An early validation of the Society for Vascular Surgery Lower Extremity Threatened Limb Classification System

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Objective: **The Society for Vascular Surgery (SVS) recently established the Lower Extremity Threatened Limb Classification System, a staging system using Wound characteristic, Ischemia, and foot Infection (WIfI) to stratify the risk for limb amputation at 1 year. Although intuitive in nature, this new system has not been validated. The purpose of the following study was to determine whether the WIfI system is predictive of limb amputation and wound healing.**

Methods: **Between 2007 and 2010, we prospectively obtained data related to wound characteristics, extent of infection, and degree of postrevascularization ischemia in 139 patients with foot wounds who presented for lower extremity revascularization (158 revascularization procedures). After adapting those data to the WIfI classifications, we analyzed the influence of wound characteristics, extent of infection, and degree of ischemia on time to wound healing; empirical Kaplan-Meier survival curves were compared with theoretical outcomes predicted by WIfI expert consensus opinion.**

Results: **Of the 158 foot wounds, 125 (79%) healed. The median time to wound healing was 2.7 months (range, 1-18 months). Factors associated with wound healing included presence of diabetes mellitus ($P = .013$), wound location ($P = .049$), wound size ($P = .007$), wound depth ($P = .004$), and degree of ischemia ($P < .001$). The WIfI clinical stage was predictive of 1-year limb amputation (stage 1, 3%; stage 2, 10%; stage 3, 23%; stage 4, 40%) and wound nonhealing (stage 1, 8%; stage 2, 10%; stage 3, 23%; stage 4, 40%) and correlated with the theoretical outcome estimated by the SVS expert panel.**

Conclusions: **The theoretical framework for risk stratification among patients with critical limb ischemia provided by the SVS expert panel appears valid. Further validation of the WIfI classification system with multicenter data is justified. (J Vasc Surg 2014;60:1535-42.)**

The Society for Vascular Surgery (SVS) Lower Extremity Guidelines Committee recently created the Lower Extremity Threatened Limb (Wound Ischemia foot Infection [WIfI]) Classification System, to stratify the risk of limb amputation in the heterogeneous population of patients presenting with critical limb ischemia (CLI).[1] The SVS WIfI classification system was developed by merging the existing CLI and diabetic foot ulcer (DFU) classification systems.[2-8]

The purpose of this classification system was not meant to function as a stand-alone clinical decision-making tool but to allow for better patient stratification in clinical trials designed to compare new strategies for treating CLI. The classification system predicts limb amputation risk based on three graded factors: wound characteristics, the degree of pedal perfusion, and the extent of infection. Owing to a paucity of natural history studies in patients with CLI, the risks of limb amputation within the categories of this new classification system were estimated by a panel of experts using a Delphi consensus process. The theoretical assumptions developed by this panel still await clinical validation.

Our group has long sought to develop a CLI classification system that would help vascular surgeons predict the likelihood of wound healing in patients with CLI and assist them in evaluating patients for possible revascularization.[9] In 2007, borrowing from the same literature used to develop the SVS WIfI classification system, we began collecting data related to wound characteristics, degree of ischemia, and extent of infection on patients presenting with foot wounds; we also monitored them prospectively The similarity of our collected data and the factors used by the SVS WIfI classification system provided a unique opportunity to use our study population to score patients according to the SVS WIfI and to compare actual patient outcomes with those predicted by the SVS panel of experts. Thus, the purpose of this study was to provide early clinical validation of the SVS WIfI classification system.

METHODS

The Greenville Health System Institutional Review Board for the study of human subjects approved this study (IRB #14947). Patient consent was deemed unnecessary.

