Long-term mortality among older adults with burn injury: a population-based study in Australia
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Abstracts in العربية, 中文, Français, Русский and Español at the end of each article.

Introduction
Burn injury is an important cause of morbidity and mortality worldwide, particularly among older adults.1–4 In high-income countries, where older adults form an increasingly large proportion of the population, the incidence of burn injury is likely to increase. 5 Compared with burn injuries in younger individuals, burn injuries in older adults cause increased physical impairment, reductions in the quality of life, loss of independence and increased mortality. 6,9 Improvements in the understanding of the pathophysiology of burns over the past decades have led to advances in medical and surgical treatment. The probability that an older adult is discharged alive after admission for an acute burn appears to be increasing. 7,10 However, compared with younger people, older adults with burn injury are still more likely to die in the year 8,11 or two years 12 following their discharge and often have to be readmitted because of pre-existing comorbidities and ongoing chronic illness. 6,9,12

Using data on adults who have been hospitalized for burns in Western Australia, we investigate long-term mortality and the proportion of mortality attributable to the original burn injury.

Methods
Our study formed part of the Western Australian population-based burn injury project – a retrospective cohort investigation that uses administrative data from the Western Australian data linkage system. Administrative health data from several core data sets – including Western Australia’s hospital morbidity data system and death register – are linked for the entire population of Western Australia. 13 The project protocol was approved by the human research ethics committees of the University of Western Australia and the Western Australian department of health.

Staff at the Western Australian data linkage system provided a de-identified extraction of hospital morbidity records for all individuals who were aged at least 45 years when admitted to a hospital in Western Australia with a first burn injury from 1 January 1980 and 30 June 2012. Other than the unique identifying numbers assigned by staff at the Western Australian data linkage system, personal identifiers were removed from the data. We used the International Classification of Diseases and Related Health Problems (ICD9) CM 940–949 or (ICD10) AM T20–T31 codes to identify burn injuries. A first burn injury was defined as the first hospital admission in a patient’s medical record in which a burn injury was given as the principal diagnosis or an additional diagnosis. A population-based comparison cohort was randomly selected from Western Australia’s electoral roll. Any person with an injury hospitalization during the study period was excluded from this cohort by staff at the Western Australian data linkage system. The resultant comparison cohort was frequency matched on birth year and sex of each burn injury case – with four controls to each case – for each year from 1980 to 2012. Data from Western Australia’s hospital morbidity data system and death register were linked to the burn and non-injured cohorts for the period 1980–2012. Hospital admissions’ data included principal and additional diagnoses, external cause of injury, age, sex, Aboriginal status, date of admission, date of discharge or other separation, mode of separation, percentage of total body surface area burned and burn depth. The data also included geocoded place of residence (census collectors’ district or postcode), geocoded indices of geographical remoteness 14 and social disadvantage. 15 Geographical remoteness was classified into five categories: major cities, inner regional,
The percentage of deaths in the Burn cohort that were attributable to burn injury was estimated after adjusting for potential confounders. All statistical analyses were performed using Stata version 12 (StataCorp. LP, College Station, United States of America).

### Results

During the study period, 6014 individuals aged 45 years or older were hospitalized in Western Australia for a first burn injury. Although 240 (4%) were recorded as having severe burns and 3248 (54%) as having minor burns, the percentage of the total body surface area affected by burns was not recorded for the remaining 2526 (42%). Overall, 1143 (19%) of patients had full-thickness burns, while 2225 (37%) had partial-thickness burns, 1082 (18%) had erythema and 1744 (29%) had burns of unspecified depth. Patients may have had multiple burns sites and depths recorded. In total, 4992 (83%) of patients were discharged to their home, 722 (12%) were transferred to acute care hospitals, 120 (2%) were transferred to facilities for elderly people and 180 (3%) died in hospital. Only 577 (10%) had additional non-burn injuries, most of which were open wounds or superficial injuries. Mortality among individuals with and without additional injury were similar (43% versus 41%; \( P = 0.356 \)). Additional injuries in the burn cohort were therefore ignored in our subsequent analyses.

