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Clinical and economic outcomes of a multidisciplinary team approach in a lower extremity amputation prevention programme for diabetic foot ulcer care in an Asian population: A case-control study

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Abstract

Present guidelines recommend a multidisciplinary team (MDT) approach to diabetic foot ulcer (DFU) care, but relevant data from Asia are lacking. We aim to evaluate the clinical and economic outcomes of an MDT approach in a lower extremity amputation prevention programme (LEAPP) for DFU care in an Asian population. We performed a case-control study of 84 patients with DFU between January 2017 and October 2017 (retrospective control) vs 117 patients with DFU between December 2017 and July 2018 (prospective LEAPP cohort). Comparing the clinical outcomes between the retrospective cohort and the LEAPP cohort, there was a significant decrease in mean time from referral to index clinic visit (38.6 vs 9.5 days, $P < .001$), increase in outpatient podiatry follow-up (33% vs 76%, $P < .001$), decrease in 1-year minor amputation rate (14% vs 3%, $P = .007$), and decrease in 1-year major amputation rate (9% vs 3%, $P = .05$). Simulation of cost avoidance demonstrated an annualised cost avoidance of USD $1.86m (SGD $2.5m) for patients within the LEAPP cohort. In conclusion, similar to the data from Western societies, an MDT approach in an Asian population, via a LEAPP for patients with DFU,

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demonstrated a significant reduction in minor and major amputation rates, with annualised cost avoidance of USD $1.86m.

KEYWORDS
diabetic foot ulcers, diabetic limb salvage, health economics, lower extremity amputation, multidisciplinary team

Key Messages

- Within an Asian context, adoption of a multidisciplinary team (MDT) approach to diabetic foot ulcer (DFU) care resulted in significantly improved clinical outcomes.
- When comparing between the retrospective cohort and the LEAPP cohort, there was a significant decrease in mean time from referral to index clinic visit (38.6 vs 9.5 days, $P < .001$), increase in outpatient podiatry follow-up (33% vs 76%, $P < .001$), decrease in 1-year minor amputation rate (14% vs 3%, $P = .007$), and decrease in 1-year major amputation rate (9% vs 3%, $P = .05$).
- Simulation of cost avoidance demonstrated an annualised cost avoidance of USD $1.86m for patients within the LEAPP cohort.

1 | INTRODUCTION

Diabetes mellitus (DM) is a major public health concern, with around 1 in 11 adults worldwide suffering from the disease, and Asia is at the epicentre of this global pandemic.[1] In patients with DM, their lifetime risk of developing a diabetic foot ulcer (DFU) is 15% to 25%,[2] with incidence of lower extremity amputation (LEA) ranging from 78 to 704 per 100 000 person-years.[3] The burden of DFU has a significant impact on mortality, with 5-year survival after an amputation at 70%.[4] In addition to LEA, patients with DFU are associated with mobility loss, poorer quality of life (QoL), and decreased overall productivity.[5]

Diabetes foot ulceration has not only a heavy clinical burden but also a substantial economic burden of disease.[6] In 2014, the estimated healthcare cost for DFU in the United States Medicare system was USD $6.2 to 18.7bn. In Singapore, the estimated gross healthcare cost per patient for hospital care (inpatient and specialist outpatient) and primary care in 2017 was USD $16 920,[7] with the mean cost per patient-year at USD $3368, $10 468, and $30 131 for DFU-only, minor amputation, and major amputation, respectively.[8]

Within the literature, management of diabetic foot wounds and prevention of LEA has the strongest evidence to advocate for a multidisciplinary team (MDT) approach. Around the world, MDT management of DFU is associated with the best outcomes in terms of limb preservation, with most data derived from Western societies.[9-11] This is also the current recommendation for the standard of care with both National Institute for Health and Care Excellence (NICE)[4] and International Working Group on Diabetic Foot (IWGDF) guidelines.[12] Although the interventions required for limb salvage are expensive, the ultimate outcome of major amputation prevention translates into long-term cost benefits as well as improvements in QoL.[13-15]

As such, we have instituted a multidisciplinary-style rapid access tertiary clinic for patients with DFU since December 2017, termed as lower extremity prevention programme (LEAPP) clinic. Within this study, we aim to evaluate the clinical and economic outcomes for patients with DFU who were seen at LEAPP clinic and compared with a retrospective cohort.

