From the Society for Clinical Vascular Surgery

Quantifying the costs and profitability of care for diabetic foot ulcers treated in a multidisciplinary setting

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ABSTRACT

Objective: Increasing Wound, Ischemia, and foot Infection (WIfI) stage has previously been shown to be associated with prolonged wound healing time, higher number of surgical procedures, and increased cost of care in patients with diabetic foot ulcers (DFUs) treated in a multidisciplinary setting. However, the profitability of this care model is unknown. We aimed to quantify the hospital costs and net margins associated with multidisciplinary DFU care.

Methods: All patients presenting to our multidisciplinary diabetic limb preservation service (January 2012-June 2016) were enrolled in a prospective database. Inpatient and outpatient costs and net margin (U.S. dollars) were calculated for each wound episode (initial visit until complete wound healing) overall and per day of care according to WIfI classification.

Results: A total of 319 wound episodes in 248 patients were captured. Patients required an average of 2.6 ± 0.2 inpatient admissions and 0.9 ± 0.1 outpatient procedures to achieve complete healing. Limb salvage at 1 year was 95.0% ± 2.4%. The overall mean cost of care per wound episode was $24,226 ± $2176, including $41,420 ± $3318 for inpatient admissions and $11,265 ± $1038 for outpatient procedures. The mean net margin was $2412 ± $375 per wound episode, including $5128 ± $622 for inpatient admissions and a net loss ($−3730 ± $596) for outpatient procedures. Mean time to wound healing was 136.3 ± 7.9 days, ranging from 106.5 ± 13.1 days for WIfI stage 1 wounds to 229.5 ± 20.0 days for WIfI stage 4 wounds ($P < .001$). When adjusted for days of care, the net margin ranged from $2.6 ± $1.3 per day (WIfI stage 1) to $23.6 ± $18.8 (WIfI stage 4).

Conclusions: The costs associated with multidisciplinary DFU care are substantial, especially with advanced-stage wounds. Whereas hospitals can operate at a profit overall, the net margins associated with outpatient procedures performed in a hospital-based facility are prohibitive, and the overall net margins are relatively low, given the labor required to achieve good outcomes. Thus, reimbursement for the multidisciplinary care of DFUs should be re-examined. (J Vasc Surg 2018;■:1-8.)

Keywords: Diabetic foot ulcer; Diabetic foot wound; WIfI; Costs; Profit; Multidisciplinary

The costs of diabetic foot ulcer (DFU) care are substantial, equaling an estimated $1.38 billion per year.[1] These costs are rapidly escalating with time, largely as a result of an increased number of hospitalizations occurring in a population of progressively sicker patients.[2] Affected patients tend to be impoverished, undereducated, and without regular health care access,[3-5] resulting in delayed wound presentation that may cost anywhere between $3609 and $50,464 to achieve healing[6,7] or between $17,103 and $32,663 for major amputation.[8,9]

The Society for Vascular Surgery Wound, Ischemia, and foot Infection (WIfI) classification system was developed as a prognostic tool to estimate a patient's risk of major amputation at 1 year.[10] Patients with advanced-stage wounds (WIfI stage 3/4) have significantly longer wound healing times and are associated with major amputation rates ranging from 5% to 64%, depending on the population studied.[11-14] Although the risk of major amputation is high in patients with advanced DFU, a number of groups have demonstrated good limb salvage outcomes with the introduction of a multidisciplinary care team.[15-18] We have previously shown that a multidisciplinary team including a vascular surgeon, surgical podiatrist, prosthetist, and endocrinologist led to low rates of major amputations even in patients with severe wounds.[14] However, the costs associated with this multidisciplinary model can be prohibitive, especially in the short term.[19]

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We recently investigated whether the charges and costs associated with DFU care increase with higher WIfI stages. For our multidisciplinary diabetic limb preservation service, the total cost of care from wound presentation to healing increased progressively from WIfI stage 1 ($3995) to stage 4 ($50,546) wounds.[6] However, the profitability of this care model is unknown. In this study, we aimed to quantify the hospital costs and net margins associated with multidisciplinary DFU care, both overall and stratified by WIfI stage.

ARTICLE HIGHLIGHTS

- **Type of Research:** Retrospective review of prospectively collected single-center diabetic foot ulcer (DFU) cohort
- **Take Home Message:** Based on data from 319 DFUs, the mean net margin was $2412 per wound episode, including $5128 for inpatient admissions and a net loss ($−3730) for outpatient procedures. When adjusted for days of care, the net margin ranged from $2.6 per day (stage 1 wounds) to $23.6 per day (stage 4 wounds).
- **Recommendation:** Although hospitals can operate at a profit overall, the net margins associated with multidisciplinary DFU care are relatively low, given the labor required to achieve good outcomes.

METHODS

All patients presenting to our multidisciplinary diabetic limb preservation service (January 2012-June 2016) were enrolled in a prospective database. The database captures sociodemographic, comorbidity, and wound data from initial consultation onward. It is updated at each hospital and clinical encounter in real time by the enrolling physicians. The Institutional Review Board approved the study. Patients signed informed consent before their data were collected. Patients with WIfI classification stage 5 wounds were excluded because their limbs are considered unsalvageable.[10] Patients with missing cost data and those without wounds were also excluded from this analysis.

