Multidisciplinary clinics reduce treatment costs and improve patient outcomes in diabetic foot disease

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ABSTRACT

Objective: Diabetic foot disease poses a significant and rising financial burden on health care systems worldwide. This study investigated the effect of a new multidisciplinary diabetic foot clinic (MDDFC) in a large tertiary hospital on patient outcomes and treatment cost.

Methods: Patients' records were retrospectively reviewed to identify all patients who had been managed in a new MDDFC between July 2014 and July 2017. The wound episode—the period from initial presentation to the achievement of a final wound outcome—was identified, and all relevant inpatient and outpatient costs were extracted using a fully absorbed activity-based costing methodology. Risk factor, treatment, outcome, and costing data for this cohort were compared with a group of patients with diabetic foot wounds who had been managed in the same hospital before the advent of the MDDFC using a generalized linear mixed model.

Results: The MDDFC and pre-MDDFC cohorts included 73 patients with 80 wound episodes and 225 patients with 265 wound episodes, respectively. Compared with the pre-MDDFC cohort, the MDDFC group had fewer inpatient admissions (1.56 vs 2.64; $P \leq .001$). MDDFC patients had a lower major amputation rate (3.8% vs 27.5%; $P \leq .001$), a lower mortality rate (7.5% vs 19.2%; $P \leq .05$), and a higher rate of minor amputation (53.8% vs 31.7%; $P \leq .01$). No statistically significant difference was noted in the rate of excisional débridement, skin graft, and open or endovascular revascularization. In the MDDFC cohort, the median total cost, inpatient cost, and outpatient cost per wound episode was New Zealand dollars (NZD) 22,407.465 (U.S. dollars [USD] 17,253.74), NZD 21,638.93 (USD 16,661.97), and NZD 691.915 (USD 532.77), respectively. The MDDFC to pre-MDDFC wound episode total cost ratio was 0.7586 ($P < .001$).

Conclusions: This study is the first to compare the cost and treatment outcomes of diabetic foot patients treated in a large tertiary hospital before and after the introduction of an MDDFC. The results show that an MDDFC improves patient outcomes and reduces the cost of treatment. MDDFCs should be adopted as the standard of care for diabetic foot patients. (J Vasc Surg 2019;70:806-14.)

Keywords: Diabetic foot wound; Economic burden; Multidisciplinary clinic; Amputation; Cost

Diabetic foot disease poses a significant and rising financial burden on health care systems worldwide. The economic burden of diabetes in the United States was estimated at 174 billion U.S. dollars (USD) in 2007[1]; 33% of that cost was related to diabetic foot disease. By 2017, the estimated cost of diabetes had risen to USD 327 billion.[2] In New Zealand, the cost of diabetes had increased from 247 million New Zealand dollars (NZD) in 2001 to NZD 600 million in 2008, and it was expected to reach NZD 1.3 billion in 2016 and NZD 1.8 billion in 2021.[3] At Auckland Hospital, a previous study looking at all diabetic foot wounds treated by the Department of Vascular Surgery between 2009 and 2014 concluded that the median cost of treatment, from initial presentation to the achievement of a final outcome, approximated NZD 30,000 (USD 23,100).[4] Furthermore, the study evidenced that 1 in every 3.5 diabetic foot wounds resulted in a major amputation and that patient mortality was close to 20%. The high treatment costs and the poor outcomes of patients with diabetic foot wounds, despite being in keeping with the numbers reported in the literature,[5-7] resulted in a departmental reflection to identify ways to improve our diabetic foot service.

The transition from a clinician-centric to a patient-centric approach to health care has shown promise in chronic diseases that, like diabetic foot disease, span the field of expertise of multiple medical and ancillary specialties. Research in the fields of cardiac failure, renal failure, and cancer has shown that the introduction of a disease-specific multidisciplinary clinic resulted in increased overall survival, slowing of disease progression, and better patient compliance[8-10] as well as decreased treatment cost.[11-13]

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In diabetic foot disease, research shows that multidisciplinary diabetic foot clinics (MDDFCs) result in a reduction in major amputation rates[14,15] and mortality.[16,17] The validity of this growing body of evidence was reflected by the adoption of the MDDFC as the recommended model of care for diabetic foot disease by both the International Working Group on the Diabetic Foot and the Society for Vascular Surgery.[18,19]

Whether MDDFCs reduce diabetic foot wound treatment cost remains less certain as few studies have investigated the topic. The limited available evidence that mainly consists of economic model analyses[20-23] suggests that MDDFCs can have a beneficial effect on treatment costs, but the translation and applicability of these studies' results in our practice are questionable because of high variability in health care system setup, costing and reimbursement models, and clinic constructs.

