100 patients.  
Caractéristiques pratiques de la prise de l’IPS sur 100 patients.

| Ankle pressure measured | 98 |
| Need to protect ulcer | 76 (76%) |
| Mean duration of measurement | 5 minutes (2–10) |
| The procedure was | |
| Easy to use | 93% |
| Neither painful or unpleasant | 57% |
| Somewhat unpleasant | 21% |
| Somewhat painful and unpleasant | 15% |
| Very painful | 7% |
Table 5  AAI results in 98 patients with a valid measurement.

<table>
<thead>
<tr>
<th>AAI</th>
<th>Number of patients total = 98</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 1.3</td>
<td>13 (13.2%)</td>
</tr>
<tr>
<td>[0.9 — 1.3]</td>
<td>42 (42.8%)</td>
</tr>
<tr>
<td>&lt; 0.9</td>
<td>43 (43.8%)</td>
</tr>
</tbody>
</table>

Half of the patients stated the measurement was painless, and 21% considered the measurement to be somewhat unpleasant, giving an acceptance rate of 78%. Fifteen percent of patients felt the measurement was painful and unpleasant. For 7% the measurement was very painful. This 7% included the two patients for whom the AAI could not be measured because of the pain provoked by the ankle cuff.

Arm-ankle index: measurement results

The measurement results showed that for 13% of the patients, the artery was incompressible so the AAI was non-informative. For 87%, the AAI was informative. For the accepted criteria, the measurement of the AAI determined that 42.8% of patients did not have PAOD (Table 5).

Slightly over one third of the patients who had incompressible arteries were diabetics. But for the diabetics in the study population (n = 13), 38% had incompressible arteries, so that an informative AAI was measured in 62% of the diabetic patients with leg ulcers.

Both distal pulses were palpated in only 41% of patients with a normal AAI, so that the correlation between pulse palpation and AAI was good in less than half of the patients. In patients with a pathological AAI, pulse palpation was rarely positive for both arteries (< 5%) (Table 6).

Etiologies of the ulcers

The etiologies of the ulcers in the study population reflected the recruitment of a vascular medicine department specialized in chronic wound care (Table 7).

Thus, the most common ulcers were pure venous or mixed predominantly venous ulcers, although this category accounted for less than half of the ulcers (46%). There was a large group of patients with arterial ulcers or mixed predominantly arterial ulcers, which accounted for 17%. Martorell’s ulcer, generally not mentioned in large published series, accounted for more than 10% of the recruitment. For three patients with this ischemic hypertensive ulcer, there was an associated PAOD. Rare causes (vascularitis, pyoderma, cancer) or multifactorial etiologies (association of a rare cause and polyarthritis, thrombocytopenia, heart failure) accounted for 20% of the recruitment. It can be noted that PAOD was common among patients with a rare or multifactorial etiology (11 of 20 patients). In all, more than one out of two patients had a diagnosis of PAOD.

Results of the arterial duplex Doppler exploration

The ultrasound exploration was incomplete in 8% of patients (both lower limb arteries not explored) (Table 8).

The correlation analysis thus included 90 patients, i.e., all patients with an AAI measurement and a complete arterial duplex Doppler exploration.

The ultrasound search for arteriopathy was negative in 85.7% of patients with a normal AAI. PAOD was identified in six patients, one with a tight stenosis of the superficial anterior tibial pulse alone absent (n = 28) 37 2
Both pulses present (n = 22) 38 1
Pathological AAI (n = 39) 38 1
Incompressible arteries (n = 9) 6 36
Normal AAI (n = 42) 6 36
Arteriopathy negative 3 6
Arteriopathy positive 2 20
n = 49

Table 6  Pulse palpation as a function of AAI.

<table>
<thead>
<tr>
<th>Normal AAI</th>
<th>Pathological AAI &lt; 0.9</th>
<th>n = 42</th>
<th>n = 43</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both pulses palpated</td>
<td>17 (41.5%)</td>
<td>2 (4.6%)</td>
<td></td>
</tr>
<tr>
<td>Absence of one or both pulses</td>
<td>25 (58.5%)</td>
<td>41 (95.4%)</td>
<td></td>
</tr>
</tbody>
</table>

Table 7  Etiologies of the 100 ulcers.