2 | METHODOLOGY

A case-control (prospective cohort comparison against a retrospective cohort) study was performed at a university tertiary hospital in Singapore with over 1700 acute inpatient beds and 9000 healthcare staff, 2700 outpatient visits, and 450 emergency department attendances daily.[16] We included all patients above the age of 21 years, with pre-existing DM and referred for foot ulcers (distal to malleolus). Patients with venous ulcers or ulcers of mixed arteriovenous aetiology were excluded from the study. The study followed the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines.[17]

Retrospective analysis was performed for patients referred to the conventional vascular surgery specialist

outpatient clinic between 1 January 2017 and 31 October 2017, while prospective analysis was performed for patients referred to the multidisciplinary LEAPP clinic between 1 December 2017 and 30 June 2018. All patients had completed a 1-year follow-up at the time of analysis. Figure 1 illustrates the difference in the clinical and referral work flow between the retrospective cohort and the LEAPP clinic.

Within the retrospective cohort, there were a total of 11 conventional vascular surgery specialist outpatient clinic room-sessions per week. Within the prospective LEAPP cohort, these same 11 clinic room-sessions per week are concurrently running with LEAPP clinics and patients with DFU were specifically allocated to be reviewed at LEAPP clinics, which constitutes 2 clinic room-sessions per week. This represents a 9.1% increase in the clinic resource allocation between the retrospective and prospective cohort. Although patients in the retrospective cohort were seen primarily by the vascular surgeons at the conventional vascular surgery specialist outpatient clinics, with patients requiring separate appointments to be reviewed by endocrinology and/or podiatry, the LEAPP clinic adopts an MDT approach in managing patients with DFU, with podiatry, vascular surgery, and endocrinology as core team members. Support members included diabetic nurse clinicians, wound nurses, orthopaedic surgeons, infectious disease physicians, prosthetics and orthotic technicians, and plastic and reconstructive surgeons. Referral sources to the clinic include patients with DFU from primary care, emergency department, and tertiary specialist outpatient clinics and from the wards post discharge. The referrals are screened by a vascular surgeon thrice a week and patients who fulfil the inclusion criteria are booked into a LEAPP clinic appointment at the next available date, usually within the next 5 working days. LEAPP clinic is held every Tuesday and Thursday mornings, with an average of 12 to 15 patients reviewed at each session. Each clinic session has a vascular surgeon and endocrinologist reviewing the patients, in conjunction with two podiatrists, a diabetic nurse clinician, and/or a wound nurse. In addition to providing expedited access, the key interventions at LEAPP clinic include optimisation of glycaemic control and medical risk factors, prompt revascularisation, active wound care, appropriate offloading, and patient education. As per IWGDF guidelines, patients with neuropathic ulcers received medical optimisation, wound care, and appropriate off-loading while patients with ischaemic ulcers received medical optimisation, revascularisation, wound care, and appropriate off-loading.[15]

Factors and outcomes were evaluated using descriptive statistics. Percentages were used for categorical data, and means with SDs were used for continuous data. Comparisons between groups for categorical data were made using chi-squared tests, whereas comparisons between groups for continuous data were made using Student's *t*-test. All *P* values of <.05 were considered