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Table I. Comparison of study data categories with the Wound characteristic, Ischemia, and foot Infection (*WIfI*) grades

Study data categories		*WIfI*	
Wound characteristics[a]		Wound grade[b]	
Wound size		0	No rest pain
1	<1 cm^2	1	Small, shallow ulcer
2	1-3 cm^2		No exposed bone, unless limited to distal phalanx
3	>3 cm^2		No gangrene
Wound depth		2	Deeper ulcer with exposed bone joint, or tendon, not involving the tissue heel
1	Ulcer not extending to SQ		Shallow heel ulcer without calcaneal involvement
2	Ulcer extending to SQ tissue		Gangrenous changes limited to digits
3	Ulcer extending to bone or joint space	3	Extensive, deep ulcer involving forefoot/midfoot
Wound type			Deep, full thickness heel ulcer + calcaneal involvement
1	Ulcer		Extensive gangrene involving forefoot/midfoot
2	Gangrene		Full thickness heel necrosis + calcaneal involvement
Location		Infection grade	
1	Forefoot	0	No symptoms or signs of infection
2	Midfoot	1	Local infection involving only skin, SQ tissue
3	Heel	2	Local infection with erythema >2 cm, or involving structures deeper than skin, SQ (eg, abscess, osteomyelitis)
Infection categories		3	Local infection with signs of SIRS
1	None	Ischemia grade	
2	Erythema	0	TP >60 mm Hg
3	Purulence		ABI >0.8
4	Systemic evidence of infection		AP >100 mm Hg
Ischemia categories[c]		1	TP 40-59 mm Hg
1	TP >60 mm Hg		ABI 0.6-0.79
	ABI >0.9		AP 70-100 mm Hg
	Palpable pulse	2	TP 30-39 mm Hg
	AP >80 mm Hg		ABI 0.4-0.59
2	TP 30-60 mm Hg		AP 50-70 mm Hg
	ABI 0.5-0.9	3	TP <30 mm Hg
	AP 50-79 mm Hg		ABI <0.39
3	TP <30 mm Hg		AP <30 mm Hg
	ABI <0.5		
	AP <50 mm Hg		

ABI, Ankle-brachial index; *AP,* systolic ankle pressure; *SIRS,* systemic inflammatory response syndrome; *SQ,* subcutaneous tissue; *TP,* toe pressure.
[a]Study only included patients with foot wounds.
[b]WIfI classification dictates that wound depth take priority over wound size.
[c]If ABI and TP resulted in different grades in patients with diabetes mellitus, TP was used to determine grade.

Description and application of the SVS WIfI Classification System. Developed in 2013, the SVS WIfI system provides an objective classification for wound nonhealing and limb amputation based on three independent risk factors: wound extent (eg, size, depth, presence of gangrene), degree of ischemia, and extent of foot infection. All three factors are individually graded on a scale of 0 to 3. For example, a shallow, small foot ulcer would be classed as a grade 1 wound (W-1), whereas a large wound extending to the joint space with gangrene would be classed as a grade 3 wound (W-3). Severity of ischemia and extent of infection are likewise graded on scales from 0 to 3. A detailed description of the SVS WIfI grading is presented in Table I.

After a patient has been graded on each of the three categories, the grades are combined to create a WIfI spectrum score. The expert consensus panel evaluated each WIfI spectrum score to predict the risk of limb amputation at 1 year and in a separate analysis, the likelihood that the patient would benefit from limb revascularization. A grid of potential WIfI spectrum scores, including the predictions of the consensus panel regarding the risk of limb amputation at 1 year (very low risk, low risk, moderate risk, high risk) for each score, is provided in Table II. The risk category of a WIfI spectrum score determines the clinical stage of disease. WIfI spectrum scores deemed to be very low risk for limb amputation at 1 year are categorized as clinical stage 1 disease. Spectrum scores deemed low risk, moderate risk, and high risk for limb amputation at 1 year are categorized as clinical stage 2, stage 3, and stage 4 disease, respectively.

Patients. All patients presenting to our tertiary referral center between June 2007 and March 2011 with CLI (Rutherford class V or VI) scheduled to undergo a revascularization procedure were prospectively collected in a database. Data related to foot wound characteristics, extent of infection, and degree of ischemia were entered into the database according to specific categories. Those categories were similar but not identical to the grades used by the WIfI classification system.

