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## Angiography Scores Can Predict Amputation in Diabetic Feet

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### Abstract

Diabetic foot is a complication of diabetes mellitus, with a risk of amputation. One of the risk factors for amputation is peripheral arterial occlusive disease. Angiography is a diagnostic method used to visualize blood vessels, plan therapeutic actions, and predict prognosis, including the likelihood of amputation. The validity of angiography scores in predicting amputation in diabetic foot patients is assessed. This study is a diagnostic test to determine the validity of angiography scores in predicting amputation in 23 diabetic foot patients at Prof. Dr. I.G.N.G. Ngoerah General Hospital. Data analysis used the Receiver Operator Curve (ROC) and diagnostic tests to obtain the Area Under the Curve (AUC), cutoff point, sensitivity and specificity, Negative Predictive Value (NPV), Positive Predictive Value (PPV), Positive Likelihood Ratio (PLR), and Negative Likelihood Ratio (NLR). The study results showed a cutoff point for angiography scores of 33% with an AUC of 0.9841 (>0.7) for the percent score and a cutoff point of 6 with an AUC of 0.9960 for the total score (>0.7). The sensitivity and specificity of the angiography scores were very good for predicting amputation in diabetic foot, at 92.9% and 88.9% (CI 95%), respectively. With PPV of 92.9% and NPV of 88.9%, the diagnostic value of angiography scores in predicting amputation in diabetic foot patients is supported. This study shows that angiography scores have good validity in predicting amputation in diabetic foot patients.

**Keywords:** diabetic foot; angiography score; amputation; diagnostic test

### INTRODUCTION

The increasing prevalence of diabetes mellitus (DM) worldwide has led to a rise in diabetes-related complications. In 2011, the number of DM patients globally was estimated to be 366 million, and it is projected to reach 552 million by 2030.(1) In Indonesia, the World Health Organization (WHO) estimates that the prevalence of diabetes mellitus (DM) will increase from 8.4 million in 2000 to approximately 21.3 million by 2030.(2)

Diabetic foot is one of the common chronic complications encountered in patients with diabetes mellitus (DM). Diabetic foot complications in patients with type 2 DM can result in amputation.(3) Diabetes patients are 12-46 times more likely to undergo amputation compared to non-diabetes

patients.(4) It is estimated that diabetic foot complications can affect 25% of diabetes patients.(5) Future amputations can impact quality of life and are associated with increased mortality. Peripheral artery disease (PAD) is a major risk factor for diabetic foot and is associated with severe clinical manifestations and the risk of amputation. (6) Various diagnostic methods are used to detect PAD in diabetic foot, such as the Ankle Brachial Index (ABI), Doppler ultrasonography, and angiography. Among these methods, angiography provides superior diagnostic information and is useful for planning treatment and further actions.(7)

The increasing use of angiography to assess vascular conditions in diabetic foot patients has led to a reduction in the uniformity of morphological criteria that

can explain the degree of peripheral vascular system involvement.(8) Several scoring systems and classifications are used to evaluate angiography results, including the Bolinger Scoring System, Graziani Classification, Trans Atlantic Inter-Society Consensus (TASC I and TASC II), Joint Vascular Societies Council Classification, and Faglia Scoring.(9–11) According to recent data, the Faglia Scoring System is reported to better represent the overall lower extremity peripheral vasculature and is simpler and easier to apply.(12)

This study aims to validate the Faglia angiography score in predicting amputation in diabetic foot patients.

## METHODS

This study is an observational diagnostic test on 23 diabetic foot patients at Prof. Dr. I.G.N.G. Ngoerah General Hospital. The sample was obtained from medical records of diabetic foot patients who underwent angiography procedures meeting the inclusion and exclusion criteria from January 2016 to December 2018.

### Data Collection

The data collected were secondary data including age, gender, amputation status or location, ulcer degree based on the Wagner classification, and angiography scores. The Wagner classification of diabetic foot includes grade 0 (intact skin with deformities due to neuropathy), grade 1 (localized superficial ulcer), grade 2 (deeper ulcer involving tendon, ligament, muscle, or joint without bone involvement, cellulitis, or abscess), grade 3 (deep abscess with or without osteomyelitis), grade 4 (gangrene of toe or distal foot), and grade 5 (whole foot gangrene). Angiography scores were obtained from lower extremity angiograms by determining the degree of stenosis measured using the diameter of the lu-

men at the stenosis area divided by the diameter of the lumen expressed as a percentage (%), which was then converted into a total score. Amputation was determined by a cardiothoracic vascular surgeon based on clinical considerations such as the degree of infection, gangrene, sepsis, and peripheral artery disease.

