RESEARCH

The impact of comorbidities on wound healing in the community: the value of using linked hospital data

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Abstract

Aim To explore the comorbidities of community wound patients, and their impacts on healing.

Methods Records of patients treated for a wound in Western Australia by a community healthcare service during 2017/2018 were linked to hospital admissions data for the prior 12 months. The Charlson Comorbidity Index (CCI) and the Elixhauser Comorbidity Index (ECI) were calculated using ICD-coded diagnoses from the linked data. Cox proportional hazards regression examined associations between comorbidities and healing.

Results Wound care was provided to 14,479 patients with 25,968 wounds. Most wounds healed (76.11%) and most patients were hospitalised (84.51%) at least once in the 12 months prior to their community wound admission. Two-thirds had one or more ECI comorbidity and over half had one or more CCI comorbidity. There was variation in comorbidity profiles across the wound categories. Patients with pressure injuries had the highest CCI scores (mean 3.26, SD 3.17) and ECI scores (mean 3.32, SD 2.36). For each wound category, the model that best explained the relationship between wound healing and comorbidities was based on the presence of different subsets of comorbidities.

Conclusion Linkage of hospital data to community data improved understanding of the comorbidity burden and differences in wound healing outcomes for different wound categories.

Keywords data linkage, wound healing, comorbidities, and community care

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Introduction

A large number of wounds are treated in the community and place a significant burden on health care resources and patients.[1] Over 420,000 Australians experience a chronic wound annually, which costs over $3 billion in government spending with patients often paying high out-of-pocket costs.[2] Unhealed wounds can significantly impact a patient's quality of life and increase the risk of hospital admissions.[3,4] Wound healing is a complex process that is influenced by multiple factors such as age, gender, medications, nutrition, alcohol and smoking. Additionally, comorbidities may significantly alter, delay, or inhibit normal wound healing. This often occurs with chronic disorders such as diabetes and renal failure, and it can also occur secondary to risk factors such as aging and substance abuse.[5]

Understanding the impact of comorbidities on wounds treated in the community is important for treatment planning, resource allocation and informing patient expectations about anticipated wound healing times. However, the accurate documentation of comprehensive comorbidities in the community home care setting is challenging and impacted by the comprehensiveness of patient care records, the accuracy of medical histories, the level of information provided at time of referral, and patient recollection of relevant

health information. Linking community data with hospital admission data mitigates some of these issues and provides access to high quality International Classification of Diseases (ICD) diagnosis codes that supports the construction of comorbidity profiles.

The objectives of this research were to:

- Demonstrate the value of using linked hospital data to create comorbidity profiles for community wound care patients, without imposing additional data collection burden on wound care clinicians
- Examine the association of patient comorbidities on wound healing.

Methods

Setting and sample

Silver Chain Group Limited (Silverchain) is a large Australian not-for-profit community health and aged care service. Wound management comprises a significant component of clinical care delivery in the home. In 2023, the organisation's clinicians treated 57,932 wounds across Australia, the majority of which were in Western Australia. The wound profile of these patients is diverse, and wounds are categorised as: acute, chronic acute, foot ulcers, leg ulcers, pressure injuries, tumours (malignant and benign) and other (predominantly open dermatological lesions). The proportion of all wounds that healed while under the organisation's care in 2023 was 77%, although this varied across different wound categories.[6] All patients who had a wound treated by Silverchain in Western Australia in 2017/18 and had at least one inpatient hospital admission in the year prior, were included in the analysis. The exception was the small number of wounds that were categorised as "other" or "tumours". These were omitted due to their small numbers.

Data Collection

This paper was a retrospective, linked data cohort. Wound data is collected at the point-of-care in patients' homes or wound clinics using mobile devices connected to a wound module that forms part of organisation's purpose-built digital management system. The data includes assessments, treatment plans, consumables used to treat, and wound images.

For this study, the wound data for Western Australian patients in 2017/18 was linked with WA inpatient admissions (not emergency department presentations) for the 12 month period prior to their first wound treated by the organisation in 2017/18. The organisation's extensive patient data (demographic and clinical) and wound data, including category and type, treatment, consumables, length of stay and outcomes), was linked with WA hospital morbidity data for hospital admissions in the year prior to the wound admission to the organisation. This created a unique dataset of wounds (found only in the organisation data) and hospital admissions that provided diagnoses for the comorbidity indexes (found only in the hospital morbidity data). Table 1 shows how we classified wound categories and wound types.

