# Comparison of the accuracy of two wound classification systems for diabetic foot ulcer healing

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## Abstract

**Background:** Diabetic foot ulcers (DFUs) remain a significant clinical challenge, requiring precise classification systems to aid prognosis and treatment planning. The Wagner classification is widely used but offers limited detail on specific wound characteristics, while the SHID (Suriadi, Haryanto, Imran, Defa) system provides a more comprehensive evaluation but lacks validation.
**Purpose:** This study was designed to evaluate and compare the predictive validity of the Wagner and SHID classification systems in forecasting DFU healing outcomes.
**Methods:** A prospective cohort study was conducted at Kitamura Clinic and Doctor Soedarso Pontianak Hospital between August 2021 and July 2022, involving 89 DFU patients. Both systems were evaluated based on sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and likelihood ratios. Predictive validity was determined using receiver operating characteristic (ROC) curve analysis and the Youden index.
**Results:** A cut-off grade of >2 provided optimal predictive value for both systems. The SHID classification demonstrated a sensitivity of 92%, specificity of 62%, PPV of 27.5%, and NPV of 98%, while the Wagner classification showed a sensitivity of 58%, specificity of 77%, PPV of 28%, and NPV of 92.2%. Positive likelihood ratios were 2.4 for SHID and 2.5 for Wagner. ROC analysis yielded an area under the curve (AUC) of 0.786 (95% CI: 0.69–0.87) for SHID and 0.703 (95% CI: 0.60–0.80) for Wagner. The Youden index was higher for SHID (0.540) compared to Wagner (0.349).
**Conclusion:** Although both systems are effective for predicting DFU healing within 12 weeks, SHID's superior AUC and Youden index suggest greater clinical utility in screening and managing DFUs.

**Keywords:** diabetic foot ulcer; sensitivity, specificity, wound classification, wound healing prediction

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## Introduction

In a number of nations, including Indonesia, diabetes is one of the diseases with the highest prevalence. According to the International Diabetes Federation (IDF), Indonesia ranks fifth in terms of the number of diabetes patients. There are 19.5 million Indonesians between the ages of 20 and 79 who suffer from this ilness (Magliano et al., 2021). The IDF also predicts that Indonesia will maintain its fifth-place ranking in 2045. In fact, diabetes cases in Indonesia will reach 28.6 million or increase by 46.6% (Magliano et al., 2021). DFU is one of the complications associated with diabetes.

In Indonesia, the incidence of DFU is quite high at 48.6%, while the incidence of wound recurrence is 51.4% (Jais et al., 2022). DFU are a common and highly abnormal complication of long-term and inadequately treated diabetes. Approximately 19% to 34% of the estimated 537 million diabetics worldwide will develop DFU in their lifetime. 20% of individuals with DFU require a lower extremity amputation, either minor (below the ankle), major (above the ankle), or both and 10% will die within one year of

their initial DFU diagnosis (McDermott et al., 2023). Therefore, the implementation of DFU prevention strategies that can develop even worse is very important, and will likely contribute to reducing the burden on national health services.

Diabetes-related foot ulcers are non-healing wounds on the epidermis of the feet of diabetics. There are a number of factors that can affect the outcome of a DFU, including healing time and the danger of lower extremity amputation (Kaminski et al., 2022; Kawuryan, 2018). Wound classification systems are useful tools to support clinical judgement, aid effective communication between healthcare professionals, assist triage of referrals to timely specialist services and to guide clinical decision-making and prognosis in certain situations, and support clinical auditing and benchmarking (Kaminski et al., 2022). A number of review articles on DFU classification systems, including Wagner and SHID, have been published. A DFU classification system intended to provide a risk assessment or prognosis for an individual patient will require more detailed information and evaluation compared with a DFU classification system designed for the comparison of outcomes between populations, the latter which would ideally be simple, quick and require no specialised equipment (Kaminski et al., 2022).

