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Chronic wounds in a multiethnic Asian population: a cost of illness study

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ABSTRACT

Objective To estimate the 'cost of illness' arising from chronic wounds in Singapore.

Design Incidence-based cost of illness study using evidence from a range of sources.

Setting Singapore health services.

Participants We consider 3.49 million Singapore citizens and permanent residents. There are 16 752 new individuals with a chronic wound in 2017, with 598 venous ulcers, 2206 arterial insufficiency ulcers, 6680 diabetic ulcers and 7268 pressure injuries.

Primary outcome measures expressed in monetary terms are the value of all hospital bed days lost for the population; monetary value of quality-adjusted life years (QALYs) lost in the population; costs of all outpatient visits; and costs of all poly clinic, use of Community Health Assist Scheme (CHAS) and emergency departments (EDs) visits. Intermediate outcomes that inform the primary outcomes are also estimated.

Results Total annual cost of illness was $350 million (range $72–$1779 million). With 168 503 acute bed days taken up annually (range 141 966–196 032) that incurred costs of $139 million (range 117–161 million). Total costs to health services were $184 million (range $120–$1179 million). Total annual costs of lost health outcomes were 2077 QALYs (range −2657 to 29 029) valued at $166 million (range −212 to 2399 million).

Conclusions The costs of chronic wounds are large to Singapore. Costs can be reduced by making positive investments for comprehensive wound prevention and treatment programmes.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Reliable and relevant data sources were used to update the results.
⇒ First study to quantify the national cost of chronic wounds in a multiethnic Asian population.
⇒ Some important costs were excluded as no information was available.
⇒ The sample size for the preference-based utility weights for quality-adjusted life years were small.
⇒ Some outcomes were not adjusted for comorbidities and so might overstate the true costs.

INTRODUCTION

Chronic wounds are those that fail to heal in a time sufficient for 'normal' healing. They tend to present as a comorbid rather than primary condition among older individuals. Other risk factors are diabetes, poor nutrition, incontinence and reduced mobility.[1] They have been described as causing a 'silent epidemic' that affects a large proportion of the world's population.[2] Chronic wounds are prevalent among vulnerable individuals living at home and residents of long-term care facilities. They are commonly associated with extended hospital stays but patient safety programmes have reduced healthcare-associated events.[3]

The burden of cost is particularly large[4] with 3% of the total UK National Health Service budget[5] and 4% of healthcare expenditure in Scandinavian countries used to manage the consequences of chronic wounds.[6] The goal of reducing the prevalence of chronic wounds has failed to attract sustained investment from those who pay for health services.[7] This contrasts with other major diseases, where payers are prepared to invest in 'cancer moonshots' for example,[8] that will hopefully lead to better outcomes in the future. This inequity is puzzling as the technology for reducing chronic wounds is available now, saves more than it costs to implement,[9] and will cause large and certain gains to health outcomes.

Ulcers of the skin are the most common type of chronic wounds and include venous ulcers, arterial ulcers, diabetic foot ulcers and pressure ulcers or injuries. These are associated with a wide range of economic costs.[2] Affected individuals require frequent evidence-based treatments and if the condition becomes overwhelming, an admission to hospital is inevitable. Many patients will be admitted for other reasons, and the wound may independently prolong hospital stay.[10] Debridement, minor amputations and major amputations are common among higher risk groups.[11][12] Chronic wounds are prevalent among residents of aged care facilities and

will incur additional costs for staff time and consumables. Home nursing services as well as charities and volunteer groups that support the frail and elderly in their homes also manage patients.[13] Out-of-pocket expenditures will arise for patients and family members who travel to access services and purchase consumable items.[14] Productivity losses will arise as the patients are unable to perform their normal activities, be they paid or unpaid, and family members will have to take time from waged and unwaged productive activity. Health-related quality of life, which has monetary value,[15] will be reduced. All these costs can be structured by a 'cost of illness' method.[16]

The aim of this study is to estimate the 'cost of illness' arising from chronic wounds in Singapore. Our results could be used to stimulate decision-makers to invest in known prevention and management programmes. The findings will also aid researchers who wish to model the cost savings or the cost-effectiveness of specific interventions.