Definitions. The WIfI classification system has been extensively described previously.[10] In brief, the wound characteristics, level of ischemia, and degree of infection are graded individually and then combined to obtain a clinical stage designed to correlate with risk of major amputation in 1 year.[10] All limbs are assigned a WIfI classification based on provider consensus at the time of initial presentation. Whereas the original intent of the WIfI classification was to analyze outcomes by limb, we have shown that the WIfI classification also applies to individual wounds as well.[14,20] For the purposes of this analysis, patients with multiple wounds were assigned a WIfI stage based on their worst wound at initial presentation. Patients with wounds on both limbs were assigned a WIfI stage for each limb separately.

Inpatient and outpatient costs and net margins were calculated for each wound. All cost and margin data were collected from the Johns Hopkins financial office and are reported in 2016 U.S. dollars. The cost data include all hospital-based costs (not charges), including both direct and indirect and variable and fixed costs that the hospital incurs to provide care for a given encounter. Professional fees are not included in the hospital costs that we report because the hospital does not capture professional fee costs. However, professional fee charges and professional fee revenue were captured and reported on a per-patient basis for a given wound episode. Net margin represents the profit that the hospital makes on an encounter; it is calculated as the net revenue minus the total hospital costs. Of note, our outpatient procedures are performed in a hospital-based facility. Because all care provided in this study was performed in hospital-based facilities, we were able to capture all services rendered by our team. However, we could not account for costs within rehabilitation facilities or hyperbaric oxygen treatments.

Costs and net margins were calculated for each wound episode, which is defined as the time from initial visit until complete wound healing. They were also calculated on a per-day basis for each WIfI stage, adjusting for the mean number of days from presentation to healing. Wounds were considered healed if they maintained complete epithelialization for 6 weeks after functional status was restored.[21,22]

Multidisciplinary diabetic limb preservation service. Our multidisciplinary diabetic limb preservation service consists of a vascular surgeon, surgical podiatrist, endocrinologist, dedicated wound care nurse, physician assistant, and prosthetist.[14] Consultations are obtained from infectious diseases, plastic surgery, and orthopedic foot and ankle surgery services on an as-needed basis. The service attends to both inpatient consultations and outpatient referrals.

All patients undergo noninvasive vascular laboratory testing and three-view foot radiography on initial presentation. Those with abnormal results undergo lower extremity angiography, with endovascular or open revascularization as appropriate. Once revascularization is achieved, the wounds are débrided to healthy tissue. Any evidence of osteomyelitis on radiography or magnetic resonance imaging is resected, and aggressive local wound care is employed. All wounds are offloaded with the help of our prosthetist, and patients are discharged after débridement to home with regular home care visits, a rehabilitation center, or a skilled nursing facility on the basis of their physical status and their home situation. Patients are observed in the clinic on a regular basis

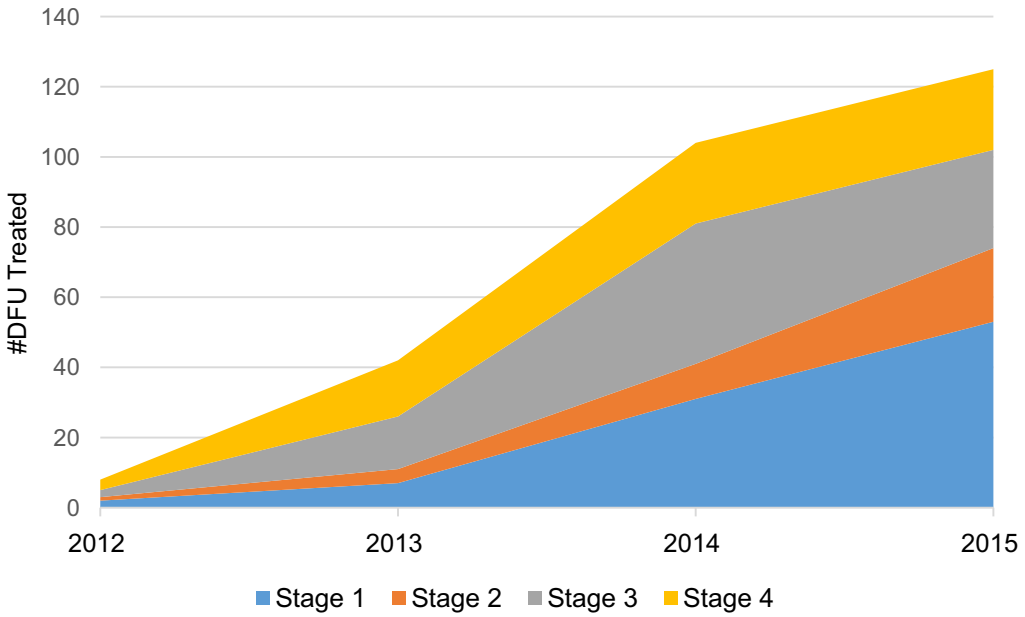

Fig. There was a progressive increase in the number of diabetic foot wounds treated per year during the course of the study ($P = .02$). The data for 2016 are not shown because cost data were available only through June 2016. *DFU,* Diabetic foot ulcer.