Our non-injury cohort comprised 25759 individuals. Table 1 summarizes the baseline sociodemographic characteristics and comorbidity scores for both study cohorts. Compared with the non-injury cohort, the burn cohort had significantly higher proportions of Aboriginal people, people who were socially disadvantaged and people living...
outside major cities. The adults in the burn cohort were also significantly more likely to have pre-existing comorbidity than those in the non-injury cohort.

Over the study period, 2498 (42%) of the adults in the burn cohort and 7018 (27%) of those in the matched non-injury cohort died. Unadjusted Kaplan–Meier survival plots for the overall burn cohort versus the non-injury cohort (Fig. 1), and for the three separate categories for burn severity versus non-injury (Fig. 2), all showed higher survival estimates for those who had not suffered burns. Log rank tests – in which the unadjusted equality of survivorship between the non-injury cohort and the total burn cohort ($P < 0.001$) or each of the three categories for burn severity ($P < 0.001$) was assessed – all indicated that there were excess deaths in the burn cohort.

Compared with the adults in the non-injury cohort who died during the study period, the adults in the burn cohort who died were younger at the time of death – with a median age of 76 years (interquartile range: IQR: 67–85) versus 82 years (IQR: 73–88; $P < 0.001$).

Over the 33-year study period, the adults in the burn cohort were followed up for 0.01–32.5 years (median: 9; IQR: 3–16) to give a total of 59,882 person-years while those in the non-injury cohort were followed up for 0.01–32.5 years (median: 13; IQR: 6–23) to give a total of 488,443 person-years. Over the study period, the burn and non-injury cohorts had all-cause mortality rates of 419.4 and 143.7 deaths per 10,000 person-years, respectively – giving an unadjusted mortality rate ratio for burn injury of 2.9 (95% confidence interval, CI: 2.7–3.0). After adjustment for year of admission, age, sex, Aboriginal status, social disadvantage, remoteness and pre-existing comorbidity, the overall long-term adjusted mortality rate ratio for burn injury was 1.4 (95% CI: 1.3–1.5). Mortality attributable to burns was 29% (Table 2).

The all-cause mortality rate among females was 538.7 deaths per 10,000 person-years in the burn cohort and 253.1 deaths per 10,000 person-years in the non-injury cohort, giving an unadjusted mortality rate ratio for burn injury of 2.1 (95% CI: 2.0–2.3). The adjusted mortality rate ratio for females was 1.6 (95% CI: 1.5–1.7). Among males, the all-cause mortality rate in the burn cohort was also higher than that in the non-injury cohort – 359.9 versus 126.0 deaths per 10,000 person-years – giving an unadjusted mortality rate ratio of 2.8 (95% CI: 2.7–3.0). The adjusted mortality rate ratio for males was 1.3 (95% CI: 1.2–1.4).

The results of Cox regression models for subgroups of the burn cohort, classified by burn severity and age, are presented in Table 2. In these models, after adjustment for potential confounders, all of the subgroups of the burn cohort had a higher risk of death than the non-injury cohort. Individuals aged at least 65 years when they experienced the burn injury had a lower attributable risk (23%), than individuals aged 55–64 years (33%) and individuals aged 45–54 years (38%).

Discussion

Current estimates of the mortality related to burns have usually been based on deaths in hospital or within a few weeks of discharge. In this study, however, follow-up lasted for a median of 9 years.

Up to the end of follow-up – and after adjusting for known potential confounders – our burn cohort was found to

![Fig. 1. Survival of all burn patients after hospital discharge and matched non-injured controls, Western Australia, 1980–2012](image1)

![Fig. 2. Survival of all burn patients by burn severity after discharge and matched non-injured controls, Western Australia, 1980–2012](image2)
have 1.4-fold higher all-cause mortality than the non-injury cohort. The excess long-term mortality attributable to burn injury was 725 of the 2498 total deaths recorded in the burn cohort. These 725 deaths after discharge represent 12% of those hospitalized for burn injury while only 3% died in hospital after the index admission. These results, which indicate that the long-term mortality from burns is much higher than indicated by in-hospital mortality data, challenge the definition of fatal outcomes used in most assessments of burn injuries.

