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## Original Article

## A retrospective study of ABI and TBI during the healing of ulcer among diabetic patients

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## ABSTRACT

**Objective:** To assess the role of ABI and TBI in the detection of ulcer wounds among diabetic patients.  
**Methods:** A retrospective approach is used to enroll 192 diabetic patients to detect their ulcer wounds using ABI and TBI index. HbA1c and lipid profile were other important variables in determining the efficacy of screening test. Frequency analysis and Pearson Correlation were used to analyze the data through SPSS.

**Findings:** The results have shown that 57.1% male and 42.9% female were treated in <0.60 ABI group; 67.4% male and 32.6% female were treated in 0.60–0.90 ABI group; 65.9% male and 34.1% female were treated in 0.90–1.30 ABI group; and 63.8% male and 36.2% female were treated in >1.30 ABI group. The correlation showed insignificant association between ABI and ulcer outcomes, but significant association between TBI and ulcer outcomes at 5% level of significance.

**Conclusion:** The study concluded that ABI should be based on standardized normal values to be used as an effective biomarker in screening diabetic foot ulcer patients.

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## 1. Introduction

Diabetic foot ulcer is a debilitating complication of diabetes mellitus. It is accompanied by peripheral arterial disease and neuropathy of lower extremity. Foot ulcers are commonly known as refractory complications among individuals, suffering from diabetes mellitus. Lower extremity amputation is one of the major complications, associated with diabetic foot ulcers [1]. There are several techniques to diagnose peripheral artery disease, some of which are Transcutaneous Partial Pressure of Oxygen (TcPO<sub>2</sub>) measurement, Ankle Brachial Index (ABI) and Toe Pressure Index method (TPI). Foot ulcers are mainly associated with break in continuity of thickened foot skin, which include surgical wounds and drainage of abscess. The local symptoms that help in the diagnosis of foot ulcer include; peripheral neuropathy, peripheral artery disease, and foot infection [2].

The risk of developing peripheral artery disease among patients

with diabetic foot ulcers was most common amongst cigarette smoking population. Subsequently, the reduction or cessation of smoking increased the long-term survival of patients with peripheral vascular disease. Some ways to reduce cigarette smoking are the use of anti-depressant bupropion and nicotine replacement therapy by using nicotine patches. A combination of nicotine patches and bupropion helps to abstain from smoking. However, a blend of bupropion, nicotine replacement therapy and counselling proved to be ideal for cessation of smoking [3].

In diabetic patients with insensate feet, it is very essential to take preventive measures to avoid foot ulcers. Along with appropriate footwear, they must also get orthotic inserts that are used to prevent undue pressure and distribute weight evenly across the foot. Due to peripheral neuropathy, diabetic patients are not aware of the presence of ulcerative lesions and infections. Systolic blood pressure of the leg is normally 10–20% higher than the blood pressure in the arm. The chances of peripheral vascular disease become much higher, when the blood pressure in the legs is lower than the pressure in the arms [4].

Tissue perfusion is the delivery of blood through the circulatory system, and adequate tissue perfusion is needed for the healing of ulcers. Additionally, the arterial insufficiency needs to be suspected

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if the diabetic foot ulcer fails to heal within a specific time period. Ankle Brachial Index is an essential screening method for the detection of peripheral artery disease. ABI is the ratio of blood pressure in the ankle to blood pressure in the upper arm or the brachium. Lower blood pressure in the leg in comparison to the pressure in the brachium indicates blocked or damaged capillaries due to Peripheral Artery Disease (PAD). Ankle Brachial Pressure Index is calculated and determined by taking higher blood pressure of the two blood vessels at the ankle. This calculated value is divided by the brachial arterial systolic blood pressure. The ankle brachial index test assists a physician to know, if the legs of a diabetic patient are getting optimal amount of blood supply. If the difference between the two brachial readings is greater than 10 mm/Hg then the higher two brachial values are obtained. The normal level of the ankle brachial index is between 0.90 and 1.30 level. A value below 0.90 indicates that the blood is reaching the legs and the feet with a lot of difficulty. A measurement index between 0.40 and 0.90 shows a possibility of having mild to moderate peripheral artery disease. Any measurement that is lower than 0.40 is a danger signal for severe disease and for ultimate chances of limb amputation [4].

