Title: The costs arising from pressure ulcers attributable to malnutrition

Short Title: Cost of pressure ulcer attributable to malnutrition

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Non Standard Abbreviations:

AF – attributable fraction

$AU – Australian dollars

AIHW – Australian Institute of Health and Welfare

JCAHO – Joint Commission for Accreditation of Healthcare Organisations

P_e - exposure prevalence

PU – pressure ulcer

OR – odds risk

RR – relative risk

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ABSTRACT

The costs arising from pressure ulcers attributable to malnutrition

Aim:

To estimate the economic consequences of pressure ulcers attributable to malnutrition.

Method:

Statistical models were developed to predict the number of cases of pressure ulcer, associated bed days lost and the dollar value of these losses in public hospitals in 2002/2003 in Queensland, Australia. The following input parameters were specified and appropriate probability distributions fitted:

- Number of at risk discharges per annum
- Incidence rate for pressure ulcer
- Attributable fraction of malnutrition in the development of pressure ulcer
- Independent effect of pressure ulcer on length of hospital stay
- Opportunity cost of hospital bed day

One thousand random re-samples were made and the results expressed as (output) probabilistic distributions. ~~The mean and variance for each output distribution is presented.~~

Results:

The model predicts a mean 16060 (SD 5 671) bed days lost and corresponding mean economic cost of AU$12 968 668 (SD AU$4 924 148) (EUROS 6 925 268 SD 2 629 495; US$ 7 288 391 SD 2 767 371) of pressure

ulcer attributable to malnutrition in 2002/2003 in public hospitals in Queensland, Australia.

Conclusion:

The cost of pressure ulcer attributable to malnutrition in bed days and dollar terms are substantial. The model only considers costs of increased length of stay associated with pressure ulcer and not other factors associated with care.

Key Words*:* pressure ulcers, malnutrition, economic cost

Comment [QSOE1]: I would use US$ only

INTRODUCTION

Pressure ulcers are a major burden on health care systems. In the USA, the Joint Commission for Accreditation of Healthcare Organisations (JCAHO) estimates that there are between 1.3 and 3 million adults with pressure ulcer in the USA and that the costs of treatment of pressure ulcers are in the order of US$500 to US$ 40 000 per ulcer depending of the severity of the stage of the ulcer [1]. The annual cost of treating pressure ulcers in the UK was estimated to be approximately £ 750 million (1998 prices) with the total cost of treatment for a patient with a full thickness ulcer estimated at £ 30 000 [2].

An important part of the cost is the prolonged length of stay in hospital; bed days have a positive economic value if there are waiting lists for hospital services [2]. In an Australian study, the opportunity cost of prolonged length of hospital stay due to pressure ulcers was predicted. It was estimated that in 2001-2002 there was a median of 95 695 cases of pressure ulcer, with a median of 398 432 beds days lost, and associated opportunity costs of a median AU$285 million in Australian public hospitals [3].

Malnutrition has been shown to be associated with an increased risk of developing pressure ulcers in a number of studies [4-9]. Indeed, a study undertaken by this author has determined the effect of malnutrition on the presence of pressure ulcers in Queensland public hospitals. The odds risk of having a pressure ulcer when malnourished, when controlling for ~~a number of~~ demographic variables including age, medical specialty and type of facility, was 2.6 (95% CI 1.8-3.5, p<0.001) [10]. No studies have been published that

have examined the economic consequences of malnutrition in the development of pressure ulcers. Some studies have examined the impact of poor nutritional status on clinical outcome and extended length of hospital stays on the subsequent economic costs and found in all cases that malnutrition is associated with increased economic costs [11-16].

The purpose of this study was to estimate the economic consequences of pressure ulcers attributable to malnutrition.