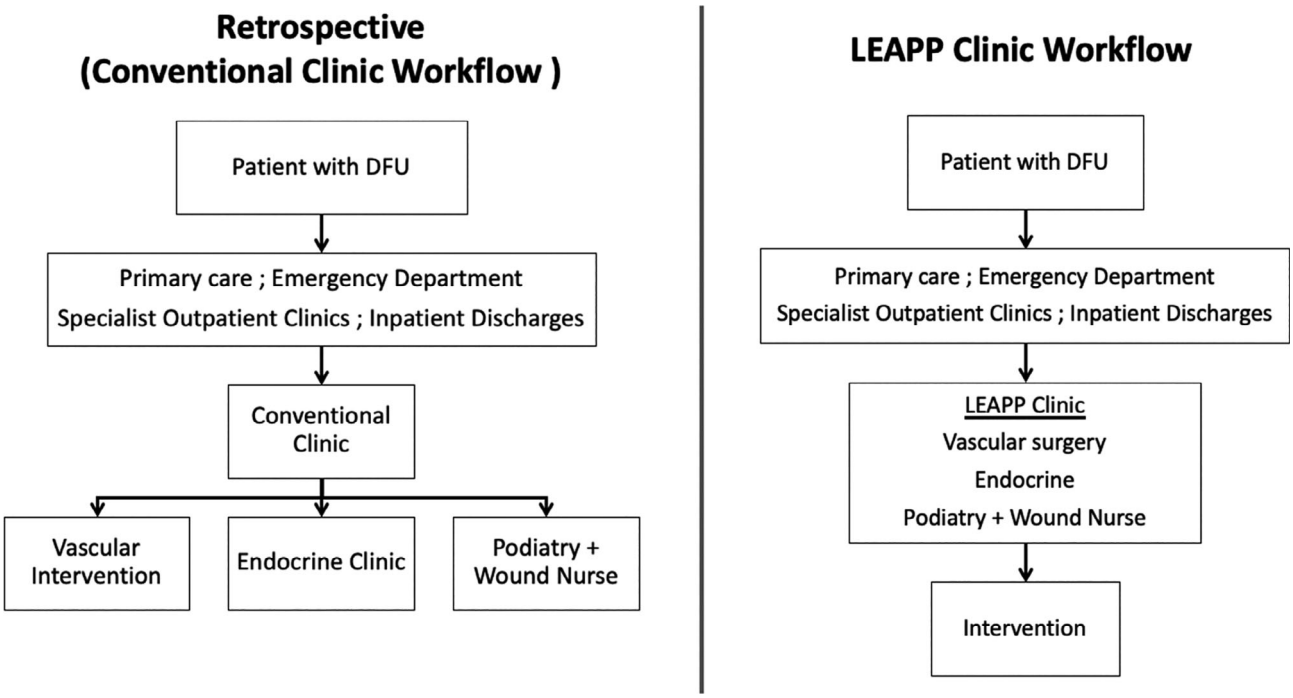

FIGURE 1 Difference in workflow between the retrospective cohort and the LEAPP clinic. LEAPP, lower extremity amputation prevention programme

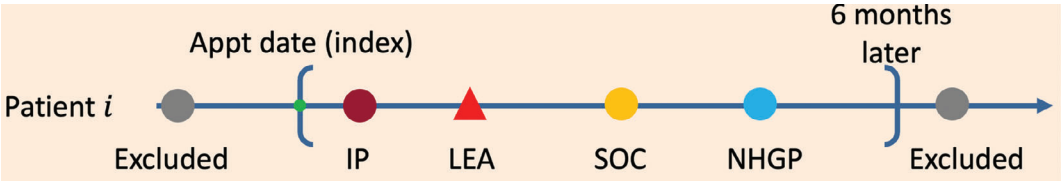

FIGURE 2 Gross healthcare costs from the index clinic appointment, with a 6-month time frame of any inpatient admission (IP), lower extremity amputations (LEA), DFU-related specialist outpatient clinic visits (SOC), and DFU-related primary care visits at polyclinics National Healthcare Group Polyclinics (NHGP). DFU, diabetic foot ulcer

