

ROLE OF SERIAL ANKLE-BRACHIAL PRESSURE INDEX (ABPI) AS A PROGNOSTIC TOOL TO PREDICT SUCCESS OF LOWER LIMB REVASCULARIZATION IN PAD/CLTI

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Abstract

Background: Peripheral artery disease (PAD) and chronic limb-threatening ischemia (CLTI) lead to severe, life-threatening conditions, which include ulcers, gangrene, and even the loss of a limb. Although revascularization helps reverse these issues, predicting long-term success is difficult. Ankle-brachial pressure index (ABPI) measurement is a low-cost, risk-free option for detecting healing and predicting limb-saving success following lower limb revascularization.

Objectives: To evaluate the long-term probability of success of lower-limb revascularization and to find early hemodynamic markers associated with improved limb salvage. Focus on serial ankle-brachial pressure index measurements in PAD/CLTI patients.

Methodology: This prospective study was conducted Department of Vascular Surgery CMH Peshawar from July 2024 to Dec 2024 over a six-month follow-up period. A total of 60 adult patients diagnosed with peripheral artery disease (PAD) or chronic limb-threatening ischemia (CLTI) and scheduled for lower-limb revascularization were enrolled. Inclusion criteria required age ≥ 18 years, Rutherford class 4–6 disease, and the ability to provide informed consent. Patients with non-compressible arteries (ABPI >1.30), acute limb ischemia, prior major amputation of the target limb, or incomplete hemodynamic data were excluded. All patients underwent standardized clinical evaluation, Doppler assessment, and appropriate imaging such as CT angiography or digital subtraction angiography prior to intervention. Revascularization was performed using endovascular angioplasty, stenting, surgical bypass, or hybrid techniques based on anatomical and clinical findings. Ankle-brachial pressure index (ABPI) was measured using a handheld Doppler and sphygmomanometer at baseline (pre-procedure), 48 hours post-procedure, one month, three months, and six months. The primary study outcome was successful limb salvage, defined as clinical improvement, wound healing, and absence of major amputation at six months. Secondary outcomes included restenosis, re-intervention, and mortality. Data analysis was performed using SPSS 24, employing paired comparisons, group analysis, logistic regression, and ROC curve assessment to identify prognostic ABPI thresholds.

Results: A total of 60 patients were included with a mean age of 60 ± 8.4 years.

The baseline mean ABPI was 0.39 ± 0.11 , increasing significantly to 0.71 ± 0.16 at 48 hours ($p < 0.001$), 0.76 ± 0.14 at one month, and 0.82 ± 0.13 at six months. Overall, 76.6% achieved successful limb salvage, while 10% required major amputation and 5% died during follow-up. Patients with successful outcomes demonstrated markedly higher early post-procedure ABPI and greater Δ ABPI improvement throughout the follow-up period compared with those who failed revascularization. The mean ABPI at six months in the success group was 0.87 ± 0.10 , compared with 0.54 ± 0.12 in the failure group ($p < 0.001$). Logistic regression identified post-procedure ABPI ≥ 0.70 and Δ ABPI ≥ 0.30 as independent predictors of a favorable outcome. ROC analysis yielded an AUC of 0.83, demonstrating good discriminative ability of ABPI in predicting limb-salvage success. These findings confirm that both early and sustained ABPI improvement strongly correlate with healing, symptom relief, and reduced amputation risk after revascularization.

Conclusion: Serial ABPI measurement is a practical, inexpensive, and reliable prognostic indicator following lower-limb revascularization in PAD/CLTI. Early hemodynamic improvement and sustained elevation in ABPI strongly predict successful limb salvage and reduced amputation rates. A post-procedure ABPI ≥ 0.70 emerged as a key threshold associated with favorable outcomes. Incorporating serial ABPI into routine follow-up can enhance risk stratification and guide timely decisions for re-intervention when required.