METHODS

An economic model was developed to predict the cost of pressure ulcer attributable to malnutrition in Queensland (Australia) public hospitals in 2002/2003. The model consisted of the following input parameters:

A. the number of relevant discharges~~separations~~ from public hospitals in Queensland in 2002/2003

B. the incidence rate for pressure ulcers

C. the attributable fraction of malnutrition in the development of pressure ulcers

D. the independent effect of pressure ulcers on excess length of hospital stay

E. the cost of a patient bed day.

Figure 1 illustrates the model.

A probabilistic sensitivity analysis model was chosen. In probability sensitivity analysis, probabilistic distributions rather than fixed values are used to represent each input parameter, and samples are drawn at random from these distributions, to generate an empirical distribution of the results. The advantage of this approach is that it can simultaneously deal with a large number of variables and therefore uncertainty for each input parameter can be represented in the results of the model. Hence this approach provides a degree of confidence that can be attached to the results [22].

The methods used to determine values for input parameters are described next:

A. A value for the number of relevant dischargesseparations from Queensland public hospitals 2002/2003 was determined by obtaining the total dischargesseparations for all Queensland public hospitals for 2002-2003 excluding same day, mental health, maternity and paediatric separationsdischarges, from the Queensland Hospital Admitted Patient Data Collection, supplied by Health Information Services, Queensland Health. All overnight dischargesseparations which included an overnight stay were considered relevant except mental health, maternity and paediatric (<18 years of age) patients as no data is available on either the incidence of pressure ulcer or the association between malnutrition and pressure ulcer in these groups. Same day dischargesseparations were not considered relevant, because if the occurrence of pressure ulcer resulted in an increased length of stay then these patients would no longer be classified as same day patients.

B. A value for incidence for pressure ulcer in Queensland public hospitals was determined from the data collected by Graves et al (2005) [17] which compared the number of cases of pressure ulcer with the total number of discharges that occurred in a three month period during 2002 and 2003 in a Queensland tertiary public hospital.

C. A value for the attributable fraction (AF) of malnutrition in the development of pressure ulcer was estimated using Levin's formula, which estimates the population attributable fraction in case-control studies [18]:

$$AF = P_e (RR - 1) / 1 + P_e (RR - 1)$$

This formula determines the population AF in case controlled/ prevalence studies when the odds risk (OR) is a reasonable estimate of the relative risk (RR) and when the exposure prevalence (P_e) in the reference population is known. In this formula, P_e is the proportion of exposed individuals in the population and RR is the relative risk of having a pressure ulcer if malnourished. The value for the prevalence of malnutrition (P_e) was obtained from data provided by Banks et al (2007) [19] for the Queensland public hospital population in 2002 and 2003. In this multicentre study, Subjective Global Assessment was used to determine nutritional status by trained dietitians (ref) The value for the odds risk of having a pressure ulcer if malnourished was obtained from Banks 2008 [10] which determined the effect of nutritional status ~~malnutrition~~ on the presence of pressure ulcers in Queensland public hospitals in 2002 and 2003, using logistic regression in a multivariable model controlling for age, gender, medical specialty and facility location (metropolitan, regional, rural/remote). In this study the presence and severity of pressure ulcers was assessed independently from nutritional status by trained auditors (usually nurses) using definitions followed by the Australian Wound Management Association (ref) These definitions are consistent with the European Pressure Ulcer Advisory Panel (ref.) A value for the relative risk was determined and compared with the odds risk value to confirm similarity prior to proceeding with the assumption that the OR could be substituted for the RR. The standard error (SE) of the AF was calculated using the following formula derived for case control data [18]:

$$SE(AF) = \sqrt{\frac{[c(b+d)]^2}{[d(a+c)]}\left[\frac{a}{c(a+c)} + \frac{b}{d(b+d)}\right]}$$

Comment [QSOE2]: I would put in the value here so the results and discussion makes sense ?33%. I am still a bit confused between the actual prevalence of malnutrition and then the value of C in Table 2. Perhaps this was where Reviewer 3 could not follow the stats. Sorry – but I reading this stone cold without any reference to your thesis.