according to the status of their wounds and vascular status per the comprehensive foot examination and risk assessment guidelines.[23]

All tests and services rendered by the multidisciplinary diabetic limb preservation service are available to both the multidisciplinary team and other providers in the hospital system. The major difference between the multidisciplinary team and care provided by other providers is that the multidisciplinary team meets in a single clinic visit and coordinates care on the basis of group consensus. Furthermore, patient care by the multidisciplinary team is based on protocol and algorithms as previously described.[14] At our institution, all patients with DFU are treated by our multidisciplinary team.

Statistical analysis. Continuous data were summarized as mean ± standard error of the mean, and categorical data were summarized as count (percentage). Wound outcomes, including time to wound healing and percentage limb salvage at 1 year, were calculated on the basis of Kaplan-Meier curves and life-table analyses. Total hospital costs and net margins were calculated per wound episode (from presentation to healing) overall as well as by WIfI stage. Costs and net margins per day of care were also calculated for each WIfI stage, adjusting for the number of days of treatment provided from wound presentation until complete healing was achieved. Difference in total and per-day costs and margins were subsequently compared across WIfI stage using analysis of variance statistics. The analysis was performed using Stata version 14.0 software (StataCorp LP, College Station, Tex). All reported P values are two tailed with α set at $P < .05$.

RESULTS

Study cohort. A total of 319 wound episodes in 248 patients were captured. There was a progressive increase in the number of wounds treated per year ($P = .02$; Fig). A complete summary of the baseline sociodemographic and comorbidity data of this cohort has previously been reported[6] and is partially summarized in Table I. There was a mean of 1.4 ± 0.1 active wounds per limb; the worst wound at initial presentation was considered for the purposes of this analysis (Table II). Mean time from wound onset to assessment by our limb preservation service was 2.6 ± 0.3 months. Mean wound area at presentation was 8.8 ± 1.2 cm^2, and mean wound depth was 0.6 ± 0.04 cm. There was a fairly even distribution of WIfI stages overall, including 30.7% (n = 98) WIfI stage 1, 15.7% (n = 50) stage 2, 29.8% (n = 95) stage 3, and 23.8% (n = 76) stage 4 wounds.

Summary of care overall. Mean time to wound healing for all patients was 136.3 ± 7.9 days. Limb salvage at 1 year was 95.0% ± 2.4%. Overall, patients required 2.56 ± 0.15 inpatient admissions and 0.92 ± 0.08 outpatient procedures to achieve complete healing. The mean total number of procedures (inpatient and outpatient) performed per wound episode was 2.19 ± 0.14.

For the inpatient admissions, patients required an average of 2.38 ± 0.14 procedure-related admissions and 0.14 ± 0.03 nonoperative admissions. Inpatient podiatric procedures were common, occurring 1.96 ± 0.12 times per wound episode. Inpatient vascular procedures occurred 0.42 ± 0.06 times per wound episode, including 0.20 ± 0.04 open and 0.21 ± 0.03 endovascular revascularization procedures.

Table I. Demographics and baseline wound characteristics of diabetic foot ulcer (DFU) patients treated by our multidisciplinary diabetic limb preservation service

Variable	Overall (N = 248)
Age, years	58.1 ± 0.73
Male sex	150 (60.5)
Race	
White	83 (33.5)
Black	157 (63.3)
Asian	3 (1.2)
Other/unknown	5 (2.0)
Insurance status	
Medicare	137 (55.2)
Medicaid	45 (18.1)
Private or self-pay	64 (25.8)
None	2 (0.8)
Comorbidities	
Hypertension	203 (81.9)
Dyslipidemia	125 (50.4)
Coronary artery disease	61 (24.6)
Congestive heart failure	39 (15.7)
Peripheral vascular disease	97 (39.1)
Chronic kidney disease	48 (19.4)
Dialysis	30 (12.1)
Smoking status	
Current	65 (26.2)
Former	77 (31.1)
Never	106 (42.7)

Categorical variables are presented as number (%). Continuous variables are presented as mean ± standard error of the mean.

Table II. Summary of wound characteristics and care for total wound episode per leg (presentation to wound healing)

Characteristic	(N = 319)
Wound characteristics	
No. of active wounds[a]	1.4 ± 0.1
Wound area,[b] cm^2	8.8 ± 1.2
Wound depth,[b] cm	0.6 ± 0.04
WIfI stage	
1	98 (30.7)
2	50 (15.7)
3	95 (29.8)
4	76 (23.8)
Time from onset to assessment, months	2.6 ± 0.3
Care per wound episode	
Inpatient admissions	2.56 ± 0.15
Outpatient procedures	0.92 ± 0.08
Total No. of procedures, inpatient and outpatient	2.19 ± 0.14
Time to wound healing, days	136.3 ± 7.9

WIfI, Wound, Ischemia, and foot Infection.
Categorical variables are presented as number (%). Continuous variables are presented as mean ± standard error of the mean.
[a]Per limb.
[b]Worst wound per limb at initial presentation.