Comorbidity profiles

Currently, no wound-specific comorbidity index exists. Instead, we used two well-established comorbidity indices: the Charlson Comorbidity Index (CCI)[7] and the Elixhauser Comorbidity Index (ECI).[8] Both indices contain a list of comorbidities defined by ICD diagnosis codes. We searched for these ICD codes in all available diagnosis fields recorded in the linked WA inpatient data. The CCI has multiple versions; we used the Charlson/Metcalfe version that contained 17 comorbidities.[9] The ECI[10] contains 31 comorbidities. There are 10 comorbidities common to both indices. The CCI calculates a weighted score. The ECI score is calculated by counting the presence of each of the comorbidities. The higher the value of the CCI or ECI score, the greater the comorbidity burden.[7,8] For each patient, we created binary variables (present/absent) for each of the comorbidities included in the indices, and then calculated the comorbidity scores for each index. These comorbidity details were then joined to each patient's wound data using a unique patient identifier.

Wound healing

Unhealed wounds were defined as:

- Acute wounds: unhealed after a maximum of 90 days following admission for wound care in the community.
- All other wounds: unhealed after a maximum of 12 months following admission for wound care in the community.

These time frames are a conservative estimate of wound healing time and were based on expert clinical opinion.

Analysis

Analysis was restricted to the first wound admitted for community home care for each patient in 2017/18 (n=11,287 patients), where the patient had been hospitalised in the previous 12 months. Frequencies and proportions were reported for categorical variables and median and mean for continuous variables.

Cox proportional hazards analyses were used to explore the association between wound healing outcome (0=healed, 1=not healed) and patient characteristics with comorbidity burden was the main variable of interest. We decided that the most clinically meaningful approach was to perform separate Cox proportional hazard analyses for each wound category rather than a combined analysis that included all wound categories. The patient characteristics considered during this analysis were:

- Age
- Sex
- Comorbidity, as measured by:
  - CCI score
  - presence/absence of each of the 17 CCI comorbidities
  - ECI score
  - presence/absence of each of the 31 ECI comorbidities
- Wound type (for each wound category)
- Total hospital inpatient days in the past 12 months (for any reason)

Initially, univariate Cox proportional hazards models were used to explore the effect of each patient characteristic on wound healing. Characteristics with a log rank statistic with a p-value less than or equal to 0.2 for a particular patient characteristic, were explored further in the multivariable Cox proportional hazards models. Client age, gender and wound type were forced into all Cox proportional hazards regression models irrespective of their statistical significance. This is a common regression decision for age and gender and a clinically meaningful decision for wound type. We applied a backward elimination strategy. Client characteristics that met the univariate analysis criteria were added concurrently to the initial multivariable Cox proportional hazards model. Subsequent models removed the patient characteristics one by one if they did not achieve a level of statistical significance (p value<0.05) following adjustment for all the other predictor variables included in the same model.

For each wound category, two regression models were explored for each comorbidity index. One model was based on the overall comorbidity score and the other model was based on the presence/absence of each separate comorbidity in each index. This resulted in the following four different Cox proportional hazard models:

- Model 1: CCI score
- Model 2: ECI score
- Model 3: presence/absence of the CCI comorbidities
- Model 4: presence/absence of each of the ECI comorbidities

Akaike's Information Criterion (AIC) was used to determine which of the four models provided the 'best fit' for each wound category. The model with the lowest AIC value was the best fitting model if it was at least two AIC points/units lower than the AIC values of the other models considered.

Results

Wound care was provided to 14,479 WA patients with 25,968 wounds in 2017/18. Most wounds healed (n=19,764; 76.11%). At least one linked inpatient record was found for 12,236 patients (84.51%) in the 12-months prior to their first wound admission in 2017/18. Wounds from 949 (7.76%) patients were excluded from subsequent analysis because they could not be categorised to a wound category (Table 1). Therefore, the analysis described used a subset of patients (n=11,287, 92.24%).

