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Pressure injuries in Australian public hospitals: A cost of illness study

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ABSTRACT

Background: Pressure injuries are a leading hospital adverse event, yet they are mostly preventable. Understanding their financial costs will help to appreciate the burden they place on the health system and assist in better planning and management of health expenditures to prevent pressure injuries.
Objective: To estimate the cost of pressure injuries in Australian public hospitals in 2020 demonstrating its economic burden in a well–resourced health system.
Methods: A cost of illness study with a 12-month time horizon was conducted. Resource use for the treatment of pressure injuries and productivity loss due to pressure injuries were derived using a bottom-up approach. Parameters of the cost estimates were obtained from secondary sources and literature syntheses. A simulation with 10,000 draws was used to generate statistical properties of the cost estimates.
Results: Based on a prevalence of 12.9%, the total cost of pressure injuries in Australian public hospitals was $9.11 billion [95% confidence intervals: 9.02, 9.21]. The two largest shares of costs were accounted for by the opportunity cost of excess length of stay of $3.60 billion [3.52, 3.68] and treatment costs of $3.59 billion [3.57, 3.60]. Productivity loss associated with pressure injuries amounts to $493 million [482, 504]. Hospital-acquired pressure injuries account for a total of $5.50 billion [5.44, 5.56], whereas pressure injuries present on admissions costed $3.71 billion [3.70, 3.72]. In terms of severity, Stage 2 pressure injuries contributed the most to total treatment costs, total excessive length of stay, and total loss of healthy life years. Australian society is willing to pay $1.43 billion [1.40, 1.45] to save 6,701 [6,595; 6,807] healthy life years lost by pressure injury.
Conclusions: Reducing preventable pressure injuries and stopping the progression of Stage 1 pressure injuries will likely result in an immense cost-saving for Australia and will likely have similar benefits for other countries with comparable profiles.
Tweetable abstract*:* Australian public hospital study provides comprehensive analysis of the cost of pressure injury, including estimates of direct and indirect medical costs, and indirect non-medical costs - such as productivity and quality of life.

What is already known

- Pressure injuries are a potentially preventable adverse event that occurs in about 13% of overnight hospitalised patients.
- Pressure injuries have adverse consequences for patients, their families and the health system.
- Costs for treating pressure injuries are consistently estimated to be larger than costs for prevention.

What this paper adds

- The total cost of pressure injuries in Australian public hospitals in 2020 was approximately $9.11 billion per year, of which treatment cost was $3.59 billion.
- Hospital-acquired pressure injuries account for over half of total costs, with a total of $5.50 billion per year.
- Stage 2 pressure injuries contributed the most to total treatment costs, excessive length of stay, and loss of healthy life years.
- Reducing hospital-acquired pressure injuries by 50% would result in saving hospitals $1.10 billion in treatment costs.

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1. Introduction

Pressure injuries, also referred to as pressure ulcers, are one of the most common complications in many hospitals world-wide (Rodgers et al., 2020; Padula and Delarmente, 2019; Slawomirski et al., 2017). Hospital-acquired pressure injuries are an important indicator of the quality of care in hospitals (Michel et al., 2009; Fernando-Canavan et al., 2021). Prevention, early diagnosis, and treatment of pressure injuries is, therefore, a global priority, formalised in international and national safety and quality health service standards (Australian Commission on Safety and Quality in Health Care 2017; Agency for Healthcare Research and Quality 2014; Power et al., 2012). Despite efforts to reduce this adverse health outcome, their prevalence remains high at 12.9% of all overnight hospital admissions (Rodgers et al., 2020). Pressure injuries are also associated with poor patient outcomes such as reduced quality of life due to pain and psychological distress (Gorecki et al., 2009; Kim et al., 2019), as well as excess hospital length of stay (Graves and Zheng, 2014; Hauck et al., 2017).

Pressure injuries are costly. Almost a decade ago, Nguyen et al. Nguyen et al. (2015) estimated pressure injuries costs in Australian public hospitals revealed that pressure injuries incurred $983 million in treatment costs, and $820 million in costs associated with excess length of stay. In the United States, Padula and Delarmente Padula and Delarmente (2019) estimated cost of hospital-acquired pressure injury in 2016 was $US26.8 billion; 59% of the costs were attributed to more severe pressure injuries of Stages 3 and 4. They concluded that prevention and early intervention efforts had the greatest effect on lowering costs. In the United Kingdom, the treatment costs of pressure injuries ranged from £1.4 billion to £2.1 billion in 2000 (Bennett et al., 2004). Recent Organisation for Economic Co-operation and Development data showed that 15% of hospital expenditure was spent on treating safety failures with pressure injuries was the most burdensome (Slawomirski et al., 2017).