Outpatient procedures were less common. On average, patients underwent 0.51 ± 0.08 outpatient podiatric procedures, 0.41 ± 0.07 outpatient vascular interventions, and 0.25 ± 0.06 outpatient diagnostic angiograms per wound episode.

Costs and margins overall. The mean overall cost of care per wound episode was $24,226 ± $2176, including $41,420 ± $3318 for inpatient admissions and $11,265 ± $1038 for outpatient procedures. The mean net margin was $2412 ± $375 per wound episode overall, including $5128 ± $622 for inpatient admissions and a net loss of $−3730 ± $596 for outpatient procedures (Table III). When calculated on a per-day basis, the net margin was $17.4 ± $5.4 per day overall.

Margins stratified by WIfI stage. When wound episodes were stratified by WIfI stage (Table IV), the overall net margin increased significantly with increasing WIfI stage (stage 1, $186 ± $285; stage 4, $5242 ± $1145; $P < .001$). The net margin for inpatient admissions did not reach statistical significance based on WIfI stage (stage 1, $1883 ± $1810; stage 4, $6884 ± $1279; $P = .07$). Outpatient procedures were associated with a persistently negative net margin regardless of wound severity (stage 1, $−3951 ± 1130; stage 4, $−3114 ± $804; $P = .78$).

The mean time to wound healing increased significantly with increasing WIfI stage, ranging from 106.5 ± 13.1 days for stage 1 wounds to 229.5 ± 20.0 days for stage 4 wounds ($P < .001$). After adjusting for number of days of care provided, the overall net margin associated with DFU care was only $2.6 ± $1.3 for stage 1 wounds, $19.5 ± $11.0 for stage 2 wounds, $25.7 ± $7.4 for stage 3 wounds, and $23.6 ± $18.8 for stage 4 wounds ($P = .35$; Table IV).

Margins stratified by insurance payer. When wound episodes were stratified by insurance payer, the overall net margin varied significantly (Table V; $P = .008$). Overall net margins were highest for Medicare patients ($4758 ± $873), followed by private insurance or self-pay patients ($4593 ± $1382), then Medicaid patients ($824 ± $839). As expected, there was a substantial loss for patients with no insurance ($−8351 ± $11,063). The net margins for inpatient admissions followed the same trend as the overall net margins; inpatient net margins were highest for Medicare ($6283 ± $909), followed by private insurance or self-pay ($6200 ± $1385), then Medicaid ($2307 ± $717), then no insurance ($−8351 ± $11,063; $P = .004$). In contrast, the net margins for outpatient procedures were negative for all payers and did not significantly differ by insurance type ($P = .25$; Table V).

Table III. Summary of mean inpatient and outpatient hospital costs and net margins for total wound episode (presentation to wound healing)

	Total cost	Net margin
Overall, inpatient and outpatient	24,226 ± 2176	2412 ± 375
Inpatient admissions	41,420 ± 3318	5128 ± 622
Outpatient procedures	11,265 ± 1038	−3730 ± 596
Endovascular intervention	10,222 ± 1196	−2873 ± 799
Diagnostic angiography	7284 ± 1243	−2323 ± 864
Podiatric procedure	11,900 ± 1671	−4393 ± 1006

All costs are shown in U.S. dollars ± standard error of the mean.

Professional fee charges and revenue. The overall mean professional fee charges per patient per wound episode equaled $3702 ± $377, including $4164 ± $613 in inpatient professional fee charges and $1571 ± $211 in outpatient professional fee charges (Table VI). The overall mean professional fee revenue per patient per wound episode was $1089 ± $100, including $1094 ± $164 in inpatient professional fees and $493 ± $52 in outpatient professional fees.

DISCUSSION

The cost of care of DFU is soaring.[1,2] Excellent limb salvage outcomes can be achieved using a multidisciplinary approach to care,[14-18] but the profitability of this care model is unknown. In this study, we aimed to quantify the hospital costs and margins associated with multidisciplinary DFU care, both overall and stratified by wound severity. We found that care for a single wound episode treated by a multidisciplinary limb preservation service—from presentation to healing—costs approximately $24,226 ± $2176. Overall net margins are approximately $2412 per wound episode and increase with increasing WIfI stage, although outpatient procedures are associated with a net loss. When adjusted for number of days required to achieve wound healing, net margins are less than $18 per day. Taken together, these data suggest that although a multidisciplinary approach to DFU care can be profitable, the overall net margins are relatively low, given the labor required to achieve good outcomes.