Peripheral vascular disease can be detected with Toe Brachial Index (TBI). It is computed by dividing systolic pressure, obtained from the great toe by the brachial artery. Wound healing is impaired, if the toe pressure is less than 40 mmHg. Ankle Brachial Index is not the ideal methodology, when examining patients with medial artery calcification. Systolic toe pressure is suitable for evaluating patients with this disease. Additionally, in cases where there is severity of peripheral ischemia too, Ankle Brachial Index is not much of assistance. Good healing of the wound is indicated in a toe pressure that was greater than 30 mmHg. The ankle brachial index valuation has been proven to be much superior than the toe pressure calculation index technique. The toe pressure evaluation is more beneficial when the patients are suffering from explicit calcification [5].

Intensive long care is required for healing the diabetic foot ulcers that have developed among the diabetic patients, as it negatively affects the life quality of the patients and causes great distress to them. The existing data regarding the complication of lower extremity amputation due to foot ulcers and peripheral artery disease is inadequate and limited. Clinical epidemiological data plays an important role in creating guidelines on the prevention and care of the diabetic foot [2]. There is much controversy in clinical application of the risk factor prevailing among populations with a heterogeneous environment. Therefore, the present study will conduct retrospective study about Ankle Brachial Index (ABI) and Toe Brachial Index (TBI) to heal the foot ulcers among the diabetic patients. The studies that have investigated the significance of ABI and TBI in healing of ulcers among diabetic patients

have proved to be effective in treating the lower limbs with adequate arterial perfusion [6]. Therefore, the present study aims to examine ABI and TBI for treating foot ulcers among the diabetic patients. Therefore, the study has mainly focused on two factors including ABI and TBI and assess their role in severity of ulcers and other risk factors among the diabetic patients.

## 2. Methodology

The study is based on retrospective approach to evaluate ABI and TBI and assess their role in the healing process of foot ulcers. The study has recruited 192 diabetic patients, who visited admitted in the Rajiv Gandhi Centre for Diabetes and Endocrinology, of Jawaharlal Nehru Medical College Hospital, Aligarh Muslim University, Aligarh, India. These patients were suffering from ulcers in their foot during the period December 2012–June 2017. Patients with inflammatory or infectious diseases or under treatment of anti-inflammatory drugs, autoimmune and rheumatic diseases, cancer, hematological diseases, severe renal or liver failure, as well as those who were under treatment with anti-inflammatory drugs, were excluded. All the recruited patients gave informed consent to take part in this research. The study was carried out in accordance with the principles of Declaration of Helsinki as revised in 2001. The medical reports of all the patients were assessed to confirm diabetes. Age, gender, weight, BMI, blood pressure, duration of diabetes, HbA1c, and lipid profile of all the participants were recorded. The duration of ulcer, site, and size of ulcer, history of smoking, history of previous amputation, and clinical outcome were noted in every patient. Clinical assessment for signs of infection (swelling, exudates, surrounding cellulitis, odor, tissue necrosis, crepitation and pyrexia) was made by classifying the ulcers and determining the presence of clinical signs of infection. Ulcer size was determined by multiplying the longest and the widest diameters and expressed in centimeters square. The wound was graded and staged at the time of hospitalization according to the University of Texas Wound classification system as grade 1 (superficial wound, not involving, tendon, capsule or bone), grade 2 (wound penetrating to tendon or capsule) and grade 3 (wound penetrating bone or joint). The obtained data was analyzed using Statistical Package of Social Sciences (SPSS) version 20.0.