Compared with the non-injury cohort, the subgroups of the burn cohort with severe burns, minor burns or burns of unspecified severity each showed significantly increased risk of all-cause mortality during the study follow-up. We failed to demonstrate a positive relationship between burn severity and mortality because, within the burn cohort, we found the mortality to be highest for those with minor burns. Explanations for this phenomenon may be that people with the most severe burns died during the index hospital admission and/or the survivors of severe burns included in the analyses represented a relatively more robust patient population.

While burn injury principally affects the skin, it is associated with depression of humoral and cell-mediated immunity, sustained high levels of oxidative stress and prolonged elevation of hypermetabolic and stress hormones. In children, metabolic and inflammatory changes have been found to last for at least three years after severe burns. Such changes have the potential to induce a range of health conditions including insulin resistance, increases in the risk of fracture, sepsis and infections, enlargement of the liver, cardiac stress and dysfunction, and hormonal abnormalities. Recent research has also shown elevated cancer incidence after burn injury, particularly among female burn survivors. Systemic responses are induced by both minor and moderate burns and may have contributed to the increased long-term mortality found, for both minor and severe burns, in this study. It has also been reported that patients who survive admission to an intensive care unit have poorer survival than the general population – perhaps indicating that any episode of critical illness or treatment for such illness can shorten life expectancy.

Our analysis by age group indicated that the mortality rate ratios – and consequent attributable risk percentages – for burn injury decreased slightly with increasing age. Although the proportion of deaths attributable to burn injury was smaller for the elderly individuals than the middle-aged or young-old individuals, the absolute number of deaths was greatest among the elderly individuals.

Some of the consequences of burn injury appear to be experienced long after the initial period of recovery. Minor burns in elderly people tend to lead to longer hospital stays and higher in-hospital mortality when compared with younger adults. Among elderly people, burn injuries may worsen pre-existing health conditions, hamper good nutrition, reduce mobility and independence and prevent them from regaining their previous state of health. An ageing population is characterized by an increasing prevalence of frailty.

The strengths of our study are the inclusion of a non-injured comparison group and a follow-up period designed to reveal the long-term mortality risk associated with burns among older adults. Previous single-centre studies have lacked a control group or followed patients for no more than two to three years. Long-term mortality of injury has been investigated previously, but with few burn cases. We assumed that, after adjustment for confounding, the excess in mortality in the burn cohort was predominantly associated with burn injuries. Our use of linked health administrative data enabled both the identification of a cohort of adults hospitalized for a first burn injury and the estimation of the pre-existing comorbidities in that cohort. We included indices of social disadvantage, geographical remoteness and access to services.

As a consequence of incomplete data for the percentage of the total body surface area affected for many people with burn injury, we were unable to show the effects of burn severity on long-term mortality. A non-injured control cohort was used to examine the potential systemic health impacts of trauma caused specifically by burn injury sufficiently serious to require hospitalization. Future research will examine potential differences between burn and non-burn injury and long-term health impacts.

The fact that the Western Australia hospital morbidity data system is assessed continually for both quality and accuracy strengthens our findings. Our main finding is expected to be generalizable to other populations with similar demographic characteristics and comparable health-care systems to those of Australia.

In conclusion, our findings that the long-term all-cause mortality was increased in the burn injury cohort suggest...
that any estimate of the mortality burden from burn injury based on in-hospital deaths alone will underestimate the true burden. These findings have implications for the clinical management of burn injury and should encourage the development of programmes for both long-term support for people with burn injury and the prevention of such injury.

Acknowledgements
The authors thank the staff of the health information linkage branch for access to the Western Australian data linkage system, the Western Australian health data custodians and the Western Australian department of health.

