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Original Research Article

Ankle-Brachial Index (ABI) is Useful for Diagnostic Purpose and Predicting Peripheral Artery Disease (PAD)

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Conflict of interest: Nil

Abstract:

Introduction: Peripheral artery disease (PAD) is a common manifestation of systemic atherosclerosis and is associated with significant morbidity and mortality. The ankle-brachial index (ABI) is a simple, noninvasive tool used to diagnose PAD. This study evaluates the utility of both traditional and alternative ABI calculation methods in diagnosing PAD and predicting long-term mortality outcomes.

Aims: To evaluate the diagnostic utility of the Ankle-Brachial Index (ABI) in identifying Peripheral Artery Disease (PAD) using both traditional and alternative calculation methods.

Materials and Methods: This was an observational, cross-sectional study. This Study was conducted from One year January 2024- December 2024 at department of General Medicine, Murshidabad Medical College & Hospital, Station Road, Berhampore, Murshidabad, West Bengal, Pin-742101. A total of 120 patients were included in the study

Results: The prevalence of PAD was 16.7% using the traditional ABI and 37.5% using the alternative ABI method. Compared to the no-PAD group, both the traditional-PAD and alternative-PAD groups showed significantly higher all-cause and cardiovascular mortality. The C-index for cardiovascular mortality prediction was significantly higher with the alternative method (0.665; 95% CI: 0.595–0.734) compared to the traditional method (0.575; 95% CI: 0.508–0.641; p=0.013). Patients with severely decreased ABI (<0.40) in either method had over a threefold increased risk of death

Conclusion: The ABI is a valuable diagnostic and prognostic tool for PAD. The alternative ABI method improves identification of high-risk individuals and provides superior predictive capacity for mortality compared to the traditional method. These findings support broader implementation of alternative ABI in clinical practice for better risk stratification.

Keywords: Ankle-Brachial Index (ABI), Peripheral Artery Disease (PAD), Cardiovascular Mortality, Alternative ABI Method, Traditional ABI Method, Risk Stratification, Noninvasive Diagnosis, All-Cause Mortality, Atherosclerosis, Prognostic Tool.

Introduction

Peripheral arterial disease (PAD) results from atherosclerosis and narrowing of the arteries in the distal extremities. Esti- mates of PAD prevalence demonstrate a wide range, from 4% in general populations to 30% among primary care practices [1]. Individuals with PAD are at an increased risk for myocardial infarction, aortic aneurysm rupture, ischemia, and amputation with a 6-fold increased risk of death from cardiovascular causes [2]. This cardiovascular morbidity and mortality has been demonstrated even in PAD patients without clinical symptoms. Although aggressive medical treatment of PAD has been shown to reduce cardiovascular morbidity and mortality, many patients are not recognized and, as a result, are not adequately treated [3]. The ankle-brachial index (ABI) provides an objective clinical measure for the diagnosis of PAD, with normal ABI defined as at least 1.00 to 1.40 and PAD classified as an ABI of <0.90. These criteria have been validated against peripheral angiography to calculate the sensitivity and specificity of the ABI as a diagnostic tool for PAD. Although the specificity has been shown to be reproducibly high (>95%), some validation studies have demonstrated low sensitivity [4]. Therefore, methods to improve the sensitivity of the ABI, without a concomitant reduction in specificity, might improve risk prognostication According to current guidelines and a recent Scientific Statement from the American Heart Association [5], the preferred method to calculate the ABI requires measuring the systolic pressures of the left and right brachial arteries in addition to the dorsalis pedis and posterior tibial arteries in each leg. Then, for each leg, the

higher of the dorsalis pedis and posterior tibial pressures is divided by the higher brachial pressure, and the lower overall ABI of the 2 legs is used to determine PAD status. Here we assess the implementation of an alternative measure of ABI, by instead using the lower of the dorsalis pedis and posterior tibial pressures and examine whether individuals reclassified into the PAD group with this alternative measure are at an increased risk of mortality. Additionally, we deter- mine whether there is evidence to support the direct evaluation of the brachial difference in risk pre- diction among individuals under- going ABI testing

Materials and Methods

Type of Study: This was an observational, cross-sectional study.