METHOD
Scope of the analyses
We include all resident Singapore citizens and permanent residents (n=3.49 million) and exclude resident foreign nationals and long-term employment pass holders (n=526000) in 2017.[17] Singapore has a multiethnic Asian population comprising of residents who are 76% Chinese, 15% Malay and 7.5% Indian descent.[18] The perspective for this analysis includes the costs incurred by health services and the losses to health benefits, expressed as quality-adjusted life years (QALYs) foregone. We do not represent the 'societal' perspective as there are no data on private out of pocket costs, but we do review this omission in the Discussion section. We estimate the expected annual costs arising from incident cases of venous ulcers, arterial insufficiency ulcers, diabetic ulcers and pressure injury.

Scope of the modelling
We use statistical models to estimate four primary outcomes (A to D) for the year 2017, see figure 1.

First, are the monetary *'value of all hospital bed days lost for the population'*. The information used is summarised in Part A of figure 1 and is labelled 'Inpatient Acute Sector Costs'. Second, are the *'monetary value of QALYs lost in the population'*. The information used is summarised in Part B of figure 1 and is labelled 'Lost Heath Outcomes'. Third, are the *'costs of all outpatient visits'*. The information used is summarised in Part C of figure 1 and is labelled 'Outpatient Clinics Costs'. Fourth, are the *'costs of all poly clinic, use of Community Health Assist Scheme (CHAS) and*
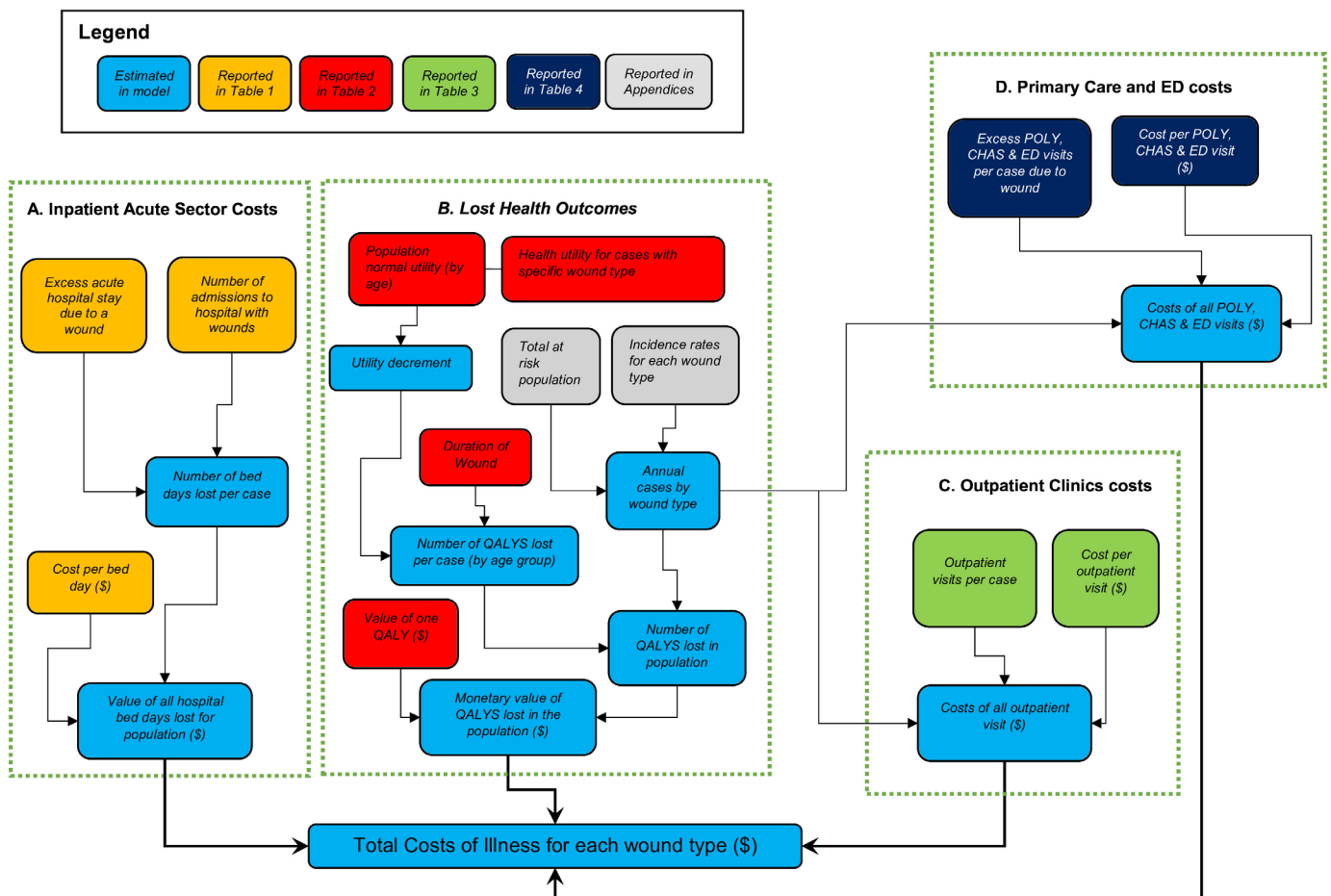