Comorbidity profile

This wound cohort had a diverse comorbidity profile when measured using either the CCI or the ECI (Table 2). The CCI comorbidity scores ranged from 0 (no comorbidity burden) to 16 (high comorbidity burden). Forty-seven percent (n=5304) of wound patients had a CCI score of zero. The ECI comorbidity scores ranged from 0 (no comorbidity burden) to 14 (high comorbidity burden). Thirty-four percent (n=3898) of wound patients had an ECI score of zero.

There was considerable variation in comorbidity profiles across the wound categories (Figure 1). Patients with

Table 1. Wound categories and types

Wound Category*	Wound type
Acute	Abrasion
	Abscess
	Burns
	Peristomal ulceration
	Suture line intact
	Wound pin site
	Wound skin graft
	Skin tear
Chronic acute	Fistula
	Flap
	Open incisional wound
	Dehiscence
	Perianal/pilonidal sinus
Foot ulcers	Atypical
	Ischaemic
	Neuro-ischaemic
	Neuropathic
Leg ulcers	Arterial
	Atypical
	Lymphoedema
	Mixed
	Venous
Pressure Injuries	Stage 1 – Stage 4
	Unstageable
	Suspected deep tissue injury

* The wound categories of 'tumour' and 'other wounds' were excluded due to small numbers.

pressure injuries, leg or foot ulcers had the highest median CCI and ECI score compared with other wound categories such as acute wounds.

Table 3 shows the 10 most frequent types of the comorbidities identified using the CCI and ECI for the 11,287 wound patients with hospital admissions data. Six of the top 10 comorbidities were common to both the CCI and ECI indices: diabetes (with or without complications), cancer (with or without metastases), renal disease/failure, and congestive heart failure.

Table 4 shows the healing status of the wounds included in this analysis. Most wounds (n=8767, 76.9%) healed during the study period, ranging from 59% for pressure injuries to 79.8% for acute wounds.

Association between comorbidities and wound healing

For each wound category, all four Cox proportional hazards models showed that comorbidity significantly increased the risk of unhealed wounds (Table 5). A one unit increase in the CCI score (Model 1) increased the risk of an unhealed wound by 8-12%, depending on the wound category. A one unit increase in the ECI score (Model 2) increased the risk of an unhealed wound by 7-13%, depending on the wound category. However, neither of these score-based approaches were the best fitting models for any of the wound categories.

Models 3 and 4 included the individual comorbidities for each of the comorbidity indices rather than a single score (Table 6. Association between comorbidity and other significant variables on wound healing6). The best fitting model for each wound category included different subsets of comorbidities. For leg ulcers and foot ulcers, a collection of CCI comorbidities produced the best fitting model. For acute wounds, chronic acute wounds, and pressure injuries, a collection of ECI comorbidities produced the best fitting model. Metastatic cancer was associated with a higher risk of an unhealed wounds across all models and wound categories. For pressure injuries, diabetes with complications and history of blood loss anaemia improved the likelihood of wound healing. For foot injuries, uncomplicated diabetes improved the likelihood of wound healing.

Discussion

The organisation's nurses collect comprehensive wound assessment data at point-of-care in the community to allow comprehensive treatment and monitoring of wound