INTRODUCTION

Peripheral arterial disease (PAD) represents a progressive atherosclerotic occlusive disorder primarily affecting the lower extremities, resulting in significant functional impairment and adverse cardiovascular outcomes. Chronic limb-threatening ischemia (CLTI) is the most advanced presentation of PAD, characterized by ischemic rest pain, non-healing ulcers, and gangrene [1]. Without timely and appropriate treatment, CLTI carries a high risk of limb loss, amputation, and mortality within the first year. Globally, PAD affects more than 200 million individuals, with a rising prevalence in low- and middle-income countries due to aging populations and increasing rates of diabetes, hypertension, dyslipidemia, and smoking. In South Asia, including Pakistan, the burden of PAD and associated limb loss is particularly high due to late diagnosis, limited access to specialized vascular care, and inadequate awareness of early symptoms [2,3]. Revascularization remains the cornerstone of limb salvage in patients with CLTI. Endovascular techniques such as angioplasty and stenting, along with surgical bypass procedures, have significantly improved

the ability to restore blood flow to ischemic limbs [4]. However, predicting procedural success and long-term limb salvage remains challenging. Anatomical imaging, though essential, does not fully reflect the functional improvement in tissue perfusion. Clinical parameters alone may be unreliable in patients with neuropathy, advanced diabetes, or non-compressible vessels [5]. Therefore, there is a need for simple, objective, reproducible, and cost-effective hemodynamic markers that accurately assess revascularization success and predict clinical outcomes [6]. The ankle-brachial pressure index (ABPI) is a widely used noninvasive tool for diagnosing PAD. It is easy to perform, inexpensive, reproducible, and available even in resource-limited settings. ABPI quantifies the ratio of Ankle to brachial systolic pressure, providing an objective measure of peripheral perfusion [7]. Although ABPI is commonly used to diagnose PAD, its value as a prognostic indicator following revascularization is less frequently explored, particularly in low-resource healthcare environments. Serial ABPI measurements may allow clinicians to monitor early hemodynamic changes, detect restenosis,

and identify patients at high risk of re-intervention or limb loss [8]. Several studies have suggested that an improvement in ABPI following revascularization correlates with favorable limb-salvage outcomes, wound healing, and functional recovery. Conversely, limited improvement in ABPI may indicate persistent ischemia or early re-occlusion. Despite this, variability in measurement protocols, timing of assessment, and patient characteristics has limited the generalizability of findings. Moreover, there is scarce local data from Pakistan evaluating the prognostic utility of ABPI in CLTI patients undergoing revascularization. Given the increasing demand for vascular services and the need for standardized follow-up protocols, it is essential to determine whether serial ABPI can reliably predict clinical success after revascularization procedures [9,10]. This study aims to fill this knowledge gap by assessing the role of serial ABPI measurements at different intervals following revascularization and determining their association with limb-salvage outcomes. Understanding these relationships may strengthen clinical decision-making, guide timely re-interventions, and improve long-term patient outcomes.

Study Objective:

To assess the prognostic value of serial ankle-brachial pressure index measurements in predicting successful lower-limb revascularization outcomes and identifying key hemodynamic indicators associated with improved limb salvage in PAD/CLTI patients.

Materials and Methods:

Study Design & Setting:

This prospective study was conducted in the Department of Vascular Surgery CMH Peshawar from July 2024 to Dec 2024 over a six-month follow-up period, following standardized revascularization and assessment protocols.

Participants

Participants included adults aged 18 years or older diagnosed with PAD or CLTI undergoing lower-limb revascularization. Eligible patients provided informed consent and attended

scheduled follow-up visits. Patients with non-compressible arteries, acute limb ischemia, prior major amputation in the affected limb, or incomplete ABPI data were excluded to ensure standardized outcome assessment and accurate hemodynamic evaluation.

Sample Size Calculation

The sample size was estimated based on expected differences in pre- and post-revascularization ABPI values, with a significance level of 0.05 and a power of 80%. Based on previous studies demonstrating a moderate effect size, a minimum of 60 participants was required to detect clinically meaningful changes in ABPI and associated outcomes.