Figure 1 A diagram to show how the various parameters update the outcomes. CHAS, Community Health Assist Scheme; ED, emergency department; POLY, Polyclinics; QALYs, quality-adjusted life years.

emergency departments (ED) visits'. The information used is summarised in Part D of figure 1 and is labelled 'Primary Care and ED costs'. CHAS is a mechanism for funding all Singapore citizens to attend medical and/or dental care at participating general practitioner and dental clinics. CHAS is particularly designed to support the management of chronic diseases.

Data, parameters and assumptions
Inpatient acute sector costs
Two outcomes, shown by blue boxes in figure 1, are estimated: '*Number of bed days lost per case'* and '*Value of all hospital bed days lost for population ($)'.* To estimate the '*Number of bed days lost per case'* we combined information on the '*Number of admissions to hospital with wounds'* with information on '*Excess acute hospital stay due to a wound'.* To estimate the '*Number of admissions to hospital with wounds'* we retrieved a population cohort of all inpatient admissions to acute hospitals in Singapore between 2012 and 2019 from the Singapore Ministry of Health, and applied the cases from 2017. From the entire dataset, we identified all inpatient episodes with any occurrence of venous ulcers, arterial insufficiency ulcers, diabetic ulcers and pressure injury or any combination of these wounds as a primary or secondary diagnosis based on the ICD-9 codes in online supplemental appendix 1.

To estimate '*Excess acute hospital stay due to wound'* we extracted the length of hospital stay and relevant covariate information that could be used to explain variation in the length of stay, see online supplemental appendix 2. A parsimonious multivariable generalised linear model (GLM) with a gamma link function was used to accommodate the skew typical of lengths of stay data.[19] The outcome of interest was the length of stay associated with chronic wound management in the inpatient setting. Other covariates included were age, gender, race and comorbid chronic diseases. The statistical model generated a coefficient for 'wound type' expressed as a rate ratio, that showed the amount of increase in length of stay associated with the presence of wound, given that other factors that predicted length of stay had been accounted for. This rate ratio was used to moderate the mean length of stay for the entire sample and an excess length of stay associated with the wound was estimated. In online supplemental appendix 3, we show a summary of the results of the multivariable GLM and in online supplemental appendix 4, we show the full model results.

To estimate the '*Value of all hospital bed days lost for population ($)'* we combined the '*Number of bed days lost per case'* with the '*Cost per bed day ($)'.*

All the data inputs used for this part of the model are shown in table 1.

Lost health outcomes
Five outcomes, shown by blue boxes in figure 1, are estimated: *Annual cases by wound type; Number of QALYs lost per case (by age group); Utility decrement; Number of QALYS lost in population; and Monetary value of QALYS lost in the population ($).* The first four are intermediate outcomes that contribute information to the primary outcome of '*Monetary value of QALYs lost in the population ($)'.*

To estimate '*Annual cases by wound type',* we apply the incidence rates for each wound type to the '*Total at risk population'.* We used published incidence rates for 2017 from a population-based study of wounds among those admitted to Singapore acute care hospitals from 2000 to 2017.[20] For this work the authors identified relevant ICD-10 codes for for occurrences of venous ulcers, arterial insufficiency ulcers, diabetic ulcers and pressure ulcers or injuries, see online supplemental appendix 1, and applied them to the Singapore Ministry of Health central claims database, which includes records of all admissions to public and private acute care hospitals. The incidence rates by age band are reported alongside the at-risk population enabling the number of incident cases to be estimated, see online supplemental appendix 5 for more detail.