Demarré et al. (2015) conducted a systematic review of pressure injury costs and found that national treatment costs of pressure injuries varied from €338.86 million to €2.59 billion in 2002. They also found that only two out of 17 reviewed studies included indirect costs and concluded that the costs to treat severe pressure injuries was higher than prevention. We updated the literature search from Demarré et al. (2015) and found no additional studies that estimated the indirect non-medical costs of pressure injuries, such as costs associated with productivity and quality of life loss, which are commonly used in health economics (Annemans, 2008). The inclusion of indirect non-medical costs represents a comprehensive approach to health economic evaluations and reflects the societal impact of pressure injuries. These indirect costs may account for a large proportion of total costs, and their omission may reflect significant inaccuracies in the societal cost, and ultimately leading to suboptimal decision making (Krol et al., 2011). Further, there are no previous study estimates that cost both hospital-acquired pressure injuries and those present on hospital admission. Hospital-acquired pressure injuries refer to pressure injuries that occur during an inpatient hospital stay (Rondinelli et al., 2018), while pressure injuries on admission refer to pressure injuries that are acquired in the community and are present when patients present to the hospitals (Rodgers et al., 2020).

This study aims to estimate the cost of pressure injury for Australia using the latest available data and including the costs of productivity loss and reduction in quality of life associated with pressure injuries. We also estimate hospital costs associated with both hospital-acquired pressure injuries and pressure injuries present on admission.

2. Methods

In this cost of illness study, we applied a bottom-up approach (estimate total costs from the lowest level of detailed quantities and aggregate up) to estimate the cost of pressure injury using a 12-month time horizon. Pressure injury cost was estimated using 2020 data of overnight separations across Australian states and territories, including prevalence rates and other parameters synthesised from the literature. We classified pressure injury costs into two groups: direct and indirect costs. In this study, direct costs included treatment cost (direct medical costs), and indirect costs include the opportunity cost of increased length of stay (indirect medical costs), and costs associated with quality of life loss and productivity loss (indirect non-medical costs). These components of pressure injury costs were estimated as follows:

(1) Treatment costs (which are direct medical costs) were estimated using pressure injury treatment cost per separation in each of the four pressure injury categories in the United Kingdom reported by Dealey et al. Dealey et al. (2012), who tallied resources required to treat pressure injury in each stage by the treatment protocol (European Pressure Ulcer Advisory Panel 2019), and multiplied their respective prices to estimate the pressure injury treatment costs for Australia. Since both Australia and the UK follow the same international guidelines for pressure injury treatments (European Pressure Ulcer Advisory Panel 2019; Queensland Health 2021), it is reasonable to assume that the resources required for pressure injury treatment in both countries were similar. A previous pressure injury cost study in Australia also applied the unit cost of pressure injury treatment in the United Kingdom (Nguyen et al., 2015). We updated the unit cost of pressure injury treatment in Australia from Nguyen et al. (Nguyen et al., 2015) using the Australian consumer price index Australian Bureau of Statistics, Consumer Price Index (2020). Total treatment costs were estimated by multiplying the unit cost with the number of pressure injury separations in each pressure injury stage. The number of pressure injury separations by stage was, in turn, estimated by multiplying the overnight separations in 2019–2020 period (Australian Institute of Health and Welfare 2020), the prevalence rate of pressure injury (Li et al., 2020), and the proportion of each pressure injury by stage (Rodgers et al., 2020).

(2) Excess length of stay due to pressure injury (indirect medical costs) represents an opportunity cost to hospitals as these excess bed-days could be used to admit other patients. This study calculated excess length of stay associated with each pressure injury separation by Fernando-Canavan et al. Fernando-Canavan et al. (2021) and the average daily cost of overnight separations (Independent Hospital Pricing Authority 2020) to estimate the opportunity cost of each pressure injury separation. The total opportunity cost was estimated by multiplying the opportunity cost of each separation with the number of pressure injury separations.

(3) Adverse effects of pressure injury (indirect non-medical costs) include premature deaths or reduced quality of life due to pain and suffering. Hauck et al. (2017) estimated the number of healthy years lost due to premature deaths and reduced quality of life by hospital safety incidents, including pressure injuries. We used the rate of healthy years lost by pressure injury (Hauck et al., 2017) and the 2020 Australian population to estimate the total number of healthy years lost by pressure injury in Australia. The cost of quality of life loss was then estimated by multiplying the total number of healthy years lost and the value of a statistical life year in Australia (Office of Best Practice Regulation 2019).

(4) Excess length of stay resulting from pressure injury also incurred costs associated with absenteeism and reduced work hours (indirect non-medical costs) for patients, which is referred to as productivity loss cost. We estimated the productivity loss cost by multiplying the total excess length of stay

Table 1
Variable description and cost estimation.