Table II. Consensus expert estimate of 1-year amputation risk based on the Wound characteristic, Ischemia, and foot Infection (WIfI) Spectrum Score

W grade	*Ischemia 0*				*Ischemia 1*				*Ischemia 2*				*Ischemia 3*			
W-0	VL	VL	L	M	VL	L	M	H	L	L	M	H	L	M	M	H
W-1	VL	VL	L	M	VL	L	M	H	L	M	H	H	M	M	H	H
W-2	L	L	M	H	M	M	H	H	M	H	H	H	H	H	H	H
W-3	M	M	H	H	H	H	H	H	H	H	H	H	H	H	H	H
	fI-0	fI-1	fI-2	fI-3	fI-0	fI-1	fI-2	fI-3	fI-0	fI-1	fI-2	fI-3	fI-0	fI-1	fI-2	fI-3

fI, Foot infection grade; *H,* high 1-year amputation risk; *L,* low 1-year amputation risk; *M,* moderate 1-year amputation risk; *VL,* very low 1-year amputation risk; *W,* wound grade.

A comparison of the data categories of our study and WIfI grades is provided in Table I.

A vascular surgery faculty member or resident characterized the foot wound and extent of infection. Photographs of the foot were obtained before the revascularization procedure. After the revascularization procedure, a pulse examination, the ankle-brachial index (ABI), a toe pressure, and an absolute ankle pressure were obtained to characterize pedal perfusion. Postprocedural wound management was not standardized.

The wound, perfusion, and infection data, along with the photograph taken at the time of revascularization, were used to assign a SVS WIfI wound, ischemia, and infection grade. Those grades were combined to create a WIfI spectrum score and clinical stage for each patient. The predicted outcome for that clinical stage, as determined by the consensus panel of experts, was compared with the actual outcome of the studied patients.

Data collection and primary end points. Collected and analyzed data included patient demographics, comorbidities, intervention type, and outcomes. The diagnosis of patient comorbidities (diabetes mellitus, hypertension, hyperlipidemia, coronary artery disease, end-stage renal disease) was established by history and the medical record. Primary end points were wound nonhealing and major limb amputation at 1 year. WIfI wound, ischemia, infection grades, and spectrum scores were analyzed to determine their relationship to primary end points. The study excluded patients presenting with vasospastic and collagen vascular disease, vasculitis, Buerger disease, acute limb ischemia, atheroembolic disease, and arterial trauma.

This study did not analyze outcomes (eg, wound healing or amputation-free survival) by procedure type but rather by the extent of pedal perfusion achieved after the intervention. A number of patients underwent multiple revascularization procedures, which changed the ischemia score and potentially altered the course of wound healing for those patients. Accordingly, rules were established to account for three potential scenarios for patients who underwent multiple revascularization procedures during follow-up:

Scenario 1: If the secondary intervention happened <6 weeks after the initial intervention, we used the date of first intervention as time 0 for calculating time-dependent outcomes and the best grade of the two ischemic grades to determine the perfusion score. For example, if the WIfI ischemia grade increased from I-3 to I-2 after intervention, the I-2 grade was used.

Scenario 2: If the secondary intervention happened >6 weeks beyond the initial intervention and the ischemia grade decreased or was unchanged after the second intervention, we took the date of first intervention as time 0 for calculating time-dependent outcomes and used the initial ischemia grade to determine the perfusion score.

Scenario 3: If the secondary intervention happened >6 weeks beyond the initial intervention, if the wound had not healed at the time of the second intervention, and if the ischemia grade increased to a higher category after the second intervention, then we determined the initial wound to be a failure of wound healing and obligingly rescored the wound at the second intervention to derive new wound, perfusion, and infection grades. The time from the first to second intervention was used to calculate time-dependent outcomes, with the date of the second intervention becoming time 0 for calculating time-dependent outcomes.

Statistical analysis. Bivariate analysis was performed to determine factors crudely associated with wound healing and limb salvage using Kaplan-Meier life-table methods and the log-rank test. Multivariate logistic regression analysis was conducted to determine independent predictors of outcome at 1 year ($P < .05$). Wound characteristics, extent of infection, degree of ischemia, and patient characteristics identified in bivariate analysis to be associated with outcome were entered into the initial model. A backward selection strategy was used to determine the final model, with a P value $\leq .05$ required for variables to remain in the model. Logistic regression was used to evaluate the crude association of increasing the WIfI clinical stage with wound healing and limb amputation at 12 months. Discrimination of the model was evaluated according to the concordance index. All analyses were completed with SAS 9.3 software (SAS Institute Inc, Cary, NC). Statistical significance was determined at an $\alpha = .05$.