### Data Analysis

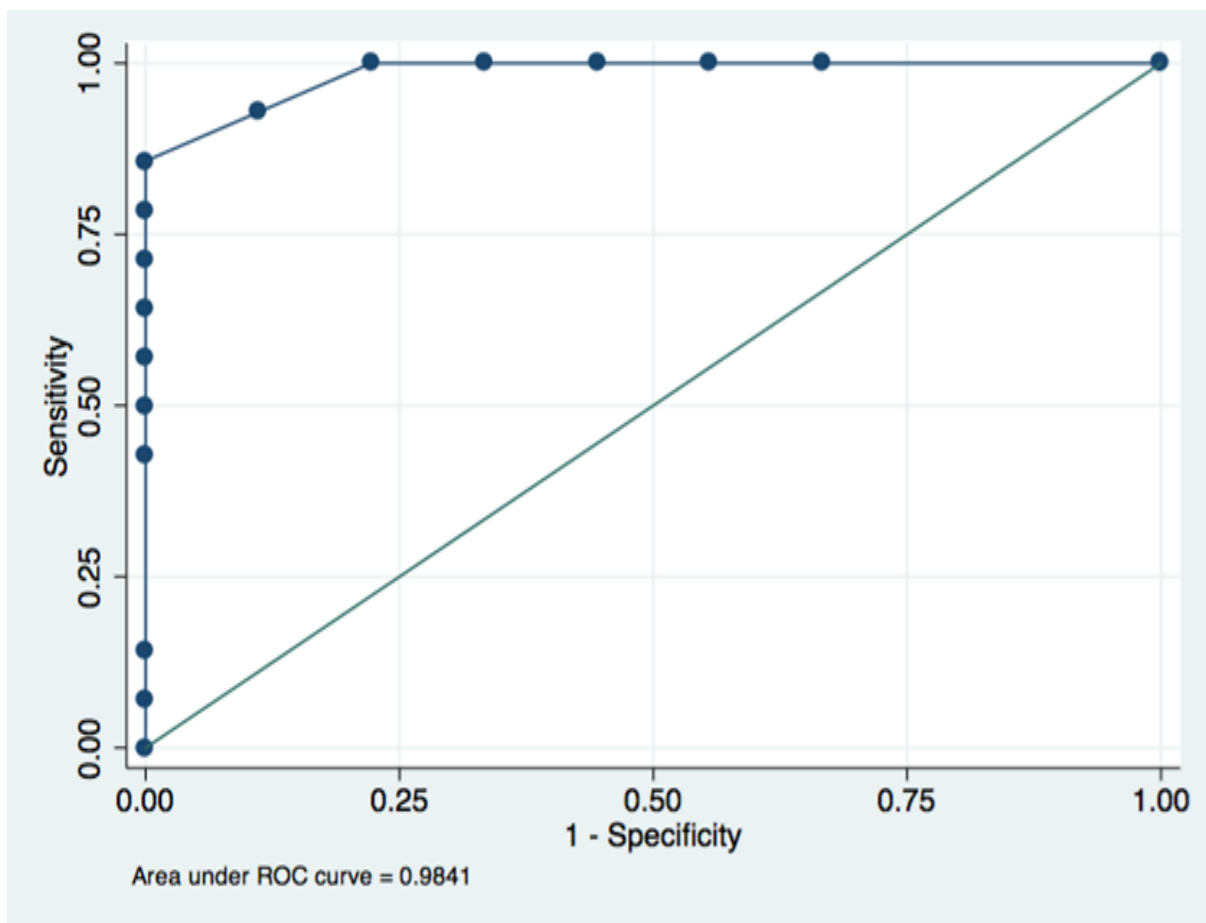
After data collection, it was evaluated using descriptive statistics (frequency distribution) for categorical data, and (mean, standard deviation) for numerical data. The ability of angiography scores to predict amputation was analyzed using the receiver operator curve (ROC) based on the area under the ROC curve and identifying the best cutoff point. Sensitivity, specificity, and accuracy of the diagnostic test were analyzed using a 2x2 table with the gold standard diagnosis in the columns and the test results in the rows. The entire statistical analysis process was performed using SPSS version 15.

## RESULTS

A total of 23 samples were involved in the study, consisting of 13 men and 10 women, with an average age of  $59 \pm 12.2$  years. Among the samples, 14 (60.9%) had a Wagner ulcer grade of 4. The mean angiography percentage score was  $39 \pm 26.7$ , while the total angiography score mean was  $7.39 \pm 5.64$ . Regarding amputation status, 9 (39.1%) patients had a negative amputation status, while 14 (60.9%) patients had a positive amputation status (Table 1). Angiography of all vascular segments showed occlusion or stenosis mostly in the anterior tibial artery (73.9%), superficial femoral artery (60.9%), posterior tibial artery (60.7%), peroneal artery (56.5%), and popliteal artery (52.2%).