	Variables/parameters	Descriptions	Sources
A	Number of overnight separations	Observed data	Australian Institute of Health and Welfare (2020b)
B	Population	Observed data	Australian Bureau of Statistics (2021b)
C	Pressure injury prevalence rate	Means 12.9%, 95%CI: [9.5%,16.8%] Beta distribution	Rodgers et al. (2020)
D	Hospital-acquired pressure injury prevalence rate	7.9% [5.7%, 10.3%] Beta distribution	Rodgers et al. (2020)
E	The proportion of pressure injury stages	44.8%, 42.1%, 5.2% & 6.9% for stages 1,2,3,4, respectively. Uniform distribution	Rodgers et al. (2020)
F	Cost per separation	$3028, $11,409, $19,231, $24,771 for stage 1,2,3,4, respectively. Uniform distribution	Nguyen et al. (2015) Australian Bureau of Statistics, Consumer Price Index (2020)
G	Excess length of stay	3.9 days [2.81,4.99] Gamma distribution	Fernando-Canavan et al. (2021)
H	Healthy life-years loss	26 years/100,000 population [24.7, 27.3] Gamma distribution	Hauck et al. (2017)
I	The statistical value of a life year	$213,000 Uniform distribution	Office of Best Practice Regulation (2019)
K	Average overnight hospital costs	$2347 Uniform distribution	Independent Hospital Pricing Authority (2020)
L	Proportion of employment in the population	62.8% Uniform distribution	Australian Bureau of Statistics (2021a)
M	Average wage earning	$1280.3/week Uniform distribution	Australian Bureau of Statistics (2020)
N	Recuperation rate	2 Uniform distribution.	Nghiem et al. (2021)
O	Treatment costs	$A \times C \times E \times F$	
P	Opportunity costs (excess length of stay)	$A \times C \times E \times G \times K$	
Q	Quality of life loss costs	$B \times H \times I$	
R	Productivity loss costs	$A \times C \times E \times G \times L \times M \times N$	
	Total pressure injury costs	$O + P + Q + R$	

Note: Parameters of Gamma and Beta distributions are generated from means and 95% CI collected from the literature. Uniform distributions are drawn within 10% of the means for variables that are less likely to vary substantially. Costs of hospital-acquired pressure injuries are estimated similarly using the hospital-acquired pressure injuries prevalence rate. Pressure injuries on admission costs are the difference between pressure injury costs and hospital-acquired pressure injuries costs. Due to the lack of prevalence rate of pressure injuries on admission, they are estimated as the difference between the prevalence rate of pressure injury and that of hospital-acquired pressure injuries.

(Fernando-Canavan et al., 2021) plus a recuperation period of the same length (Nghiem et al., 2021) with the average weekly earnings (Australian Bureau of Statistics 2020) and the proportion of people employed in Australia (Australian Bureau of Statistics 2021a; Australian Bureau of Statistics 2021b).

The total pressure injury cost was the sum of all four cost components. Costs of hospital-acquired pressure injuries were estimated based on their prevalence (Rodgers et al., 2020). Due to the lack of specific prevalence data for pressure injuries on admission, it was estimated as the difference between the prevalence of pressure injuries and that of hospital-acquired pressure injuries. Therefore, the estimated costs of pressure injuries on admissions only represented their hospital costs because the pre-hospitalisation period was not observed. Statistical properties (e.g., means and confidence intervals) of cost estimates were generated using a Monte Carlo simulation with 10,000 draws. Gamma distributions were used to simulate skewed outcomes such as added length of hospital stays and healthy life year loss, Beta distributions were used to simulate prevalence rates, and uniform distributions were used to simulate parameters that are less likely to vary, including the unit cost of pressure injury treatment, employment to population ratio, average earning and statistical value of a life year (Table 1).

Each cost component was estimated using the product of the average cost per separation and the number of separations. The number of separations is estimated by multiplying the prevalence rate with the population at risk of pressure injury. We assume that overnight separations are the population at risk of pressure injury because it is less likely that same-day hospital admissions will develop a hospital-acquired pressure injury. Detailed estimation methods for each cost component are presented below. The estimation of pressure injury costs in this study was conducted using *R* version 4.02 (R Core Team 2020).