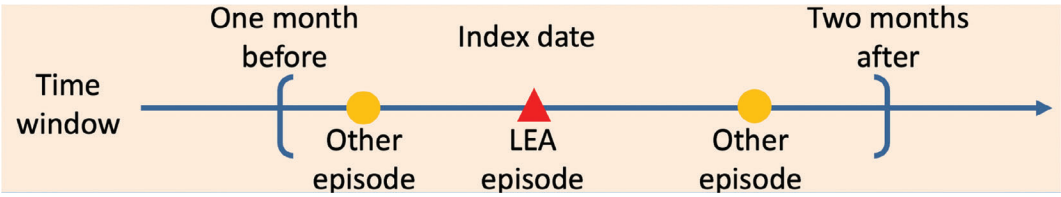

FIGURE 3 Simulation of cost avoidance is performed by summation of gross charges of any episode 1 month prior to an index LEA episode and any episode 2 months after to an index LEA episode. LEA, lower extremity amputation

statistically significant, and all *P* values were two tailed. SPSS 13.0 (Chicago, IL) was used for statistical analysis.

Health economic analysis was performed by the evaluation of cost avoidance for both retrospective and prospective cohorts. In a 6-month time frame from the index clinic appointment date, gross healthcare costs of any inpatient admission (IP), LEA, DFU-related specialist outpatient clinic visits (SOC), and DFU-related primary care visits at polyclinics (National Health Group Polyclinics, which are government-subsidised primary care) were calculated (Figure 2). Major LEA rate of LEAPP patients was adjusted to match the patient profiling of retrospective cohort by weighted logistic regression. Covariates considered in risk adjustment include age, gender, ethnicity, chronic disease prevalence (of chronic kidney disease stage 3, coronary heart disease, heart failure, and previous stroke) and previous major LEA. Based on the risk-adjusted major LEA rates between the two groups, simulation of cost avoidance is performed by summation of gross charges of any episode 1 month prior to an index LEA episode and any episode 2 months after to an index LEA episode (Figure 3). This study had been approved by the institution ethics review board (National Healthcare Group Domain Specific Review Board 2020/00500), with data from standing database TTSH/2019-00076.

TABLE 1 Baseline characteristics between retrospective and LEAPP cohort

	Retrospective cohort (n = 84)	LEAPP cohort (n = 117)	*P* value
Mean age in years (SD)	63.4 (12.6)	63.9 (12.8)	N/S
Male gender (%)	47 (56)	77 (66)	N/S
Ethnicity (%)			N/S
Chinese	62 (74)	74 (63)	
Malay	6 (7)	11 (9)	
Indian	11 (13)	25 (21)	
Others	5 (6)	7 (6)	
Mean HbA1c% (SD)	8.0 (4.3)	8.0 (4.2)	N/S
Chronic diseases (%)			
Hypertension	75 (89)	106 (91)	N/S
Hyperlipidaemia	77 (92)	112 (96)	N/S
Chronic kidney disease stage 3	54 (64)	71 (61)	N/S
Coronary heart disease	39 (46)	50 (43)	N/S
Heart failure	24 (29)	23 (20)	N/S
Previous stroke	29 (35)	32 (27)	N/S

Abbreviations: LEAPP, lower extremity amputation prevention programme; N/S, nonsignificant.

3 | RESULTS

Between January 2017 and October 2017, 84 patients fulfilled the inclusion criteria within the retrospective cohort, while between December 2017 and July 2018, 117 patients fulfilled the inclusion criteria within the LEAPP cohort. Both groups had similar baseline characteristics, with mean glycated haemoglobin (HbA1c) of 8%

TABLE 2 Clinical outcomes between retrospective and LEAPP cohort

	Retrospective cohort (n = 84)	LEAPP cohort (n = 117)	*P* value
Mean time (days) from referral to index visit (SD)	38.6 (7.4)	9.5 (3.2)	<.001
Mean time (days) from index visit to vascular diagnostic imaging (SD)	24.2 (4.8)	9.9 (2.9)	<.001
Mean time (days) from index visit to revascularisation (SD)	39.0 (5.2)	32.6 (5.6)	.015
Further medical optimisation (%)			
Single antiplatelet therapy	N/A	16 (14)	N/A
Statin therapy	N/A	12 (10)	N/A
Diabetes optimisation	N/A	15 (13)	N/A
Further podiatrist follow-up (%)	28 (33)	89 (76)	<.001
Amputation rates (%)			
1-y minor amputations	12 (14)	4 (3)	.007
1-y major amputations	8 (9)	3 (3)	.05

Abbreviations: LEAPP, lower extremity amputation prevention programme; N/A, not available.