The overall costs of care for a multidisciplinary limb preservation service that we report are higher than most of those previously described for DFU care.[24-26] However, each of these previous studies is based on insurance claims and did not involve the implementation of a co-ordinated care team. In contrast, Apelqvist et al[27] have demonstrated that the costs of care for DFU treated by a multidisciplinary team are similar to the costs that we report. In that study, all patients were treated by a multidisciplinary foot care team consisting of an orthopedic surgeon, podiatrist, diabetes nurse, endocrinologist, and orthotist from the time of initial presentation until the time of complete wound healing. This is consistent with our multidisciplinary model, which consists of a vascular surgeon, surgical podiatrist, endocrinologist, physician assistant, prosthetist, and dedicated wound care nurse. It is therefore not surprising that the total cost of DFU care that we report ($24,226) is in line with that of the Apelqvist study.[27]

Although the costs of DFU care associated with a multidisciplinary model are substantial, the outcomes are excellent.[28-30] For example, Larsson et al[29] reported that after the implementation of a multidisciplinary program for the treatment of DFUs, the incidence of major amputations decreased by 78%. Similarly, Van Gils et al[30] have shown that the creation of a multidisciplinary high-risk foot clinic designed to treat foot ulcer patients at risk for lower extremity amputation resulted in 5-year limb salvage rates as high as 83%. In our study, limb salvage was 95% at 1 year, despite the fact that more than half of all the wounds we treated were WIfI stage 3 or stage 4. This is in contrast to previously reported limb salvage rates ranging between 36% and 80% for WIfI stage 4 limbs.[11-13] Therefore, it appears that the high costs associated with a multidisciplinary approach to care may be worth the favorable outcomes achieved by this paradigm.

Some of the largest concerns with implementing a multidisciplinary limb preservation team revolve around the substantial cost and time burden associated with the care of these complex patients.[7] Whereas a number of previous studies have reported on the costs of DFU care,[6,7,24-26] the profitability of DFU care is unknown. In this study, we demonstrate that the mean net margin for a single episode of DFU care is $2412. Given that we treated 319 wounds during the course of our 4-year study period, the total net margin for our multidisciplinary limb preservation service was approximately $769,428, or $192,357 per year. This is an important finding because it demonstrates that despite the high costs of multidisciplinary DFU care, the development of a limb salvage team can be profitable. Previous studies examining the economic feasibility of multidisciplinary DFU care have relied on theoretical models to demonstrate effectiveness.[7,31,32] Using a hypothetical cohort of 10,000 patients with diabetes, Ollendorf et al[31] demonstrated that implementation of a multidisciplinary clinic could reduce the cost of DFU care by as much as $2900 to $4442 per person. However, we believe that our study is the first to demonstrate evidence of hospital profitability for multidisciplinary DFU care using prospectively collected financial data. Of note, the net margins that we report in this study do not include professional fees; we have reported professional fee revenue separately to allow readers to understand how it may affect the overall margins, but unfortunately our hospital does not collect data on professional fee costs.

Importantly, outpatient procedures were associated with a negative net margin in our study. The overall loss

Table IV. Breakdown of net margin stratified by Wound, Ischemia, and foot Infection (WIfI) stage for total wound episode (presentation to wound healing) and per day of care

Net margin	Stage 1 (n = 98)	Stage 2 (n = 50)	Stage 3 (n = 95)	Stage 4 (n = 76)	*P* value
Overall, inpatient and outpatient					
Total wound episode	186 ± 285	1023 ± 564	3174 ± 666	5242 ± 1145	<.001
Per day of care	2.6 ± 1.3	19.5 ± 11.0	25.7 ± 7.4	23.6 ± 18.8	.35
Inpatient admissions					
Total wound episode	1883 ± 1810	2880 ± 911	4933 ± 804	6884 ± 1279	.07
Per day of care	7.4 ± 6.8	51.4 ± 18.1	41.6 ± 9.5	36.1 ± 22.3	.76
Outpatient procedures					
Total wound episode	−3951 ± 1130	−4757 ± 1756	−4320 ± 1500	−3114 ± 804	.78
Per day of care	−15.9 ± 6.4	−65.6 ± 30.4	−38.9 ± 14.4	−27.6 ± 11.7	.38

All costs are shown in U.S. dollars ± standard error of the mean.

Table V. Breakdown of net margin stratified by insurance provider for total wound episode (presentation to wound healing) per patient

Net margin	Medicare	Medicaid	Private or self-pay	None	*P* value
Overall, inpatient and outpatient	4758 ± 873	824 ± 839	4593 ± 1382	−8351 ± 11,063	.008
Inpatient admissions	6283 ± 909	2307 ± 717	6200 ± 1385	−8351 ± 11,063	.004
Outpatient procedures	−3030 ± 714	−5670 ± 1718	−3744 ± 1139	–	.25

All costs are shown in U.S. dollars ± standard error of the mean.