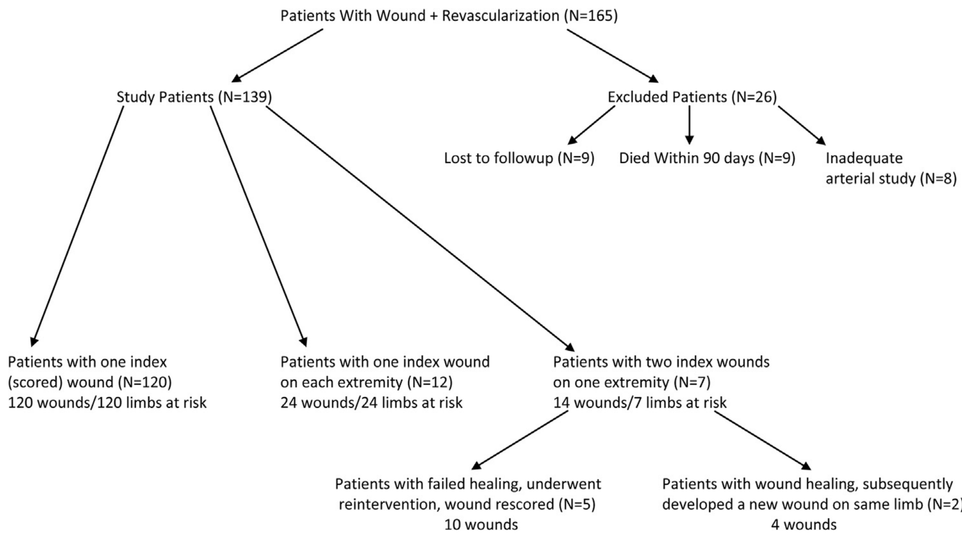

Fig. Flow diagram of study population.

RESULTS

During the study period, 165 patients presenting with a foot wound underwent an index revascularization procedure for limb salvage, and 26 were excluded because they were lost to follow-up (n = 8), died ≤90 days of study enrollment (n = 9), or did not have a complete postprocedural noninvasive vascular examination (n = 9). Of the remaining 139 study patients, 120 had one ulcer, 12 had bilateral lower extremity ulcers, and 7 had two ulcers on the same extremity, of whom 2 patients developed a second ulcer after healing of the first, and in 5 patients an ulcer was rescored after a second intervention (scenario 3 in the Methods section). Therefore, 158 wounds were graded and comprised the basis for this analysis (Fig). Mean patient follow-up was 27.5 ± 11 months.

Patient demographics with comorbidities are provided in Table III. During the follow-up period, 62% of foot wounds (98 of 158) were managed in a wound clinic. Complete wound healing occurred in 79% (125 of 158), with a median time to wound healing of 2.7 months (range, 1-18 months). The overall amputation rate was 13% (20 amputations in 151 limbs at risk) at 1 year. Bivariate analysis demonstrated that smoking ($P = .03$), wound size ($P = .02$), wound depth ($P = .001$), and ischemia ($P < .001$) were crudely associated with wound healing. Smoking ($P = .027$), wound size ($P = .026$), and ischemia ($P < .001$) were also crude predictors of limb amputation. Multivariate analysis showed that advanced ischemia and infection grade were independently associated with reduced wound healing and increased risk of amputation at 1 year. Diabetes was also independently associated with limb amputation at 1 year.

After we converted the wound, ischemia, and infection data for the study cohort to WIfI grades and subsequently to a WIfI clinical stage (1-4), the outcome of patients within each of those stages was compared (Tables IV and V). Logistic regression analysis showed a statistically significant increase in limb amputation and a reduction in wound healing at 1 year with an advanced WIfI clinical stage (Table V).

A comparison of the predicted and observed 1-year outcomes of limb amputation and wound healing by the WIfI clinical stage is provided in Table VI. The predicted vs observed outcome for limb amputation at 1 year for each clinical stage was similar.