TABLE 3 Healthcare-related episodes and costs within 6 months from index clinic visit

	Retrospective cohort (n = 84)	LEAPP cohort (n = 117)	Change[a]
Hospital specialist outpatient clinics	8.9	14.0	+5.1
Gross charge per patient (SGD)	1675	1859	+184
Primary care outpatient clinics	7.9	10.9	+3.0
Gross charge per patient (SGD)	547	705	+158
Inpatient admissions	0.9	0.9	0
Gross charge per patient (SGD)	10 632	9228	−1404
Emergency department episodes	0.9	0.9	0
Gross charge per patient (SGD)	330	312	−18
Ambulatory surgery procedures	0.1	0.3	+0.2
Gross charge per patient (SGD)	69	540	+471
Total gross charge per patient within 6 months (SGD)	13 253	12 645	−608

Abbreviations: LEAPP, lower extremity amputation prevention programme; SGD, Singapore dollars.
[a]All results are statistically nonsignificant.

across both groups and majority of patients had comorbidities of hypertension, hyperlipidaemia, and chronic kidney disease stage 3 (Table 1).

Comparing the clinical outcomes between the retrospective cohort and the LEAPP cohort, there was a significant decrease in mean time from referral to index clinic visit (38.6 vs 9.5 days, $P < .001$) and also mean time from index visit to vascular diagnostic imaging and revascularisation (24.2 vs 9.9 days $P < .001$ and 39.0 vs 32.6 days $P = .015$, respectively) (Table 2). Post index clinic visit, there was a significant increase in outpatient podiatry follow-up (33% vs 76%, $P < .001$) within the LEAPP cohort while between 10% and 14% of patients within the LEAPP cohort had further medical optimisation, such as commencement of single antiplatelet therapy, commencement of statin therapy, and diabetes medication optimisation. Significantly, there was a marked decrease in 1-year minor amputation rates within the LEAPP cohort (14% vs 3%, $P = .007$) and also a decrease in major amputation rates within the LEAPP cohort (9% vs 3%, $P = .05$).

When evaluating the number of healthcare-related episodes and costs within 6 months from the index clinic visit and related healthcare costs (Figure 2), there was no

TABLE 4 Simulated annualised cost avoidance for major LEA

	2018 attributable gross charge (SGD)	Simulated cost avoidance for 33% major LEA reduction (SGD)
Major LEA episodes	6.0m	2.0m
Other DFU-related episodes	1.4m	0.5m
Total	7.4m	2.5m

Abbreviations: DFU, diabetic foot ulcers; LEA, lower extremity amputation; SGD, Singapore dollars.

statistical significance between the retrospective cohort and LEAPP cohort (Table 3). However, within the LEAPP group, there is a trend towards increased number of specialist and primary care outpatient clinic visits (+5.1 and +3.0 difference per patient, respectively) with increased healthcare costs (+SGD $184 and +SGD $158 difference per patient, respectively). This is balanced against reduced inpatient gross charge per patient within the LEAPP cohort (−$1404 difference), which resulted in a decreased total gross charge per patient within 6 months (USD $9875 or SGD $13 253 for retrospective cohort vis-à-vis USD $9425 or SGD $12 645 for LEAPP cohort).

Using weighted logistic regression for covariates of age, gender, ethnicity, chronic disease prevalence, and previous major LEA, the risk-adjusted major LEA rates for the retrospective and LEAPP cohorts are 13.1% and 8.8%, respectively. This meant that LEAPP is likely to reduce major LEA rate by 33%, when compared with the retrospective control group. Hence, using a 33% reduction in major LEA, simulation of cost avoidance by summation of gross charges of any episode 1 month prior to an index LEA episode and any episode 2 months after to an index LEA episode (Figure 3) resulted in an annualised cost avoidance of USD $1.86m (SGD $2.5m) for patients within the LEAPP cohort (Table 4).