Wagner is a commonly used classification (Oyibo et al., 2001), while SHID is a new Indonesian classification. Unfortunately, in Indonesia, the reliability assessment of the Wagner scale is fair to substantial, with inter-rater reliability study demonstrating a kappa coefficient (κ=0.43 - 0.77) in comparison to the SHID scale, which exhibits a higher kappa coefficient of [κ]=0.81 -1.00 (Suriadi et al., 2016). Other (Suriadi et al., 2016) studies have also reported that the classification of Wagner wounds demonstrates moderate reliability in the inter-observer agreement between the initial evaluation and the reevaluation for the Wagner classification (Kappa = 0.55; 95% CI: 0.507–0.593) (Bravo-Molina et al., 2018), as well as Krippendorff's α agreement between observers α of Wagner = 0.374 (Alahakoon et al., 2023). Subsequently, in the validity assessments reported in various studies, sensitivity values were observed to fluctuate between 0.75 and 0.88, whereas specificity values ranged from 0.71 to 0.94 (Chuan et al., 2015; Gunawan et al., 2024; Jais et al., 2022; Jeon et al., 2017).

The sensitivity and specificity values for the Wagner classification of wounds are generally favorable. However, due to the comparatively low reliability observed when assessed against the SHID in previous studies, there is a critical need to conduct validity studies on both classification systems. Despite the existence of various wound classification systems, none has been recognized as a definitive gold standard. Empirical studies have demonstrated that the sensitivity and specificity of these assessments can be reliably determined to an adequate level, even in the absence of an established gold-standard reference test (Habibzadeh, 2023; Lim, 2021). The aim of this study was to evaluate the predictive validity of the Wagner and Shid classifications in relation to wound healing outcomes in patients with diabetic wounds.

## Materials and Methods

### Design

The present study employed a prospective cohort design. This method facilitates the longitudinal examination of diabetic foot ulcers by tracking patients from the initial assessment. It facilitates the implementation of the Wagner and SHID classifications at baseline and the subsequent comparison of these scores with wound-healing outcomes obtained throughout the 12-week follow-up period. This methodology guarantees immediate data acquisition, diminishes recollection bias, and offers a more precise evaluation of the predictive validity of competing categorization systems.

### Setting and sample

This study conducted at Kitamura Clinic and Wound Clinic Doctor Soedarso Pontianak Hospital from August 2021 to July 2022. A purposive sampling technique was used in this study. This study involved the participation of two nurses who have certifications in wound care. They were graduates of a nursing degree and had more than one year of experience in wound care. Each of them, one nurse was an employee at the wound clinic of the hospital, and one nurse was an employee at Kitamura Clinic.

The inclusion criteria for the samples consist of individuals diagnosed with DFUs, encompassing both new and recurrent ulcers. There is no age restriction for the participants, and the selection is not limited to badly infected wounds or DFU with complications, patients without complications such as kidney or heart failure, stroke, and others or those who are unable to perform activities. Additionally, the study includes patients who are receiving outpatient treatment. Respondents were recruited through a simple stepwise process. All patients presenting with diabetic foot ulcers at both clinical settings were initially screened by research assistants. Those meeting the inclusion criteria were identified through medical records and initial clinical assessment. Eligible patients were then approached during their visit, informed about the study, and invited to participate. Individuals who agreed provided written consent, after which baseline assessments were completed, and participants were followed weekly for 12 weeks.