## 3. Results

The ulcer outcomes were reported in patients, who had undergone treatment for intact skin (Table 1). The results have shown that 57.1% male and 42.9% female were treated in <0.60 ABI group; 67.4% male and 32.6% female were treated in 0.60–0.90 ABI group; 65.9% male and 34.1% female were treated in 0.90–1.30 ABI group; and 63.8% male and 36.2% female were treated in >1.30 ABI group.

**Table 1**  
Demographic data and baseline characteristics.

N	ABI Groups				P value
	>1.30	0.90–1.30	0.60–0.89	<0.60	
Male/Female	1.36 ± .486	1.34 ± .477	1.33 ± .474	1.43 ± .514	0.907
Ulcer duration	38.76 ± 33.12	41.44 ± 48.38	58.53 ± 77.49	46.0 ± 45.18	0.029
Ulcer size > 4 cm <sup>2</sup>	1.723 ± .4521	1.79 ± .40568	1.90 ± 0.29	1.92 ± .267	0.095
Hospital stay	21.45 ± 12.072	21.76 ± 13.926	28.05 ± 22.95	30.57 ± 16.58	0.126
HbA1c (>7%)	10.202 ± 2.0241	9.785 ± 2.111	9.13 ± 1.99	9.07 ± 1.56	0.041
WBC count (10 <sup>3</sup> /μl)	9.39 ± 3.165	10.39 ± 5.04	9.01 ± 3.169	10.62 ± 3.41	0.000
Serum creatinine (mg/dl)	1.167 ± 0.503	1.19 ± 0.539	1.302 ± .6432	1.31 ± 0.464	0.000
LDL-C (mg/dl)	74.64 ± 18.276	77.60 ± 17.262	74.35 ± 21.56	74.57 ± 16.440	0.586
TC(mg/dl)	135.89 ± 12.979	136.98 ± 13.62	138.49 ± 17.586	134.50 ± 6.870	0.586
HDL-C (mg/dl)	34.53 ± 3.263	34.49 ± 3.206	35.16 ± 4.514	34 ± 1.359	0.523

Data are mean ± sd or n(%) unless otherwise indicated. LDL-C, low density lipoprotein cholesterol; HDL-C, high density lipoprotein cholesterol; TC: Total Cholesterol.

**Table 2**  
Outcome data of Diabetic foot ulcer patients.

Demographic data		Impaired ulcer healing	Improved Ulcer Healing	Healed with intact skin
Sex	Male	8 (47.05%)	23 (34.84%)	36 (33.02%)
	Female	9 (52.94%)	43 (65.15%)	73 (66.97%)
Size of Ulcer (cm <sup>2</sup> )		23.429 ± 50.768	22.671 ± 50.175	24.45 ± 54.33
ABI		1.75 ± 9.55	1.761 ± 9.601	1.771 ± 9.652
TBI		0.975 ± 0.313	0.9799 ± 0.311	0.982 ± 0.310
HbA1c %		9.681 ± 2.052	9.679 ± 2.058	9.68 ± 2.065
HSP70 (pg/ml)		3401.9 ± 1587.65	3397.603 ± 1581.569	3406.181 ± 1600.86
HSP47 (ng/ml)		2.567 ± 0.608	2.563 ± 0.608	2.572 ± 0.612

ABI: ankle-brachial index, TBI: toe-brachial index, HSP70: Heat shock proteins 70, HSP47: Heat shock proteins 47.

The findings have shown that mean value of grade of ulcer is  $1.21 \pm .690$  in  $>1.30$  ABI group;  $2.12 \pm .724$  in  $0.90-1.30$  ABI group;  $3.07 \pm .737$  in  $0.60-0.89$  ABI group and  $4.36 \pm .497$  in  $<0.60$  ABI group. The findings have shown that mean value of HbA1c is  $10.202 \pm 2.0241$  in  $>1.30$  ABI group;  $9.785 \pm 2.111$  in  $0.90-1.30$  ABI group;  $9.13 \pm 1.99$  in  $0.60-0.89$  ABI group and  $9.07 \pm 1.56$  in  $<0.60$  ABI group.