Table III. Patient demographics and comorbidities

Variables	*No. (%) or mean ± SD (N = 139)*
Wounds	158
Age, years	70 ± 11
Gender	
Female	53 (38)
Male	86 (62)
Race/ethnicity	
African American	30 (22)
Caucasian	106 (76)
Hispanic	3 (2)
Smoking status	
Never	48 (34)
Former	44 (32)
Current	47 (34)
Diabetes	
None	48 (34)
Type 1	5 (4)
Type 2	78 (56)
Type unspecified	8 (6)
Hypertension	130 (93)
Hyperlipidemia	99 (71)
Coronary artery disease	87 (63)
End-stage renal disease	19 (14)

SD, Standard deviation.

Table IV. Observed 1-year outcomes by Wound characteristic, Ischemia, and foot Infection (*WIfI*) clinical stage

WIfI clinical stage	*Wounds, No.*	*Limbs at risk, No.*	*Patients, No.*	*Outcome at 1 year*		
				Wound healing, No. (%)	*Limb salvage, No. (%)*	*Amputation-free survival, No. (%)*
Stage 1	40	37	36	37/40 (92.5)	36/37 (97.3)	31/36 (86.1)
Stage 2	64	63	58	50/64 (78.1)	56/63 (88.9)	48/58 (82.8)
Stage 3	46	43	37	30/46 (65.2)	33/43 (76.7)	26/37 (70.3)
Stage 4	8	8	8	3/8 (37.5)	5/8 (62.5)	3/8 (37.5)

Table V. Measured Wound characteristic, Ischemia, and foot Infection (*WIfI*) clinical stage odds ratios (*OR*s) and 95% confidence intervals (*CI*s) for wound healing and limb loss ≤1 year

WIfI clinical stage	*1-year wound healing, OR (95% CI)*	*1-year limb amputation, OR (95% CI)*
Stage 1	1.00 (Referent)	1.00 (Referent)
Stage 2	0.29 (0.08-1.08)	4.8 (0.6-40.5)
Stage 3	0.15 (0.04-0.57)	10.8 (1.3-88.8)
Stage 4	0.05 (0.01-0.31)	23.4 (2.2-270.2)
Concordance index	0.69	0.71

DISCUSSION

Innumerable prior studies have identified specific factors (eg, diabetes mellitus, ischemia, and infection) to be associated with pedal wound nonhealing and limb amputation. Existing CLI and DFU classification systems are based on those same factors. Such classification systems stratify the risk of wound nonhealing and limb amputation for clinical trials research comparing treatment modalities. These systems may help guide therapy but have significant limitations, which were eloquently discussed by Mills et al[1] in their article describing the WIfI classification system. Chief among the limitations of previous classification systems is their failure to consider pedal perfusion and wound characteristics on a spectrum of severity.

Current classification systems, which include ischemia as a factor in their risk stratification, establish a specific cutoff measurement of pedal perfusion (eg, ABI >0.75). Pedal wounds with perfusion above that cutoff are expected to heal, whereas those with perfusion below this critical cutoff are expected not to heal and, ultimately, to result in limb loss.

The notion that a specific cutoff measure exists has been challenged by two studies that give some insight into the natural history of CLI without revascularization. Marston et al[10] reported a series of 142 patients presenting with both lower extremity wounds and lower extremity ischemia (ABI <0.7 or toe pressure <50 mm Hg) who were managed with meticulous wound care but no revascularization procedure. At 12 months, 52% of the wounds had healed, and only 23% required limb amputation.[10] Elgzyri et al[11] studied 602 patients with DFUs who had toe pressures <45 mm Hg or an ankle pressure <80 mm Hg and did not undergo a revascularization procedure. Wounds healed in 50% of patients, and only 17% required a major limb amputation.[11]

The SVS Lower Extremity Guideline Committee recognized the need for a new classification system that would consider the diversity of the CLI patient population and the many factors that influence outcome. As a result, the committee created a system that grades the extent of tissue injury, the severity of ischemia, and the extent of infection individually before then combining those grades to derive a clinical severity stage from which predictions regarding the risk of limb loss can be made. Their effort was hampered by the absence of solid natural history studies on which could be established the risk of their clinical severity grades. Thus, the risk of each stratum was to be assessed by a panel of experts using a Delphi consensus process. The committee hopes to validate the system theoretical predictions with data obtained from registries such as the SVS Vascular Quality Initiative.