2.1. Treatment costs

The unit cost of pressure injury treatment for each stage was updated from Nguyen et al. (2015) using the consumer price index of Australia between 2013 and 2019 (Australian Bureau of Statistics, Consumer Price Index 2020). The number of pressure injury separations for each stage was estimated using total overnight separations (Australian Institute of Health and Welfare 2020b), pressure injury prevalence rates (Rodgers et al., 2020), and the proportion of each pressure injury stage (Rodgers et al., 2020). Apart from stages 1 (44.8%), 2 (42.1%), 3 (5.2%) and 4 (6.9%), Rodgers et al. (2020) also reported 0.5% of pressure injury cases were unstageable, and 0.5% of cases were deep tissue injuries. Unfortunately, there was no unit cost information on the treatment of deep tissue and unstageable injuries. Deep tissues injuries occurred most frequently in heels (Coyer et al., 2017; VanGilder et al., 2010; Wynn, 2021), which as they evolve, are frequently able to be reclassified as a Stage 2 rather than a more severe stage. However, deep tissue injuries in other body positions (e.g., sacrum,coccyx, buttocks) are more likely to evolve to Stage 4. Thus, we reassigned half of the deep tissue injuries to Stage 2 and the remaining to Stage 4. We reassigned half of unstageable pressure injury to Stage 3 and the other half to Stage 4 pressure injury, because unstageable pressure injuries have been described as a severe group, which corresponds to Stages 3 and 4 (Smith et al., 2018) (Table 2). The unit cost of treatment for each pressure injury stage was estimated (Dealey et al., 2012),

Table 2
Average treatment cost and excess length of stay per PI stage.

PI Stage	Average treatment cost (A$)	Excess LOS (days)	Per cent of PI[a]
Stage 1	3028	1.54	44.80%
Stage 2	11,409	5.18	42.35%
Stage 3	19,231	7.00	5.45%
Stage 4	24,771	8.54	7.40%

[a]Rodgers et al. (2020) and adjusted for unstageable and deep tissue injuries. PI: Pressure Injury; LOS: length of stay.

using the costs of resources required by international guidelines (European Pressure Ulcer Advisory Panel 2019a). The original unit treatment costs, presented in British Pounds in 2011 (Dealey et al., 2012), were converted to Australian dollars in 2015 with adjustment for inflation, exchange rate and purchasing power by Nguyen et al. (2015). We undertook further adjustment for inflation to convert to 2020 Australian dollars by using the Australian consumer price index (Australian Bureau of Statistics, Consumer Price Index 2020). The treatment cost for each stage was estimated as the product of unit treatment cost and the number of pressure injury separations; and the total treatment cost was the sum of all stage costs (Table 2).

2.2. Excess lengths of stay

Excess hospital length of stay is considered as an opportunity cost for hospitals as these additional bed days could be used to treat other patients. Fernando-Canavan et al. (2021) reported the mean length of hospital stay resulting from pressure injury was 3.9 days with a 95% confidence interval from 2.81 days to 4.99 days. We assume that extra length of stay in each stage is proportional to the time to heal, which was 28, 94, 127 and 155 days for stages 1, 2, 3, and 4, respectively (Dealey et al., 2012). Using this assumption and the proportion of pressure injury cases by each stage (Rodgers et al., 2020), we estimated that the excess length of stay of pressure injury patients in stages 1, 2, 3 and 4 was 1.54, 5.18, 7.00 and 8.54 bed-days, respectively (Table 2). The total excess length of stay was estimated as the sum of excess length of stay associated with pressure injury separations in four stages. The total cost associated with excess length of stay was estimated by multiplying the total excess bed-days with the average cost per bed-day for overnight admissions, which was $2347 in the 2019–2020 financial year (Australian Institute of Health and Welfare 2020b).

2.3. Quality of life loss

Apart from treatment resources and excess length of stay, pressure injuries are associated with adverse health outcomes such as pain, discomfort and premature mortality. Effects of these adverse health outcomes can be represented as healthy life years loss. To our best knowledge, Hauck et al. (2017) was the only study that estimated the loss of healthy life years associated with patient safety incidence, including pressure injuries. They found that pressure injury was associated with 26 [24.7, 27.3] healthy life years loss per 100,000 population. This healthy life years loss was estimated as the difference between healthy life years of hospitalised patients with and without pressure injuries. Assuming that the healthy life years loss is proportional to the time-to-heal in each stage (Dealey et al., 2012), we estimated that healthy life years loss for stages 1, 2, 3, and 4 were 10.3, 34.5, 46.7 and 57.0 per 100,000 population, respectively. The cost of quality of life loss (Annemans, 2008) was estimated as the product of the total healthy life years loss and the value of a statistical life year in Australia, which was $213,000 for 2019–2020 period (Office of Best Practice Regulation 2019). The value of a healthy life year, which has been used in various cost of illness studies (Pezzullo et al., 2019; Watts et al., 2021), represents the willingness-to-pay of the Australian society to save one additional healthy year (Viscusi, 1993; Viscusi, 2014).

2.4. Productivity loss

Assuming that one bed-day of excess length of stay was associated with one day absence from work to recover from the illness (Nghiem et al., 2021), the cost of productivity loss was estimated as the total number of days absent from work, multiplied by the average earnings of $1280.3 per week (Australian Bureau of Statistics 2020), and the proportion of employed people in the population at 62.8% (Australian Bureau of Statistics 2021a).