In this context, an MDDFC was created at Auckland Hospital in July 2014. This study aimed to investigate its effect on wound treatment cost and outcomes.

ARTICLE HIGHLIGHTS

- **Type of Research:** Retrospective, single-center cohort study
- **Key Findings:** After institution of a multidisciplinary diabetic foot clinic, there was a reduction in hospital admissions, fewer major amputations (3.8% vs 27.5%), a lower mortality rate (7.5% vs 19.2%), and a reduction in total costs.
- **Take Home Message:** This study suggests that a multidisciplinary diabetic foot clinic can lead to improved patient outcomes with lower costs.

METHODS

Ethics approval. Institutional ethics approval was granted by the Low Risk Ethics Committee at the regional hospital network. The need for consent of individual patients was waived as data presented in this study are pooled and deidentified.

Primary end points. The primary end points were to calculate the cost of diabetic foot wound treatment at the Department of Vascular Surgery of Auckland Hospital after the introduction of a new MDDFC and to compare it with the treatment costs effective before the clinic's introduction.

Secondary end points. The secondary end points were as follows:

- to characterize the demographics and risk factor profile of patients with diabetic foot wounds treated at Auckland Hospital's MDDFC. Demographic variables included sex, age, and ethnicity. Risk factor variables included the recorded diagnosis of ischemic heart disease, hypercholesterolemia, hypertension, chronic kidney disease, and smoking status.
- to characterize the treatment and outcomes of diabetic foot wounds managed by Auckland Hospital's MDDFC. Treatment variables included the number of inpatient admissions, number of outpatient clinics, and number and type of surgical (major and minor amputations, excisional débridements, skin grafts, and open reperfusion surgery) and endovascular procedures performed. Outcome variables included the wound outcome, classified as healed (wound healed), lost (patient lost to follow-up), died (wound not healed by the time of patient's death), and required major amputation, and the wound episode length.
- to compare the treatment and outcomes of diabetic foot wounds after the introduction of Auckland Hospital's MDDFC with those effective before the clinic's introduction.

MDDFC service setup. Our MDDFC team consists of a vascular surgeon, a vascular registrar, an endocrinology registrar, a podiatrist, a diabetic foot nurse specialist, and an orthotist. The clinic, which is held fortnightly on hospital grounds, exclusively deals with patients suffering from an active diabetic foot wound; it began in July 2014 and is coordinated by a diabetic foot nurse specialist. Patients seen at the clinic are assigned a room and are successively seen by multidisciplinary clinic team members who rotate between rooms. The vascular surgeon assesses the wound for surgical management (need for revascularization, surgical débridement, and amputation). The endocrinologist assesses the patient's diabetic control and optimizes diabetic treatment in addition to optimizing any other medical parameters. The diabetic foot nurse specialist focuses on patient education (diet, exercise, medication, wound care). The podiatrist and orthotist work in close collaboration to optimize footwear, offloading, and foot care. Each clinic concludes with a multidisciplinary discussion in which the cases of all patients are reviewed. This allows the integration of all the multidisciplinary clinic team members' expertise and results in a coordinated patient-specific management plan that consists of the recommendation for acute or elective inpatient treatment, further outpatient care, or discharge of the patient from the clinic to community podiatrists and district nurses (Fig 1). Clinic-based treatments, such as superficial wound débridement, dressing changes, and provision of orthotic footwear, are also performed at the clinic. All clinicians, within the hospital or from the community, and podiatrists can refer to the clinic.

Before the MDDFC, patients with diabetic foot wounds were referred to the Department of Vascular Surgery and either admitted as an inpatient or reviewed in a general vascular surgery outpatient clinic. Input