The impetus for our study happened in 2007. Bothered by the existing CLI and DFU classification schemes, each categorizing pedal perfusion by establishing a single cutoff measurement, we reasoned that a reliable classification system that graded multiple factors shown to influence wound healing and limb salvage could be a valuable management tool for selecting patients for intervention. We hypothesized that wound size and location, wound depth and location, and extent of active infection all probably play a role in wound healing and that "minor" wounds might well require lesser degrees of pedal perfusion.

Because the WIfI grades and the wound, ischemia, and infection categories of our study were generated from the same validated CLI and DFU classification systems, it is not surprising that the data categories of our study are similar to the WIfI grades. However, the WIfI classification system is unique from other classification systems in the way it combines the wound, ischemia, and infection grades to create the WIfI Clinical Spectrum Score. The spectrum score, which was developed similar to the TMN staging system for cancer, predicts the risk of limb amputation at 1 year. The similarities between our data categories and the WIfI grades made it fairly easy to convert our data to WIfI grades and thus obtain a WIfI clinical spectrum score and clinical stage for each patient. Patient outcomes (limb amputation and wound nonhealing at 1 year) for each WIfI

Table VI. Comparison of expert predicted and data derived 1-year outcomes (limb amputation, wound nonhealing) by Wound characteristic, Ischemia, and foot Infection (*WIfI*) clinical stage from Kaplan-Meier life table analysis

		Predicted outcome, %	*Observed outcome, %*	
Estimated WIfI classification	*No.*	*Limb amputation*	*Limb amputation*	*Nonhealed wound*
Stage 1—very low risk	40	~3	3 ± 3	8 ± 4
Stage 2—low risk	64	~8	10 ± 4	19 ± 5
Stage 3—moderate risk	46	~25	23 ± 6	30 ± 7
Stage 4—high risk	8	~50	40 ± 22	63 ± 21

clinical stage were compared with the outcomes predicted by the SVS panel of experts.

Our study shows that wound size, depth, degree of ischemia, and extent of infection correlate with wound healing and limb salvage. This is not at all surprising because similar findings have been shown in other studies and form the basis of previous CLI and DFU classification systems. However, our study also shows that the WIfI clinical stage outcome predictions of the expert panel for the 1-year amputation rate parallel the actual outcomes of patients in our study. Although the WIfI classification system was designed as a predictive model for limb salvage at 1 year, as well as an estimation of likelihood of benefit of revascularization, we found that the WIfI clinical stage also correlated quite nicely with wound healing rates, which arguably is an even more important patient-centered outcome for most than mere limb survival.

One major difference between the data we gathered and WIfI system bears mentioning. The WIfI system is designed so that the wound, infection, and ischemia grading are all performed before a revascularization procedure and are then measured again after the procedure. In designing our study to measure the effect of ischemia on wound healing, we were unwilling to simply observe wounds with moderate and severe degrees of ischemia for patients we thought would benefit from a revascularization procedure. As such, our study measured pedal perfusion after the revascularization procedure. We reasoned that the ischemia score after the revascularization procedure would provide a reasonable approximation of the likelihood of wound healing for those patients who had an incomplete revascularization outcome. In other words, our study assumes that the ischemia grade dictates the likelihood of wound healing and limb amputation regardless of whether the patient had a revascularization procedure.

One might argue that a minor improvement in tissue perfusion after a revascularization procedure could be enough to change the healing of a wound. However, we believe an intervention that results in only marginal improvement in measurable tissue perfusion will likely have a negligible influence on wound healing. Because the natural history data are lacking on the relationship of wound dimensions, the extend of ischemia, and infection, we believe that our method of measuring perfusion after revascularization is a better method for validating WIfI clinical stage outcomes predicted by the panel of experts. As studies are developed to ultimately validate the WIfI classification system, this issue will need to be addressed. Finding an adequately sized population of patients with wounds having marginal circulation who are willing to forego treatment to establish WIfI validation may be difficult.