### Instruments

This study utilized several instruments for data collection, including the Wagner (Shah et al., 2022) and SHID (Jais et al., 2022) wound classification systems. Additionally, vascular Doppler, blood pressure measurement, and a monofilament test were employed. Demographic information was

**Table 1. Characteristic of participants**

| Variables | |
|---|---|
| Gender n (%) | |
| Male | 42 (47.2) |
| Female | 47 (52.8) |
| Age, mean ( SD) | 56.6 (9.7) |
| Education | |
| Elementary school | 13 (14.6) |
| Yunior high school | 5 ( 5.6) |
| Senior high school | 50 (56.2) |
| Higher education | 21 (23.6) |
| Smoking n (%) | |
| Smoke | 12 (13.5) |
| No smoke | 77 (86.5) |
| Healing time n (%) | |
| ≤ 12 weeks | 77 (86.5) |
| > 12 weeks | 12 (13.5) |
| Mean DMIST score, mean (SD) | 6.7 (2.4) |
| Blood pressure , mean (SD) | |
| Systole | 136.5 (17.4) |
| Diastole | 86 ( 6.9) |
| HbA1c, median (min-max) | 8.5 (6.1 – 15.2) |
| Neuropathic n (%) | |
| Positive | 20 (22.5) |
| Negative | 67 (77.5) |
| Ankle Brachial Index, median (min-max) | 1 (0.7 – 1.6) |
| Wound site | |
| Forefoot | 43 (48.3) |
| Midfoot | 26 (29.2) |
| Hindfoot | 6 ( 6.8) |
| Malleolus | 1 ( 1.1) |
| Above malleolus | 13 (14.6) |

Note : SD, standard deviation, min-max (minimum – maximum)

**Table 2.The sensitivity and specificity for score of the SHID**

| Criterion | Sensitivity | Specificity | +LR | -LR | +PV | -PV |
|---|---|---|---|---|---|---|
| ≥1 | 100 | 0 | 1 | | 13.5 | |
| >1 | 100 | 31 | 1.5 | 0 | 18.5 | 100 |
| >2 | 92 | 62 | 2.4 | 0.1 | 27.5 | 98 |
| >3 | 33 | 88 | 2.9 | 0.8 | 30.8 | 89.5 |
| >4 | 8 | 94 | 1.3 | 1 | 16.7 | 86.7 |
| >5 | 0 | 99 | 0 | 1 | 0 | 86.4 |
| >6 | 0 | 100 | | 1 | | 86.5 |

gathered using a questionnaire form and DMIST tool.

DMIST is a diabetic foot ulcer assessment scale was created based on seven distinct domains: depth, maceration, inflammation/infection, size, the type of tissue present in the wound bed, characteristics of the wound edge, and tunneling/undermining (Oe et al., 2020). This assessment tool is referred to as DMIST, which is an acronym representing the seven domains. The DMIST scale functions as a

**Table 3.The sensitivity and specificity for score of the Wagner**

| Criterion | Sensitivity | Specificity | +LR | -LR | +PV | -PV |
|---|---|---|---|---|---|---|
| ≥1 | 100 | 0 | 1 | | 13.5 | |
| >1 | 100 | 21 | 1.3 | 0 | 16.4 | 100 |
| >2 | 58 | 77 | 2.5 | 0.5 | 28 | 92.2 |
| >3 | 0 | 95 | 0 | 1 | 0 | 85.9 |
| >4 | 0 | 100 | | 1 | | 86.5 |