Inclusion Criteria

Age ≥ 18 years
Diagnosed PAD/CLTI (Rutherford class 4–6)
Planned for endovascular or surgical revascularization
Able to provide informed consent
Willing to complete follow-up assessments

Exclusion Criteria

Non-compressible arteries (ABPI > 1.30), Acute limb ischemia, Prior major amputation in the target limb, Missing or incomplete ABPI data, Severe infection requiring primary amputation

Diagnostic and Management Strategy

All patients underwent clinical assessment Doppler evaluation and CT angiography when indicated. Revascularization included angioplasty, stenting, or bypass surgery. ABPI was recorded pre-procedure and during postoperative follow-ups. Patients received guideline-based antiplatelet therapy, wound care, and monitoring for restenosis or complications.

Statistical Analysis

Data were analyzed using SPSS 24. Continuous variables were expressed as mean \pm SD, while categorical variables were presented as percentages. Paired tests assessed ABPI changes. Group differences were evaluated using chi-square and t-tests. Logistic regression identified independent predictors, and ROC analysis

determined optimal ABPI thresholds predicting successful limb-salvage outcomes.

Ethical Approval Statement

Ethical Approval was obtained from the institutional review board before study initiation. All participants provided written informed consent, and confidentiality was maintained throughout the study process. The study adhered to ethical guidelines for human study, ensuring patient safety, data protection, and responsible conduct of clinical investigation.

Results:

A total of 60 patients with PAD/CLTI were included, with a mean age of 60 ± 8.4 years, predominantly male, and diabetic. Baseline hemodynamic assessment demonstrated severe ischemia, reflected by a mean pre-procedure ABPI of 0.39 ± 0.11 . Following revascularization, there was a significant and sustained improvement in perfusion across all follow-up intervals. ABPI increased to 0.71 ± 0.16 at 48 hours ($p < 0.001$), 0.76 ± 0.14 at one month, 0.79 ± 0.13 at three months, and 0.82 ± 0.13 at six months, indicating continuous enhancement in limb blood flow. Overall, **60 patients (76.6%)** achieved successful limb salvage, while **14 patients (23.4%)** experienced failure, including **six major amputations (10%)** and **three deaths**

(5%). Patients with successful outcomes demonstrated consistently higher ABPI values at all postoperative time points, particularly at 48 hours and 6 months. The six-month ABPI among the success group was 0.87 ± 0.10 , significantly higher than 0.54 ± 0.12 in the failure group ($p < 0.001$). Similarly, the improvement from baseline (Δ ABPI) was substantially greater in the success group (0.47 ± 0.12) compared with those who failed (0.17 ± 0.09 ; $p < 0.001$). Multivariate logistic regression identified **post-procedure ABPI ≥ 0.70** (OR 4.82, $p < 0.001$) and **Δ ABPI ≥ 0.30** (OR 5.36, $p < 0.001$) as strong independent predictors of successful outcomes. ROC curve analysis demonstrated good discriminatory ability (AUC = **0.83**), confirming the prognostic value of serial ABPI monitoring after revascularization.

Intervention Outcome:

Revascularization resulted in significant hemodynamic improvement, reflected by early and sustained increases in ABPI. Most patients achieved limb salvage, while poor ABPI response correlated strongly with amputation risk. An elevation of ABPI to ≥ 0.70 post-procedure reliably indicated procedural success and long-term favorable outcomes.

Table 1. Baseline Characteristics of Patients Undergoing Lower-Limb Revascularization (n = 60)

| Variable | Mean \pm SD / n (%) |
|----------------------------------|-----------------------|
| Age (years) | 60 \pm 8.4 |
| Gender (Male/Female) | 42 (70%)+18(30%) |
| Diabetes Mellitus | 36 (60%) |
| Hypertension | 40 (66.7%) |
| Smoking History | 28 (46.7%) |
| Dyslipidemia | 22 (36.7%) |
| Chronic Kidney Disease | 8 (13.3%) |
| Rutherford Classification | |
| - Class 4 (Ischemic rest pain) | 18 (30%) |
| - Class 5 (Minor tissue loss) | 28 (46.7%) |
| - Class 6 (Major tissue loss) | 14 (23.3%) |
| Affected Limb - Right | 32 (53.3%) |

| | |
|-------------------------------------|-------------|
| Baseline ABPI | 0.39 ± 0.11 |
| Type of Revascularization Procedure | |
| - Endovascular intervention | 38 (63.3%) |
| - Surgical bypass | 12 (20%) |
| - Hybrid revascularization | 10 (16.7%) |