The prevalence of ABI and TBI among diabetic patients with ulcer foot is illustrated in Table 2. Furthermore, the table shows the mean values of ABI, TBI, HbA1c, HSP70 and HSP40 with ulcer outcomes (impaired, improved, and healed with intact skin). The results have shown that the prevalence of ABI was reported in patients with impaired outcomes ( $1.75 \pm 9.55$ ), healed with intact skin ( $1.771 \pm 9.652$ ), and improved outcomes ( $1.761 \pm 9.601$ ) (Fig. 1). For TBI, the results have shown its prevalence among patients healed with intact skin ( $0.982 \pm 0.310$ ), improved outcomes ( $0.9799 \pm 0.311$ ), and impaired outcomes ( $0.975 \pm 0.313$ ) (Fig. 2) (see Fig. 3) (see Fig. 4).

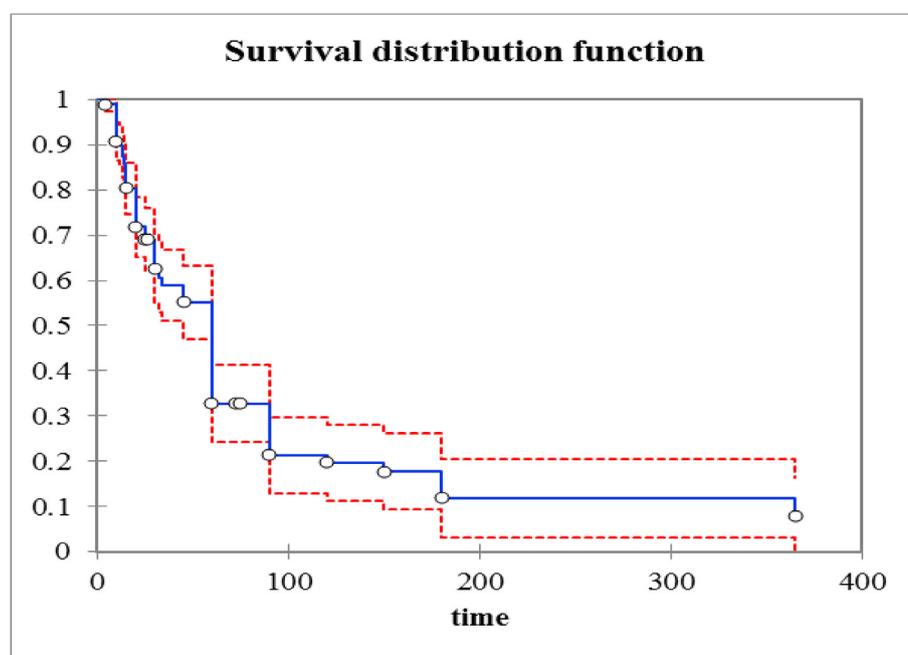
The results have shown that the frequency of HbA1c was reported in patients with impaired outcomes ( $9.681 \pm 2.052$ ), healed with intact skin ( $9.68 \pm 2.065$ ), and improved outcomes ( $9.679 \pm 2.058$ ). For HSP70, the results have shown its extent among patients healed with intact skin ( $3406.181 \pm 1600.86$ ), improved outcomes ( $3397.603 \pm 1581.569$ ), and impaired outcomes ( $3401.9 \pm 1587.65$ ). For HSP40, the results have shown its extent

among patients healed with intact skin ( $2.572 \pm 0.612$ ), improved outcomes ( $2.563 \pm 0.608$ ), and impaired outcomes ( $2.567 \pm 0.608$ ).

The correlation between ulcer healing outcomes, and ABI and TBI is reported in Table 3. The study has reported an insignificant correlation between patients and adiponectin ( $p = .053$ ). The correlation between TBI and HbA1c ( $p = .026$ ), TBI and serum creatinine ( $p = .046$ ), is significantly reported. Similarly, the correlation between TBI and HSP 70; TBI and HSP 47; TBI and Adiponectin; TBI and HDL-C; TBI and LDL-C and TBI and WBC is insignificantly reported (Table 3).