Comment [QSOE3]: Make sure this goes in

where a, b, c and d are represented by corresponding figures in a standard layout two by two prevalence table (refer to Table 1).

D. A value for the independent effect of pressure ulcer on excess length of stay was taken from Graves et al. (2005) [17] .The setting for this research was a Queensland tertiary public hospital and the authors collected data regarding demographics and all observable risk factors that may contribute to excess length of stay for 1747 individuals. Excess length of stay was determined in comparison to the expected diagnosis related group (DRG) length of stay. The analysis of pressure ulcer on excess length of stay controlled for all other observable factors that may have also contributed to variation in excess length of stay, including age, gender, ethnicity, discharge destination, level of care, type of hospital, previous admissions, medical unit, diagnoses, complications, procedures, infection status, falls status, body mass index, severity of disease, wound status, presence of nasogastric tube, parenteral nutrition. -

E. The value of the cost of a patient bed day to the Queensland public health system was determined from Australian Hospital Statistics 2002-03 [20]. A high and low value was found. Because most of the costs of running a hospital are fixed in the short run [21], there will be few cash savings from releasing bed days. Instead the marginal bed day has an economic value in some alternate use and this is the value we sought.

Values for the model input parameters are presented in Table 2.

Using a probabilistic sensitivity analysis approach, o~~Probability distributions rather than fixed values were used to represent each model parameter. The advantage of this method is that uncertainty for each model parameter can be represented in the results of the model. O~~ne thousand samples were drawn at random from each distribution, using Microsoft Excel and Visual Basic Programming language, to generate an empirical distribution of the outputs. Probability distributions for specified input parameters were assigned according to standardized methodology for statistical modeling [22]. See the Statistical Appendix for more information.

Cost values were determined in Australian dollars (AU$) and then converted to US dollars (US$) as at 1 January 2003. The exchange rates on this date were AU$ 1 = 0.562 US$ (www.oanda.com)

Comment [QSOE4]: You mention US$ and UK pounds in the introduction so I would stick with US$ rather than introduce yet another currency.

RESULTS

The economic model predicts a mean of 3666 (SD 555) cases of pressure ulcer attributable to malnutrition in Queensland public acute hospitals in 2002/2003 (Figure 2). There were approximately 2.4 million patient bed days in Queensland public hospitals in 2002/2003 [20]. The mean number of bed days lost to pressure ulcer that were attributable to malnutrition was predicted to be 16050, which represents approximately 0.67% of total patient bed days in Queensland public hospitals in 2002/2003 (Figure 3). ~~Values for the model input parameters are presented in Table 2.~~ Summary statistics for model outputs are shown in Table 3 and histograms of the outputs are shown in Figures 2, 3 and 4. ~~This model predicts a mean of 3666 (SD 555) cases of pressure ulcer attributable to malnutrition in Queensland public acute hospitals in 2002/2003 (Figure 2). There were approximately 2.4 million patient bed days in Queensland public hospitals in 2002/2003 [20]. The mean number of bed days lost to pressure ulcer that were attributable to malnutrition was predicted to be 16050, which represents approximately 0.67% of total patient bed days in Queensland public hospitals in 2002/2003 (Figure 3).~~ The corresponding mean economic cost of pressure ulcer attributable to malnutrition in Queensland public acute hospitals in 2002/2003 was estimated to be US$ 7 288 391 (SD 2 767 371) (AU$ 12 968 669 ~~+~~ (SD$ 4 924 148) (see Figure 4) ~~(EUROS 6 925 268 SD 2 629 495; US$ 7 288 391 SD 2 767 371).~~

Comment [QSOE5]: It seems better to put the input values into the methods where the details have been explained. I realised they are results but it just makes it easier to read.