3. Results

There were 395.9 [95% Confidence Intervals 394.8, 397.0] thousand pressure injury separations in Australia in 2020. Most pressure injuries were minor, including 177.5 [176.9, 178.0] thousand in Stage 1, and 167.6 [167.1, 168.1] thousand in Stage 2. In total, pressure injuries were associated with $9.11 billion [9.02, 9.21] in direct and indirect costs (Table 3). The direct medical (treatment) cost account for 39.4% (i.e., 3590.1/9112.4), while indirect medical

Table 3
Summary of results.

Outcomes	Stage 1	Stage 2	Stage 3	Stage 4	Total
Pressure injury cases ('000)	177.5 [176.9, 178.0]	167.6 [167.1, 168.1]	21.6 [21.5, 21.6]	29.3 [29.2, 29.4]	395.9 [394.8, 397.0]
Treatment cost ($m)	537.2 [535.4, 538.9]	1913.4 [1907.2, 1919.6]	414.7 [413.4, 416.1]	724.7 [722.4, 727.1]	3590.1 [3579.4, 3600.7]
Excess length of stay ('000)	272.1 [266.1, 278.0]	863.2 [844.3, 882.1]	149.9 [146.7, 153.2]	248.5 [243.0, 253.9]	1533.7 [1500.2, 1567.2]
Cost of excess length of stay ($m)	638.8 [624.8, 652.8]	2026.8 [1982.3, 2071.3]	352.0 [344.3, 359.7]	583.4 [570.6, 596.2]	3601.1 [3522.2, 3680.0]
Healthy life year loss (years)	1188 [1,169, 1,207]	3773 [3,713, 3,833]	655 [644, 665]	1085 [1,068, 1,102]	6701 [6595, 6807]
Cost of healthy life year loss ($m)	253.2 [249.1, 257.2]	804.0 [791.2, 816.8]	139.5 [137.3, 141.7]	231.3 [227.6, 234.9]	1428.0 [1405.3, 1450.6]
Cost of productivity loss ($m)	87.5 [85.6, 89.5]	277.6 [271.5, 283.8]	48.2 [47.2, 49.3]	79.9 [78.2, 81.7]	493.3 [482.4, 504.2]
Total pressure injury costs ($m)	1516.7 [1500.0, 1533.4]	5021.8 [4968.5, 5075.1]	954.5 [945.2, 963.8]	1619.4 [1603.9, 1634.8]	9112.4 [9018.1, 9206.8]

Note: Means are presented. 95% confidence intervals are in brackets.

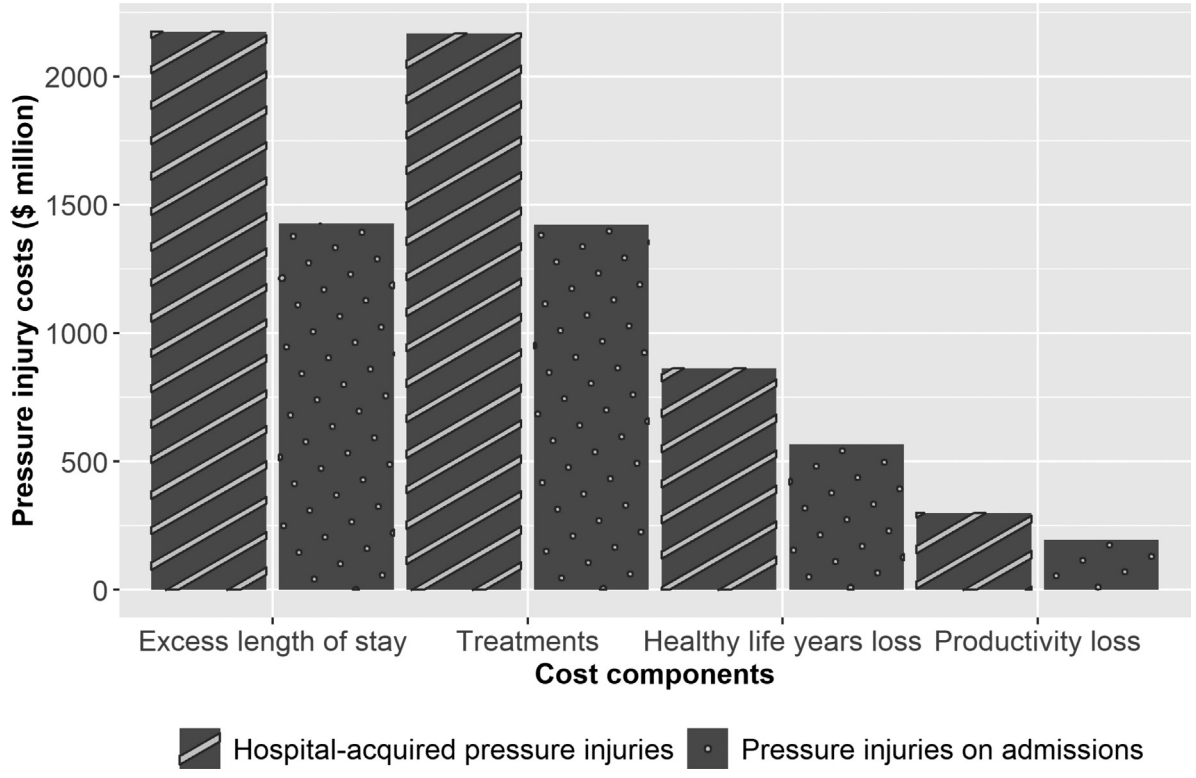

Fig. 1. Pressure injury costs by types and components.

