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RESEARCH ARTICLE

Cost-effectiveness of guideline-based care provision for patients with diabetes-related foot ulcers: A modelled analysis using discrete event simulation

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Abstract

Aims: The provision of guideline-based care for patients with diabetes-related foot ulcers (DFU) in clinical practice is suboptimal. We estimated the cost-effectiveness of higher rates of guideline-based care, compared with current practice.

Methods: The costs and quality-adjusted life-years (QALYs) associated with current practice (30% of patients receiving guideline-based care) were compared with seven hypothetical scenarios with increasing proportion of guideline-based care (40%, 50%, 60%, 70%, 80%, 90% and 100%). Comparisons were made using discrete event simulations reflecting the natural history of DFU over a 3-year time horizon from the Australian healthcare perspective. Incremental cost-effectiveness ratios were calculated for each scenario and compared to a willingness-to-pay of AUD 28,000 per QALY. Probabilistic sensitivity analyses were conducted to incorporate joint parameter uncertainty.

Results: All seven scenarios with higher rates of guideline-based care were likely cheaper and more effective than current practice. Increased proportions compared with current practice resulted in between AUD 0.28 and 1.84 million in cost savings and 11–56 additional QALYs per 1000 patients. Probabilistic sensitivity analyses indicated that the finding is robust to parameter uncertainty.

Conclusions: Higher proportions of patients receiving guideline-based care are less costly and improve patient outcomes. Strategies to increase the proportion of patients receiving guideline-based care are warranted.

KEYWORDS

cost-effectiveness analysis, diabetes-related foot ulcers, discrete event simulation, guideline-based care

1 | INTRODUCTION

Foot disease contributes to ~60% of the global diabetes disability burden, ~33% of the total diabetes healthcare costs, and is increasingly considered a leading cause of global disease and healthcare cost burdens.[1–3] Diabetes-related foot disease, which includes foot ulcers and infections, is caused by the underlying diabetes complications of peripheral neuropathy and peripheral artery disease.[4] Diabetes-related foot ulcers (DFUs) typically take months to heal and result in lower quality of life and higher risks of hospitalisation, amputation and mortality.[3–5]

Care for people with DFU remains a major clinical challenge.[6] The most recent global evidence-based guidelines from the International Working Group on Diabetic Foot (IWGDF) recommend adhering to several core principles of DFU care, including regular DFU assessment, sharp debridement, wound dressings, infection treatment, pressure offloading and foot care education.[7] However, adherence to these recommendations in real-world clinical practice has been reported to be suboptimal and ranges between 20% and 52% in European and US studies.[8,9] Various reasons have been attributed to this suboptimal DFU care, including attitudes of health professionals, lack of incentives for health providers to change behaviour and challenges with patient adherence.[10]

Evaluation of the cost and health benefits of increasing the provision of guideline-based care to patients with DFU has been consistently recommended by global IWGDF guidelines,[7] and most recently voted the top national priority research question among diabetes-related foot disease patients, health professionals, research and industry stakeholders in Australia.[11] A recent systematic review on the cost-effectiveness of guideline-based diabetes care found evidence to suggest that guideline-based DFU care can reduce costs and increases health benefits compared with existing clinical practice.[12] However, the review concluded that most studies to date were based on data from older clinical trials, retrospective cohorts of expert opinion and future economic studies that utilise more recent data from real-world cohorts were needed.[12]

What's new

- Adherence to guidelines for diabetes-related foot ulcer (DFU) in real-world practice is suboptimal. Although some evidence exists in support of guideline-based care, cost-effectiveness-analyses utilising real-world data and investigating more realistic scenarios are lacking.
- Among 1000 patients, complete adherence care generated 56 additional quality-adjusted life-years and saved 1.8 million over 3 years compared with current practice. Other scenarios with increased proportions of guideline-based care were also likely cost-saving.
- This new evidence should promote greater uptake of guideline-based care for DFU to reduce future disease and economic burdens.

This study aims to estimate the costs and quality-adjusted life-years (QALYs) associated with complete adherence to guideline-based care, compared with current practice, to understand the current impact of unwarranted variation away from guideline-based care. Our secondary aim was to estimate the costs and QALYs associated with increasing increments in the proportion of patients receiving guideline-based care compared with current practice, to understand the likely cost-effectiveness of greater levels of adherence to guideline-based care than current practice.