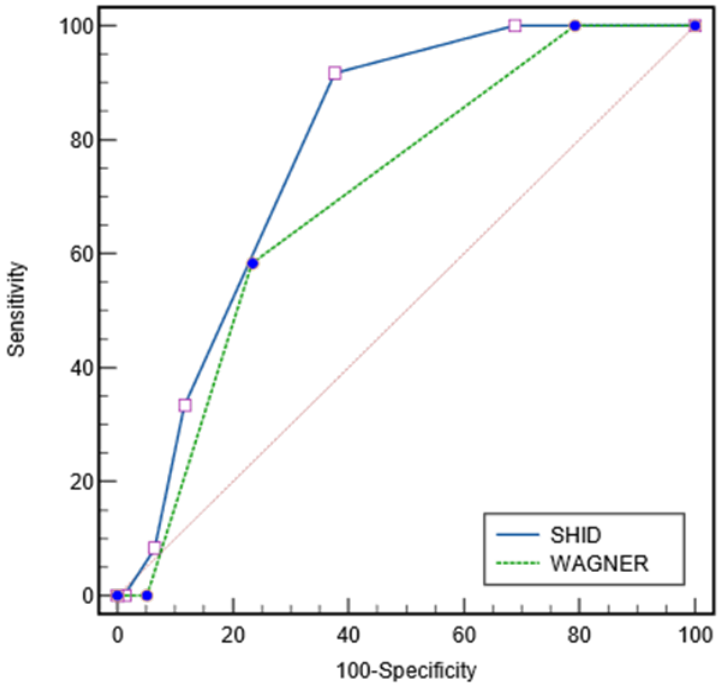


**Figure 1. The receiver operator characteristic curve of the SHID and Wagner for wound healing within ≤ 12 and > 12 weeks follow-up (n 89). SHID : AUCs were 0.786 (95% CI: 0.69 – 0.87) and Wagner, the AUCs were 0.703 (95% CI: 0.60–0.80). Youden index was 0.540 for SHID and 0.349 for Wagner.**

summative rating scale comprising seven subscale scores that range from 0 to 9 (with only one subscale reaching a score of 9). The overall scores can vary from 0 to 34, with higher scores indicating a poorer prognosis for wound healing.

## Data collection

The data collection process was carried out by two research assistants who conducted wound assessments utilizing classification systems upon the patients' admission to the clinic and the polyclinic. In addition, they measured the ankle-brachial index (ABI) with a handheld vascular Doppler, assessed blood pressure, evaluated HbA1c levels, and determined neuropathy status through the monofilament test, while also collecting demographic information from the patients. The research assistants performed weekly follow-ups throughout the recovery process, assessing wound progress using the DMIST tool. Patients were observed for a duration of up to 12 weeks or until clinical assessment confirmed wound healing.

## Data analysis

Descriptive statistics described patient characteristics. In order to assess the precision of the two wound classification systems, diagnostic probabilities (specifically sensitivity and specificity) were computed over the spectrum of scores generated by the respective instruments. To assess predictive validity, we analyzed the accuracy of the Wagner and SHID wound classifications. The diagnostic probabilities, including sensitivity, specificity, PPV, NPV, PLR, and negative predictive value (NLR), were computed across the spectrum of Wagner and SHID classification scores (Lim, 2021; Šimundić, 2009; Trevethan, 2017).

Sensitivity is defined as the proportion of individuals diagnosed with the target condition who yield a positive test result, specifically, the percentage

of patients exhibiting wound healing within a 12-week timeframe whose scores fall below or equal to the established cut-off. In contrast, specificity refers to the proportion of individuals without the target condition who present a negative test result, denoting the percentage of patients whose scores are equal to or exceed the cut-off threshold. Positive Predictive Value is the proportion of patients who test positive and indeed have the target condition, represented as the percentage of patients with scores below or equal to the cut-off who experience wound healing within 12 weeks. Conversely, NPV indicates the proportion of patients with a negative test result who do not possess the target condition, quantified as the percentage of those with scores above the cut-off who do not achieve wound healing within the same 12-week period.

According to Suriadi et al., (2008), the likelihood ratio is calculated as the sensitivity divided by 1 - specificity, indicating the ratio of probabilities that a positive test result occurs in a patient with wound healing within 12 weeks compared to a patient without such healing in that timeframe. For both patients with and without wound healing occurring within 12 weeks, the Wagner and SHID wound classification scores were ascertained during the initial assessment.