#### 4. Discussion

The results have shown significant association between TBI and ulcer outcomes among diabetic patients with ulcer foot disease. Furthermore, the results have shown effective treatments of diabetic patients with intact skin, while least patients reported impaired outcomes. Patients with improved outcomes also reported an effective treatment to heal the wounds of foot ulcer. These findings have been supported comprehensively by previous studies. For instance, Brownrigg et al. [1] found an adverse impact of ABI on the healing outcomes of diabetic patients and ultimately leads to poorer performance; whereas, the likelihood of TBI was less affected with the presence of neuropathy. The variations existed in the performance of ABI for the diagnosis of diabetic



**Fig. 1.** Kaplan Meier curve of probability of healing of ulcer in diabetic patients with ABI.

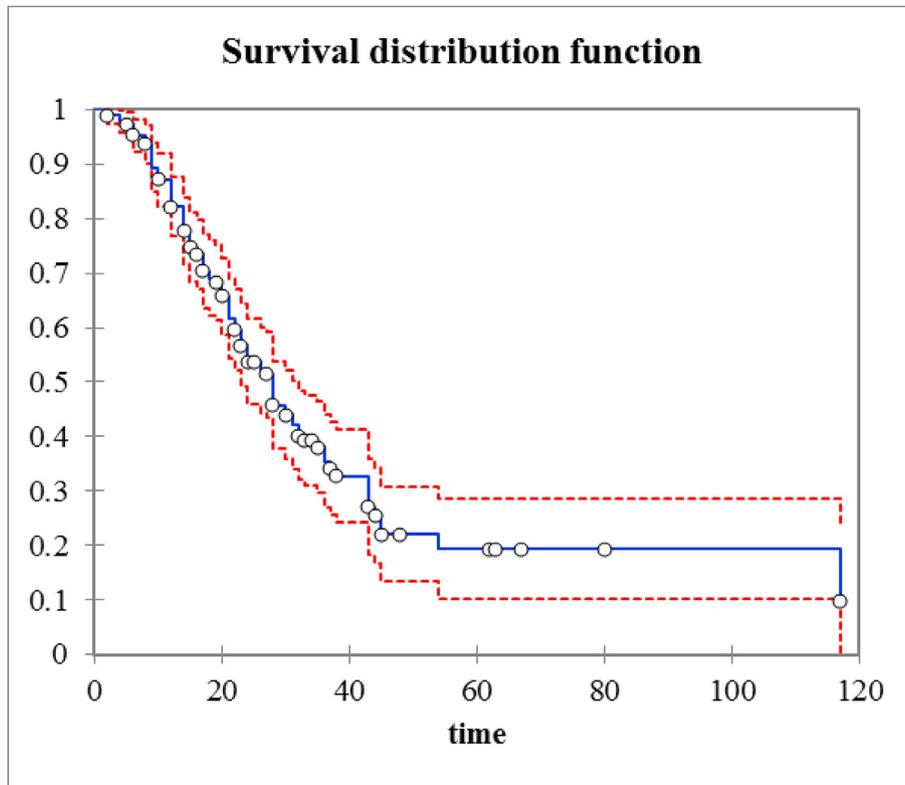


Fig. 2. Kaplan Meier curve of probability of healing of ulcer in diabetic patients with TBI.