2 | METHODS

A discrete event simulation model was developed to estimate costs and QALYs across multiple patient cohort scenarios, each with a different proportion of patients receiving guideline-based care. Current practice and seven hypothetical scenarios were simulated, with increasing proportions of people receiving guideline-based care (Figure 1a). The cost-effectiveness of each scenario was determined by comparison with current

practice. The proportion of guideline-based care for the current practice comparator scenario was estimated to be 30% of patients receiving guideline-based care based on the observed findings from our prospective patient cohort (cohort description and patient baseline characteristics in Table S2).[13,14] A 3-year time horizon was adopted, which was consistent with both a clinically relevant time frame for promoting healing and preventing recurrence, as well as the duration of the cohort. This study was reported in accordance with the consolidated health economic evaluation reporting standards (CHEERS) statement (Table S1).[15]

2.1 | Discrete event simulation model

Our model represents a cohort of people with DFU who visit Diabetic Foot Services, and simulates individual disease trajectories based on a set of possible events that can occur under each scenario, with costs and QALYs accumulating over time. The key structural element of discrete event simulation models are events, which are typically chosen to represent clinically important events that can occur throughout the disease history and are associated with significant costs and health-related quality of life impacts.[16]

The model structure was based on previous work of our group: a state-based Markov model,[17] which had been built on previous models developed for the economic evaluations of treatments for DFUs. However, the Markov model synthesised data input from national and international literature when an Australian patient cohort was not available. In this study, we built on the previous work and refined the structure, in accordance with best practice guideline for cost-effectiveness analysis,[18] and the model was informed by the data from the recently available real-world multi-site Australian cohort,[13,14] with longer-term outcomes calibrated to the best available evidence from independent studies. We adopted discrete event simulation techniques which allowed us to model events as experienced by our real-world cohort, while also being able to account for the individual heterogeneity within the cohort. Thus, six possible events were included in the model: healing, recurrence, hospitalisation (without amputation), minor amputation, major amputation and death (Figure 1b). To determine the timing and order in which events occur for each individual with DFU, the model calculated time-to-event estimates for every possible event (as shown in Figure 1b, for example, T12 represents the transition from having a DFU to healing) and selected the event with the shortest time. Following events other than death, participants remained at risk of future events and the time to the next event was updated accordingly. Once 3 years of time had elapsed, the accumulated cost and QALY estimates of individuals were aggregated to the cohort level for each scenario. The model was developed and analysed in TreeAge Pro 2021 (R2.1; TreeAge Software, Inc.).

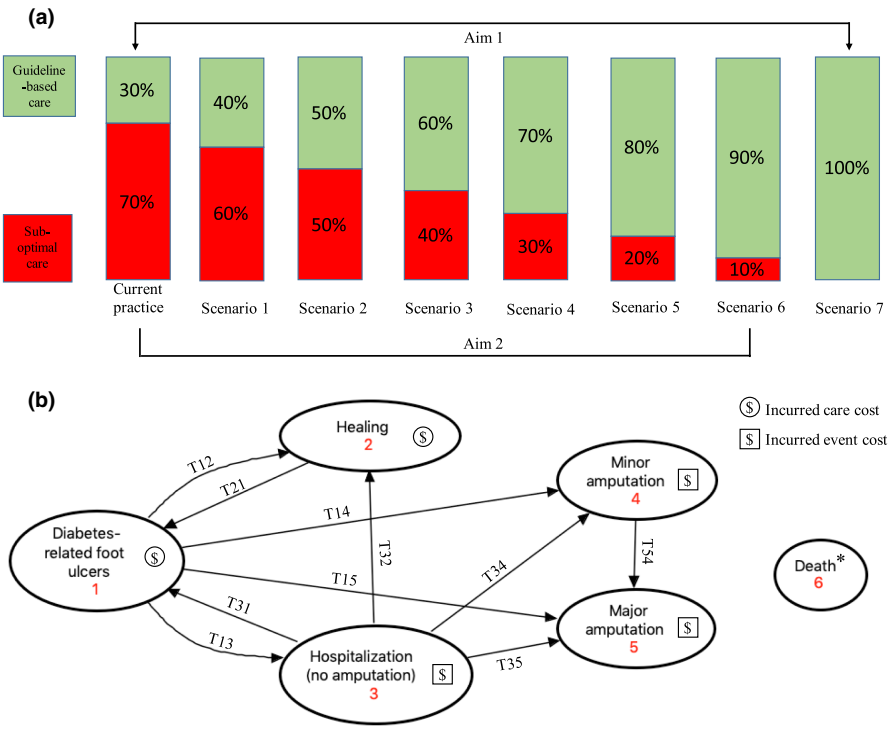

FIGURE 1 (a) Current practice and seven scenarios; (b) Discrete event simulation model structure. *All states can transit to death. Time-to-event parameter for each transition is labelled as T + start state number + transit state number. Care cost and event cost explained in Method-Cost subsection.