**Table 1.** Characteristics of 23 Patients with Diabetic Feet

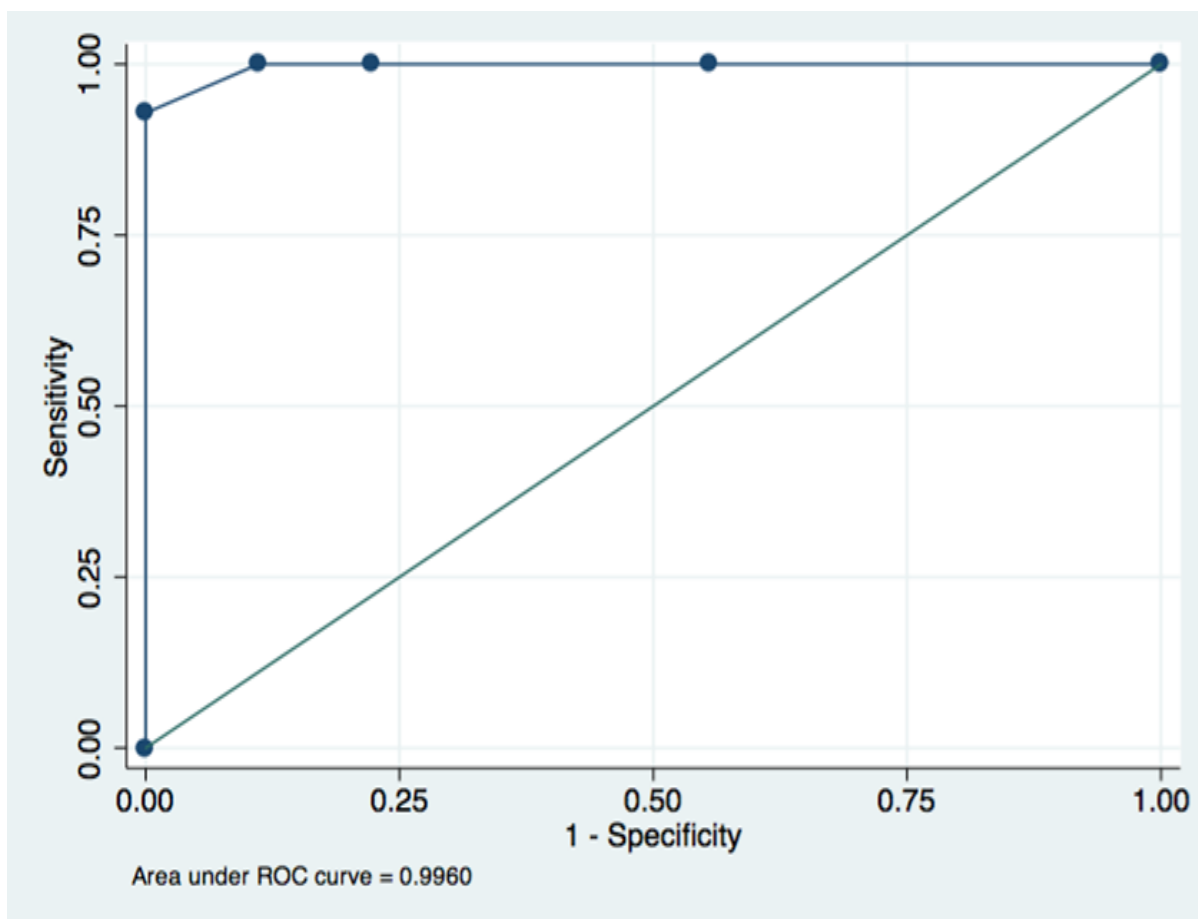
Variable	Sample (n = 23)
Age, mean ± SD	59 ± 12.2
Minimum - maximum	42 – 89
Gender	
Male	13 (56.5%)
Female	10 (43.5%)
Ulcer grade	
Wagner 1	0 (0%)
Wagner 2	3 (13.0%)
Wagner 3	5 (21.7%)
Wagner 4	14 (60.9%)
Wagner 5	1 (4.4%)
Percentage of score, mean ± SD	39.5 ± 26.7
Minimum – maximum	0 – 79
Total score, mean ± SD	7.39 ± 5.64
Minimum – maksimum	0 – 15
Amputation	
No	9 (39.1%)
Yes	14 (60.9%)



**Figure 1.** ROC Curve for the Ability of Angiography Scores to Predict Amputation in Diabetic Foot Based on Percentage Scores

In diabetic foot patients, the ROC curve was used to determine the relationship between sensitivity and specificity of angiography scores in predicting amputation. From the ROC curve analysis, the area under the ROC curve for the percentage score was 0.9841 and for the total score was 0.9960, with the best sensitivity and

specificity values at a cutoff point of  $\geq 33\%$  for the angiography percentage score, and  $\geq 6$  for the total angiography score (Figure 1). Therefore, an angiography percentage score of  $\geq 33\%$  and a total score of  $\geq 6$  indicate the necessity for foot amputation (Figure 2).