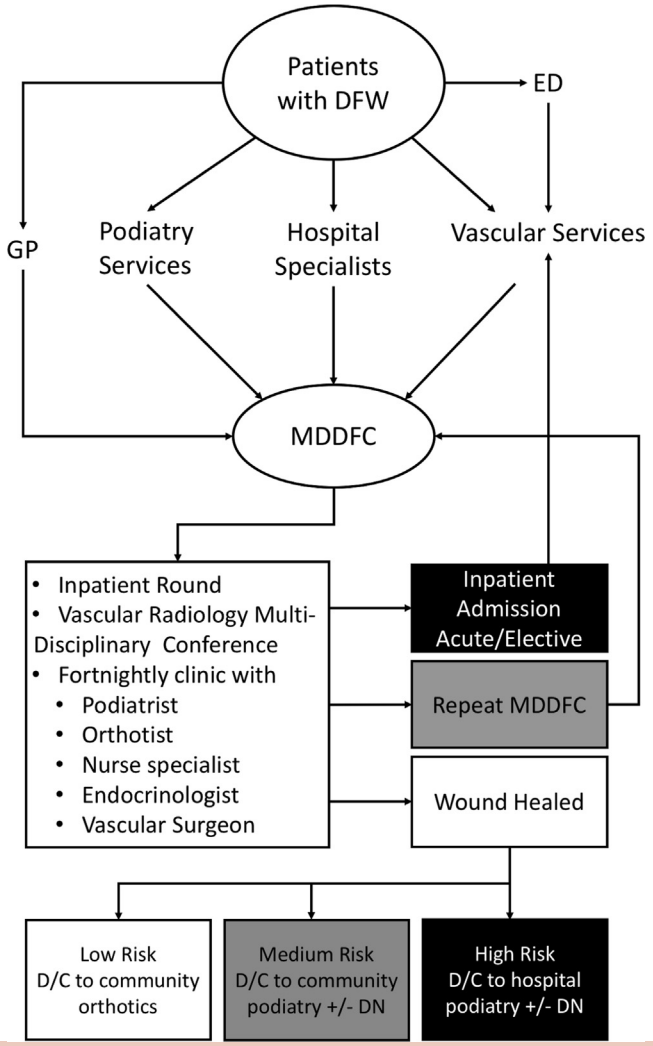

Fig 1. Service setup from July 2014 onward after the establishment of the multidisciplinary diabetic foot clinic (*MDDFC*). *D/C,* Discharge; *DFW,* diabetic foot wound; *D/N,* district nurse; *ED,* emergency department; *GP,* general practitioner.

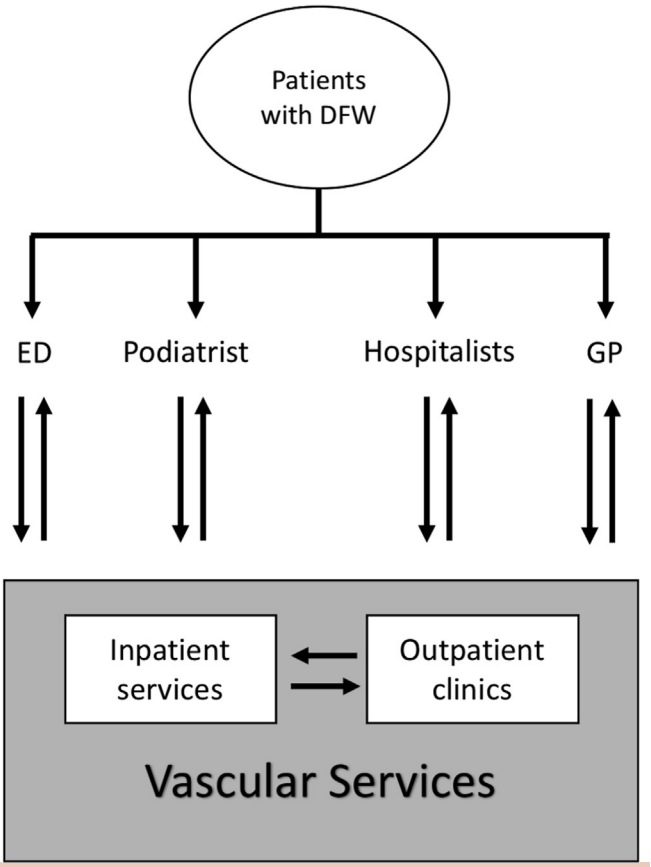

Fig 2. Service setup before July 2014 and before the establishment of the multidisciplinary diabetic foot clinic (MDDFC). *DFW,* Diabetic foot wound; *ED,* emergency department; *GP,* general practitioner.

from other medical specialists or allied health professionals had to be sought through individual consultations (Fig 2).

Patient and wound episode identification and selection. Clinic lists from July 2014 to July 2017 were retrospectively reviewed to identify patients who had been treated for a diabetic foot wound at the MDDFC during the study window. The MDDFC lists yielded 158 individual patients who had attended the clinic at least once.