DISCUSSION

The modelling undertaken for this study predicts that the cost of malnutrition on the Queensland public health system, measured in bed days ~~are~~ is substantial at US$ 7.28M ($AU13 million). ~~The~~ This mean dollar value ~~of approximately $AU13 million~~ does not represent actual cash savings, but rather the opportunity cost of patient bed days not available for use by other patients. Bed days were chosen in this study to determine economic costs, due to a current lack of beds available for patients requiring hospital treatment, contributing to waiting lists in many public metropolitan and regional hospitals in Queensland [23,24]. A reduction in the incidence of pressure ulcer attributable to malnutrition, would increase hospital throughput and reduce waiting lists as previously blocked beds would be made available, and hence bed days were considered a valuable currency for this research. Increased throughput would have implications for operating costs of the hospital as variable costs would be expected to increase [25]; however increased throughput is considered to be highly valuable to the public health system.

In this study, the opportunity costs of pressure ulcer attributable to malnutrition are predicted to be considerable at 33% of the total predicted opportunity costs from extended lengths of stay due to pressure ulcers (see section C Table 2). ~~Malnutrition is considered to be largely preventable [2,15,26] and hence a large proportion of pressure ulcers attributable to malnutrition are very likely preventable~~. This substantial attributable fraction was ~~whilst~~ estimated using an epidemiological approach based on an assumed ~~causal~~contributing pathway in which malnutrition ~~causes~~occurrs befor and influences pressure ulcer development, however causality between malnutrition and the

Comment [QSOE6]: This statement is contradictory. I am not really happy with the use of causality. One of your examiners warned against this. I have tired to reword.

development of pressure ulcers has yet to be established (Thomas 2006). It has been argued that the association of malnutrition and pressure ulcers has often not been adjusted for co-morbidity or other factors, and merely indicates that sicker patients are more likely to develop pressure ulcers (Thomas 2006). Patients with pressure ulcer are likely to manifest an inflammatory response from which it is difficult to distinguish malnutrition. One study however which did adjust for severity of illness when determining factors associated with developing pressure ulcers in the residential aged care setting, found oral eating problems and recent weight loss, strong predictors of malnutrition, remained independent factors for developing pressure ulcers (Horn 2004). Due to the multifactorial pathogenesis of pressure ulcers and the dependence between many factors associated with the development of pressure ulcer and malnutrition it is unlikely that a direct causal relationship will ~~be able to~~ be established. There is also the potential of reverse causality of pressure ulcers causing malnutrition. This is a recognized limitation of this study. However, the results of the estimated attributable fraction are ~~is~~ largely supported by the results of a meta-analysis study where the development of pressure ulcers in individuals was significantly reduced by nutritional support compared to standard care (OR = 0.74, 95% CI 0.62-0.88) [27]. The assumption in this study was that nutrition support was preventing and/or treating malnutrition, which in turn reduced the incidence of pressure ulcer. Hence the assumption that malnutrition may be considered a causal factor in pressure ulcer in the current study is considered reasonable.

The estimated opportunity cost savings described in this study represent a maximum value that might be achieved if there were no malnutrition. It is unlikely however that there would ever be no malnutrition, as malnutrition develops secondary to various disease states. But it is likely that in a large number of cases malnutrition can be prevented or the signs, symptoms and effects reduced if treated more appropriately [2,15,26], and this would have a large impact on the incidence of pressure ulcers (and other complications), and subsequent economic costs. Further work is required to estimate the cost effectiveness of nutritional interventions that reduce the incidence of pressure ulcers; and compare this with other strategies that claim to reduce the incidence of pressure ulcers.

This model only considers the costs of extended length of stay associated with pressure ulcers attributable to malnutrition and not other costs associated with treatment and care or broader patient burden issues. The additional costs saved from avoided cases of pressure ulcer with respect to treatment would also be substantial.