Summarizes baseline demographic, clinical, and procedural characteristics of the 60 patients undergoing revascularization for PAD/CLTI. The majority were male and diabetic, with severe ischemia reflected by a markedly reduced baseline ABPI.

Table 2. Serial ABPI Measurements at Different Time Intervals (n = 60)

| Time Point | ABPI (Mean ± SD) | p-value (vs baseline) |
|--------------------------|------------------|-----------------------|
| Pre-procedure (Baseline) | 0.39 ± 0.11 | - |
| 48 hours post-procedure | 0.71 ± 0.16 | <0.001 |
| 1 month | 0.76 ± 0.14 | <0.001 |
| 3 months | 0.79 ± 0.13 | <0.001 |
| 6 months | 0.82 ± 0.13 | <0.001 |

Table 2 demonstrates significant improvement in ABPI values following revascularization, indicating progressive enhancement in limb perfusion from 48 hours to 6 months when compared with baseline measurements.

Table 3. Comparison Between Successful and Failed Revascularization Outcomes

| Variable | Successful Outcome (n = 46) | Failed Outcome (n = 14) | p-value |
|-----------------------------|-----------------------------|-------------------------|---------|
| Mean Age (years) | 59.2 ± 7.9 | 62.8 ± 9.1 | 0.18 |
| Male Gender | 33 (71.7%) | 9 (64.3%) | 0.60 |
| Diabetes Mellitus | 26 (56.5%) | 10 (71.4%) | 0.32 |
| Baseline ABPI | 0.40 ± 0.10 | 0.37 ± 0.12 | 0.45 |
| 48-hour ABPI | 0.75 ± 0.14 | 0.57 ± 0.11 | <0.001 |
| 6-month ABPI | 0.87 ± 0.10 | 0.54 ± 0.12 | <0.001 |
| ΔABPI (Baseline → 6 months) | 0.47 ± 0.12 | 0.17 ± 0.09 | <0.001 |
| Major Amputation | 0 (0%) | 6 (42.8%) | <0.001 |
| Mortality | 1 (2.1%) | 2 (14.3%) | 0.07 |

Table 3 compares demographic and hemodynamic parameters between patients achieving successful limb salvage and those with failed outcomes. Significant differences in post-procedure ABPI and ΔABPI underscore the prognostic value of serial ABPI measurements.

Table 4. Logistic Regression Analysis Predicting Successful Revascularization

| Predictor | Adjusted OR | 95% CI | p-value |
|---------------------------|-------------|------------|---------|
| Age | 0.96 | 0.89–1.03 | 0.22 |
| Diabetes Mellitus | 0.71 | 0.31–1.58 | 0.40 |
| Baseline ABPI | 1.20 | 0.48–2.99 | 0.68 |
| Post-procedure ABPI ≥0.70 | 4.82 | 1.98–10.44 | <0.001 |
| ΔABPI ≥0.30 | 5.36 | 2.14–11.28 | <0.001 |
| Endovascular vs Surgical | 1.28 | 0.55–2.81 | 0.51 |

Table 4 displays the results of multivariable logistic regression. Post-procedure ABPI ≥ 0.70 and Δ ABPI ≥ 0.30 were strong independent predictors of successful limb salvage after revascularization.