and non-medical costs (i.e., excess length of stay, healthy life years loss, productivity loss) account for the remaining 60.6%.

The total treatment cost was $3.59 billion [3.58, 3.60], in which Stage 2 pressure injuries contributed the largest cost of $1.91 billion [1.90, 1.92], equal to 53.2%. While the costs per pressure injury (i.e., unit costs) were greater for Stage 3 and 4 PI (Table 1), because Stage 2 occurs much more frequently, their overall cost is higher than those of Stage 3 and 4. Pressure injuries were associated with 1.53 million bed-days [1.50, 1.57] of excess length of stay across Australian public hospitals. Stage 2 was the biggest contributor, accounting for 863.2 [844.3, 882.1] thousand bed-days (56.4%). The total opportunity cost associated with excess length of stay was $3.60 billion [3.52, 3.68], making it the largest component of pressure injury costs.

Pressure injuries were associated with a total loss of 6701 [6,595; 6,807] healthy life years as a result of premature deaths, pain and suffering. Using the latest guideline for the value of a statistical life year in Australia (Office of Best Practice Regulation 2019), the total cost associated with healthy life years loss by pressure injuries was $1.43 billion [1.40, 1.45]. Stage 2 is the largest contributor with 3773 [3,713; 3,833] healthy life years loss, which is valued at $804 million [791, 817]. Productivity loss associated with pressure injury accounts for a large sum of $493 million [482, 504] despite being the lowest cost component.

Amongst Australian states, New South Wales accounted for the largest share of pressure injury costs with a total of $2.89 billion [2.86, 2.92], followed by Victoria with $2.25 billion [2.22, 2.27], and Queensland with $1.92 billion [1.90, 1.94]. In contrast, the Northern Territory recorded the lowest estimated costs with $140.2 million [138.7, 141.7] (Appendix 1).

Appendix 2 As expected from the prevalence rates (12.9%, of which 7.9% were hospital-acquired pressure injuries), most of the pressure injury costs were associated with hospital-acquired pressure injuries (Fig. 1). Amongst the cost components, hospital-acquired pressure injuries treatment costs ($2.2 billion) are most notable because it represents the potential cost saving that hospitals have control over. Thus, if reducing hospital-acquired pressure injuries cases by 50%, Australian public hospitals would save $1.1 billion in treatment costs.

4. Discussion

This study presents a comprehensive analysis of the cost of pressure injury in Australian public hospitals and includes estimates of direct medical costs, indirect medical costs, and indirect non-medical costs such as productivity and quality of life loss. The estimated total cost of pressure injury in Australia in 2020 was $9.11 billion, of which treatment costs were $3.59 billion. Stage 2 pressure injury contributed 42.4% of the treatment cost. Treatment costs for Stage 4 pressure injury accounted for the second-highest proportion at 20.2% despite having only 7.4% of total pressure injuries cases. Indirect medical costs (excess length of stay) and indirect non-medical costs (healthy life years loss and productivity loss) accounted for 60% of the total pressure injury cost. These figures highlight the significant cost burden of pressure injury, with Stage 2 cost being three times higher than that of Stage 4, which rank as the second-highest total cost. This financial burden represents an urgent imperative for the continued improvement of the prevention of hospital-acquired pressure injuries in the acute care setting.

Our finding that hospital-acquired pressure injuries and their treatment account for the largest share of total costs are in line with the international literature. Hospital-acquired pressure injuries are common adverse events in many countries, with reported prevalence rates ranging from 6.4% to 17.6% in studies conducted in the United States, the United Kingdom, Sweden and elsewhere (Hauck et al., 2017; Padula et al., 2020b; Gunningberg et al., 2013; Al Mutairi and Hendrie, 2018). The estimated total treatment cost of $3.6 billion identified in this study accounts for 2.9% of government expenditure on health (Australian Institute of Health and Welfare 2020a). The proportion

of treatment pressure injury costs are in line with previous international studies, which ranges from 1.2% for the Netherlands to 5.2% for Spain (Bennett et al., 2004; Franks, 2007; Russo et al., 2006; Severens et al., 2002; Stern et al., 2011). Given that health systems are striving to improve the quality of care while containing costs, our up-to-date findings support previous claims that it makes good monetary sense to invest in pressure injury prevention strategies (Padula and Delarmente, 2019).