<table>
<thead>
<tr>
<th>Etiologies of the 100 ulcers.</th>
<th>n = 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Venous disease alone</td>
<td>29</td>
</tr>
<tr>
<td>mixed venous predominance</td>
<td>17</td>
</tr>
<tr>
<td>Arterial disease alone</td>
<td>9</td>
</tr>
<tr>
<td>mixed arterial predominance</td>
<td>8</td>
</tr>
<tr>
<td>Mixed</td>
<td>6</td>
</tr>
<tr>
<td>Hypertension (Martorell’s ulcer)</td>
<td>11</td>
</tr>
<tr>
<td>Rare cause</td>
<td>8</td>
</tr>
<tr>
<td>Multifactorial</td>
<td>12</td>
</tr>
</tbody>
</table>

Table 8  Correlations between the ultrasound results versus AAI and pulse palpation in 90 patients.

<table>
<thead>
<tr>
<th>Ultrasound results</th>
<th>n = 90 patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arteriopathy positive</td>
<td>49</td>
</tr>
<tr>
<td>Arteriopathy negative</td>
<td>41</td>
</tr>
<tr>
<td>Normal AAI (n = 42)</td>
<td>6 36</td>
</tr>
<tr>
<td>Incompressible arteries (n = 9)</td>
<td>3 6</td>
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<td>38 1</td>
</tr>
<tr>
<td>Both pulses present (n = 22)</td>
<td>2 20</td>
</tr>
<tr>
<td>Both pulses absent (n = 39)</td>
<td>37 2</td>
</tr>
<tr>
<td>Posterior tibial pulse alone absent (n = 28)</td>
<td>11 17</td>
</tr>
<tr>
<td>Anterior tibial pulse alone absent (n = 1)</td>
<td>1 0</td>
</tr>
<tr>
<td>Normal AAI and both pulses present (n = 18)</td>
<td>0 18</td>
</tr>
</tbody>
</table>
femoral artery with patent leg arteries, two with an obstruction of the anterior and posterior tibial arteries, two with a well-compensated obstruction of the anterior tibial artery, and one with a stenosis of the anterior tibial artery which had been dilated previously and an obstruction of the peroneal artery. Neither of the distal pulses could be palpated in three of these six patients.

The ultrasound exploration identified PAOD in 97% of patients with a pathological AAI. The arterial ultrasound was normal in only one patient with a pathological AAI. Among patients with incompressible arteries, the ultrasound was positive for arteriopathy in one third.

The loss of both distal pulses was well correlated with the presence of PAOD of the lower limbs: the ultrasound exploration identified PAOD of the lower limbs in 94.8% of patients whose two distal pulses could not be palpated.

Sensitivity and specificity of AAI and pulse palpation for the diagnosis of PAOD of the lower limbs in patients with leg ulcers

The sensitivity and specificity of AAI for the diagnosis of PAOD of the lower limb in patients with leg ulcers was calculated for the population with an AAI measurement, a complete duplex Doppler exploration, and compressible arteries, i.e., 81 patients.

The sensitivity of AAI less than 0.9 for the diagnosis of PAOD of the lower limbs was 84.7% with 97% specificity.

The sensitivity of absence of a single pulse for the diagnosis of PAOD of the lower limbs was 83% with 54.5% specificity.

The sensitivity of the absence of both distal pulses for the diagnosis of PAOD of the lower limbs was 94.4% with 90% specificity.

Sensitivity and specificity of AAI for the diagnosis of PAOD of the lower limbs by measuring the AAI using the posterior tibial artery alone

We calculated the sensitivity and the specificity of the AAI measured exclusively on the posterior tibial artery for the diagnosis of PAOD of the lower limbs. The sensitivity was 81% with 100% specificity.

Sensitivity and specificity of AAI for the diagnosis of PAOD of the lower limbs considering only the highest AAI

Considering this configuration, there were nine cases of incompressible arteries instead of 20; the sensitivity was then 69% with 100% specificity.

Discussion

This is the first study, to our knowledge, which has focused on the feasibility of AAI measurements in a population of unselected patients with leg ulcers of various etiologies seen consecutively in a vascular medicine unit.

Several descriptive studies of management practices used for leg ulcers have mentioned AAI measurements [12–14], but without describing the technique used (measurement of the systolic pressure of an ankle artery? Both arteries? Which one?), and without examining the technical difficulties encountered (painful procedure for the patient, difficult identification of the artery on the Doppler, presence of an extensive ulcer or an ulcer situated over the artery...).

In the present series, it was possible to measure the systolic pressure of the ankle arteries in 98% of patients. For two patients, the measurement was not made because cuff inflation caused too much pain to pursue the procedure. Both of these patients had ischemic hypertensive ulcers (known to be painful) requiring level 3 analgesia.