DISCUSSION

In this study, serial measurements of the ankle-brachial pressure index (ABPI) before and after lower-limb revascularization demonstrated robust prognostic value: patients who exhibited substantial and sustained ABPI improvement had significantly higher limb salvage rates at 6 months [12]. These findings reinforce the concept that hemodynamic recovery, not just anatomical success, is critical for clinical outcomes after revascularization [13,14]. Our limb salvage rate ($\approx 76.6\%$) aligns reasonably with reported success rates in recent literature for patients with chronic limb-threatening ischemia (CLTI) undergoing revascularization. Recent reviews note that, although revascularization strategies (endovascular or surgical) have improved, outcomes remain variable across patients, underscoring the importance of reliable predictors of success [15,16]. A key recent work by Prognostic and predictive value of ultrasound-based (ABPI) measured during pre- and post-procedural exams showed that ultrasound-derived ABPI (ABPI) has significant prognostic power in predicting clinical outcomes after endovascular therapy [17]. Their findings support our observation that noninvasive pressure-index monitoring, pre- and post-procedure, can effectively stratify risk [1, 8]. Older, but data from Clinical impact of improvement in the Ankle-brachial index after endovascular therapy for peripheral arterial disease (2020), conducted in over 1,300 patients, found that an increase in $ABI \geq 0.15$ was associated with lower rates of target limb re-intervention or major amputation over long-term follow-up. While their adjusted hazard ratios for mortality lost statistical significance, the composite endpoint (re-intervention or amputation) remained significantly lower in the improved-ABI group [19]. In our cohort, the observed threshold (Δ ABPI ≥ 0.30) may reflect more advanced baseline ischemia, yet the direction is consistent: greater hemodynamic gain correlates with better limb outcomes [20]. Moreover, the role of ABPI

as a prognostic marker beyond diagnosis alone remains recognized. The recent population-based study using the Ankle-brachial index and subsequent risk of severe ischemic leg outcomes demonstrated that low ABI independently predicted future severe ischemic leg events. This supports the notion that, even outside acute revascularization settings, ABI is a robust marker of vascular risk, reinforcing its potential utility in follow-up and prognostication [21,22]. Nevertheless, some recent data suggest limitations of ABI-based prognostication. For instance, studies on diabetic foot and below-the-knee (BTK) interventions have shown that, even with technically successful revascularization, wound healing and limb salvage depend heavily on additional factors, such as distal vessel status, pedal arch patency, and infection variables not captured by ABI alone. [23] A recent systematic review of machine-learning models for postoperative limb outcomes noted that advanced models (incorporating clinical, anatomical, and hemodynamic parameters) achieved higher predictive accuracy than logistic regression based on limited variables [24]. These findings suggest that while serial ABPI is useful, optimal prognostication may require multimodal assessment [25]. The strength of our study lies in its prospective design, repeated ABPI measurements at standardized intervals, and a clear association between ABPI trajectory and limb-salvage outcomes [26]. In resource-limited settings where advanced imaging (toe pressures, transcutaneous oxygen, duplex surveillance) may not be readily available, serial ABPI offers a pragmatic, inexpensive, and noninvasive method for follow-up [27]. Given the evidence from both our study and recent literature, implementing serial ABPI into routine post-revascularization protocols can help stratify risk and identify patients who may benefit from early re-intervention or closer surveillance [28].

Limitations

However, several limitations require acknowledgment. First, our study follows patients for only 6 months; late restenosis, reocclusion, or amputations beyond this period may not be captured. Second, ABPI measurements may be less reliable in patients with medial arterial calcification (common in patients with diabetes and chronic kidney disease). Still, we excluded those with non-compressible vessels – potentially limiting generalizability. Third, we did not include other hemodynamic indices (toe-brachial index, transcutaneous oxygen tension) or imaging modalities; hence, our prognostic model relies solely on ABPI. Finally, our sample size is modest and comes from a single center; larger multicenter studies would provide stronger external validity.

Conclusion

Serial ABPI monitoring is a simple, inexpensive, and reliable tool for assessing hemodynamic improvement after lower-limb revascularization in PAD/CLTI. Early and sustained ABPI elevation strongly predicts limb salvage and reduced amputation risk. Incorporating serial ABPI into routine follow-up enhances prognostication and guides timely re-intervention for high-risk patients.

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