Table 2. Charlson and Elixhauser Comorbidity Index scores

Summary measures	CCI	ECI
Median (IQR)	1 (0–3)	1 (0–3)
Range	0–16	0–14

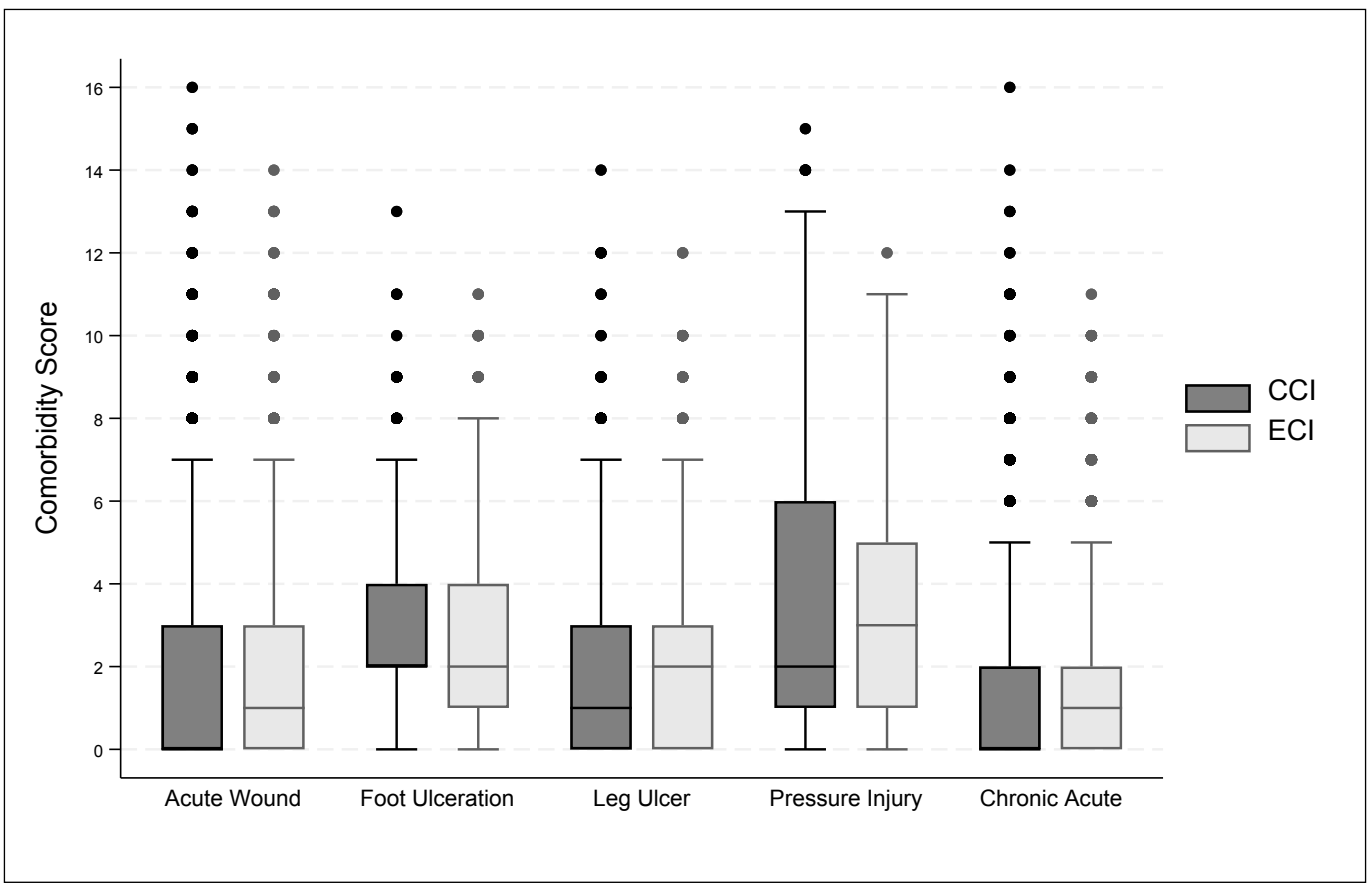

Figure 1: Median Elixhauser and Charlson Comorbidity Index scores by wound category
(NB: Boxes show the median and interquartile range with outliers displayed as dots)

Table 3. Top 10 comorbidities based on linked hospital data

Rank	CCI[ac]	No. patients (%)	ECI[ac]	No. patients (%)
1	Diabetes, complicated[b]	2140 (18.96)	Fluid and electrolyte disorders	2724 (24.13)
2	Diabetes, uncomplicated	1646 (14.58)	Diabetes, chronic complications[b]	2314 (20.50)
3	Cancer	1133 (10.04)	Cardiac arrythmia	1826 (16.18)
4	Congestive heart failure	1064 (9.43)	Hypertension, uncomplicated	1626 (14.41)
5	Renal disease	945 (8.37)	Solid tumour without metastases	1607 (14.24)
6	Metastatic cancer	938 (8.31)	Diabetes, uncomplicated	1564 (13.86)
7	Chronic obstructive pulmonary disease	751 (6.65)	Congestive heart failure	1064 (9.43)
8	Peripheral vascular disease	687 (6.09)	Renal failure	945 (8.37)
9	Acute myocardial infarction	379 (3.36)	Weight loss	958 (8.49)
10	Cerebrovascular disease	342 (3.03)	Metastatic cancer	938 (8.31)