There are a number of limitations of this study, mainly related to the input parameters used in the model, and the assumption of ~~causality of between~~a direct link where malnutrition ~~and~~contributes to pressure ulcers as discussed above. The value for the incidence of pressure ulcer during admission was determined in one tertiary hospital over a three month period. However the value used (4.6%) is at the lower end of the 5-10% range reported in most other recently published studies [4,28-30], and may underestimate the total

number of pressure ulcers predicted and hence opportunity costs. The value for the prevalence of malnutrition was obtained from a population significantly older than the public acute care population and may have lead to an over estimate of the attributable fraction. However the value used (32.6%) is well within the range of other recently published studies [31-35]. The value for the excess length of stay due to pressure ulcers was determined in only one tertiary hospital and hence may not be applicable to apply across the entire state wide public hospital population [17]. Only one value was used for the excesstended length of stay for all stages of pressure ulcers, as reported by Graves et al (2005) [17]. Pressure ulcers are classified by the depth of tissue damage from Stage I (least) to Stage IV (most) [36]. It would be expected that different stages of pressure ulcer would result in differences in the extended length of stay, with Stage I unlikely to contribute to an extended length of stay, and and Stage IV contributing the most. However this figure is reported as a median for all stages of pressure ulcer and applied in this model accordingly to provide mean costs for all stages of pressure ulcer. In addition, the model which determined the independent effect of pressure ulcers on excess length of stay, which controlled for all other observable variables which may extend length of stay, only explained 18.7% of the variation in excess length of stay, hence there are other factors effecting excess length of stay that were not able to be observed. However the estimated independent median excess length of stay due to the presence of pressure ulcer of 4.31 days 95% CI, 1.85-6.78) is considered conservative and substantially less than previously reported (refs). Only the value of patient bed days lost to the hospital system from pressure ulcers was determined, and not other factors associated with treatment and

care and lost productivity due to pressure ulcers, and so the actual economic cost arising from pressure ulcers is likely to be underestimated.

Strengths of this modeling study are the use of local data to inform the input parameters and the use of sound epidemiological and economic analysis methods. This is the first research to determine the economic consequences of malnutrition, in relation to pressure ulcers, that uses a rigorous method.

CONCLUSION:

This study estimated approximately one third of pressure ulcers attributable to malnutrition in Queensland public hospitals in 2002/2003. This represents a substantial number (approximate mean of 16000) of patient bed days lost to pressure ulcers attributable to malnutrition, corresponding to a mean economic cost of approximately AU$13 million (EUROS/ US$ 7 million) for 2002/2003 in Queensland public hospitals. The cost effectiveness of nutrition intervention in the prevention of pressure ulcer requires investigation.

Comment [QSOE7]: Be consistent with the currency

Statistical Appendix

The values for the 'number of separations' were obtained from census data and so are fixed in the model. A Beta distribution was chosen for the 'incidence of pressure ulcer' parameter because this distribution is conjugate with the binomial and so used for probability data being restricted to values between 0 and 1, and is continuous [22]. A Beta distribution in Excel was specified using BETAINV (RAND) (α, β), with α representing the 'number of events' and β the 'number of nonevents'. The number of pressure ulcers reported by Graves et al (2005) [3] was used to specify α and the total number of discharges less the number of pressure ulcers reported was used to specify β. A Beta distribution was also chosen for the parameter 'attributable fraction of malnutrition' because this distribution is a prior for probabilities, restricted to values between 0 and 1 and is continuous [22]. A Beta distribution in Excel was specified as described above. The method of moments for the Beta distribution was used to specify α and β, where:

$\alpha = \bar{u}\,(\bar{u}\,(1-\bar{u})/\,s^2\,) - 1$ and $\beta = (\bar{u}\,(1-\bar{u}\,)/\,s^2 - 1) - \alpha$ [22]. The attributable fraction of malnutrition in the development of pressure ulcers and standard error were used to specify the mean ($\bar{u}$) and variance (s) respectively. The method of moments estimates population parameters such as mean, variance and median by equating sample moments with unobservable population moments and then solving those equations for the quantities to be estimated (en.wikipedia.org). In this case, the method of moments was used with population mean and standard deviation to determine the α and β. A Gamma distribution was fitted to the parameter that described 'increase in length of stay due to pressure ulcers' because it is constrained on the interval 0 to