Next, the patients' electronic records (admission notes, referral letters, operation notes, interventional radiology reports) were reviewed to identify specific wound episodes (defined as the period from the first recorded reference to the wound to the moment at which a final wound outcome was achieved). To qualify for our study, wound episodes had to satisfy the following inclusion criteria: the entire wound episode was within the study period of July 2014 to July 2017; the patient had a diagnosis of diabetes mellitus; and the patient had attended at least one MDDFC. Wound episodes were excluded if the wound had been partially treated by other departments within our hospital or by another hospital and if records from the wound episode were incomplete and costing information relating to the wound could not be obtained. Using this methodology, we identified 61 patients who had one or more relevant wound episodes.

Records from all patients who had been admitted under the vascular surgery unit for management of lower limb disease during the study window were also reviewed to identify diabetic foot wound patients who had attended the MDDFC but had not been captured by the MDDFC lists. Three databases were used to gather and to cross-reference this information:

- Theater lists. Procedure codes identified all patients who had undergone lower limb revascularization surgery (lower limb bypass graft, endarterectomy, thrombectomy), major and minor amputations, surgical débridement, or closure (including skin graft) of a wound.

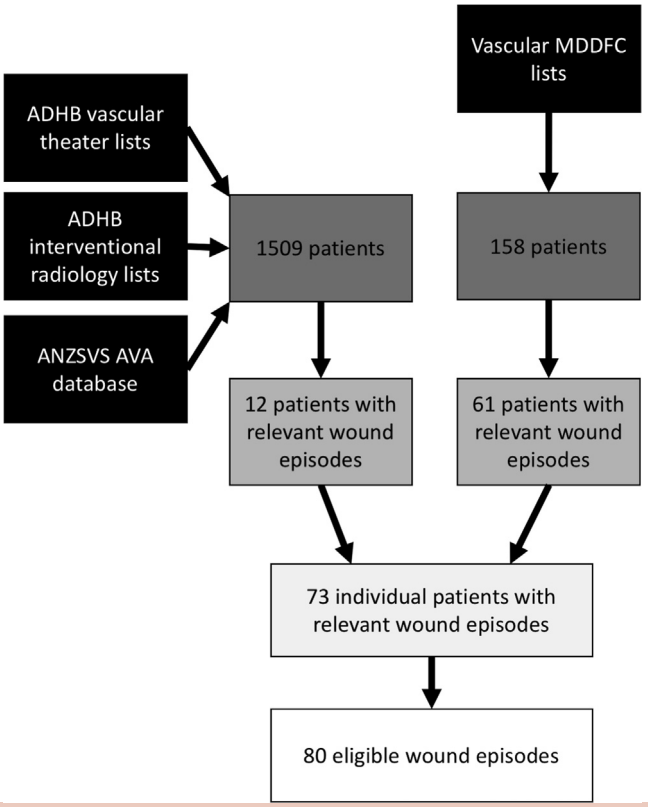

Fig 3. Architecture of study recruitment. *ADHB,* Auckland District Health Board; *ANZSVS,* Australian and New Zealand Society for Vascular Surgery; *AVA,* Australian Vascular Audit; *MDDFC,* multidisciplinary diabetic foot clinic.

- Interventional radiology procedure lists. These lists identified all patients who had undergone aortoiliac or lower limb diagnostic and interventional angiography.
- The Australian and New Zealand Society for Vascular Surgery's Australasian Vascular Audit database. This database, which records all vascular and endovascular interventions performed by the Department of Vascular Surgery (does not include procedures performed by other departments), was used to identify patients who had undergone open or endovascular surgery that had not been captured on the theater or interventional radiology lists.

The electronic patient files of 1509 patients who had been admitted under the Department of Vascular Surgery for interventions on the lower limbs and who had not been previously identified by the MDDFC lists were reviewed for eligible wound episodes. This yielded 12 additional patients. In total, our study included 73 patients with a total of 80 relevant wound episodes. A pictorial representation of the patient recruitment architecture is provided in Fig 3.

Wound episode-related data extraction. Patients' electronic clinical records were reviewed to identify the demographic, risk factor, treatment, and outcome variables detailed in our end points.

Cost calculation. To calculate the cost of each wound episode, the unique financial code for each relevant inpatient admission and outpatient clinic was collected and provided to the financial department. Costs were calculated at an event level, and resource utilization was identified by episodes of care. Patient activity and patient demographic data captured in the clinical systems were entered into Power Performance Manager, as were the financial data from the General Ledger. The expenditure data were allocated to particular episodes of care on the basis of resource utilization, resulting in a total individual estimated cost for each patient wound episode. The methodology used was fully absorbed activity-based costing. All costs in this study are stated in New Zealand dollars. The exchange rate from NZD to USD at the completion of the study was 0.77. USD equivalent costs using this exchange rate are provided with the NZD values.