Table 1 Data inputs used to estimate the outcomes for the 'Inpatient Acute Sector Costs'

Parameter	Estimate	Distribution used for uncertainty	
Excess acute hospital stay due to wound (days)			
Arterial	2.37	Gamma (757, 0.0031)	Estimated by multivariable generalised linear model
Venous	0.79	Gamma (84, 0.0094)	
Diabetic	2.26	Gamma (742, 0.003)	
Pressure	1.61	Gamma (724, 0.0022)	
Number of admissions to hospital with wounds			
Arterial	14536	Fixed	*
Venous	19210	Fixed	
Diabetic	16999	Fixed	
Pressure	49879	Fixed	
Cost per bed day ($)	823	Normal (823, 2.78)	*

*Ministry of Health, *Administrative database*, Ministry of Health (MOH). Accessed in 2021.

Table 2 Data inputs used to estimate the outcomes for the 'Lost Health Outcomes'

Parameter	Estimate	Distribution used for uncertainty	
Health utility for cases with specific wound type			
Arterial: baseline	0.44	Beta (0.24, 0.30)	Singapore Wound Registry
Venous: baseline	0.57	Beta (0.60, 0.46)	
Diabetic: baseline	0.64	Beta (0.21, 0.12)	
Pressure: baseline	0.18	Normal (−0.18, 0.50)	
Arterial: month 1	0.52	Beta (0.23, 0.21)	
Venous: month 1	0.68	Beta (0.89, 0.41)	
Diabetic: month 1	0.71	Beta (0.04, 0.02)	
Pressure: month 1	0.00	Normal (0.00, 0.56)	
Arterial: month 3	0.54	Beta (0.13, 0.11)	
Venous: month 3	0.74	Beta (0.81, 0.28)	
Diabetic: month 3	0.72	Beta (0.28, 0.11)	
Pressure: month 3	0.18	Normal (0.18, 0.54)	
Arterial: month 6	0.58	Beta (0.16, 0.12)	
Venous: month 6	0.74	Beta (0.83, 0.28)	
Diabetic: month 6	0.74	Beta (0.05, 0.02)	
Pressure: month 6	0.11	Normal (0.11, 0.59)	
Population normal utility (by age group)			
<40	0.980	Beta (350, 7)	23
40–49	0.950	Beta (636, 33)	
50–59	0.940	Beta (535, 34)	
60–69	0.960	Beta (193, 8)	
70–79	0.890	Beta (189, 23)	
≥80	0.890	Beta (189, 23)	
Value of one QALY ($)	80 000	Fixed	24
Durations of arterial wounds in days (by age group)			
<40	133	Normal (133, 92)	Singapore Wound Registry
40–49	129	Normal (129, 109)	
50–59	331	Normal (331, 394)	
60–69	223	Normal (223, 269)	
70–79	307	Normal (307, 438)	
≥80	205	Normal (205, 153)	
Durations of venous wounds in days (by age group)			
<40	133	Normal (133, 92)	
40–49	129	Normal (129, 109)	
50–59	331	Normal (331, 394)	
60–69	223	Normal (223, 269)	
70–79	307	Normal (307, 438)	
≥80	205	Normal (205, 153)	
Durations of diabetic wounds in days (by age group)			
<40	177	Normal (177, 88)	
40–49	325	Normal (325, 550)	
50–59	224	Normal (224, 216)	
60–69	314	Normal (314, 430)	
70–79	256	Normal (256, 305)	
≥80	160	Normal (160, 138)	

Continued

Table 2 Continued

Parameter	Estimate	Distribution used for uncertainty
Durations of pressure injury in days (by age group)		
<40	55	Normal (55, 11)
40–49	86	Normal (86, 24)
50–59	115	Normal (115, 1)
60–69	103	Normal (103, 59)
70–79	105	Normal (105, 115)
≥80	62	Normal (62, 52)
QALY, quality-adjusted life year.		