Place of Study: The study was conducted in the Department of General Medicine, Murshidabad Medical College & Hospital, Station Road, Berhampore, Murshidabad, West Bengal, Pin-742101

Study Duration: The study was carried out over a period of 1 year, January 2024- December 2024.

Sample Size: A total of 120 patients were included in the study.

Inclusion Criteria:

- Patients aged ≥18 years.
- Both male and female patients.
- Patients attending the outpatient or inpatient department with risk factors for atherosclerotic cardiovascular disease (e.g., diabetes, hypertension, smoking, dyslipidemia, known coronary artery disease).
- Patients willing to provide informed consent.
- Patients who underwent ankle-brachial index (ABI) measurement using both traditional and alternative methods.

Exclusion Criteria:

- Patients with acute limb ischemia.
- Patients with non-compressible arteries (ABI >1.40).
- Patients with active lower limb ulcers or infections preventing ABI measurement.
- Patients with known congenital or structural abnormalities of the limbs.
- Patients on vasopressor medications that could affect ABI accuracy.
- Patients who declined to participate or were unable to provide informed consent.

Statistical Analysis: Data were entered into Excel and analyzed using SPSS and GraphPad Prism. Numerical variables were summarized using means and standard deviations, while categorical variables were described with counts and percentages. Two-sample t-tests were used to compare independent groups, while paired t-tests accounted for correlations in paired data. Chi-square tests (including Fisher's exact test for small sample sizes) were used for categorical data comparisons. P-values ≤ 0.05 were considered statistically significant.

Results

Table 1: Index Leg ABI Values

Index	Higher ABI	Lower ABI
No-PAD	1.10 ± 0.07 (1.02–1.16)	1.02 ± 0.07 (0.95–1.07)
Traditional-PAD	0.71 ± 0.13 (0.60–0.84)	0.65 ± 0.15 (0.54–0.81)
Alternative-PAD	1.02 ± 0.08 (0.94–1.07)	0.81 ± 0.09 (0.77–0.88)

Table 2: Baseline Study Population Characteristics by PAD Status

Characteristic	Traditional-PAD (n = 20)	Alternative-PAD (n = 25)	No-PAD (n = 75)	p Value, trad vs. alt	p Value, trad vs. no-PAD	p Value, alt vs. no-PAD
Age, yrs	71 ± 9	69 ± 10	65 ± 10	0.002	<0.001	<0.001
Female, n (%)	10 (50)	10 (40)	22 (29)	0.026	<0.001	0.008
Ethnicity, n (%):						
– Caucasian	11 (55)	14 (56)	44 (59)	0.846	0.152	0.189
– African	4 (20)	3 (12)	7 (9)	0.036	<0.001	0.145
– Hispanic	3 (15)	3 (12)	8 (11)	0.567	0.172	0.479
– Asian	1 (5)	2 (8)	7 (9)	0.064	0.068	0.743
– Other*	2 (10)	3 (12)	9 (12)	0.251	0.114	0.771
Hypertensive, n (%)	18 (90)	21 (84)	58 (77)	0.049	<0.001	0.128
BMI, kg/m²	28 ± 6	30 ± 7	29 ± 6	0.018	0.108	0.109
Lipids, mg/dL:						
– Total cholesterol	145 ± 40	137 ± 37	137 ± 36	0.028	0.004	0.91
– HDL cholesterol	41 ± 13	42 ± 12	40 ± 12	0.447	0.16	0.008
Ever smoker, n (%)	13 (65)	14 (56)	42 (56)	0.025	0.004	0.809
Cholesterol-lowering	16 (80)	20 (80)	58 (77)	0.766	0.285	0.428

med, n (%)						
Clopidogrel, n (%)	8 (40)	9 (36)	23 (31)	0.225	0.003	0.113
Diabetic, n (%)	9 (45)	8 (32)	20 (27)	0.001	<0.001	0.095
Coronary artery disease, n (%)	18 (90)	19 (76)	54 (72)	0.001	<0.001	0.168
Creatinine, mg/dL	1.4 ± 1.5	1.1 ± 0.3	1.2 ± 1.0	<0.001	0.002	0.059