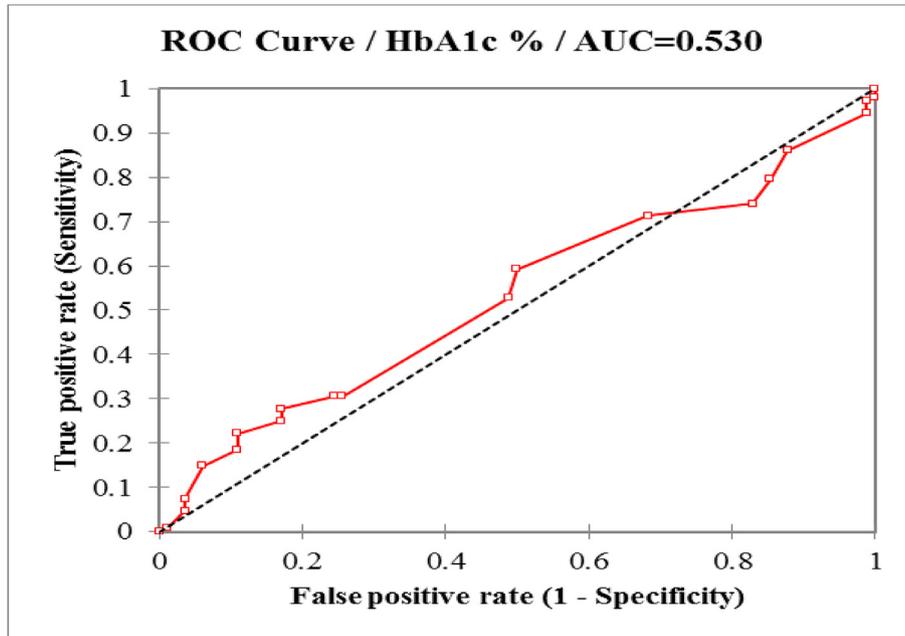


Fig. 3. ROC curve of HbA1c in predicting ABI (mmHg).

patients with ulcer wounds and revealed the efficacy of TBI for the diagnosis of diabetic patients with ulcer wounds. Høyer, Sander-mann & Petersen [7] also reported the diagnosis of diabetic foot ulcer with ABI and TBI. The study reported an insignificant and unreliable detection for the diabetic foot ulcer patients. In addition, the study has indicated a sensitivity of 90–100% for TBI among diabetic patients in the detection of ulcer wounds. Based on these

findings, the study recommends that ABI should be assessed with its well-defined and evidence-based findings for the detection of ulcer wounds among diabetic patients. Sonter & Chuter [8] revealed significant associations with poorer scores for social function, the physical component summary score, and physical domains role through lower TBI values. Based on these findings, the study has recommended that TBI should be used as a quality of life



Fig. 4. Images of diabetic foot ulcers.

**Table 3**  
Correlation between ulcer healing outcomes, ABI and TBI.

	ABI		TBI	
	r	P	r	p
ABI	1	1	.112	.121
TBI	.112	.121	1	1
HSP-70 (pg/ml)	0.048	0.505	0.020	.784
HSP-47 (ng/ml)	−0.013	.856	0.075	.299
Adiponectin (ng/ml)	0.140	0.053	0.032	.659
25(OH)-D (ng/ml)	−0.059	.413	−0.014	.843
HbA1c (%)	0.016	.825	0.162	0.026
HDL-C (mg/dl)	0.049	0.501	−0.022	.759
LDL-C (mg/dl)	0.005	.947	−0.007	.927
WBC( $\times 10^9/L$ )	0.05	.949	.021	.776
S. Creatinine (mg/dl)	−0.046	.529	−0.104	−0.046
Serum Albumin (SA) (gm%)	0.105	.146	0.097	.182
Serum Globulin (SG) (gm%)	−0.026	.716	−0.040	.578

ABI: ankle-brachial index, TBI: toe-brachial index, HSP70: Heat shock protein 70, HSP47: Heat shock protein 47, 25 (OH)D; 25 hydroxy vitamin-D; LDL-C, low density lipoprotein cholesterol; HDL-C, high density lipoprotein cholesterol.

and automated equipment for diabetic foot ulcers. Similarly, a limited association was found between TBI and physical and social aspects of health-related quality of life. Álvaro-Afonso et al. [9] reported the clinical utility of ABI in diabetic patients with foot ulcers and arterial calcification. The study has found a high prevalence of ABI among patients with diabetic foot ulcers as compared to patients without diabetic foot ulcers. Similarly, the study reported a weaker correlation between patients with an ABI and TBI. Based on these findings, the study recommended that the detection of diabetic foot ulcer can be underestimated by falsely considered