The estimated pressure injury costs in this study were substantially higher than the previous estimate by Nguyen et al. Nguyen et al. (2015). This was primarily driven by differences in the estimate of the prevalence rate. Our study is based on the latest meta-analysis of 14 Australian studies (Rodgers et al., 2020), and is consistent with a systematic review of international studies by Li et al. (2020). Another difference was study also includes two additional components of indirect costs: healthy life years loss and productivity loss. Although hospitals do not bear the cost of healthy life years lost or lost productivity costs, ignoring these cost components would underestimate the total cost of pressure injury to society. In this era, where health services are striving to be more patient-centred, considering these latter costs helps to better understand the burden pressure injuries pose to patients and their families. Finally, given our data on pressure injury prevalence was prior to the COVID-19 pandemic, and several studies have show treatments such as placing patients in the prone position which significantly increases pressure injury risk (Patton et al., 2021; Team et al., 2021; Binda et al., 2021; Ibarra et al., 2021; Jiang et al., 2021; Shearer et al., 2021), our costs may be underestimated.

An important finding of our study is that in terms of direct medical costs, less severe pressure injuries (Stage 2) are substantially more expensive to treat overall compared to more severe pressure injuries (Stage 3 and 4). While the unit cost of Stage 2 was $11,409 compared to the higher Stage 3 unit cost of $19,231 and Stage 4 unit cost of $24,771, Stage 2 accounts for a substantially larger proportion of the total pressure injury cases (i.e. 42%), compared to Stage 3 (5.4%) and Stage 4 (7.4%) (Table 2). Therefore, the overall cost for Stage 2 was $1.9 billion compared to $415 million and $725 million for Stage 3 and 4, respectively. Our findings are consistent with the findings of the European study by Demarré et al. (2015a), who reported the mean unit treatment cost for Stage 4 pressure injury was higher than stage 2 (€2500.00, €1709.50 respectively), yet the overall treatment cost for stage 2 (€69.25 million) was substantially higher than Stage 4 (€45.00 million). These have implications for health care providers, highlighting the economic imperative to focus on early recognition of pressure injury damage and prompt preventative interventions. Measuring sub-epidermal moisture appears to be one activity that may assist in early recognition, with a United States analysis showing its use may be cost-effective (Padula et al., 2020a). Additionally, the recent international guidelines provide numerous other recommendations for preventative strategies (European Pressure Ulcer Advisory Panel 2019b). Importantly, by reducing the prevalence of the most common types of pressure injuries (i.e., Stages 1 and 2), significant total pressure injury cost savings may be realised. These potential savings result from a reduction in pressure injury treatment cost, the reduction of associated length of stay costs, and from the downstream benefit of a reduced total number of Stages 1 and 2 that have the potential to progress to more severe pressure injury stages.

Additional costs associated with hospital-acquired pressure injuries relate to longer hospital length of stay, which can increase 2 to 3 times (Jackson et al., 2011). In some places, financial penalties are imposed on hospitals when patients develop pressure injuries (Nelson, 2003), as their prevention is considered an indicator of the quality of care and avoidable adverse events (Power et al., 2012). Prevention of hospital-acquired pressure injuries, therefore, has the potential to save healthcare dollars, free-up hospital beds and improve the overall quality of the patient's hospital experience, which are consistent with national and international priorities. Unnecessary pain and suffering experienced by patients with hospital-acquired pressure injuries may also explain the high number of legal claims for damages associated with preventable pressure injuries (Shreve et al., 2010; Van Den Bos et al., 2011).

Despite the treatment cost of pressure injuries is of most interest to hospital managers because it affects their operational budgets, indirect costs (i.e., excess length of stay, healthy life year loss, productivity loss) reveal the substantial economic impact of pressure injury on Australian society. The opportunity costs associated with excess length of stay estimated in this study is slightly higher than that of treatment costs ($3.59 vs $3.60 billion). This finding is in line with Nguyen et al. Nguyen et al. (2015), who reported that the opportunity cost excess length of stay was similar to that of treatment costs ($819 vs $893 million). The 6700 healthy life years loss by pressure injuries was higher than 5441 years loss by delirium (Pezzullo et al., 2019), but it accounted for only 0.13% of the total five million healthy life years loss to all diseases in Australia (Australian Institute of Health and Welfare 2021). The cost of productivity loss estimated in this study ($493 million) was slightly higher than that of delirium at $438 million (Pezzullo et al., 2019)

Appendix 1
Estimated pressure injury costs by components and locations.