2.2 | Model inputs

The model inputs including time-to-event, resource use and costs, and utility are summarised in Tables 1 and 2 and included a combination of data derived from a large prospective cohort of patients with DFU (cohort description and characteristics, and definition of guideline-based care in Table S2) and published sources.

2.2.1 | Cohort description

A prospective cohort of patients with DFU attending multisite outpatient Diabetic Foot Services in the Australian state of Queensland, between 1st July 2011 and 1st June 2016, was used.[13,14] Clinical data for this cohort, including treatment performed with each visit, have been reported in detail elsewhere[14] The brief, the data were captured in the Queensland High Risk Foot Database, and linked to the Queensland hospital discharge database which included all clinical and administrative information for all hospital admissions in Queensland.[19] Overall, 3385 consecutive patients followed up for at least 3 years were eligible (patient baseline characteristics in Table S2), and 3122 patients with care data were included in the model to derive the events and corresponding time-to-event parameters. Discrete episodes of disease were defined that aligned with the six events included in the model, which included healed DFU, recurrent DFU, hospitalisation (no amputation), minor amputation, major amputation and death.

2.2.2 | Time-to-event parameters

Parametric survival analysis was applied to fit every possible transition between the specified events using

TABLE 1 Model input: time-to-event parameters

			Subgroup				
			Guideline-based care		Suboptimal care		
	Data source	Total *N* (%)[a]	*N* (%)[a]	Parameters[b]	*N* (%)[a]	Parameters[b]	Distribution
From DFU to		3122 (100)	693 (100)		2202 (100)		
Healing (T12)	Cohort data	1961 (67.7)	532 (76.8)	(0.0171, 0.96)	1429 (64.9)	(0.00655, 0.96)	Weibull
Hospitalisation (T13)	Cohort data	534 (18.4)	89 (12.8)	(0.00238, 1.04)	445 (20.2)	(0.00377, 1.04)	Weibull
Minor amputation (T14)	Cohort data	170 (5.9)	23 (3.3)	(0.00151, 1.01)	147 (6.7)	(0.00176, 1.01)	Weibull
Major amputation (T15)	Cohort data	70 (2.2)	12 (1.7)	(0.000449, 0.98)	58 (2.6)	(0.00112, 0.98)	Weibull
Death (T16)	Cohort data	144 (4.9)	29 (4.2)	(0.000625, 1.23)	115 (5.2)	(0.000675, 1.23)	Weibull
From healed to		2089 (100)	923 (100)		1166 (100)		
DFU (T21)	Cohort data	1266 (60.6)	618 (66.9)	(0.00223, 1.05)	648 (55.6)	(0.0027, 1.05)	Weibull
Death (T26)	Life tables[20]	-	-	(0.000145, —)	-	(0.000145, —)	Exponential
From hospitalisation to		921 (100)	211 (100)		700 (100)		
DFU (T31)	Cohort data	498 (54.4)	111 (50.2)	(0.053, 0.70)	387 (55.7)	(0.055, 0.70)	Weibull
Healing (T32)	Cohort data	87 (9.5)	29 (13.1)	(0.0125, 0.85)	58 (8.3)	(0.0109, 0.85)	Weibull
Hospitalisation (T33)	Cohort data	196 (21.4)	44 (19.9)	(0.0362, 0.63)	152 (21.8)	(0.0494, 0.63)	Weibull
Minor amputation (T34)	Cohort data	101 (11.0)	29 (13.1)	(0.0357, 0.58)	72 (10.3)	(0.0296, 0.58)	Weibull
Major amputation (T35)	Cohort data	16 (1.7)	3 (1.3)	(0.00326, 0.72)	13 (1.9)	(0.00441, 0.72)	Weibull
Death (T35)	Cohort data	23 (2.5)	5 (2.2)	(0.0026, 0.87)	18 (2.6)	(0.00336, 0.87)	Weibull
From minor amputation to		572 (100)					
Major amputation (T45)	Cohort data	24 (4.2)	-	(0.00748, 0.75)	-	(0.00748, 0.75)	Weibull
Death (T46)	Literature[21]	-	Probability in Table S4				
From major amputation to							
Death (T56)	Literature[21,22]	-	Probability in Table S4				

Abbreviation: DFU, diabetes-related foot ulcer.