The Receiver Operating Characteristic curve serves as a graphical depiction of sensitivity (true positives) plotted on the y-axis against one minus specificity (false positives) on the x-axis across all potential cut-off scores for a given test. Consequently, the ROC curve illustrates the balance between the true positive rate and the false positive rate for every possible dichotomous cut-off score pertaining to the test. The Area Under the Curve of the ROC is computed to evaluate the overall validity of the wound classification system. AUC is recognized as a summary statistic of the ROC, with higher AUC values indicative of more precise tests. An AUC of 0.5 denotes a lack of diagnostic capability in predicting outcomes. The ROC method represents one approach to validating diagnostic tools and is extensively used for the standardization of medical diagnoses, decision-making criteria, as well as the development and calibration of questionnaires or evaluation tools (Lim, 2021; Šimundić, 2009). Tests without diagnostic competence predict outcomes with an AUC of 0.50. MedCalc 15.8 (Ostend, Belgium) was used for all statistical analyses.

### Ethical consideration

This study was conducted after the approval of the Ethics Committee at the Institute of Technology and Health Muhammadiyah Ponianak, with the assigned number: 99A//KEP/II).I/AU/D/2021. Prior to commencing the study, the researchers provided a comprehensive elucidation of the study's objectives, the methodologies employed for data acquisition, and the advantages associated with subject involvement. The participants were provided with the chance to pose inquiries and were given the assurance that they had the option to discontinue their involvement in the study at any given point. The confidentiality of their personal information was maintained.

## Results

### Characteristic of participants

There were 89 DFU patients that enrolled. Table 1 depicts the characteristics of the patients. The mean (SD) age was 56.6 (9.7) years, with 47.2% of patients male and 52.8% female. Elementary school had 14.6%, junior high had 5.6%, senior high had 56.2%, and higher education had 23.6%. 86.5% of patients did not smoke, whereas 13.5% did. The wound healing time at 12 weeks was 86.5%, with 13.5% taking longer. The mean (SD) DMIST score was 6.7 (2.4), systolic blood pressure was 136.5 (17.4), and the diastolic blood pressure was 86 (6.9). The median of HbA1c was 8.5 (6.1 - 15.2), while ABI was 1 (0.7 - 1.6). Neuropathy affected 22.5% of patients, whereas 77.5% did not. The wound regions were 48.3% in the forefoot, 29.2% in the midfoot, 6.8 in the hindfoot, 1.1% in the malleolus, and 14.6% above the malleolus.

### Predictive validity

The sensitivities, specificities, PPV, NPV, and LR were calculated for the SHID and Wagner scores and ranged from 1- 6 and 1- 5 respectively. The predictive validity test indicated that a SHID and Wagner cutoff score of >2 produced the best sensitivity, specificity, PPV, and NPV (92%, 62%, 27.5%, and 98%) and (58%, 77%, 28% and 92.2% respectively). Then The SHID was found to be a small to moderate diagnostic tool with a PLR of 2.4 and Wagner 2.5 . In Figure 1, sensitivity was plotted vs. 1-specificity for each possible score of the SHID to generate the ROC; the AUC was 0.786 (95% CI: 0.69 – 0.87) and for Wagner, the AUCs were 0.703 (95% CI: 0.60–0.80, respectively. Then youden index was 0.540 for SHID and 0.349 for Wagner.

## Discussion

The SHID and Wagner were found to be a viable instrument for assessing DFUs in this study, and it can predict wound healing time of 12 and > 12 weeks. The comparison of SHID and Wagner revealed that SHID produced high sensitivity and specificity. The SHID is the new assessment tool developed specifically to assess DFU classification and developed in 2021 (Suriadi, 2021). According to a research conducted by Jais et al. (2022), the predictive validity test revealed that the cut-off score of ≤ grade 2 for SHID shown a sensitivity and specificity of 74% and 97% respectively. Similarly, the cut-off score of ≤ grade IB for TU showed a sensitivity and specificity of 77% and 92% respectively. Furthermore, the cut-off score of ≤ grade 2 for Wagner exhibited a sensitivity of 84% and a specificity of 71%. Our analysis remains

consistent with the prior study on SHID wound categorization, as described, however it contradicts the findings of the Wagner study (Jais et al., 2022).