4 | DISCUSSION

This is the first study from an Asian population, which comprehensively evaluated the clinical and economic outcomes of an MDT approach in LEA prevention for DFU management. Around the world, MDT management of DFU is associated with the best outcomes in terms of limb preservation, with most data derived from Western societies.[9-11] Both National Institute for Health and Care Excellence (NICE)[4] and IWGDF guidelines recommend an MDT approach for DFU management as the standard of care.[12] In Singapore, data from 2002 to 2007 concluded that an MDT approach with the implementation of a clinical pathway was effective in reducing average inpatient length of stay, major amputation rates, and diabetic foot complications.[18] In an earlier study, 10 years ago at our institution, a similar LEAP inpatient programme resulted in a lower LEA rate of 29%, as compared to the pre-LEAP cohort ($P < .001$), with a lower related death rate (1% vs 19%, $P < .001$), fewer in-hospital days per patient (17.8 days vs 23.16 days, $P = .048$), and a generated cost savings of USD $1912 (SGD $2566) per patient during admission.[19] However, due to manpower and administrative limitations, the resource-intensive MDT approach was halted for the past 10 years and only reinstated in its current format since December 2017, to push towards the goal of providing a rapid and efficient way to deal with the complex and relentless nature of DFU, henceforth minimising DFU-related major amputations.

Recent 10-year retrospective study looking at 156 593 local patients with type 2 DM revealed rapid progression of 2.3 months from diabetes-related lower extremity complications to first amputation.[20] This underscores the importance to have a diabetic foot care pathway and a coordinated foot care service for diabetic patients.[21] Within our study, upon institution of the MDT LEAPP clinic, there was a significant decrease in mean time from referral to index clinic visit (38.6 vs 9.5 days, $P < .001$) and also a significant decrease in mean time from index visit to vascular diagnostic imaging and revascularisation (24.2 vs 9.9 days, $P < .001$ and 39.0 vs 32.6 days, $P = .015$, respectively). It is known that patients with DFU who also have chronic limb ischaemia will benefit from earlier imaging and vascular intervention, as evidenced by higher limb salvage rates.[22] The coordinated and MDT approach allowed for DFU-related healthcare providers, such as vascular surgeons, endocrinologists, podiatrists, and wound nurses, to provide a continuum of care from the outpatient clinic to admission and subsequently after inpatient discharge back to outpatient postoperative care, in a process that not only allows seamless care of complex diabetic foot wounds but also provides holistic care in terms of diabetic control, footwear optimisation, and patient education.[23] DFU is associated with a 43% to 55% five-year mortality,[24-27] and nearly doubles the risk over and above diabetes (risk ratio 1.89), mostly attributable to cardiovascular complications.[28] This underscores the importance of controlling associated cardiovascular risk factors such as hypercholesterolemia, hypertension, and ischaemic heart disease to improve clinical outcomes for patients with DFU.[29]

In a systematic review on the efficacy of MDT in reducing major amputations for patients with DFU, four

essential team-related elements identified included teams being composed of medical and surgical disciplines, larger teams benefiting from having a "captain" with a nuclear and ancillary team structure, clear referral pathways, and care algorithms supported by timely and comprehensive care.[30] Within LEAPP, we have the vascular surgeons "captaining" the team, with active input from endocrinologists, podiatrists, and wound nurses, thus forming the nuclear team structure. Ancillary team members include orthopaedic surgeons, infectious disease physicians, prosthetics and orthotic technicians, and plastic and reconstructive surgeons. All patients with pre-existing DM and referred for foot ulcers (distal to malleolus) are seen in LEAPP clinics, with the referrals screened by a vascular surgeon thrice a week. Similar to the four key tasks identified by the systematic review, we focus on metabolic profile optimisation, local wound management, revascularisation, and infection control in our MDT approach. Hence, similar to 94% (31/33) of studies within the systematic review, which reported a reduction in LEA after institution of an MDT approach,[30] we saw a significant decrease in 1-year minor amputation rates within the LEAPP cohort (14% vs 3%, $P = .007$) and also a decrease in major amputation rates within the LEAPP cohort (9% vs 3%, $P = .05$).