[a]Proportions do not sum up to 100% of the starting populations as a certain proportion was censored (e.g. lost to follow-up) and was not listed. *N* of subgroups of guideline-based care and suboptimal care may not add up to the total *N*, as care was defined based on longitudinal data through follow-up, during which some sample was lost. *N* and parameters by subgroup were used as model input.

[b]Time-to-event parameters are expressed with two parameters: (scale parameter, shape parameter), modelled using 1 week as a unit of time. Cohort data were based on the cohort of patients with DFU ($n = 3385$) who presented to Diabetic Foot Services in Queensland, Australia.

TABLE 2 Model input: cost and utility

Parameters	Distribution	Guideline-based care	Suboptimal care	Data source
Costs (Mean [SD], in *Australian dollars*)				
Care costs, outpatient (*per week*)				
DFU	Gamma	310.5 (236.7)	176.1 (185.7)	Cohort data
Healed DFU	Gamma	124.9 (112.4)	71.9 (85.1)	Cohort data
Event costs, inpatient (*per event*)				
Hospitalisation	Gamma	15,477 (14839)		Cohort data
Minor amputation	Normal	30,530 (14059)		Cohort data
Major amputation	Normal	47,327 (15503)		Cohort data
Utility (Mean [SD])				
DFU	Beta	0.75 (0.03)		[23]
Healed	Beta	0.84 (0.03)		[23]
Hospitalisation		Penalty of 0.026		[24]
Minor amputation	Beta	0.68 (0.05)		[23]
Major amputation	Beta	0.62 (0.05)		[23]

Abbreviations: DFU, diabetes-related foot ulcer; SD, standard deviation.

plausible statistical distributions including exponential, Weibull, Gompertz, lognormal and log-logistic. The best-fitting distribution was chosen for each transition based on the lowest Akaike information criterion and Bayesian information criterion. Each transition was then modelled with the chosen distribution, with the care group as a covariate, to derive model parameters (Table 1).

2.2.3 | Costs

This study adopted the Australian health system perspective. There were two categories of costs: care costs in the outpatient Diabetic Foot Services, and event costs for hospitalisation, minor and major amputation in an inpatient setting (Table 2).

Care costs in the outpatient foot services were calculated for each defined disease episode, including DFU episodes and healed episodes. Episodes were defined as the time from the initial visit until the outcome event occurred. Episode care costs were then broken down to an average weekly cost to align with the model parameterisation requirements. Care costs included the following: healthcare consultations,[25] consumables including dressings, pressure offloading devices, footwear[25] and antibiotics as defined by the clinical experts, to which Australian Pharmaceutical Benefits Scheme items were applied (Table S5).[26]

Event costs for hospitalisation, minor and major amputation in the inpatient setting were estimated using national hospital pricing data based on the Diagnosis-Related Group code assigned to each hospitalisation record.[25] The cost was expressed in 2020 Australian dollars, and a discount rate of 5% per year was applied to costs in the model consistent with prior recommendations.[27]

2.2.4 | Utility

Quality-adjusted life-years are a generic measure of health benefits that combine both quality and quantity of life. They are estimated by multiplying the time spent in a given health state by the utility value associated with that state. Estimates of utility values associated with each health state in the model were derived from published literature (Table 2). Utility values associated with all events were modelled to accumulate with time, except for hospitalisation, where a one-off utility penalty was applied when hospitalisation occurred. The utility penalty of hospitalisation was estimated at 0.026 per event. This was based on an annualised penalty of 0.20 from published literature, applied to a period of 6 weeks which was assumed to reflect the period of both hospitalisation and post-hospitalisation quality of life.[24] QALYs were discounted at a rate of 5% per year.[27]

2.3 | Comparator and scenarios

A graphical representation of the current practice comparator and scenarios investigated is displayed in Figure 1a. Briefly, the comparator was current practice where 30% of patients received guideline-based care while 70% received suboptimal care. The intervention scenarios under investigation contained incrementally increased guideline-based care provisions by 10% compared to current practice.

Thus, scenario 1 had 40% guideline-based care and 60% suboptimal care, through to the ideal scenario 7 with 100% guideline-based care.