**Figure 2.** ROC Curve for the Ability of Angiography Scores to Predict Amputation in Diabetic Foot Based on Total Scores

Sensitivity and specificity were used to evaluate the ability of angiography scores to predict amputation in diabetic foot patients. The optimal cutoff point for the angiography score to predict amputation (percentage score) is  $\geq 33\%$ , with a sensitivity of 92.86% and specificity of 88.89%. Meanwhile, the angiography score to predict amputation (total score) is  $\geq 6$ , with a sensitivity of 92.86% and specificity of 100%. A 2x2 diagnostic test table was used to analyze the ability of the angiography

score at a cutoff point of  $\geq 33\%$  to predict amputation in diabetic foot patients. The sensitivity and specificity of the angiography score to predict amputation in diabetic foot were found to be 92.9% and 88.9% (95% CI) with a positive predictive value (PPV) of 92.9% (66.1-99.8%), a negative predictive value (NPV) of 88.9% (51.8-99.7%), accuracy of 91.3%, a positive likelihood ratio (PLR) of 8.36 (1.31-53.3), and a negative likelihood ratio (NLR) of 0.0804 (0.012-0.539) (Table 2).

**Table 2.** Diagnostic Test of Angiography Scores for Predicting Amputation

Angiography Score	Amputation		Sensitivity (%)	Specificity (%)	NPP (%)	NPN (%)
	Yes	No	(CI 95%)	(CI 95%)	(CI 95%)	CI (95%)
≥ 33	13	1	92.9%	88.9%	92.9%	88.9%
< 33	1	8	66.1-99.8	51.8-99.7	66.1-99.8	51.8-99.7

**DISCUSSION**

Peripheral artery occlusive disease is a common complication in patients with diabetes mellitus, and if left untreated, it is associated with high morbidity and an increased risk of foot ischemia, amputation, and death.(13)

A retrospective study on diabetic foot patients who underwent angiography aimed to determine the validity of angiography scores in predicting amputation in diabetic foot. Based on the diabetic foot ulcers, the majority of patients (60.9%) had a Wagner grade 4 ulcer. The grade of diabetic foot ulcers affects wound healing, with 56.7% of grade 4 ulcers at risk of amputation.(11) Peripheral artery disease is a predictor of healing impediments, accompanied by persistent infection, and is the primary reason for amputation in diabetic foot.(14) In this study, amputation was observed in the majority of patients (60.9%). Other studies have reported a 66.3% amputation rate in diabetic foot patients who underwent angiography.(12) Hemodynamic factors, such as strong blood flow pressure in larger arteries, facilitate damage to the intimal layer, leading to platelet aggregation and thrombosis.(15) This study found occlusion in blood vessels, particularly in the anterior tibial artery (73.9%), posterior tibial artery (60.7%), and superficial femoral artery (60.9%).

To further evaluate the validity of angiography scores in predicting amputation in diabetic foot patients, we analyzed the data using the ROC curve. In this study, the area under the ROC curve for both percentage scores and total scores (>70%) can

be used to predict amputation in diabetic foot patients. Additionally, the ROC analysis provided optimal cutoff points for angiography scores >33% and ≥6, indicating good sensitivity and specificity for predicting amputation in diabetic foot. The same study reported that an angiography score ≥7 can predict the need for surgical revascularization in diabetic foot.(10)

For clinical purposes, the predictive validity of angiography scores is necessary to accurately determine whether amputation will occur in diabetic foot patients. The analysis results showed that angiography scores correctly predicted amputation in 92.9% of cases and correctly predicted no amputation in 88.9% of diabetic foot patients. These predictive values can fluctuate significantly depending on disease prevalence.(16)

Since the relationship between angiography findings and vascular resistance has been established, the preoperative angiography benefits have become important in determining the degree of atherosclerosis in the lower extremity arteries of diabetic foot patients.(17) Accurate angiography predictions are indicated by the likelihood of amputation in diabetic foot patients. In this study, based on an AUC value of 0.98, the positive likelihood ratio (PLR) was 8.36 and the negative likelihood ratio (NLR) was 0.08. Therefore, angiography scores have good diagnostic value for predicting amputation in diabetic foot patients. Additionally, it has been reported that the angiography scoring of peripheral artery disease in diabetic foot patients is relevant to bypass graft patency and limb salvage.(18)

**CONCLUSIONS**

The results of this study indicate that angiography scores have good validity for predicting amputation in diabetic foot patients. Moreover, although there are many scoring systems for angiography evaluation, the scoring system used in this study is the simplest, easiest to apply, and can effectively represent the overall lower extremity vasculature.

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