Funding: The project was supported by a Raine Medical Research Foundation Priming grant and a senior research fellowship (JMD) funded, via the Fiona Wood Foundation, by Woodside corporate sponsorship.

Competing interests: None declared.

Mortality à long terme des adultes âgés victimes de brûlures : une étude en population menée en Australie

Résumé

Méthodes Nous avons réalisé une étude longitudinale appariée en population, à partir de données administratives extraites des registres de décès et du système de données sur la morbidité des hôpitaux d’Australie occidentale. Une cohorte de 6 014 individus, âgés d’au moins 45 ans au moment de leur première hospitalisation pour brûlures, sur la période de 1980 à 2012, a été identifiée. Une cohorte comparative d’individus n’ayant pas souffert de brûlures a été aléatoirement sélectionnée dans les listes électorales d’Australie occidentale (n = 25 759) pour appariement avec la cohorte des patients victimes de brûlures. Nous avons utilisé des courbes de Kaplan-Meier et une régression des risques proportionnels de Cox pour analyser les données et obtenir les résultats.

L’étude a permis d’évaluer la mortalité à long terme des adultes âgés victimes de brûlures, notamment leur impact sur la mortalité des adultes au-delà de 45 ans. Les résultats montrent une augmentation significative de la mortalité à long terme chez les patients victimes de brûlures, indépendamment de la gravité de leur blessure. Ces résultats soulèvent l’importance de la prévention des brûlures et de la recherche sur des stratégies de soins et de soutien pour ce groupe d’âge. Les risques de décès augmentent également avec l’âge et la gravité de la brûlure, ce qui souligne l’importance de la prise en charge précoce et adaptée.

Conclusion Les résultats de cette étude soulignent l’importance de la prévention des brûlures et du suivi à long terme des patients victimes de brûlures, en particulier les adultes âgés. Les stratégies de prise en charge devraient être adaptées à l’âge et à la gravité de la brûlure pour minimiser le risque de décès à long terme.
La mortalidad a largo plazo entre los adultos de edad avanzada con quemaduras: un estudio poblacional en Australia

Objetivo.
Evaluar si las quemaduras en adultos de edad avanzada están asociadas con los cambios en la mortalidad por todas las causas a largo plazo y estimar el aumento del riesgo de muerte atribuible a las quemaduras.

Métodos.
Se llevó a cabo un estudio poblacional longitudinal emparejado sobre la base de datos administrativos proporcionados por el sistema de datos de morbilidad y el registro de defunciones de los hospitales de Australia Occidental. Se identificó una cohorte de 6014 individuos que tenían como mínimo 45 años cuando fueron hospitalizados con quemaduras. La cohorte fue comparada con una subcohorta de personas que no habían sufrido quemaduras seleccionadas aleatoriamente del censo electoral de Australia Occidental (n=25 759), con los pacientes. Se utilizaron el método de Kaplan-Meier y la regresión de Cox de riesgos proporcionales para analizar los datos, las razones de tasas de mortalidad generados y los porcentajes de riesgo atribuible.

Resultados.
De todos los hospitalizados con quemaduras, 180 (el 3%) murieron en el hospital y 2498 (el 42%) murieron después de haber sido dados de alta. Los individuos con quemaduras tenían una tasa de mortalidad 1,4 veces mayor a la de los individuos sin quemaduras (intervalo de confianza, IC, del 95%: 1,3–1,5). En esta cohorte, la mortalidad a largo plazo atribuible a las quemaduras resultó ser del 29%. El riesgo de mortalidad se incrementó tanto por quemaduras graves como por quemaduras leves, con unas razones de tasas de mortalidad ajustadas de 1,3 (IC del 95%: 1,1-1,9) y 2,1 (IC del 95%: 1,9-2,3) respectivamente.

Conclusión.
Las quemaduras están asociadas al aumento de la mortalidad a largo plazo. En nuestra población de estudio, confiar exclusivamente en los datos relativos a las muertes en hospitales llevaría a una subestimación de la verdadera carga de mortalidad asociada con las quemaduras.
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