2.4 | Base-case analysis

For current practice and each of the comparator scenarios, 10,000 persons were simulated in a model where the assumed proportion of persons was allocated to the guideline-based care pathway, with the remaining allocated to the suboptimal care pathway. The total costs and QALYs under each scenario were compared with current practice (30% of patients receiving guideline-based care), and the cost-effectiveness of each scenario was assessed using the incremental cost-effectiveness ratio (ICER), where the incremental cost (ΔC) was divided by incremental QALYs (ΔE).

A decision rule for cost-effectiveness is given by the ICER being below the decision-maker's maximum willingness-to-pay (WTP) threshold for an additional QALY. In this study, a WTP of AUD 28,000 was chosen, which reflects a conservative estimate of the opportunity cost of additional healthcare expenditure in the Australian setting.[28] To further express the total benefit as economic value, a net monetary benefit (NMB) was calculated for each scenario compared with the current practice. NMB represents the difference between the economic value of health benefits and the cost associated with a specific strategy, by using the equation: $\text{NMB} = (\text{WTP} \times \Delta\text{QALY}) - \Delta\text{Cost}$.

2.5 | Sensitivity analysis

Probabilistic sensitivity analysis was performed to quantify the impact of joint parameter uncertainty on the model. This was done by running 2000 Monte Carlo simulations of 3000 persons, with each simulation randomly sampling from the modelled probability distributions. Results are visually presented on the cost-effectiveness plane. The proportion of simulations in which a scenario was dominant (i.e. less costly and more QALYs), as well as the proportion considered cost-effective assuming a WTP of $28,000 per QALY, were calculated and described.

3 | RESULTS

3.1 | Base-case analysis

Results of the base-case analysis are presented in Table 3. Over a 3-year time horizon, the total cost estimated for current practice was $49,918 per patient, which comprised

TABLE 3 Base-case cost-effectiveness results (presented per person)

% of guideline-based care	Current practice	Scenarios with increase													
		40%		50%		60%		70%		80%		90%		100%	
	30%		Diff		Diff		Diff		Diff		Diff		Diff		Diff
Costs (total)	49,918	49,639	−278	49,017	−901	48,929	−988	48,853	−1064	48,537	−1381	48,779	−1138	48,075	−1843
Outpatient service	15,065	16,210	1145	17,307	2241	18,274	3209	19,372	4307	20,596	5531	21,703	6638	22,872	7807
Hospitalisation	27,916	26,885	−1031	25,352	−2564	24,319	−3597	23,402	−4514	22,135	−5781	21,533	−6383	19,949	−7967
Minor amputation	4521	4267	−255	4131	−390	4093	−428	3890	−632	3694	−827	3481	−1040	3313	−1208
Major amputation	2415	2277	−137	2227	−188	2243	−172	2189	−226	2112	−303	2063	−352	1940	−475
QALY	2.012	2.023	0.011	2.029	0.017	2.031	0.019	2.042	0.030	2.050	0.038	2.058	0.045	2.068	0.056
NMB			579		1388		1527		1910		2437		2412		3420
ICER	Comparator	Dominant		Dominant		Dominant		Dominant		Dominant		Dominant		Dominant	

Note: Cost-effective: ICER lower than the willingness-to-pay of AUD $28,000 per QALY; Diff: difference between the scenario and current practice (30% optimal care); Dominant: cost-saving and more effective; ICER: Incremental cost (Cost of scenario − Cost of current practice)/Incremental effectiveness (QALY of scenario − QALY of current practice); NMB, net monetary benefit, calculated with the equation: NMB = QALY × willingness-to-pay costs; willingness-to-pay used was AUD$ 28,000.

Abbreviation: QALY, quality-adjusted life years.

$15,065 for outpatient DFU care cost, $27,916 for hospitalisation, and $4521 and $2415 for minor and major amputation, respectively. The ideal scenario (where 100% of patients received guideline-based care) resulted in a $1843 cost-saving and additional 0.056 QALY per person, dominating current practice with a NMB of $3420. When applied to a cohort of 1000 patients, this translated to a total cost saving of $1.8 million, with 56 additional QALYs generated.

The remaining scenarios with 40%–90% of patients receiving guideline-based care were also all considered dominant relative to current practice, resulting in an average cost saving between $278 and $1381 per person, respectively, and between 0.011 and 0.045 additional QALYs per person, respectively. When applied to a cohort of 1000 patients, this translated to a total cost saving of $0.28–1.38 million, with 11–45 additional QALYs generated.