Data comparison and statistical analysis. To investigate the new MDDFC's effect on treatment cost and patient outcome, we compared our study population with a cohort of 225 patients with 265 diabetic foot wound episodes who had been managed before the introduction of the new clinic (January 2009-June 2014). The inclusion and exclusion criteria in this cohort were the same as those employed in this study, excluding the requirement to attend at least one MDDFC. Further details of the study design can be found in the original paper.[4] To investigate for statistically significant differences between the control (pre-MDDFC) group and the case (MDDFC) group, our data were fitted to a generalized linear mixed model with log as link function. A Poisson distribution was selected because of the multinomial nature of the data distribution. Patient was included as random factor to account for wound episodes generated by one same patient. Statistical significance in this study was defined as a P value $\leq .05$; differences failing to achieve this level of significance were presented as not statistically significant.

RESULTS

Patient characterization. Seventy-three individual patients were included in our study. The patients were predominantly men and had an average age of 66.7 $\pm$ 11.9 years. The most represented ethnic group was European (57.5%), followed by Maori (19.2%) and Pacific Islander (17.8%). Forty patients (54.8%) were active tobacco smokers at the time of the wound episode. Ischemic heart disease, chronic kidney disease, hypercholesterolemia, and hypertension were common in our population of patients. The demographic and risk factor profile of the MDDFC group was comparable to the control group.

During the study period, the 73 patients generated 80 eligible wound episodes. Sixty-eight patients (93.2%)

Table I. Study population demographic and risk factor profile

Cohort	Before MDDFC	After MDDFC
Male	64.9	80.8
Age, years, average	69.6	66.7
Smoker	9.3	54.8
Ex-smoker	36.9	9.6
Hypertension	84.4	80.8
Hypercholesterolemia	46.7	71.2
Ischemic heart disease	44.4	30.1
Chronic kidney disease	40.0	42.5

MDDFC, Multidisciplinary diabetic foot clinic.
Values are reported as percentages unless otherwise indicated.

had only one wound episode, three (4.1%) had two wound episodes, and two (2.7%) had three episodes. The pre-MDDFC group of 225 patients had generated 265 eligible wound episodes. Table I summarizes the characteristics of the two groups.

Wound episode characterization and outcomes. Each wound episode generated an average of 1.56 inpatient admissions and 2.95 outpatient clinics. In comparison, the average number of vascular surgery inpatient admissions and outpatient clinics per wound episode in the pre-MDDFC group was 2.64 and 3.08, respectively. The reduction in the number of inpatient admissions per wound episode proved to be statistically significant ($P \leq .001$); the reduction in outpatient clinics failed to achieve statistical significance. The median length of wound episode in the MDDFC group was 171.5 days compared with 176 days in the pre-MDDFC group; this difference failed to reach statistical significance. In both groups, 55% of wound episodes had an inpatient admission recorded as the episode's first event. Patients who first presented as inpatients were generally referred to the vascular department by the emergency department for acute wound management. Patients who first presented at the clinic were referred by practitioners in and out of the hospital. Nine patients in the MDDFC group did not have an inpatient admission as part of the wound episode. Table II provides an overview of the wound episode characteristics.

In the MDDFC group, 3.75% of wound episodes underwent a major amputation, 47.5% required one or more minor amputations, 41.25% required one or more surgical débridements, and 12.5% underwent wound closure with a skin graft. In terms of revascularization, 18.75% underwent one or more open surgical procedures and 51.25% underwent one or more endovascular procedures. The average number of major and minor amputations, excisional débridements, skin grafts, and open and endovascular revascularization procedures per wound episode was 0.038, 0.538, 0.613, 0.125, 0.213, and 0.8, respectively. In contrast, the average number of the same procedures in the pre-MDDFC group was 0.275, 0.317, 0.460, 0.083, 0.249, and 1.038, respectively.[4] The rate of progression to a major amputation of wounds requiring a minor amputation was 2.6% in the MDDFC group and 16.25% in the pre-MDDFC group. The reduction in the rate of major amputation was statistically significant ($P \leq .001$), as was the increase in the rate of minor amputation ($P \leq .01$). The other correlates failed to reach statistical significance (Table III).