Involvement of podiatry within the MDT DFU management is crucial. Within our study cohort, we saw a significant increase in outpatient podiatry follow-up (33% vs 76%, $P < .001$) for patients seen by LEAPP. Having podiatry colocated providing prompt wound care and offloading in LEAPP improves the compliance of patients' attendance to podiatry follow-up unlike in the retrospective cohort who had to separately attend another physical podiatry clinic. This one-stop clinic provided convenience for patients with DFU, indirectly also saving the time and transport of patients and their caregivers. A systematic review and meta-analysis on the effect of podiatry in a team approach for DFU and LEA showed that including podiatrists within the MDT have a significant and positive effect on patient outcomes, in terms of total LEAs and major LEAs.[31] Management of DFU involves not only complex wound-related and vascular-related interventions but also appropriate custom-made footwear and offloading insoles. These interventions were shown to be effective in not only treating DFUs but also preventing foot ulcer recurrence in people with diabetics.[32] This is especially important, given that up to 40% of patients with healed DFU are at risk or recurrence within the year.[33]

It is estimated that up to one-third of the direct costs of care for diabetes may be attributed to the lower extremity, with the estimated amount at USD $79bn globally in 2017, which is comparable to USD $80bn for cancer in 2015.[34] In England, the cost of diabetic foot care in 2010 to 2011 is estimated at GBP £580m, around 0.6% of England's National Health Service expenditure.[35] An integrated and structured approach in the management of DFU can reduce DFU-related complications, infections, and amputation rates, which will translate to reduced economic and patient costs.[36] However, although proven with improved clinical outcomes, the labour and resource-intensive MDT care model for DFU is costly and reimbursement may be inadequate.[37] Increasing evidence suggests that the costs for implementing DFU teams may be offset in the long run by improved access to care and reductions in foot complications and in amputation rates. In New Zealand, implementation of an MDT foot care team reduced major amputation rates (3.8% vs 27.5%, $P < .001$), mortality rates (7.5% vs 19.2%, $P < .05$), and reduced costs associated with DFU wound episodes by 25%.[38] This cost reduction is similar to findings from our study population, whereby reduction in major LEA resulted in an annualised cost avoidance of USD $1.86m (SGD $2.5m) for patients within the LEAPP cohort. This cost avoidance should be the driving factor in ensuring long-term financial sustainability of MDT care in the form of the LEAPP clinic for our patients with DFU.

Similar to the published literature, of which 33 other studies did not include any with randomised control trials,[30] the main limitation of our study is in its case-cohort study design and relatively short 1-year outcome measurements. In addition, we focused primarily on the service and clinical outcomes, without stratification against DFU severity or classification. MDT care had been shown to decrease mortality rates and hospital length of stay while improving DFU healing and QoL.[39] These are aspects that we will strive to evaluate in our follow-up study, with emphasis on DFU subtypes (neuropathic, ischaemic, or mixed ulcers), disease stratification (wound, ischemia, and foot infection (WIfI) and global limb anatomic staging system (GLASS) classification), and QoL indicators. In addition, as we seek to build a sustainable and scalable diabetic limb preservation programme,[40] we will perform more robust health economic evaluation with cost-effectiveness and cost-utility analysis in our future studies.

5 | CONCLUSION

Similar to data from Western societies, an MDT approach in an Asian population, via LEAPP for patients with DFU, demonstrated a significant reduction in minor and major amputation rates, with annualised cost avoidance of USD $1.86m (SGD $2.5m). It is associated with decreased waiting times

for specialists review, vascular investigations, vascular interventions, and improved podiatry and medical care. More robust health economic evaluation with cost-effectiveness and cost utility analysis is required to justify and build a sustainable and scalable diabetic limb preservation programme.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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