The SHID was highly sensitive for a cutoff score of > 2 in our investigation, but it had low specificity and positive predictive value, implying a significant false-positive rate. This finding suggests people who are not at risk of developing infection complications may benefit from preventative care. For Wagner results demonstrate that a cutoff score of > 2, with a sensitivity of 0.58 and specificity of 0.77. This means that 58% of the clinical sample was correctly identified as having wound healing time ≤ 12 weeks, even across a diverse clinical sample, while 42% were missed and not identified as belonging to the clinical group when they should have been. Almost all typically developing individuals (77 %) were correctly identified as not having wound healing time ≤ 12 weeks, and only 23 % were identified as having wound healing time ≤ 12 weeks when they actually did not because their score fell below the cutoff of > 2.

In a comparison of various scoring systems conducted at Cheonan Hospital in Korea involving 137 patients, the Wagner score demonstrated a sensitivity of 75% and specificity of 66%. Among the scoring systems evaluated, the Wagner scoring system yielded the most predictive results (Jeon et al., 2017). Its simplicity is one of its key advantages when compared to other scoring systems; however, it does not provide specific assessments related to infection, vascularization, and neuropathy in diabetic foot ulcers. Additionally, another study found that the Wagner score had a sensitivity of 77.2% and a specificity of 80% (Gunawan et al., 2024). Although both studies mentioned above demonstrate reasonable sensitivity and specificity values, their study cannot be directly compared to our study, as both utilized a retrospective design and employed wound assessment through photographs without obtaining direct data from patients during the evaluation process. There are significant limitations when assessing the actual condition of wounds using photography, as factors such as wound depth, the presence of tunneling and undermining, and other signs may not be clearly observed (Mohafez et al., 2016).

Upon examination of the Area Under the Curve (AUC) values for both the Wagner and SHID wound classifications, which fall within the range of 0.70 to 0.80, it can be concluded that both classifications are considered acceptable (Mandrekar, 2010; White et al., 2023). Similarly, the positive likelihood ratios for both the Wagner and SHID classifications are identical, further supporting their comparability.

Nevertheless, an analysis of the Youden index indicates that SHID presents a superior value of 0.540, compared to Wagner's value of 0.349. This finding suggests that SHID demonstrates an acceptable and balanced performance in terms of both sensitivity and specificity (Xu et al., 2014). The Youden Index assigns equal importance to sensitivity and specificity (Schisterman et al., 2008). Additionally, our study found that the AUC of the SHID was greater than 0.75, suggesting it is effective in predicting wound healing times of 12 weeks or less and more than 12 weeks (Cho et al., 2020; Jais et al., 2024).

### Limitation of the study

One primary limitation of the research conducted in this study is to the very limited size of the sample. Furthermore, it is imperative to conduct a multicenter studies in order to establish the generalizability of the findings.

### Implication of study

The results of this study have immediate implications for nursing practice. The SHID classification, noted for its superior predictive accuracy, gives nurses with a practical instrument for evaluating diabetic foot ulcers, prioritizing at-risk patients, and directing appropriate therapies to prevent complications. Its application can improve the quality of nurse assessments, facilitate clinical decision-making, and improve communication among multidisciplinary teams. These findings underscore the necessity for ongoing nursing education and future research to assess the wider implementation of SHID in enhancing patient outcomes.

## Conclusions

The results of this study corroborate the hypothesis that both the SHID and Wagner wound classification systems can be effective for assessing DFU grades in clinical environments. Specifically, our analysis of the AUC and Youden index indicates that the SHID demonstrates moderate accuracy in differentiating between wound healing times of 12 weeks or less and those exceeding 12 weeks. By accurately identifying wound healing durations in patients with DFU using the SHID, there is potential to reduce the risk of underdiagnosis, thereby facilitating timely interventions to prevent complications and ultimately enhance patient outcomes.

### Declaration of Interest

The authors report no competing interests.

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### Data Availability

The datasets generated and analyzed during this study are available from the corresponding author upon reasonable request.

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