In the MDDFC cohort, 90.0% of the wound episodes eventuated in a healed wound. In 7.5%, the patient died with an active wound, and in 2.5%, the patient was lost to follow-up; 2.5% of wounds required major amputations, 43.8% required minor amputations, and 43.8% required no amputations. In the pre-MDDFC group, only 69.8% of wound episodes ended with a healed wound. In the MDDFC group, the mortality rate and the rate of wounds that healed by major amputation were significantly lower ($P \leq .05$). The rate of wounds that healed by minor amputations was higher ($P \leq .001$; Table IV).

Cost of wound treatment. During the study period, Auckland Hospital spent NZD 2,593,219.64 (USD 1,996,779.12) treating the 80 wound episodes included in this study. The majority of the cost was from inpatient admissions (NZD 2,514,676.30; USD 1,936,300.75); outpatient clinic costs were comparatively minor (NZD 78,543.34; USD 60,478.37). Per wound episode, the median total cost was NZD 22,407.465 (USD 17,253.74). The median inpatient and outpatient costs per wound episode were NZD 21,638.93 (USD 16,661.97) and NZD 691.915 (USD 532.77), respectively.

Compared with costs in the pre-MDDFC group, the median cost ratios for total, inpatient, and outpatient cost per wound episode were 0.7586, 0.7594, and 0.8294, respectively.

Statistical analysis of these cost variables through our mixed model proved the reduction in total and outpatient cost to be statistically significant ($P < .001$). The difference in inpatient cost failed to achieve statistical significance. Results presented in this section are summarized in Table V.

DISCUSSION

The results of this study show that an MDDFC reduces the cost of treatment and improves patient outcomes. We believe that the observed reduction in treatment cost is directly related to the improved outcomes, more specifically, the reduction in inpatient admissions and major amputations.

Previous studies have shown that the majority of the cost of managing diabetic foot disease is associated with inpatient admissions and the severity of wounds; wounds that require major or minor amputation to heal cost significantly more than wounds that heal primarily.[6,24-26] Even after wound healing, the cost of

Table II. Wound episode characteristics before and after implementation of the multidisciplinary diabetic foot clinic (*MDDCF*), with log model estimates, variance, confidence intervals (*CIs*), and *P* values

Variable	Value	Ratio	Estimate	Variance	95% CI		*P*
					Lower	Upper	
Average inpatient admissions							
Before MDDFC	2.64	0.59	0.9713505	0.001428571	2.452254	2.84537	≤.001
After MDDFC	1.56		0.4462871	0.00799999	1.310436	1.863048	
Average outpatient clinics							
Before MDDFC	3.08	0.96	0.9875984	0.002849225	2.417195	2.981985	NS
After MDDFC	2.95		0.8882135	0.008761619	2.022031	2.922164	
Median length of wound episode, days							
Before MDDFC	176	0.97	5.069958	0.003701398	141.2157	179.4018	NS
After MDDFC	171.5		5.041659	0.012243612	124.4632	192.3483	

NS, Not significant.

Table III. Procedure rates per wound episode before and after implementation of the multidisciplinary diabetic foot clinic (*MDDCF*), with log model estimates, variance, confidence intervals (*CIs*), and *P* values

Variable	Value	Ratio	Estimate	Variance	95% CI		*P*
					Lower	Upper	
Rate of major amputations							
Before MDDFC	0.275	0.14	−1.28927	0.01369863	0.21882584	0.3467811	≤.001
After MDDFC	0.038		−3.283414	0.33333297	0.01204619	0.1167381	
Rate of minor amputations							
Before MDDFC	0.317	1.70	−1.148913	0.01190358	0.2557617	0.3928541	≤.01
After MDDFC	0.538		−0.6208265	0.02325549	0.3982105	0.7255114	
Rate of excisional débridement							
Before MDDFC	0.46	1.33	−0.7757088	0.008196721	0.3852804	0.5501119	NS
After MDDFC	0.613		−0.4902063	0.020408163	0.4624612	0.8112167	
Rate of skin grafting							
Before MDDFC	0.083	1.51	−2.488687	0.04545454	0.054583	0.1262688	NS
After MDDFC	0.125		−2.079442	0.09999999	0.06710939	0.2328288	
Rate of open revascularization							
Before MDDFC	0.249	0.86	−1.390075	0.01515148	0.1955021	0.3172814	NS
After MDDFC	0.213		−1.548813	0.05882352	0.1318807	0.3424023	
Rate of interventional radiology procedures							NS
Before MDDFC	1.038	0.77	0.03704127	0.003636328	0.921671	1.168417	
After MDDFC	0.8		−0.22314355	0.015624599	0.6256254	1.022976	