To estimate the '*Number of QALYs lost per case (by age group)*', we use EQ-5D-5L data. This instrument includes preference-based valuations of health states expressed as 'health utilities' on a scale between 0, the worst possible health state, and 1, the best possible health state.[21] We used EQ-5D-5L data from 799 individuals with relevant wounds from the Singapore Wound Care Registry to inform the '*Health utility for cases with specific wound type*'. Responses were recorded at entry into the registry, when the wound was first assessed in the hospital setting and then at 1, 3 and 6 months, see online supplemental appendix 6. We used a Singapore EQ-5D-3L value set[22] that was then mapped onto the EQ-5D-5L version using the SAS code in online supplemental appendix 7. The utility outcomes for the wound patients are compared with population norms for the EQ-5D index informed by Singapore preference weights for appropriate age bands,[23] this informs the '*Population normal Utility (by age)*'. Using the information described above, we are able to estimate the '*Utility Decrement*' from having a wound. The '*Duration of Wound*' was informed by the mean durations of wounds in days for the specific wound types from the Singapore Wound Registry, see online supplemental appendix 8. The '*Number of QALYs lost in population*' is the product of the '*Number of QALYS lost per case*' and the '*Annual cases by wound type*'. The '*Monetary value of QALYs lost in the population*' is the product of the '*Number of QALYS lost in population*' and the '*Value of one QALY*', which is set at the mean gross domestic product per capita for Singapore of SGD $80 000.[24] This approach assumes the value

Table 3 Data inputs used to estimate the outcomes for the 'Outpatient Clinic Costs'

	Estimate	Distribution used for uncertainty	Source
Outpatient visits per case (with consult)			Singapore Wound Registry
Arterial	8.2	Gamma (1.82:4.52)	
Venous	5.9	Gamma (0.98:5.99)	
Diabetic	8.1	Gamma (1.70:4.76)	
Pressure	6.5	Gamma (1.93:3.37)	
Outpatient visits per case (without consult)			
Arterial	8.5	Gamma (1.77:4.79)	
Venous	23.6	Gamma (1.55:15.25)	
Diabetic	14.2	Gamma (0.08:185.15)	
Pressure	9.7	Gamma (0.81:12.00)	
Cost per outpatient visit (with consult) ($)			
Arterial	110	Gamma (5.60:19.74)	
Venous	133	Gamma (2.70:49.30)	
Diabetic	112	Gamma (2.86:39.20)	
Pressure	111	Gamma (4.05:27.43)	
Cost per outpatient visit (without consult) ($)			
Arterial	117	Gamma (5.60:19.74)	
Venous	106	Gamma (2.70:49.30)	
Diabetic	114	Gamma (2.86:39.20)	
Pressure	124	Gamma (4.05:27.43)	

Table 4 Data inputs used to estimate the outcomes for the 'Primary care and ED Costs'

Parameter	Estimate	Distribution used for uncertainty	Source
Excess visits for polyclinics (all wounds)	0.91	Gamma (18.33, 0.049)	Estimated by multivariable generalised linear model
Excess visits for CHAS (all wounds)	3.54	Gamma (38.51, 0.091)	
Excess visits for ED (all wounds)	0.63	Gamma (4.18, 0.15)	
Cost per poly clinic visit	$147	Normal (147,2.5)	Ministry of Health, Administrative database, Ministry of Health (MOH). Accessed in 2021
Cost per CHAS use	$56	Normal (56,1.14)	
Cost per ED visit	$352	Normal (352,.14)	

CHAS, Community Health Assist Scheme; ED, emergency department.

of 1 year of perfect quality of life does not exceed the per capita gross domestic product.[25]

All the data inputs used for this part of the model are shown in table 2.

Outpatient clinics costs

Only one outcome, '*Costs of all outpatient visit ($)*', was estimated. Information was used for the '*Annual cases by wound type*', '*Cost per outpatient visit ($)*' and '*Outpatient visits per case*'.

To estimate '*Cost per outpatient visit ($)*', we interrogated the Singapore Wound Care Registry to identify the annual number of visits for those with chronic wounds and the reported costs per visits, this information was available by wound type. There were 573 individuals for whom these data were reported. Visits were for specialist consultations specifically for their wound, and for podiatry visit or medical tests, see online supplemental appendix 9. All the data inputs used for this part of the model are shown in table 3.

Primary care and ED costs

Only one outcome '*Costs of all POLY, CHAS & ED visits ($)*' was estimated. Information was used for the '*Annual cases by wound type*', '*Cost per POLY, CHAS & ED visit ($)*' and '*Excess POLY, CHAS & ED visits per case due to wound*'.