a. The same patient could have more than one comorbidity.
b. Refers to diabetes with end stage organ damage.
c. The CCI and ECI share some of the same comorbidities, but they do not always use the same ICD codes to identify these same comorbidities. This explains the discrepancy in some comorbidity counts, such as diabetes with complications.

Table 4: Healing status of wounds

Wound Category	Healed No. wounds (%)	Unhealed No. wounds (%)
Acute wound[a]	4739 (79.79)	1200 (20.21)
Chronic acute[b]	2223 (77.84)	633 (22.16)
Leg ulcer[b]	819 (77.34)	240 (22.66)
Foot ulceration[b]	448 (66.27)	228 (33.73)
Pressure injury[b]	447 (59.05)	310 (41.95)
Total	8676 (76.87)	2,611 (23.13)

a. Acute wound healing to 90 days.
b. All other wound healing to 12-months.

healing. They also document and have ready-access to patient data about age, nutritional status, and medications. However, there is often minimal information about patient comorbidities at the time of referral for wound care. This can hamper the clinical evaluation of barriers to healing. Many comorbidities can impact wound healing, especially those that impair, oxygenation and perfusion, cellular transport of nutrients, endocrine function, immune responses, tissue repair and regeneration, and psychosocial responses to wounding.[5,11] Our study demonstrated the significant impact of comorbidities on wound healing outcomes and therefore that such patient-centred information would be useful for guiding clinical decision making, benchmarking of healing outcomes and resourcing.

This study examined the association between comorbidity burden and five wound categories. Acute wounds are defined as 'surgical or traumatic wounds that heal by primary or secondary intention and which proceed through an orderly and timely reparative process and result in sustained anatomical integrity'.[5] They include abrasions, abscesses, burns, peristomal ulceration, suture lines (intact), wound pin sites, wound skin grafts, and skin tears. Acute wounds generally heal in an orderly and timely manner. The chronic acute category allowed for separate analysis of wounds with an acute aetiology that primarily heals by secondary intention and where healing is not so orderly or timely. These wounds included fistula, flap, open incisional wound, and perianal/pilonidal sinus. All four of our multivariable models showed a statistically significant relationship between comorbidity and wound healing across chronic acute wounds. Model 4 (subset of ECI comorbidities and the best fitting model) showed that between 1.41 times as many patients with complicated diabetes and 2.03 times as many patients with metastatic cancer had an unhealed chronic acute wound at any time in the 12 month follow-up period compared with chronic acute wound patients without these comorbidities. Additionally, alcohol and drug abuse increased the risk of chronic acute wounds not healing by 1.57 and 1.62 times and, while alcohol abuse is a known factor in impairing wound healing,[12] there is limited evidence for the impact of illicit drug use on wound healing.[12] Acute wounds comprise 40% of wounds managed annually by the organisation.[1] Our study highlights the importance of identifying comorbidities and relevant lifestyle factors on admission to wound care to ensure their

optimum management. It would also improve resource and care planning and help manage patient expectations about their healing trajectories.

The leg ulcer wound category included venous, arterial, atypical, lymphoedema and mixed ulcers. All four of our multivariable models showed that comorbidity burden delayed leg ulcer healing. Venous leg ulcers (VLUs) are the most expensive and single largest number of chronic wound types managed in this community care organisation.[1] VLUs account for an estimated 80% of all leg ulcers[1,13] and have recurrence rates of up to 69%.[14] According to the organisation's data and published reports, some patients live with their VLU for five years or more, [4,15] most often older people and women.[16] Estimates of leg ulcer prevalence vary from 0.6% to 4% in people aged over 60 years[17] and incidence increases with age.[18] With worldwide population aging, we can anticipate an increase in VLUs, hence it is important that comorbidities are considered when conducting comprehensive assessments and planning wound care interventions.