Table VI. Summary of mean professional fee charges and revenue for total wound episode (presentation to wound healing)

Professional fee	Charges	Revenue
Overall, inpatient and outpatient	3702 ± 377	1089 ± 100
Inpatient	4164 ± 613	1094 ± 164
Outpatient	1571 ± 211	493 ± 52
Office visits	1222 ± 125	438 ± 45.9
Procedures	3115 ± 916	737 ± 189

All costs are shown in U.S. dollars ± standard error of the mean.

associated with diagnostic angiography, endovascular interventions, and podiatric procedures ranged from $−2323 to $−4393, depending on the procedure performed, and did not change on the basis of WIfI stage. Notably, our outpatient facility is a hospital-based facility rather than an office-based facility. The net loss that we observed with outpatient procedures was surprising to us but reinforced the emerging concept that outpatient procedures may be best performed in an ambulatory surgery center (ASC) rather than in a hospital center.[33] The challenge with this care paradigm is twofold. First, the majority of our patients are inner-city, impoverished patients without financial means.[5] As such, it would be extremely difficult to arrange for these patients to travel to two different locations—an outpatient center and our main hospital—to receive care. Second, patients' eligibility for surgery at an ASC depends on their comorbidities. Body mass index >40 kg/m^2, obstructive sleep apnea, history of myocardial infarction, coronary artery disease with prior percutaneous coronary intervention or coronary artery bypass, and infection requiring contact precautions are contraindications to surgery at an ASC.[34] Other comorbidities, including coronary artery disease without history of myocardial infarction or percutaneous coronary intervention, pulmonary disease, diabetes, hypertension, peripheral vascular disease, cerebrovascular accident, transient ischemic attack, hypercoagulability, and current infection not requiring contact precautions, are considered relative contraindications.[34] Nearly all patients treated by our multidisciplinary limb preservation team have one or more of these conditions, and infection is almost ubiquitous. As such, it is challenging to think about an ASC setup that would allow us to accommodate DFU patients on a regular basis such that we would be able to appreciate the cost savings associated with nonhospital-based care.

The outcomes achieved by our multidisciplinary DFU care model are the reflection of the intense inpatient treatment and outpatient follow-up that our treatment paradigm engenders. On average, patients required 2.6 inpatient admissions and underwent more than two procedures per ulcer to achieve healing. Not surprisingly, this care burden increases with increasing wound severity; as we have previously demonstrated, increasing WIfI stage is associated with prolonged wound healing time, more inpatient admissions, higher number of surgical procedures, and increased cost of care.[6] Therefore, although the overall margins of our diabetic limb preservation team are positive, the profitability on a day-by-day

basis is low. For example, the net margin associated with a WIfI stage 4 wound is $5242 for the total wound episode (from initial presentation to healing). However, after adjusting for the 217 days it takes to achieve wound healing in WIfI stage 4 wounds, the net margin per day of care is only $23.6 per day. For WIfI stage 1 wounds, the net margin for day of care is only $2.6 per day. Therefore, although hospitals can operate at a profit overall, the overall net margins are relatively low given the labor required to achieve good outcomes. Given the rapid escalation in DFU volume that we have observed in just the past 5 years (Fig), the sustainability of this model long term is unclear.

The overall net margins that we observed differed significantly by insurance payer. Net margins were highest for patients with Medicare and private or self-pay insurance and significantly lower for Medicaid patients. This was interesting because Johns Hopkins Hospital is in Maryland, which operates under a global budget revenue (GBR). The GBR is an all-payer model that was designed to provide better care, better health, and lower costs for Maryland patients.[35] Under the GBR, payer reimbursement should be equivalent regardless of the type of insurance that a patient has. However, we found significantly different net margins based on insurance type. This is likely a reflection of certain insurance companies denying charges for various reasons, such as "medical necessity" or "preauthorization." At our institution, gross collection rates range from 76% (Medicaid) to 88% (out-of-state private insurance). The disparity in collections is likely to be much higher in states without all-payer systems. Whereas reimbursement rates should not affect the care provided to patients, it is important to understand that the net margins observed with one institution's practice model may not be translatable to other hospitals in other states.

The limitations of our study deserve consideration. First, we are limited to financial data through fiscal year 2016. Second, we linked the hospital financial data with prospective data collected for our multidisciplinary limb preservation service. There is a risk of incomplete or missing data with this process. Third, we did not consider posthospitalization or postprocedure costs and margins, such as those associated with our outpatient clinic or with regular scheduled home care visits or rehabilitation or nursing home placement. Fourth, our Institutional Review Board required informed consent for all data gathered for this study, and our team takes care of nearly all DFUs in our hospital system. As a result, we do not have a control group that we could use to compare hospital costs and margins against our multidisciplinary approach. In addition, we did not collect data on patient costs or quality of life. The costs of DFU care are substantial not only for institutions but for the patients themselves as a result of missed work for frequent clinic visits and procedures, for example. We do not capture those costs in this study. Finally, our experience represents one institution's experience with patients treated for DFU in a multidisciplinary setting; our findings are not necessarily translatable to other cohorts of patients or other institutions. However, we have demonstrated that hospitals can generate profit with this care paradigm, even if those profits are slim. The addition of professional fee margins may further improve the profitability of this model, although we were unable to account for them in our margins analysis because of hospital reporting limitations. Given the favorable limb salvage results that can be achieved with multidisciplinary DFU care, we urge other institutions to consider the implementation of a multidisciplinary limb preservation service whenever possible.