positive infinity and is appropriate for the skew found in resource use data, such as length of stay [22]. The Gamma distribution in Excel was specified using GAMMAINV (RAND) (α, β). The method of moments for the Gamma distribution was used to specify α and β, where $\alpha = \bar{u}^2 / s^2$ and $\beta = s^2 / \bar{u}$ [22]. The observed sample statistics reported by Graves et al (2005) [3] were used to specify the mean ($\bar{u}$) and variance (s), respectively for the Gamma distribution. A uniform distribution was chosen for the parameter 'cost of a bed day' because of the equal likelihood of a cost value between the low and high value. The uniform distribution in Excel was specified using RAND (low value-high value) + high value.

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Authorship contributions:

Merrilyn D Banks (MB), Nicholas Graves (NG), Judith D Bauer (JB), Susan Ash (SA)

Conception and design of the study:

MB and NG

Analysis and interpretation of data:

MB and NG

Drafting of manuscript:

MB

Revision of manuscript:

MB, NG, SA, JB

Provision of significant advise:

NG, SA, JB

All authors read and approved the final manuscript.

Conflict of Interest Statement:

MB undertook this research as part of her Doctoral thesis at the Queensland University of Technology and NG, SA, JB were the doctoral supervisors. MB is an employee of Queensland Health, the organization in which this research was undertaken. SA had an honorary appointment in Queensland Health. There are no other financial or personal relationships regarding this research and the organization in which it was undertaken.

There are no real or potential conflicts of interest in relation to this work.

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560 **Table 1 : Presence of pressure ulcer by nutritional status in Queensland**

561 **public hospitals- 2002 and 2003 pooled data.**

		Presence of Pressure Ulcer		
Nutritional Status		Yes	No	
	Malnourished	264 (a)	456 (b)	720 (a+b)
	Not malnourished	249 (c)	1239 (d)	1488 (c+d)
		513 (a+c)	1695 (b+d)	2208 (a+b+c+c)

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565 **Table 2 Values for input parameters used in economic model**

Input parameter	**Data**	**Source**	**Type of distribution fitted**	**Statistics used for distribution**
A. Number of relevant discharges	241 415	Health Information Services	Fixed value	
B. Incidence of PU	81 cases from 1747 individuals (4.6%)	Graves et al 2005 [17]	Beta distribution	α= 81 β = 1666
C. Attributable fraction of malnutrition in the development of PU	33.5% SE = 3.2%	Prevalence of malnutrition data (See Table 1) [19] Odds risk of developing PU if malnourished OR=2.6 (95% CI 1.8-3.5) [10]	Beta distribution	α= 69.6 β = 143.5
D. Independent	4.31 (95% CI 1.85-6.78)	Graves et al 2005 [17]	Gamma distribution	α= 11.7 β = 0.37

effect of PU on mean excess LOS	days SE = 1.26 days		
E. Cost of a bed day in Queensland public hospital	$611 - $1008	AIHW (2004) [20]	Uniform distribution

PU = pressure ulcer

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574 **Table 3 Predicted mean, variance and range values for number of cases,**
575 **bed days lost to pressure ulcer, and economic costs of pressure**
576 **attributable to malnutrition in Queensland public acute hospitals**
577 **2002/2003.**

	Pressure Ulcer attributable to malnutrition		
	Cases of pressure ulcer	**Bed days lost to pressure ulcer**	**Economic Costs**
Mean ± SD	3666 ± 555	16050 ± 5672	$ 12,968,668 ± $4,924,148
IQR 25: 75	3284: 3996	12067: 18527	$9,390,510: $15,140,163
Min - Max	2225 - 5874	4463 - 44047	$ 3,139,176 - $38,332,431

578 min= minimum value; max = maximum value; IQR 25 :75 =Interquartile range
579 25%-75%

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