NS, Not significant.

managing a patient with diabetic foot disease does not return to the preulcer cost until 2 years after diagnosis.[7]

We believe that the reduction in the rate of major amputation seen in this study is attributable to multiple factors. Better coordinated care and follow-up may have resulted in earlier and more aggressive intervention as reflected by the increase in minor amputations, débridement, and skin grafting and by the reduction in the number of wounds progressing from a minor to a major amputation.

The intangible (but perhaps more important in the longer term) benefits of adopting a patient-centered, streamlined care model include patient empowerment, improved engagement and health literacy, and stronger relationships with the health care providers, which improves compliance. These benefits are more difficult to measure, however, and will always be tainted by subjectivity.

Some postulate that the reduction in major amputation in itself will offset the additional cost of a clinic, given that amputation is one of the major drivers of cost. McCabe et al[21] demonstrated that the additional cost of a new diabetic foot clinic that provided high-risk patients (foot deformity, history of ulceration, ankle-brachial index ≤0.75) with foot care, education, and protective footwear was outweighed by the cost savings

Table IV. Wound episode outcomes before and after implementation of the multidisciplinary diabetic foot clinic (*MDDCF*), with log model estimates, variance, confidence intervals (*CIs*), and *P* values

Variable	Average, %	Ratio	Estimate	Variance	95% CI		*P*
					Lower	Upper	
Died							
Before MDDFC	19.2	0.39	−1.6479042	0.019607843	0.146214985	0.2533126	≤.05
After MDDFC	7.5		−2.5902672	0.166666637	0.03366282	0.1670983	
Lost							
Before MDDFC	10.2	0.25	−2.283893	0.037037033	0.069841117	0.1486362	NS
After MDDFC	2.5		−3.6888795	0.499996949	0.006242272	0.1001238	
Healed							
Before MDDFC	69.8	1.29	−0.359374	0.005405405	0.60432502	0.8064568	NS
After MDDFC	90.0		−0.1053605	0.013888889	0.714182679	1.1341636	
Required major amputation							
Before MDDFC	14.3	0.17	−1.9421437	0.0263149	0.104318024	0.1971134	≤.05
After MDDFC	2.5		−3.6888795	0.50000763	0.006246255	0.10006	
Required minor amputation							
Before MDDFC	20.0	2.19	−1.6094379	0.01886739	0.152766276	0.2618379	≤.001
After MDDFC	43.8		−0.8266786	0.02857167	0.314048315	0.6094803	
Required no amputation							
Before MDDFC	35.5	1.23	−1.036435	0.01063833	0.289751081	0.4342491	NS
After MDDFC	43.8		−0.8266786	0.02857138	0.314048837	0.6094793	

NS, Not significant.

Table V. Median costs per wound episode before and after implementation of the multidisciplinary diabetic foot clinic (*MDDCF*), with natural logarithmic model estimates and *P* values

Variable	Median cost (NZD)	USD equivalent	Median cost ratio	Estimate	Variance	95% CI		*P*
						Lower	Upper	
Total cost								
Before MDDFC	29537.21	22743.65	0.76	10.233916	0.004215688	24494.53	31622.56	≤.001
After MDDFC	22407.465	17253.74		9.718669	0.013762324	13199.33	20940.02	
Inpatient cost								
Before MDDFC	28491.43	21938.40	0.76	10.192661	0.002953166	24003.2071	29714.1557	NS
After MDDFC	21638.93	16661.97		10.077825	0.010642643	19442.8585	29155.9939	
Outpatient cost								
Before MDDFC	834.2	642.33	0.83	6.969595	0.003593196	945.6562	1196.685	≤.001
After MDDFC	691.915	532.77		6.55991	0.009519532	583.0698	855.3514	

CI, Confidence interval; *NS*, not significant; *NZD*, New Zealand dollars; *USD*, U.S. dollars.