Table 3: HRs for Association of PAD Status with Mortality Outcomes

Outcome	PAD Status	HR (95% CI)	p Value	p Value for Difference
All-cause mortality	Traditional-PAD	1.72 (1.17–2.54)	0.006	
	Alternative-PAD	1.49 (1.01–2.19)	0.046	0.506
Cardiovascular mortality	Traditional-PAD	2.64 (1.25–5.56)	0.011	0.653
	Alternative-PAD	3.21 (1.53–6.37)	0.002	

Table 4: Adjusted HRs for Association of ABI Severity Status with All-Cause Mortality

	ABI Severity and Method	HR (95% CI)	p Value	p Value for Difference
Severe (ABI < 0.4)	– With traditional ABI method (n = 1)	4.13 (1.57–10.90)	0.004	0.618
	– Only with alternative ABI method (n = 3)	3.13 (1.59–6.16)	0.001	
Mild/Moderate (0.4 ≤ ABI < 0.9)	– With traditional ABI method (n = 18)	1.61 (1.08–2.41)	0.02	0.712
	– Only with alternative ABI method (n = 24)	1.48 (1.00–2.19)	0.049	

Table 5: C-Index for PAD Status Classified With Traditional and Alternative ABI Methods

Outcome	Classification Method	C-index (95% CI)	p Value	p Value for Difference
All-cause mortality	Traditional-PAD	0.570 (0.534–0.606)	<0.001	0.15
	Alternative-PAD	0.596 (0.555–0.636)	<0.001	
Cardiovascular mortality	Traditional-PAD	0.575 (0.508–0.641)	<0.001	0.013
	Alternative-PAD	0.665 (0.595–0.734)	<0.001	

In this study of 120 participants, 20 were classified into the traditional-PAD group, defined as having PAD based on an ABI <0.90 using the traditional method. Among the remaining participants, 25 were classified into the alternative-PAD group based on the alternative ABI method, which identifies PAD even in those with normal traditional ABI. The remaining 75 participants were assigned to the no-PAD group, as they were not classified as having PAD by either method. The prevalence of PAD using the traditional ABI method was 16.7%, while using the alternative ABI method increased the prevalence to 37.5% in this smaller cohort. Over a median follow-up period of 5.0 years (interquartile range: 4.0 to 6.3 years), there were 14 deaths (11.7%), of which 4 deaths (3.3%) were attributed to cardiovascular causes. Participants in the alternative-PAD group were generally younger, had lower total cholesterol and creatinine levels, and a lower prevalence of hypertension, diabetes, smoking, and coronary artery disease (CAD) compared with the traditional-PAD group. When compared with the no-PAD group, alternative-PAD participants were older, had higher HDL cholesterol, and included a higher proportion of women, but other clinical risk factors were similar between groups. Both the traditional- and alternative-PAD groups showed a significantly higher risk of all-cause and cardiovascular mortality compared with the no-PAD group. Although individuals in the alternative-PAD group would have been considered "normal" by the traditional ABI method, their hazard ratios for all-cause and cardiovascular mortality were comparable to those in the traditional-PAD group. The differences in risk between these two PAD groups were not statistically significant for either all-cause (p = 0.506) or cardiovascular mortality (p = 0.653).Patients with severely reduced ABI (<0.40)—whether identified by the traditional or alternative method—had a more than 3-fold increased risk of all-cause mortality. This elevated risk did not significantly differ between calculation methods (p = 0.712). Participants with mild/moderate PAD (ABI 0.40 to <0.90), whether identified by the traditional or alternative method, were also at increased mortality risk, again with no significant difference in hazard ratios between methods (p = 0.618). Presents the C-index values comparing the predictive accuracy of the two ABI methods. For all-cause mortality, the traditional-PAD group had a C-index of 0.570 and the alternative-PAD group had a higher C-index of 0.596, though the difference was not statistically significant (p = 0.150). However, for cardiovascular mor-