3.2 | Probabilistic sensitivity analysis

Probabilistic sensitivity analysis results are presented in Figure 2 and Table S6. The ideal scenario (100% guideline-based care) was 73.4% likely to be dominant relative to current practice, and 89.8% likely to be cost-effective, compared with current practice. The remaining scenarios were considered dominant among 59.8%–71.3% of simulations and cost-effective among 69.7%–88.7% of simulations, in comparison to current practice.

4 | DISCUSSION

This study has described outcomes from the first discrete event simulation model to our knowledge to assess the cost-effectiveness of guideline-based care for patients with DFU, informed by real-world data for model parameterisation. Importantly, the comparator represented the current practice of 30% of DFU patients receiving optimal care in the real-world cohort, and scenario analysis examined the likely benefits of different proportions of patients receiving guideline-based care. Total healthcare cost was lowest in the best-case scenario which represented all people visiting Diabetic Foot Services receiving guideline-based care, and this was also likely to result in more QALYs compared with current practice. However, findings from each of the six other scenarios representing increasing proportions of people receiving guideline-based care also indicated dominance over current practice. Even the most conservative of these scenarios (40% of cases receiving guideline-based care) was likely to result in less healthcare spending as well as more QALYs for patients. The sensitivity analyses indicated that findings were robust to parameter uncertainty, and consequently, provide confidence that any level of increase in optimal care is likely to be cost-effective relative to current practice.

Although outpatient DFU care costs were higher with the increasing proportion of guideline-based care, these costs were offset by the reduced costs associated with DFU-related hospitalisation as well as minor and major amputation procedures. The parameters underpinning these lower rates of hospitalisations and amputations arose from our time-to-event analysis of a large, multi-site, real-world dataset that has previously highlighted that guideline-based care factors for DFU was associated with shorter time-to-healing, and lower hospitalisation and amputation rates.[14] Patients having received guideline-based prevention when their DFU healed, which included regular follow-up monitoring in the clinic and having appropriate footwear, were also associated with lower recurrence rates. These findings on the health gain of guideline-based care are consistent with findings from a recent meta-analysis that assessed the effectiveness of multidisciplinary teams adhering to guideline recommendations and reported a 39%–56% reduction in amputation rates.[29]

Prior studies have primarily only investigated the cost-effectiveness of 100% guideline-based care relative to a comparator, typically 0% guideline-based care. Ortegon et al.[30] evaluated the guideline-based care for patients newly diagnosed with diabetes in the Netherlands, comprising metabolic and foot care interventions. Using a state-based Markov model under a lifetime horizon, they reported the cost per QALY gain to be <25,000 US dollars, and concluded that the strategy would be cost-effective when as low as 10% prevention of foot disease was achieved.[30] Cheng et al. evaluated guideline-based care of patients with DFUs in Australia and reported such care would save AUD 9100 to 12,395 and provide an additional 0.13–0.16 QALYs per person over 5 years compared with usual care.[17] However, these prior studies have been reported to have limitations when it comes to aiding decision-making due to a lack of sensitivity analyses or model validation.[31] Furthermore, they used aggregated data rather than individual patient-level data for informing model parameterisation.[31] Although the comparator in prior studies was described as current or usual care, it was difficult to determine to what extent the comparator represented real-world clinical practice when the data inputs were extracted from clinical trials or observational studies.[17,30,32]

One highlight of the present study was that we examined a range of guideline-based care provision scenarios to explore if there was a threshold increase in guideline-based care required to achieve cost-effectiveness or dominance. We found any of the modelled increases in guideline-based care, which could also be conceptualised as a reduction in unwarranted variation, resulted in reduced costs