from preventing 11 major amputations. Horswell et al[27] showed that a multidisciplinary clinic that provided foot care, education, offloading footwear, and custom orthoses led to an 82% reduction in foot-related in-patient admissions and 51% fewer emergency department visits and was associated with a 76% reduction in inpatient charges and 50% reduction in emergency department charges in the 1-year study period. A number of other studies examining this topic have used economic modeling to show that similar programs can be cost-effective if they achieve target reductions in amputations.[22,23,28] On the other hand, Armstrong et al[29] demonstrated that the introduction of a multidisciplinary team at a large, tertiary hospital can significantly change the surgery volume and surgery type performed by a vascular department; their department performed 44.1% more vascular reconstructions, with an increase in the percentage of open bypasses compared with endovascular procedures (from 28.8% to 35.9%) and a trend toward more infrageniculate vascular procedures. This was accompanied by a 45.7% reduction in below-knee amputations and a reduction in percentage of

emergency surgery performed, 77.7% to 48.5%. This study did not investigate cost. Nason et al[20] also reported a 30% increase in endovascular revascularization procedures and a 58% reduction in major amputation after the introduction of a multidisciplinary team. These authors estimated that their multidisciplinary diabetic foot service would be cost-effective within 2 years based on the reduction in major amputations; however, it is not clear whether the additional cost of the revascularization surgery was included in their analysis. In our study, we did not observe an increase in the number of revascularization procedures performed on diabetic foot patients after the establishment of our MDDFC. This is likely due to our institution's having always been proactive with infrapopliteal revascularization in the setting of critical limb ischemia.

One of the difficulties in comparing studies on multidisciplinary team approaches in diabetic foot disease is heterogeneity—in the members of the multidisciplinary team, patient selection, treatment algorithms, and recorded outcomes, to name but a few. Cost comparison adds another element of difficulty with differing costing methodology, reimbursement schemes, and flexible currency exchange rates. As such, it is not surprising that reviewers tend to present the data in a tabulated format and have concluded that the evidence is insufficient to determine whether an MDDFC is cost-effective.[24,30] One of the main strengths of this study is the consistency in costing methodology and currency; costs from both the pre-MDDFC and MDDFC groups were collected using the same raw data and calculated using the same costing model. Furthermore, costs that were not included in the preliminary study—the cost of care under other medical teams including rehabilitation and indirect costs (time off work, carers)—were also excluded in this study. As such, our study can conclude that the minimal total cost of diabetic wound care to a vascular surgery unit can be reduced with the introduction of an MDDFC.

There are, however, a number of limitations in this study, namely, the retrospective nature of the data collection and differences in pre-MDDFC and MDDFC groups. In the initial study[4] that yielded the pre-MDDFC cohort, we were unable to capture patients who had been treated only in the outpatient setting as the patient had to have been admitted as an inpatient at least once during a wound episode to be captured in the databases. In contrast, the MDDFC cohort patient had to be seen in the MDDFC to qualify for the study. This enabled the recruitment of patients referred directly to the clinic from podiatry services, physicians, and general practitioners but likely resulted in a relative increase in cost in the pre-MDDCF cohort, which introduces potential bias in our results.

It is also possible that the difference in wound treatment, outcomes, and cost seen in our study is due to differences in the type of wounds. A formal wound scoring system is not routinely used by our department, and thus adjustment for wound type could not be performed in our analysis.

We also acknowledge that the costs presented in this study included only costs incurred by the Department of Vascular Surgery for inpatient admissions and hospital outpatient clinics. We did not capture primary care costs, such as those incurred at a general practice level or those related to community nursing or podiatry cares.

Finally, there were only 80 complete wound episodes (73 patients) within our study period since the introduction of the MDDFC compared with the pre-MDDFC group, which included 225 patients with 265 wound episodes. We continue to collect data prospectively to see whether these findings remain statistically significant.

CONCLUSIONS

Our study characterizes the cost and outcome of diabetic foot wound treatment before and after the introduction of an MDDFC at the largest Department of Vascular Surgery in New Zealand. Our results show that the cost of treating diabetic foot wounds within the Department of Vascular Surgery at Auckland Hospital was reduced by the introduction of an MDDFC. We also demonstrated that the MDDFC improved patient outcomes by significantly reducing patient mortality and major amputations.

To our knowledge, this is the first study to compare the cost and treatment outcomes of diabetic foot patients treated in a large tertiary hospital before and after the introduction of an MDDFC. MDDFCs should be adopted as the standard of care for diabetic foot patients.

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AUTHOR CONTRIBUTIONS

Conception and design: MJ, VB
Analysis and interpretation: MJ, AD, BW, VB
Data collection: MJ, KO, CC
Writing the article: MJ, KO, AD, CC, VB
Critical revision of the article: MJ, KO, AD, CC, BW, VB
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