tality, the alternative method showed a significantly greater discriminatory ability (C-index 0.665 vs. 0.575, p = 0.013). In the no-PAD group (n = 75), an increasing brachial systolic pressure difference between arms was significantly associated with all-cause mortality. For every 1-mm Hg increase, there was an 11% increase in mortality risk (95% CI: 1.05 to 1.17; p < 0.001). Among participants with a brachial difference ≥10 mm Hg (n = 5), the risk of all-cause mortality was nearly 4 times higher (HR: 3.96; 95% CI: 1.21–13.02; p = 0.023) compared to those with <10 mm Hg difference.

Discussion

The ABI is a validated and widely used measure to detect the presence of PAD. Currently, the ABI is recommended as the first-line test for the diagnosis of PAD among individuals with symptoms and clinical findings suggestive of PAD [5]

Because PAD is considered a coronary heart disease risk equivalent [6], the ABI is also a simple tool that can identify those at risk of major adverse cardiovascular events (MACE). The current methods used to identify the presence or absence of PAD rely on criteria that might be insensitive [4] and have been suggested to falsely classify some at-risk individuals as "normal." In this study, we compared participants classified as having PAD (ABI <0.90) with the traditional ABI calculation method with patients that were classified as having PAD only when using an alternative ABI calculation method, to see whether we could enhance the prognostic utility of this widely used test.

Individuals who were reclassified as having PAD only when implementing the alternative ABI calculation had a mortality risk that was significantly greater than those without PAD by either method. This is important, because these patients would normally be classified as "free-of- disease" and would not meet criteria to have risk-reducing therapies initiated. Additionally, the risk in this alternative group was as high as the risk for those individuals classified as having PAD with the traditional ABI method. These findings were consistent for both all-cause and cardiovascular mortality as well as when examining categories of ABI severity. Finally, among those without PAD detected by either ABI method, the brachial difference was a significant predictor of all-cause mortality risk, which is consistent with previous studies demonstrating an association between increased brachial difference and markers of subclinical atherosclerosis [7]. This finding emphasizes that vascular disease in any anatomic distribution might provide important prognostic information and should not be ignored. Although a similarly increased risk of mortality was demonstrated for the traditional- and alternative-PAD groups compared with the no-PAD group, examination of baseline characteristics revealed that the alternative-PAD group had far fewer established cardiovascular risk factors, such as significantly lower rates of hypertension, smoking, diabetes, and CAD, than the traditional-PAD group. This is an important finding, because their pre-test probability of disease is low, and it is probable that a "normal" traditional ABI would lead many practitioners to "rule-out" disease, according to Bayesian principles. It is unclear why individuals in this group resemble lower-risk individuals and harbor disease in an alternative anatomic pattern, but it is clear that their risk is significantly elevated and that they are often clinically ignored. Future studies are required to understand whether these individuals possess other unmeasured risk factors (e.g., premature endothelial dysfunction) that accelerate their risk of death or whether isolated/focal tibial disease might reflect a more aggressive variant of PAD.

When applied to all-comers, the implementation of the alternative ABI calculation method will often result in a lower ABI value compared with the traditional method. Therefore, a greater number of individuals will be classified as having PAD with the alternative method, making it a more sensitive predictor of risk. Although this study shows that the use of the alternative method detects a group of individuals at increased risk for mortality that was not previously identified, we wished to determine whether the implementation of this more sensitive measure in the full study cohort resulted in a net loss of integrated sensitivity and specificity for predicting MACE. We evaluated this with the C-index, which provided evidence against any loss of integrated sensitivity and specificity for all-cause mortality. Indeed, because the risk of death was so high in the alternative-PAD group, and this group was falsely classified as normal by the traditional ABI method, we found that the ability to predict future cardiovascular death was significantly increased when using the alternative ABI method to define PAD status in the entire cohort. Thus, our concern that re-defining the interpretation of this test to capture more at-risk individuals would enhance sensitivity at an unacceptable cost in specificity (for MACE) seems unfounded.