Our study has several limitations. Given the variability of patients who present with CLI and the many factors that are involved in wound healing and limb salvage, our study lacks an adequate number of patients to fully validate the WIfI Classification System. Nevertheless, our study does indicate that the consensus panel's estimates of amputation risk at each WIfI clinical stage are accurate. In a separate analysis, the WIfI consensus panel also estimated the likelihood of patient benefit from revascularization at each WIfI clinical stage. Our study was not able to validate this latter issue nor is it clear how such a determination can be accomplished.

Our study is also limited by the small number of patients with WIfI clinical stage 4 disease and severe infection (WIfI infection grade 4). There are two explanations for this. Firstly, our study only included patients who underwent a revascularization procedure. Patients who were nonambulatory, deemed unsuitable for revascularization, required "heroic" efforts to achieve limb salvage (eg, extensive wounds extending to the calcaneous), or presented with large wounds associated with florid sepsis, were only offered amputation rather than an attempt at limb salvage and accordingly were excluded. Secondly, our protocol directed that wound and infection assessment be done at the time of the revascularization procedure. Infection in most patients had been controlled with antibiotics, incision with drainage, and amputation before the revascularization procedure.

Our study also lacked a standard method of wound management. Factors such as the wound dressing, control of edema, and patient compliance with oral antibiotics can influence wound healing. Some studies have shown the use of negative pressure wound therapy and hyperbaric oxygen therapy benefits healing of chronic lower extremity wounds in patients with diabetes mellitus.[12-15] We assumed that our study patients received "optimal" wound care, although such management varied considerably. Sixty-two percent of patients in our series received care in a wound clinic where they were seen weekly until the wound healed. Some patients in our series received negative pressure wound therapy or hyperbaric oxygen treatments. Decisions to treat the wounds with those modalities were usually determined by the wound characteristics and the patient's insurance status. Such differences among study patients likewise might have influenced our limb salvage and wound healing rates. When future studies using the WIfI classification system to evaluate treatment modalities for CLI are developed, a standardized wound management protocol should be adopted to mitigate the effects of this potential confounding variable that could influence outcome.

The WIfI classification system recommends noting whether neuropathy is present. We did not evaluate patients for the presence or absence of neuropathy. Although originally included as a factor in our study, it was soon abandoned due to inconsistency in grading among physicians.

Finally, the inclusion of multiple limbs and wounds from a single patient resulted in a larger analytic sample and could constitute a lack of independence of observations. Therefore, we conducted a similar set of analyses including only a single wound per patient ($n = 139$). Estimated odds ratios from both analyses were similar; however, the precision of these estimates was generally improved when including multiple wounds and limbs.

CONCLUSIONS

Our study provides early clinical validation of the WIfI classification system. The 1-year limb salvage rate for patients in our series correlated not only with the WIfI clinical stage but also with the outcome predicted by the panel of experts who established the WIfI. Our study also showed that the WIfI clinical stage correlated with wound healing. Multicenter studies comprising more patients are justified to fully validate the WIfI classification system. In the future, once additional components such as a patient risk index are added to the WIfI classification system, the system holds promise as a tool for comparing treatment modalities in clinical trials and as a clinical decision-making tool for guiding therapy in patients with CLI.

AUTHOR CONTRIBUTIONS

Conception and design: DC
Analysis and interpretation: DC, GM, ST, EL, JE, BJ
Data collection: GM, MH
Writing the article: DC
Critical revision of the article: GM, MH, ST, EL, JE, BJ
Final approval of the article: DC, GM, MH, ST, EL, JE, BJ
Statistical analysis: BJ
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Overall responsibility: DC

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DISCUSSION

Dr Richard Neville (*Washington, D.C.*). Dr Cull, I thoroughly appreciate this important work on wound analysis from your group. I have two questions: First, what methodology did you use to actually measure the wound? Was it largest transverse diameter? Do you have a reproducible way to measure the wounds? Secondly, with this type of study it is interesting to note the wound care the patients received. Did the study involve protocol-driven wound care for each patient to assure a standard approach? For example, did some patients get free flaps, some rotational flaps, or some people just got wet-to-dry dressings? How did you account for the different kinds of wound care?