Table 5 Annual outcomes for bed days lost and QALYs lost for incident cases (n=16 752)

	Mean (min:max)
Number of QALYs lost	
Arterial	544 (−340:5436)
Venous	75 (−127:0971)
Diabetic	856 (−1670:16 962)
Pressure	602 (−520:6631)
Number of bed days lost	
Arterial	34 389 (29 269:38 674)
Venous	15 161 (10 044:22 166)
Diabetic	38 423 (33 445:43 573)
Pressure	80 530 (69 208:91 619)

QALYs, quality-adjusted life years.

For the '*Cost per POLY, CHAS & ED visit ($)*', we use estimates reported by the Singapore Ministry of Health. To estimate *Excess POLY, CHAS & ED visits per case due to wound*' the same population cohort for 2012 to 2019 who were admitted as inpatients were interrogated. We identify the use of the EDs of acute hospitals and all visits to community-based Polyclinics (POLY) and use of CHAS.

We sought to estimate the excess use of these services associated with any chronic wound. For the analysis each patient is counted only once, and those with wounds are only counted when they first appear with any wound, and the number of 12-month visits from the incidence date is the outcome variable. For those without wounds, their 12-month use starts from the first visit during the study period. A parsimonious GLM with a log link Poisson function was used for all regressions. The Poisson distribution was chosen over the negative binomial distribution based on fitting the model then doing model checks with diagnostic plots and relevant statistics. The outcome of interest was a count of the use of the services. Other covariates included were age, gender, race, Charlson Comorbidity Index and presence of comorbid conditions, see online supplemental appendix 10. The ensuing statistical models generated a coefficient for 'any wound' expressed as a rate ratio, that showed the change in the number of visits associated with the presence of wound, given that other factors that predicted variation in these outcomes. As before, the rate ratio was used to moderate the mean counts for the entire sample and an excess number of visits was estimated for all wounds, see online supplemental appendix 11. All the data inputs used for this part of the model are shown in table 4.

Uncertainty for all the outcomes shown in figure 1 was assessed by probabilistic sensitivity analysis. We take 5000 Monte Carlo resamples from all the parameters described in tables 1–4. We report the number of 'acute care bed days lost' and the number of 'QALYs lost to chronic wounds'. We then report the findings from the resamples for the primary model outcomes: *Value of all bed days lost for population; Monetary value of QALYS lost in the population; Costs of all outpatient visit; and, Costs of all POLY, CHAS & ED visits.* We sum these four primary outcomes to report the '*Total Costs of Illness for each wound type*'. These processes are shown in figure 1.

Table 6 Annual cost outcomes for the primary outcomes (n=16 752)

Value of all bed days lost for population	Mean (min:max)
Arterial	$28 302 139 ($24 148 856:$31 912 933)
Venous	$12 477 776 ($8 243 954:$18 212 629)
Diabetic	$31 622 397 ($27 431 880:$35 693 113)
Pressure	$66 276 250 ($57 237 092:$75 718 807)
Monetary value of QALYs lost in the population	
Arterial	$43 491 588 (−$27 170 499:$434 890 646)
Venous	$5 975 553 (−$10 153 391:$77 645 170)
Diabetic	$68 498 429 (−$133 624 494:$1 356 989 736)
Pressure	$48 199 291 (−$41 617 890:$530 453 557)
Costs of all outpatient visit	
Arterial	$4 233 236 ($84 899:$35 360 192)
Venous	$2 017 189 ($8957:$27 539 296)
Diabetic	$16 337 217 ($3058:$785 613 392)
Pressure	$13 859 689 ($42 824:$142 991 574)
Primary care and ED costs	
Costs polyclinic visits—all wounds	$2 245 437 ($877 197:$5 715 449)
Costs CHAS episodes of care—all wounds	$3 296 040 ($1 849 062:$5 930 304)
Costs ED visits—all wounds	$3 730 682 ($235 741:$14 456 940)

CHAS, Community Health Assist Scheme; ED, emergency department; QALYs, quality-adjusted life years.

Patient and public involvement

The data came from the Singapore Wound Registry and from the Ministry of Health. It was routinely reported data collected for the purpose of managing and planning health services. It was not possible to develop the research question or outcome measures based on the priorities, experience and preferences of the patients. Patients were not involved in the design, recruitment and conduct of the study. Patients who are interested will be able to read the paper.