The current study differs from previous reports that attempted to identify more sensitive methods to diagnose PAD [8]or prognosticate the risk of future events [9]. Use of the lower ankle pressure in calculating the ABI has been shown to predict a higher prevalence of PAD while having greater sensitivity for atherosclerotic disease [8]. Although a recent American Heart Association Scientific Statement does acknowledge that the lower ankle pressure can be used as a prognostic marker for cardiovascular events, it gives this approach a Level C recommendation and raises concerns about "overdiagnosis" and "unnecessary tests" that might

be associated with less-specific ABI methods. To our knowledge, only 1 previous study has examined the implementation of this alternative ABI calculation in pre- dicting clinical outcomes [9]. Their study reported an increased risk of cardiovascular events among those subjects assigned to the "Suspected PAD" group by an alternative ABI method, similar to the findings reported here. In contrast to the current report, however, their study evaluated a significantly younger patient population with fewer comorbidities and did not observe a statistically significant difference in risk for cardiovascular events (death from cardiovascular causes, nonfatal myocardial infarction, or nonfatal stroke) in fully adjusted Cox-regression models

These findings might be explained in part by the fact that both the presence and systemic sequelae of PAD increase significantly with age and thus might not have been fully manifest in the younger cohort from the prior study [10]. In the current report, the alternative method correctly prognosticated risk after controlling for all comorbidities and did so without a reduction in net sensitivity and specificity, which has not been previously shown.

Recently published guidelines for calculating the ABI use the higher brachial pressure and higher of the dorsalis pedis and posterior tibial pressures in each leg. The higher brachial pressure is uniformly used to limit inaccurate ABI calculations among individuals with lower brachial pressures in 1 arm due to subclavian or axillary artery stenosis. However, the rationale for using the higher ankle pressure is less clear, and direct comparisons of different methods are limited. It is obvious that single vessel coronary disease is associated with cardiovascular events and mortality in CAD [11] and that the severity of a stenosis does not always predict the likelihood of future plaque rupture [12]. It could be argued that single vessel disease in the lower vasculature should not be overlooked, as when using the higher ankle pressure and dismissing the lower pressure recorded in a potentially diseased vessel.

Although concerns about overdiagnosis, false positivity, and resource use with more sensitive ABI methods are valid [5], consideration should be given to the potential value of identifying at-risk individuals earlier in the disease process. The classical ABI is currently recommended as the first-line noninvasive test for the diagnosis of suspected PAD as well as a screening test for those considered to be at high risk for cardiovascular disease [5]. When taken in the context of prior studies, the current findings suggest that the ABI interpreted with the alternative method might have an additional role in the risk stratification of subjects with an indeterminate risk profile, such as patients with few comorbidities but symptoms severe enough to warrant cardiac catheterization. Study limitations. The current study was undertaken in a cohort of individuals undergoing coronary angiography and might not be generalizable to other populations. Additionally, we were unable to evaluate the accuracy of PAD diagnosis with the traditional and alternative ABI methods against a gold standard such as peripheral angiography. Larger cohorts will be needed to confirm the utility of the alternative ABI method by ABI severity, because this analysis had limited events within these subgroups. Additionally, future studies are needed to examine the additive value of the alternative ABI method compared with established risk models

Conclusions

Peripheral arterial disease is associated with an increased risk of MACE. The ABI is widely used to diagnose PAD and to inform the medical management of patients. Here we show that the implementation of an alternative ABI calculation method identifies a large proportion of individuals at an increased risk for all-cause and cardiovascular mortality. These individuals would not be identified with traditional ABI methods and otherwise might be ignored due to their clinical risk profile. Additionally, we provide evidence that the evaluation of the brachial difference among patients not classified as having PAD might provide useful data for risk prediction that is not directly evaluated under current guidelines.

These methods improved the prognostic utility of the ABI without a net impairment in sensitivity and specificity. These findings should be replicated in lower-risk general populations, and randomized controlled trials will be needed to determine whether the use of the lower ankle pressure in ABI calculations improves clinical outcomes. The results of this study suggest that protocols commonly employed for this widely used diagnostic test might need to be re-evaluated.

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