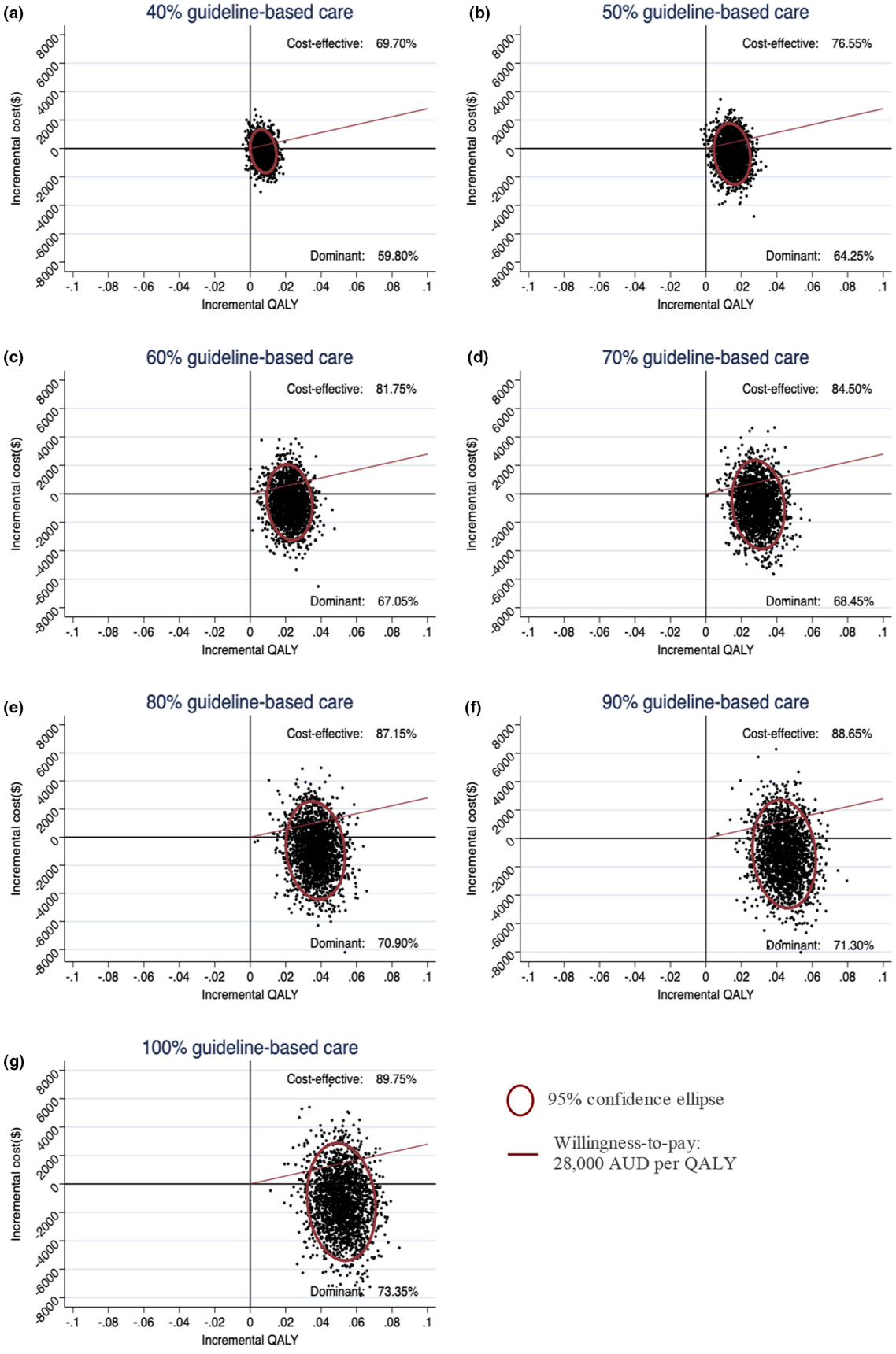

FIGURE 2 Cost-effectiveness plane of scenarios 1–7 compared with current practice, using a 3-year time horizon (probability sensitivity analysis). (a) 40% guideline-based care; (b) 50% guideline based care; (c) 60% guideline-based care; (d) 70% guideline based care; (e) 80% guideline-based care; (f) 90% guideline based care; (g) 100% guideline-based care.

and improved quality of life outcomes for patients. Small incremental changes in the provision of guideline-based care to current practice thus appear worthwhile from both a healthcare resource use and patient health outcome point-of-view, plus represents potentially more achievable reductions in unwarranted variation relative to the (likely theoretical) maximum benefit that could be yielded from the ideal scenario of 100% provision of guideline-based care. This represents an important and encouraging message for diabetes clinicians, services and policymakers to consider implementing strategies to improve the provision of diabetes-related foot disease (DFD) guideline-based care to not only benefit the health of their patients, but also yield a net economic benefit to the healthcare system through lower rates of downstream hospitalisations, amputations and death. Thus, evaluation of strategies to increase the proportion of patients receiving DFD guideline-based care in current practice is recommended as a priority for further research.