States and territories	Treatment costs	Excess length of stay costs	Healthy life year loss costs	Productivity loss costs	Total costs
New South Wales	1139.2 [1135.8, 1142.6]	1142.7 [1117.7, 1167.7]	454.3 [447.1, 461.5]	156.5 [153.1, 160]	2892.7 [2862.8, 2922.7]
Victoria	878.3 [875.7, 880.9]	881 [861.7, 900.3]	370.3 [364.4, 376.2]	120.7 [118, 123.4]	2250.2 [2227.1, 2273.4]
Queensland	763.7 [761.4, 766]	766 [749.3, 782.8]	288.8 [284.2, 293.3]	104.9 [102.6, 107.3]	1923.4 [1903.4, 1943.5]
Western Australia	346.6 [345.6, 347.6]	347.7 [340, 355.3]	148.4 [146.1, 150.8]	47.6 [46.6, 48.7]	890.3 [881.1, 899.4]
South Australia	264.3 [263.5, 265.1]	265.1 [259.3, 270.9]	98.4 [96.9, 100]	36.3 [35.5, 37.1]	664.1 [657.2, 671]
Tasmania	69.8 [69.6, 70.0]	70.0 [68.5, 71.6]	30.1 [29.6, 30.6]	9.6 [9.4, 9.8]	179.5 [177.7, 181.4]
Australian Capital Territory	69.1 [68.9, 69.3]	69.3 [67.8, 70.8]	24.0 [23.6, 24.4]	9.5 [9.3, 9.7]	171.9 [170.1, 173.7]
Northern Territory	59.1 [58.9, 59.3]	59.3 [58, 60.6]	13.7 [13.5, 13.9]	8.1 [7.9, 8.3]	140.2 [138.7, 141.7]
Australia	3590.1 [3579.4, 3600.7]	3601.1 [3522.2, 3680]	1428 [1405.3, 1450.6]	493.3 [482.4, 504.2]	9112.4 [9018.1, 9206.8]

Appendix 2
Glossary.

Terms	Definition
QALY	Quality-adjusted life year. QALY ranges from 0 (death) to 1 (perfect health) although a negative QALY, which indicate worse-than-death suffering is possible.
Value of a statistical life year	An estimate of the value society places on a year of life.
Recuperation	The additional period that a patient stay off work after being discharged from hospital to recover and ready to return to work.
Direct costs	Expenditures that can be explicitly attached to the delivery of health services to manage pressure injury
Indirect costs	Costs involved with activities that are not directly associated with treatment of pressure injuries
Opportunity costs	Value of benefits forgone by not being able to take the best alternative option as a result of treating pressure injury (e.g., patients cannot work while hospitalised)
Time horizon	Period of time that the cost are predicted for from a start to a finish date
Productivity loss costs	The value of work absence or reduced working hours due to sickless
Opportunity costs	The value forgone by not taking the best alternative action
Healthly life years	Life years in perfect health
Bottoms-up costing approach	An approach to estimate cost from the lowest level of details. Costs for each item are estimated as the product of quantities (labour, machinery, materials) and their unit costs. The total costs are the sum of all itemised costs.

(£196.9 million in 2016, conversion to Australian dollars in 2020 was conducted using a web-based tool by Shemilt et al., 2010)).

5. Limitations

The pressure injury costs in this study may be under-estimated because several costs were not included. First, we did not include same-day hospital admissions to estimate pressure injury costs, assuming that pressure injuries were less common amongst patients of this group. Second, we did not include costs of pressure injury in non-hospital settings (e.g., nursing homes, community) because recent data were not available. Third, costs of pressure injury associated with private hospital admissions were also not included because private admission data were incomplete. Particularly, there was no information on private hospital overnight admissions for one state and two territories (Australian Institute of Health and Welfare 2020b). Fourth, we did not estimate additional costs associated with excess length of stay by pressure injuries. For example, excess length of stay may result in a lower number of patients treated and hence reduce funding in the next period under an activity-based funding model (Solomon, 2014). The excess length of stay may also create spill-over costs, such as increasing healthcare costs as a result of delayed hospitalisations of other patients. Finally, the costs reflect PI only and do not consider costs for any other conditions that can be associated with the development of a PI, such as limited mobility and serious illness.

6. Conclusion

This study presents an updated estimate of pressure injury costs in Australia using the latest data from administrative sources and parameters synthesised from Australia and New Zealand studies. Our comprehensive study estimated the cost associated with quality of life loss, which has not been examined in previous studies. The inclusion of these indirect medical costs presents a robust estimation of pressure injury costs for society, the individual as well as health care providers. While the cost estimates can vary with the choice of prevalence rate, the total costs of pressure injuries at $9.11 billion were substantially larger than previous estimates. amongst the cost components, excess bed days account for the largest share at $3.60 billion, followed by treatment costs of $3.59 billion. Reduction in hospital-acquired pressure injury prevalence and prompt treatment of Stage 1 injuries remains an important priority for health care providers and has the potential to result in significant savings.

Declaration of Competing Interest

None declared.

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Supplementary materials

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