RESULTS

There were 16 752 'new' or 'incident' cases for 2017, with 598 venous ulcers, 2206 arterial insufficiency ulcers, 6680 diabetic ulcers and 7268 pressure injuries. The values obtained from the model for 'acute care bed days lost' and the number of 'QALYs lost to chronic wounds' are shown in table 5.

The values obtained from the model for the four primary outcomes are shown in table 6.

The aggregate of these cost outcomes are the 'Total Costs of Illness for each wound type' and are shown in table 7 for the entire population of Singapore, and for the average individual.

Based on our estimates pressure injuries account for 48% of the 168 503 bed days lost to chronic wounds and 38% of the $28.4 million outpatients costs. For the non-hospital sector, the costs of CHAS services and ED visits account for most of the burden. The QALY burdens are large for diabetic foot ulcers, arterial and pressure injury with venous ulcers having lesser impact. Box plots for the 'Total Costs' outcomes are shown in figure 2.

There is a 100% probability that the costs of chronic wounds are positive with the most likely value suggesting an annual cost to Singapore of $350 million. The findings are uncertain with the range of total costs between

Table 7 Annual total costs of illness for each wound type (n=16 752)

| Total costs of illness for each wound type	Mean (min:max)	
	Population	Individual
Arterial	$77 247 993 ($6 047 354:$469 696 045)	$35 364 ($383:$257 207)
Venous	$20 801 577 ($5388 353:$91 673 830)	$35 023 ($9064:$162 054)
Diabetic	$120 155 304 (−$97 359 748:$1 395 843 120)	$18 095 (−$17 094:$231 815)
Pressure	$132 358 039 ($42 035 656:$624 864 715)	$18 161 ($3829:$73 175)
Total cost of illness	$350 562 913 ($72 814 108:$1 779 366 924)	$21 002 ($2664:$100 366)
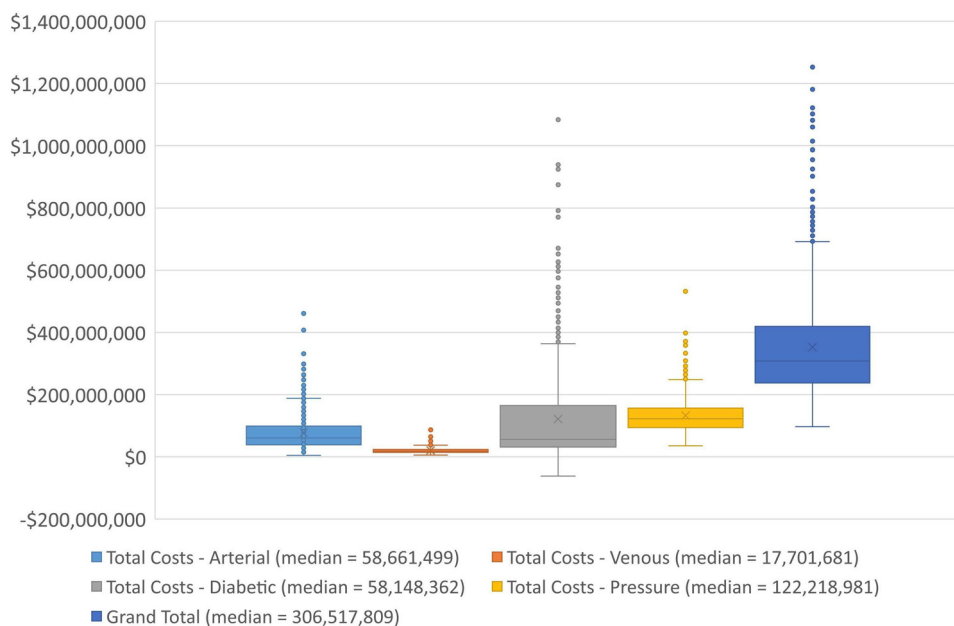
Figure 2 Total cost outcomes for the cost of illness by wound type.

$79 million and $1.78 billion. More than half of the total costs arise from use of health services ($185 million, 53%) with outpatients accounting for $37 million (10%) and the use of acute bed days accounting for $139 million (40%). The value of the lost health by QALYs is substantial at $165 million, 47% of the total burden.