Dr David L. Cull. We calculated the area by multiplying the length and width of the wound. Your second question regarding the wound care each patient received is important. Wound care was not standardized in this study. We made the assumption that all patients received optimal wound care; however, this assumption is obviously false since some patients were compliant with wound care treatment while others were not. Some patients received hyperbaric oxygen therapy or negative pressure wound therapy, while others did not. This is a limitation of our study. Sixty-two percent of patients received wound care in a wound care clinic. When we ran the bivariate analysis, we were surprised to learn that the patients who received treatment in the wound care clinic did poorer than those who did not. But on further analysis, we found that the wound care clinic patients tended to have larger wounds.

Dr Anil Hingorani (*Brooklyn, NY*). Just one brief question about the Wound characteristic, Ischemia, and foot Infection (WIfI) system. Were you able to identify a subset of patients who did not do well—90% of them did not heal, 90% of them ended up with limb loss? In your data set you said your stage 4 patients were 50/50.

Dr Cull. Although our study showed that only 40% of stage 4 patients ultimately ended up with an amputation at 1 year, our study methodology most certainly underestimated limb amputation for that stage. Our study only included patients who underwent a revascularization procedure. Because most patients presenting with stage 4 disease were not offered a revascularization procedure but rather underwent primary limb amputation, they were not included. Had they been included, the outcome for the stage 4 category would have been much worse.

Dr Frank Logerfo (*Boston, Mass*). This is a terrific effort on the part of the Society to define what patients we should operate on and to some extent what operation we should do. People with diabetes and a foot ulcer, who have significant ischemia, that means you cannot feel a pulse in the foot, should just go right to revascularization. With diabetes, the neuroinflammatory response is lost and we cannot measure the total baseline biological impairment or the susceptibility of the diabetic foot to ischemia. Therefore the term "critical ischemia" becomes undefinable. If someone has a foot ulcer and you cannot feel a pulse, whatever is going on in that foot, it cannot remain healed in daily life. The measurable circulation may be identical in two people but "critical" in one but not the other, depending on the baseline biological impairment. Some people with diabetes can have perfect circulation and still have foot ulcers because they have no neuroinflammatory response and no somatic neurologic sensation.

In your data, the patients I would look at most carefully are those in the lower classifications that wound up with amputation. Why did that happen and have you looked in detail at each of them?

Dr Cull. Since there were so few limb amputations in the stage 1 and 2 categories, we were unable to go into any more detail, beyond the analysis we did, to further refine the WIfI classification. The variability of patients presenting with limb threat makes such analysis difficult. Full validation of the WIfI classification system will take many more patients than were generated by our study. Your statement that all diabetic patients with a foot ulcer who do not have a pulse should undergo revascularization is a principle I have followed for the first 15 years of my practice. In 2007, we decided to challenge that principle with the hypothesis that a small wound that is not infected requires less perfusion to heal than a large wound or an infected wound. That hypothesis is the foundation of the WIfI classification system. Our study seems to validate that hypothesis.

Dr Pierre Karam (*Montreal, Quebec, Canada*). I have two questions. The first is how practical is it to apply the WIfI system in our practice? And the second question, in the subgroup of patients with end-stage renal disease, do you have any data on how they correlate with the WIfI staging?

Dr Cull. The bivariate analysis did not show that patients with end-stage renal disease fared any worse than those patients without renal disease. This could be due to selection bias. Again, our study only included patients who underwent a revascularization procedure. It is possible that patients with end-stage renal disease were only offered a revascularization procedure in selective cases where a favorable outcome was more certain.

Regarding your question on how practical it is to obtain the information in order to obtain a WIfI clinical stage, we found the process of grading the wound, the degree of ischemia, and the extent of infection both quick and easy. On paper, the staging looks more arduous than it is in practice. In the future, the Society for Vascular Surgery Lower Extremity Guidelines Committee hopes to add anatomic information and a patient comorbidity index in order to create a tool to guide therapy. That will add a layer of complexity to the model.