A limitation of any modelling study is that it represents a simplification of reality and is dependent on a series of assumptions. Our model parameters were largely informed by robust individual-level data; however, we did make some simplifying assumptions. Our model assumed that 30% of individuals consistently received a suite of guideline-based care, with the remaining 70% consistently receiving suboptimal care; however, this 30% proportion for current practice was based on what we found from our real-life cohort We also assumed this proportion of patients adhered to these guideline-based recommendations, which also may not always be consistent in the range of real-world settings where diabetes care is provided.

Some further limitations relating to data availability should also be acknowledged. First, utility values were informed by published international literature for QALY-related parameters, as these data were not collected among the patient cohort. Second, there were insufficient mortality data among patients in our cohort classified in the healed DFU state and post-amputation states. We, therefore, used published Australian life tables and literature to inform mortality-related parameters for patients with healed DFUs, and after minor and major amputations. Third, although more comprehensive disease modelling exists for DFD,[33] for the purpose of evaluating the cost-effectiveness of this study, we made a conservative assumption to not to include recurrence post minor or major amputation in the model. Although including recurrence may have been useful, to our knowledge there is no evidence that quality of life values are significantly different between those with and without recurrence post minor or major amputation. Fourth, short-term costs of triggering organisational changes to achieve the increased provision of guideline-based care, including potential costs associated with additional clinician training, staff behaviour change or service redesign were not within the scope of the current model. Similarly, patient behaviour and lifestyle changes, as well as costs associated with loss of productivity because of hospitalisation and amputation, were not within the scope of this modelling which was intended to inform policy from the perspective of ongoing healthcare service delivery.

Our study, however, adds new evidence for the cost-effectiveness of guideline-based care for patients with DFU, with several important strengths. First, we utilised a large prospective real-world cohort of clinic patients with DFU to derive time-to-event parameters for guideline-based care and suboptimal care thus avoiding the potential pitfalls of sampling bias associated with trial-informed time-to-event parameterisation. These parameters should also be of value for future cost-effectiveness analysis in this field. Second, we were able to use a discrete event simulation model with our patient-level data, bringing the advantage of flexibility in simulating discrete events, with further possibility to add attributes to each person simulated to address the study aims. Third, hospitalisation because of DFU, which has been associated with reduced quality of life and significant healthcare costs,[1,34] was included as an event in our DFU model for the first time in this field of research.

In conclusion, findings from this study indicate that any increase in the provision of patients with DFU receiving guideline-based care is likely to save money and improve patients' quality of life. This has important implications for potential policy and practice changes at patient, clinician, facility and healthcare system levels that may facilitate greater implementation of guideline-based DFU care into daily practice. This may include strategies to increase funding to implement increased guideline-based DFU care, prevention programmes and conducting relevant patient and health professional education to improve outcomes for patients, healthcare services and society.

AUTHOR CONTRIBUTIONS

Yuqi Zhang contributed to the conception and design of the study, data acquisition, analysis and interpretation, model building and validation, drafted and critically reviewed the paper for intellectual content. Hannah E. Carter contributed to the conception and design of the study, data analysis and interpretation, model building and validation, drafted and critically reviewed the paper. Peter A. Lazzarini contributed to the conception and design of the study, data acquisition, analysis and interpretation, drafted and critically reviewed the paper. Susanna Cramb contributed to the conception and design of the study, data analysis and interpretation, and drafted and critically reviewed the paper. Rosana Pacella contributed

to the conception and design of the study, and data acquisition, and critically reviewed the paper. Jaap J. van Netten contributed to the conception and design of the study, data analysis and critically reviewed the paper. Qinglu Cheng contributed to data analysis and interpretation and critically reviewed the paper. Patrick H. Derhy contributed to data acquisition, and critically reviewed the paper. Ewan M. Kinnear contributed to data acquisition, and critically reviewed the paper. Steven M. McPhail contributed to the conception and design of the study, data analysis and interpretation, model building and validation, drafted and critically reviewed the paper for intellectual content. All authors reviewed and approved the final version of the article. The corresponding author had full access to all the data and final responsibility for publication submission.

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CONFLICTS OF INTEREST

We declare no competing interests.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the Queensland Statewide Diabetes Clinical Network for all researchers who completed the standard ethics to access confidential health data held by the Queensland Government (Australia). Data used in this study were made available to the authors after the completion of all standard Queensland ethical and legal written approvals.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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