DISCUSSION

These findings suggest that the costs of chronic wounds to Singapore are large and account for approximately 0.07% of GDP. The total cost burden accounts for 3.14% of the 2019 Government Health Expenditure on services[26] and 2.3% of total economy-wide expenditure on services. Our estimates roughly align with those from other countries. In Australia 2% of the total national health expenditure is used for chronic wounds and in the UK 3% of the national health expenditure is taken up.[27] Two per cent of the European health budget[28] is for care of chronic wounds and for Scandinavian countries the costs were found to be 2%–4% of the total healthcare expenditure.[6]

While the findings are lower than the annual costs of diabetes in Singapore, estimated to be US$787 million in 2010,[29] the policy response to diabetes has been considerable with a 'War on Diabetes' declared in 2016 to mobilise a national programme to reduce the problem of diabetes.[30] We found two other studies reporting costs of chronic venous leg and neuroischaemic ulcers in Singapore, but neither study were at a population level instead focusing on average costs per patient.[31]

This study likely underestimates the extent of the costs of chronic wounds as relevant information was not available for many costs we suspect are present. Our data came primarily from patients who were admitted to the hospital for their wounds. Thus patients with less serious wounds managed in the community are excluded. We

were also unable to identify and include estimates of the private costs incurred by patients and family members. Other studies have found that such costs can be substantial. For the German setting Purwins *et al*[32] found patients with leg ulcers in a given year spent €424 on topical treatments and drugs, €486 on out of pocket incidentals, €254 on drug prescriptions and €740 on non-drug treatments.

Although no data were available on the time away from work and other production losses, we addressed this by estimating and valuing lost QALYs. We assume that time in reduced health states has a relationship with an ability to be economically productive. Thus, the dollar valuations of the lost QALYs can be thought of as representing lost production from chronic wounds. Most governments are willing to pay money for services that increase the number of QALYs in a population, given a programme achieves a marginal QALY below a designated cost.[33] Importantly we did not consider the costs of lost production for informal carers, which we expect are substantial.

There are further limitations to our study. Regarding the estimation of QALY losses, the sample sizes for EQ-5D were quite small for pressure injury with only 51 patients providing data. It is possible the estimate would change with a larger and more representative sample. It should be noted that the lowest health utilities arise from this sample. For example, the values for baseline were −0.18 indicating a health state valued worse than death, and a value of 0.00, the worst possible health state, was observed for month 1. Values remained low at 0.18 and 0.11 for the 3-month and 6-month follow-ups. We assumed that the observed decrement between the population norms for health utility and the estimates from the wound registry were wholly attributable to the presence of a wound. These QALY estimates did not adjust for the other health

conditions that patients may have, and as such may overstate the QALY losses.

To attribute excess acute bed days to the presence of a chronic wound we developed generalised linear regression models with the outcome of length of stay. While we did not have an exhaustive list of control variables, we did find that factors such as race, age, gender, myocardial infarction, cancer, liver disease, peptic ulcer disease, peripheral vascular disease, renal disease, chronic obstructive pulmonary disease, dementia, diabetes, heart failure, hyperlipidaemia, lymphoproliferative disease, major depression, Parkinson's, schizophrenia and stroke all played a role in explaining variation in the observed length of stay. We fitted the best models possible, but acknowledge there may be some covariate information missing.

In summary, this recurring and unnecessary cost burden is a deadweight loss to Singapore health services, and society in general. It could be reduced if evidence-based and relatively simple prevention and management programmes were implemented. International evidence[9] reveals that using optimal prevention practices for diabetic foot ulcers[34] was cost-saving in Peru,[35] Australia,[36] Thailand[37] and China.[38] For the prevention of pressure injury nursing-led interventions, a quality improvement collaborative and the standardised use of pressure injury bundles were found to be cost-saving in Denmark,[39] USA and UK.[40–43] And for the prevention of venous leg ulcers, compression therapy, clinical assessments and use of guidelines were found to be cost-saving in the UK[44 45] and USA.[46 47]

Our findings provide fundamental information for researchers who wish to model the cost-effectiveness of programmes that will improve wound outcomes in the future. Understanding the baseline of costs and QALY outcomes form a useful start-point for any evaluation of interventions.

CONCLUSIONS

The costs of chronic wounds are large in Singapore, but many of them could be avoided by making positive investments in integrated and comprehensive wound prevention and treatment programmes.

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