This 98% feasibility score was obtained in a recruitment of leg ulcer patients. This population had a selection bias because of the over-representation of ulcers caused by a rare etiology, including Martorell’s ulcer (10%), and an under-representation of venous ulcers, classically considered to be less painful.

This study demonstrated that the measurement of the AAI is feasible in patients with leg ulcers even when the ulcers are large: more than one third of the ulcers measured over 40 cm², and about half were semi-circumferential or even circumferential (8%). The edema and fluid discharge noted in more than two thirds of patients was not a problem. Similarly, the pain reported by 92% of patients (defined by VAS >0), i.e., a proportion higher than in series of prevalence surveys [15], had no impact on the measurement technique. The mean pain level (mean VAS) was 3.85 mm, in agreement with current data in the literature. Use of level 2 analgesics was noted in 75% of patients, reflecting the severity of the pain, particularly peak level (VAS 7.65).

The acceptance rate was high: when asked whether they felt the procedure was unpleasant or painful, 78% reported that it was not. For the 25% who experienced pain during the procedure, it would be advisable, in our opinion, to wait until the pain has been controlled with analgesics and/or to propose premedication before performing the measurement.

For the majority of the patients, the measurement was simple and rapid. Mean execution time was five minutes for one leg, despite the need to protect the ulcer with compresses in three-quarters of patients. For the operators, the measurement was easy in 95% of patients. The difficulty noted for 5% was related to difficulty in finding the arterial flow in a context of severe PAOD.

This study demonstrated the good diagnostic performance of the AAI for identifying PAOD of the lower limb. In compliance with HAS guidelines, the value retained for the diagnosis of PAOD was the lower of two AAIs recorded on the leg with the ulcer. Under these conditions, a pathological AAI (<0.9) yielded 84.7% sensitivity and 97% specificity for the diagnosis of PAOD in patients with a leg ulcer. Elsewhere in the literature, techniques used to measure AAI for the diagnosis of PAOD have varied. In several epidemiology studies, it was the highest figure that was retained. The critical analysis of the literature on this topic published by Klein in 2006 [16] explains well the methodological difficulties encountered for the analysis of many publications. The author advocates the measurement of both distal pulse pressures and using the lowest pressure if the difference is greater than 21 mmHg between the two and otherwise to retain the average of the two measurements. In our study, if we had...
retained the highest figure, an AAI less than 0.9 would have had 100% specificity but only 69% sensitivity for the diagnosis of PAOD. If we had used the method proposed by Klein, AAI < 0.9 would have had 86% sensitivity and 100% specificity for the diagnosis of PAOD. If we had used only the pressure of the posterior tibial artery, as has been the case in several epidemiological studies screening for PAOD of the lower limbs, the sensitivity would have been 81% with 100% specificity. The method proposed by the HAS, where the lower of the two pressures is retained, would appear to be a good compromise to maximize performance of PAOD screening.

Palpation of the distal pulses remains an interesting clinical test when both of the distal pulses are absent since its sensitivity for the diagnosis of PAOD is 94.4%, although the specificity is only 90%. When the two pulses were present and the AAI was normal, the duplex Doppler did not identify arteriopathy.

Conversely, the absence of just one distal pulse had little diagnostic value since its sensitivity was 83% with only 54.4% specificity. This means that the diagnosis of PAOD would be erroneous in one out of two cases. The missing pulse was always the posterior tibial pulse. This is not surprising since the retromalleolar region in patients with leg ulcers is often edematous or sclerotic. Palpation of the posterior tibial pulse cannot be considered reliable.

Our results are in agreement with the guidelines published by the HAS in November 2006 where it is stated that the absence of both distal pulses is a good criterion for the presence of underlying PAOD of the lower limbs with good specificity (90%). Systematic palpation of the peripheral pulses is thus warranted.

Conclusion

The AAI could be measured in 98% of patients with a leg ulcer, irrespective of the etiology, size or painfulness of the ulcer. For 75% of patients, the measurement procedure induced little or no pain. Furthermore, for 90% of the operators, the technique was easy-to-use and rapid (five minutes for one leg). Thus, the application of the HAS recommendations to measure the AAI can be easily associated with palpation of the distal pulses to enable a reliable diagnosis of peripheral occlusive arterial disease of the lower limbs in patients with leg ulcers.

Conflicts of interest

None.

References