ABI and TBI values. The findings are also supported by Bunte et al. [10]. The study examined the relationship between ABI and TBI among patients with ulcer wounds. The study has reported an increased TBI efficacy among patients as compared to ABI in terms of statistical power and median. The study has reported a positive and significant correlation between TBI and diabetic foot ulcer patients. The study; therefore, recommended that TBI evaluation can increase the diagnostic accuracy of ABI in the critical limb ischemia and diabetic foot ulcer.

In contrast, an adverse correlation was also found between ABI and TBI, and diabetic foot ulcer patients in terms of its severity [11]. Although both ABI and TBI reflected microvascular state, the study has reported an insignificant correlation between both indexes. These findings indicated that diabetic foot ulcer cannot be relied on microvascular state and; therefore, it recommended inclusion of multiple factors for the diabetic foot ulcer. It was also reported that interesting evidence of both ABI and TBI among diabetic foot ulcer patients [12]. The study has reported that both ABI and TBI are effective screening tests for diabetic foot ulcer patients. The findings are not supported by these studies as they revealed the efficacy of both ABI and TBI for diabetic foot ulcer patients. Elgyri [13] reported the effectiveness of ABI and TBI in improving the circulation of blood in the ulcer wounds. The study has reported that both ABI and TBI are effective to be used as a marker for healing process of diabetic foot ulcer patients. On the contrary, the study has also reported a likelihood of new ulcers among diabetic patients if these screening tests found to be ineffective in screening ulcer wounds. Similarly, the effectiveness of both screening tests is associated with the time to revascularization after admittance. The sensitivity and specificity of TBI index was also reported in the

detection of diabetic foot ulcer wounds [14]. The study has shown that the sensitivity of TBI was found to be reported from 45 to 100% among seven studies; 16%–100% specificity was found among five studies. The study has therefore, recommended that TBI vary in terms of its diagnostic accuracy among patients with ulcer wounds. Similarly, the study reported a paucity of diagnostic accuracy among diabetic patients and suggested to establish standardized normal values for TBI in ulcer wounds screening. Wu et al. [15] examined the safety and efficacy of placenta-derived stromal-like cells among patients with diabetic foot ulcer. The study has reported an effective screening and assessment of ABI for the diabetic patients with ulcer wounds. Thereby, the study has recommended that ABI index should be used as biomarkers and endpoints for determining the ulcer wounds in diabetic patients.

## 5. Conclusion

The study aimed to assess the critical roles of ABI and TBI in the detection of ulcer wounds among diabetic patients. A total of 192 diabetic patients were included, based on a retrospective approach and were screened through ABI and TBI index. The findings have indicated an adverse screening impact in determining ulcer wounds among diabetic patients, since p-value was greater than the 5% level of significance in all ulcer outcomes. However, TBI index was significantly used as a biomarker in determining the ulcer wounds among diabetic patients, since p-value was less than the 5% level of significance in all ulcer outcomes. Based on these findings, the study has reported a poorer performance of ABI index in detecting ulcer wounds, although it has well-defined and standardized values. This performance leads to report the presence of diabetic patients in an impaired ulcer outcome. Therefore, it is essential to establish standardized normal values of ABI to use it as an effective biomarker in determining ulcer wounds among diabetic patients. Several limitations have been identified, in which adverse outcomes of ABI in the detection of diabetic foot ulcer was critical. Previous studies have clearly shown the ineffectiveness of ABI in determining the ulcer wounds and thus requires appropriate standardized values to reveal its efficacy on the diagnostic accuracy of ulcer wounds. Patients with impaired outcomes were extensively reported with respect to wound healing and; therefore, indicates poorer performance of screening tests in detecting ulcer wounds.

## Conflicts of interest

The research has no conflict of interest and is not funded through any source.

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## Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.dsx.2018.08.018>.

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