The foot ulcer wound category included four wound types: atypical, ischaemic, neuro-ischaemic, and neuropathic. These wounds are usually associated with diabetes complications and are collectively referred to as diabetic foot disease (DFD). DFD affects over 50,000 Australians, and Aboriginal and Torres Strait Islander people are 38 times more likely to be affected.[19] DFD is a leading cause of morbidity in Australia. Annually, it accounts for 28,000 hospital admissions, 4500 amputations, 1700 deaths, and health expenditure of over A$1.6 billion.[19–21] While the impact of diabetes on healing other wound types is generally acknowledged, it is poorly studied. Our study found that one in five people receiving community wound care had complicated diabetes, and around 14% to 15% of patients had uncomplicated diabetes. Considering the incidence of diabetes in this wound patient population and the increasing prevalence of diabetes worldwide,[22] these findings reinforce the need for further research into diabetes and the impact on wound healing. Promoting self-care in diabetes management (such as healthy eating, physical activity, and blood sugar control) to stop progression to complicated diabetes and reduce wound incidence is vitally important and deserves further research.[23] Our finding that diabetes with complications improved the likelihood of leg ulcers and pressure injury healing was unexpected and perhaps due to better diabetic self-care and/or more frequent contact and monitoring by health services. This warrants further examination.

Across all wound categories, patients with a known history of metastatic cancer in the past 12 months were more likely

Table 5: Prediction of wound healing by Charlson and Elixhauser Comorbidity Index scores

Wound Category	Comorbidity Measure	AIC[c]	Hazard ratio (HR)	95% Confidence interval
Acute (n=5939)	CCI Score[a]	17,164.90	1.08	1.06 – 1.11
	ECI Score[b]	17,158.26	1.10	1.08 – 1.13
Chronic acute (n=2856)	CCI Score[a]	8544.44	1.12	1.08 – 1.15
	ECI Score[b]	8543.00	1.13	1.09 - 1.18
Foot ulcer (n=676)	CCI Score[a]	2409.73	1.08	1.02 – 1.15
	ECI Score[b]	2409.37	1.07	1.02 – 1.13
Leg ulcer (n=1059)	CCI Score[a]	2676.64	1.10	1.04 – 1.17
	ECI Score[b]	2678.78	1.10	1.04 – 1.18
Pressure injuries (n=757)	CCI Score[a]	3327.57	1.12	1.08 – 1.16
	ECI Score[b]	3352.99	1.10	1.05 – 1.15

a Model 1 – adjusted for age, gender, wound types (dependent on wound category of interest)
b Model 2 – adjusted for age, gender, wound types (dependent on wound category of interest)
c AIC – lowest score used to determine which model has the best fit

Table 6. Association between comorbidity and other significant variables on wound healing

Wound Category	Best fit model	AIC[a]	Predictors of not healing[b]	Hazard ratio (HR)[a]	95% Confidence interval
Acute (n=5,939)	ECI comorbidities[c]	17133.53	Cardiac arrythmia	1.18	1.00 - 1.39
			Other neurological conditions	1.60	1.20 - 2.14
			Metastatic cancer	1.39	1.10 - 2.13
			Solid tumour without metastases	1.36	1.11 - 1.67
			Fluid and electrolyte disorder	1.22	1.05 - 1.40
			Alcohol abuse	1.44	1.10 - 2.13
			Drug abuse	1.54	1.14 - 2.10
			Age	0.98	0.98 - 0.99
Chronic acute (n=2,856)	ECI comorbidities[c]	8539.64	Diabetes, complicated	1.41	1.17 - 1.71
			Metastatic cancer	2.03	1.52 - 2.71
			Alcohol abuse	1.57	1.07 - 2.30
			Drug abuse	1.62	1.05 - 2.47
			Coagulopathy	1.63	1.07 - 2.49
Foot ulcer (n=676)	CCI comorbidities[d]	2392.99	Peripheral vascular disease	1.40	1.03 - 1.91
			Diabetes, uncomplicated	0.69	0.48 - 0.99
			Renal disease	1.66	1.22 - 2.26
			Metastatic cancer	2.67	1.16 - 6.14
			Peptic ulcer disease	3.35	1.31 - 8.55
			Mild liver disease	1.92	1.06 - 3.48
Leg ulcer (n=1,059)	CCI comorbidities[d]	2665.88	Congestive heart failure	1.44	1.05 - 1.96
			Rheumatoid disease	4.38	2.11 - 9.07
			Renal disease	1.56	1.06 - 2.30
			Metastatic cancer	2.31	1.39 - 3.85
			Total bed days	1.006	1.002-1.009
Pressure injuries (n=757)	ECI comorbidities[c]	3263.74	Diabetes, complicated	0.76	0.58 - 0.99
			Hypothyroidism	3.11	1.13 - 8.54
			Solid tumour without metastases	2.40	1.59 - 3.64
			Metastatic cancer	1.52	1.01 - 2.31
			Coagulopathy	1.74	1.40 - 2.65
			Weight loss	1.47	1.15 - 1.90
			Blood loss anaemia	0.48	0.23 - 0.98