CONCLUSIONS

The costs associated with multidisciplinary DFU care are substantial, especially with advanced-stage wounds. While hospitals can operate at a profit overall, the net margins associated with outpatient procedures performed in a hospital-based setting are prohibitive, and the overall net margins are relatively low given the labor required to achieve good outcomes. The viability of transitioning outpatient procedures to an ASC and the longevity of this model remain to be determined. Despite these limitations, the limb salvage outcomes that we observe are favorable. As such, strong consideration should be given to improving reimbursement for the multidisciplinary care of patients with DFU.

AUTHOR CONTRIBUTIONS

Conception and design: CH, CA
Analysis and interpretation: CH, JC, HK, NM, RS, JB, CA
Data collection: CH, JC, HK, NM, RS, JB, CA
Writing the article: CH, CA
Critical revision of the article: CH, JC, HK, NM, RS, JB, CA
Final approval of the article: CH, JC, HK, NM, RS, JB, CA
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Overall responsibility: CA

REFERENCES

1. Hicks CW, Selvarajah S, Mathioudakis N, Sherman RE, Hines KF, Black JH 3rd, et al. Burden of infected diabetic foot ulcers on hospital admissions and costs. Ann Vasc Surg 2016;33:149-58.
2. Hicks CW, Selvarajah S, Mathioudakis N, Perler BA, Freischlag JA, Black JH 3rd, et al. Trends and determinants of costs associated with the inpatient care of diabetic foot ulcers. J Vasc Surg 2014;60:1247-54, 1254.e1-2.
3. Skrepnek GH, Mills JL Sr, Armstrong DG. A diabetic emergency one million feet long: disparities and burdens of illness among diabetic foot ulcer cases within emergency departments in the United States, 2006-2010. PLoS One 2015;10:e0134914.
4. Yan J, Liu Y, Zhou B, Sun M. Pre-hospital delay in patients with diabetic foot problems: influencing factors and subsequent quality of care. Diabet Med 2014;31:624-9.

5. Hicks CW, Canner JK, Mathioudakis N, Sherman RL, Hines K, Lippincott C, et al. Neighborhood socioeconomic disadvantage is not associated with wound healing in patients with diabetic foot ulcers treated in a multidisciplinary setting. J Surg Res 2018;224:102-11.
6. Hicks CW, Canner JK, Karagozlu H, Mathioudakis N, Sherman RL, Black JH 3rd, et al. The Society for Vascular Surgery Wound, Ischemia, and foot Infection (WIfI) classification system correlates with cost of care for diabetic foot ulcers treated in a multidisciplinary setting. J Vasc Surg 2018;67:1455-62.
7. Driver VR, Fabbi M, Lavery LA, Gibbons G. The costs of diabetic foot: the economic case for the limb salvage team. J Vasc Surg 2010;52(Suppl):17S-22S.
8. Tang L, Paravastu SC, Thomas SD, Tan E, Farmer E, Varcoe RL. Cost analysis of initial treatment with endovascular revascularization, open surgery, or primary major amputation in patients with peripheral artery disease. J Endovasc Ther 2018;25:504-11.
9. Yin H, Radican L, Kong SX. A study of regional variation in the inpatient cost of lower extremity amputation among patients with diabetes in the United States. J Med Econ 2013;16:820-7.
10. Mills JL Sr, Conte MS, Armstrong DG, Pomposelli FB, Schanzer A, Sidawy AN, et al. The Society for Vascular Surgery Lower Extremity Threatened Limb Classification System: risk stratification based on wound, ischemia, and foot infection (WIfI). J Vasc Surg 2014;59:220-34.e1-234.e2.
11. Zhan LX, Branco BC, Armstrong DG, Mills JL Sr. The Society for Vascular Surgery lower extremity threatened limb classification system based on Wound, Ischemia, and foot Infection (WIfI) correlates with risk of major amputation and time to wound healing. J Vasc Surg 2015;61:939-44.
12. Cull DL, Manos G, Hartley MC, Taylor SM, Langan EM, Eidt JF, et al. An early validation of the Society for Vascular Surgery lower extremity threatened limb classification system. J Vasc Surg 2014;60:1535-41.
13. Causey MW, Ahmed A, Wu B, Gasper WJ, Reyzelman A, Vartanian SM, et al. Society for Vascular Surgery limb stage and patient risk correlate with outcomes in an amputation prevention program. J Vasc Surg 2016;63:1563-73.e2.
14. Mathioudakis N, Hicks CW, Canner JK, Sherman RL, Hines KF, Lum YW, et al. The Society for Vascular Surgery Wound, Ischemia, and foot Infection (WIfI) classification system predicts wound healing but not major amputation in patients with diabetic foot ulcers treated in a multidisciplinary setting. J Vasc Surg 2017;65:1698-705.e1.
15. Vartanian SM, Robinson KD, Ofili K, Eichler CM, Hiramoto JS, Reyzelman AM, et al. Outcomes of neuroischemic wounds treated by a multidisciplinary amputation prevention service. Ann Vasc Surg 2015;29:534-42.
16. Alexandrescu V, Hubermont G, Coessens V, Philips Y, Guillaumie B, Ngongang C, et al. Why a multidisciplinary team may represent a key factor for lowering the inferior limb loss rate in diabetic neuro-ischaemic wounds: application in a departmental institution. Acta Chir Belg 2009;109:694-700.
17. Armstrong DG, Bharara M, White M, Lepow B, Bhatnagar S, Fisher T, et al. The impact and outcomes of establishing an integrated interdisciplinary surgical team to care for the diabetic foot. Diabetes Metab Res Rev 2012;28:514-8.
18. Rogers LC, Andros G, Caporusso J, Harkless LB, Mills JL Sr, Armstrong DG. Toe and flow: essential components and structure of the amputation prevention team. J Vasc Surg 2010;52(Suppl):23S-7S.
19. Matricali GA, Dereymaeker G, Muls E, Flour M, Mathieu C. Economic aspects of diabetic foot care in a multidisciplinary setting: a review. Diabetes Metab Res Rev 2007;23:339-47.
20. Hicks CW, Canner JK, Mathioudakis N, Sherman R, Malas MB, Black JH 3rd, et al. The SVS WIfI classification independently predicts wound healing in diabetic foot ulcers. J Vasc Surg 2018;68:1096-103.
21. Margolis DJ, Berlin JA, Strom BL. Interobserver agreement, sensitivity, and specificity of a "healed" chronic wound. Wound Repair Regen 1996;4:335-8.
22. Lazarus GS, Cooper DM, Knighton DR, Percoraro RE, Rodeheaver G, Robson MC. Definitions and guidelines for assessment of wounds and evaluation of healing. Wound Repair Regen 1994;2:165-70.
23. Boulton AJ, Armstrong DG, Albert SF, Frykberg RG, Hellman R, Kirkman MS, et al. Comprehensive foot examination and risk assessment: a report of the Task Force of The Foot Care Interest Group of the American Diabetes Association, with endorsement by the American Association of Clinical Endocrinologists. Diabetes Care 2008;31:1679-85.
24. Holzer SE, Camerota A, Martens L, Cuerdon T, Crystal-Peters J, Zagari M. Costs and duration of care for lower extremity ulcers in patients with diabetes. Clin Ther 1998;20:169-81.
25. Harrington C, Zagari MJ, Corea J, Klitenic J. A cost analysis of diabetic lower-extremity ulcers. Diabetes Care 2000;23:1333-8.
26. Stockl K, Vanderplas A, Tafesse E, Chang E. Costs of lower-extremity ulcers among patients with diabetes. Diabetes Care 2004;27:2129-34.
27. Apelqvist J, Ragnarson-Tennvall G, Persson U, Larsson J. Diabetic foot ulcers in a multidisciplinary setting. An economic analysis of primary healing and healing with amputation. J Intern Med 1994;235:463-71.
28. Zayed H, Halawa M, Maillardet L, Sidhu PS, Edmonds M, Rashid H. Improving limb salvage rate in diabetic patients with critical leg ischaemia using a multidisciplinary approach. Int J Clin Pract 2009;63:855-8.
29. Larsson J, Apelqvist J, Agardh CD, Stenstrom A. Decreasing incidence of major amputation in diabetic patients: a consequence of a multidisciplinary foot care team approach? Diabet Med 1995;12:770-6.
30. Van Gils CC, Wheeler LA, Mellstrom M, Brinton EA, Mason S, Wheeler CG. Amputation prevention by vascular surgery and podiatry collaboration in high-risk diabetic and nondiabetic patients. The Operation Desert Foot experience. Diabetes Care 1999;22:678-83.
31. Ollendorf DA, Kotsanos JG, Wishner WJ, Friedman M, Cooper T, Bittoni M, et al. Potential economic benefits of lower-extremity amputation prevention strategies in diabetes. Diabetes Care 1998;21:1240-5.
32. Ortegon MM, Redekop WK, Niessen LW. Cost-effectiveness of prevention and treatment of the diabetic foot: a Markov analysis. Diabetes Care 2004;27:901-7.
33. Advancing Surgical Care. ASCs: a positive trend in health care. Available at: http://www.ascassociation.org/advancingsurgicalcare/aboutascs/industryoverview/apositivetrendinhealthcare. Accessed February 25, 2018.
34. Kingery MT, Cuff GE, Hutzler LH, Popovic J, Davidovitch RI, Bosco JA. Total joint arthroplasty in ambulatory surgery centers: analysis of disqualifying conditions and the frequency at which they occur. J Arthroplasty 2018;33:6-9.
35. Maryland Health Services Cost Review Commission. Global budget revenue. Available at: http://www.hscrc.state.md.us/Documents/global-budgets/Global-Budget-Revenue-Final-10-7-15-Overview-ppt.pdf. Accessed February 25, 2018.

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