a Lowest AIC score used to determine the best fitting model.
b Only significant predictors displayed
c Model 4 - adjusted for age, gender, wound types (dependent on wound category of interest)
d Model 3 - adjusted for age, gender, wound types (dependent on wound category of interest) total bed days (leg ulcers only)

to have an unhealed wound compared to wound patients without metastatic cancer. This risk increase ranged from 1.39 times (39%) for acute wounds to 2.67 times for foot ulcers (167%). It is possible that part of the reason for the increased risk was due to the long follow up period of 90 days for acute wounds and 12 months for all other wounds. The reason for these patients' wounds not healing could potentially be that they died with their wounds. Further investigation of this is required to determine if this is the case.

Our study shows that several comorbidities delay wound healing across different categories of wounds. The use of the Charlson and Elixhauser Comorbidity Indices to understand why some wounds take longer to heal than others was novel. Further research is needed to incorporate actual healing times and indicators of wound chronicity. Such information will improve clinical education, care planning, and help manage patient expectations about their healing trajectories.

Limitations

This study applied the Charlson and Elixhauser Comorbidity Indices for a novel purpose beyond their original purpose. There may be other comorbidities relevant to wound healing that neither of these indices consider. Regardless, this analysis has shown that both indices are highly relevant for wound healing in a community wound care setting. A second limitation is that we applied the Charlson and Elixhauser Comorbidity Indices to inpatient records in the 12 months prior to each patient's first wound in 2017/18. In Australia, comorbidities are only recorded in inpatient records if they impact the care received during a hospital stay. Consequently, we may have underestimated the comorbidity burden of people receiving community wound care. Also, we excluded community wound patients we could not develop a comorbidity profile for, due to the absence of a hospital admission in the previous 12 months. Therefore, our results might not be generalisable to these patients.

There is no international consensus on the anticipated time for a wound to heal. There is also little research published in this area, apart from specific wound categories such as venous leg ulcers.[27] We assessed healing outcomes at 90 days for acute wounds and 12 months for all other wounds based on expert clinical judgement. These follow up durations were deliberately conservative.

Conclusion

This study demonstrated that linking data from a community health care organisation with hospital admission data is a feasible approach to describe the comorbidity profiles of patients who received community wound care. As expected, many comorbidities were associated with the risk of unhealed wounds. The prevalence and burden of wounds worldwide highlights the need for a wound-specific comorbidity index to better understand wound healing trajectories and inform care planning. Currently, we are collecting comprehensive, prospective data about patient comorbidities as part of routine community wound care practice so we can refine the findings reported in this article and use the data to develop a wound-specific comorbidity index.

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Author contribution

The authors confirm equal joint responsibility for the following: study conception and design, analysis and interpretation of the results, and draft manuscript preparation. No responsibility is claimed for data collection because this study performed secondary analysis on existing data. All authors reviewed the results and approved the final version of the manuscript.

Conflict of interest

The authors declare no conflicts of interest.

Ethics statement

Ethical approval was provided by the Western Australian Department of Health Human Research Ethics committee (RGS0000003198) and Silverchain's Human Low Risk Ethics Committee (EC00132).

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