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The cost-effectiveness of a patient centred pressure ulcer prevention care bundle: Findings from the INTACT cluster randomised trial



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ABSTRACT

Background: Pressure ulcers are serious, avoidable, costly and common adverse outcomes of healthcare.

Objectives: To evaluate the cost-effectiveness of a patient-centred pressure ulcer prevention care bundle compared to standard care.

Design: Cost-effectiveness and cost-benefit analyses of pressure ulcer prevention performed from the health system perspective using data collected alongside a cluster-randomised trial.

Settings: Eight tertiary hospitals in Australia.

Participants: Adult patients receiving either a patient-centred pressure ulcer prevention care bundle (n = 799) or standard care (n = 799).

Methods: Direct costs related to the intervention and preventative strategies were collected from trial data and supplemented by micro-costing data on patient turning and skin care from a 4-week substudy (n = 317). The time horizon for the economic evaluation matched the trial duration, with the endpoint being diagnosis of a new pressure ulcer, hospital discharge/transfer or 28 days; whichever occurred first. For the cost-effectiveness analysis, the primary outcome was the incremental costs of prevention per additional hospital acquired pressure ulcer case avoided, estimated using a two-stage cluster-adjusted non-parametric bootstrap method. The cost-benefit analysis estimated net monetary benefit, which considered both the costs of prevention and any difference in length of stay. All costs are reported in AU\$(2015).

Results: The care bundle cost AU\$144.91 (95%CI: \$74.96 to \$246.08) more per patient than standard care. The largest contributors to cost were clinical nurse time for repositioning and skin inspection. In the cost-effectiveness analysis, the care bundle was estimated to cost an additional \$3296 (95%CI: dominant to \$144,525) per pressure ulcer avoided. This estimate is highly uncertain. Length of stay was unexpectedly higher in the care bundle group. In a cost-benefit analysis which considered length of stay, the net monetary benefit for the care bundle was estimated to be –\$2320 (95%CI –\$3900, –\$1175) per patient, suggesting the care bundle was not a cost-effective use of resources.

Conclusions: A pressure ulcer prevention care bundle consisting of multicomponent nurse training and patient

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education may promote best practice nursing care but may not be cost-effective in preventing hospital acquired pressure ulcer.

What is already known about the topic?

- Pressures ulcers are an avoidable adverse event that result in poor patient outcomes and escalate healthcare costs.
- Few studies have explored the cost-effectiveness of a patient-centred care bundle as a pressure ulcer prevention strategy.

What this paper adds

- This economic evaluation alongside a large cluster-randomised trial suggests a care bundle is unlikely to be cost-effective in preventing pressure ulcers but these findings are inconclusive.
- The largest contributors to prevention costs related to clinical nurse time for repositioning and skin inspection, which are components of best nursing practice.

1. Introduction

Pressure ulcers (PUs) are amongst the most common iatrogenic events associated with healthcare, and also one of the most costly. They have substantial impact on patients in terms of reduced health-related quality of life (HRQOL) and extended length of hospital stay (LOS) (Sebba Tosta de Souza et al., 2015; Hengstermann et al., 2007; Vetrano et al., 2014; Gorecki et al., 2009). In Australia, PUs are associated with a median increase of 4.3 days in LOS for acute admissions (Graves et al., 2005). In the USA, the mean LOS in patients who developed Stage II – IV PU during admission was significantly greater (20.9 days) than patients who did not develop PU (12.7 days) after adjusting for other predictors of LOS (Allman et al., 1999). This increase in LOS results in increased healthcare costs, ranking PUs as the fifth most costly complication in public hospitals in Australia (Jackson, 2011). The total cost attributed to PU in Australian public hospitals is estimated to exceed AU\$1.8 billion per annum (approximately US\$1.3 billion; AU\$ ~ US \$0.74 at June 2016) or 1.9% of public hospital expenditure (Nguyen et al., 2015). The majority of this cost is attributed to PU treatment (AU \$983 million) with the remainder being the opportunity cost associated with lost bed days (AU\$820 million or 525,000 bed days) (Nguyen et al., 2015). However, the cost of treating PU varies widely by Stage, with the mean treatment cost per patient ranging from AU\$2747 for Stage I to \$22,467 for Stage IV; whilst, the majority of additional bed days are attributed to Stage II to IV PU (Nguyen et al., 2015).

PUs are considered preventable, and as such are at the forefront of hospital safety agendas (Australian Commission on Safety and Quality in Health Care, 2011; Rosenthal, 2007; Power et al., 2012). Pressure ulcer prevention (PUP) has the potential for substantial improvements in HRQOL and to save the health system millions of dollars. Although the cost of PUP strategies per individual may be low (Demarre et al., 2015a, 2015b), the need for common application of these suggests an imperative to find the most cost-effective strategy. Few trials of PUP have included economic evaluations (Gillespie et al., 2014; Reddy et al., 2006). Thus, the cost-effectiveness of PUP remains poorly understood.

Pragmatic care bundles consisting of multi-faceted structured interventions have the potential to improve patient safety and quality of care in care settings through for example reduced falls and infections (Chaboyer et al., 2015; van Gaal et al., 2011; Boyd et al., 2011). Such interventions could have a beneficial impact on patients, their families and the health care system, through improved HRQOL and reduced hospital LOS. Patient-centred care bundles are now recognised as an important strategy to explore further in the quality and safety agenda (Chaboyer et al., 2015). The patient is arguably an underutilised

resource in care settings, representing an undervalued contribution to the health system.

PUP is one area high on the health quality and safety agenda where the potential economic benefits of a patient-centred care bundle have not been previously assessed. We performed a cost-effectiveness analysis (CEA) and cost-benefit analysis (CBA) using data from a pragmatic cluster-randomised trial (c-RT); the INtroducing A Care bundle To prevent pressure ulcer in at-risk patients (INTACT) trial (Chaboyer et al., 2015, 2016), to compare the direct healthcare costs and effects of a pressure ulcer prevention care bundle (PUPCB), relative to standard care.

2. Materials and methods

2.1. Study design

The INTACT trial recruited 1600 adult medical and surgical patients at risk of PU across eight tertiary hospital sites in Australia. The trial methodology and clinical findings have been detailed elsewhere (Chaboyer et al., 2015, 2016). Sites were stratified by PU incidence rate and randomised for patients to receive either (i) a multicomponent PUPCB program consisting of information and education resources targeted to patients (DVD, poster, brochure, face-to-face education) and nurse training package; or (ii) standard care which was aligned with regional guidelines. The primary outcome was incidence of hospital acquired pressure ulcer (HAPU) of any stage (Haesler, 2014). Hospital length of stay (LOS) was recorded for all participants and was used to estimate time in the study, with the study endpoint and therefore time horizon for economic evaluation being either diagnosis of a new HAPU, day of discharge or transfer to another hospital or critical care, or 28 days; whichever occurred first. The trial reported a HAPU incidence rate of 14.4 per 1000 person-days across the whole sample; 9.6 per 1000 person-days in the PUPCB group and 20.1 per 1000 person-days in the standard care group (incidence rate ratio 0.48; 95% CI: 0.33, 0.69; $p < 0.0001$) (Chaboyer et al., 2016). However, this reduction in risk was not statistically significant after adjusting for clustering and pre-specified covariates (adjusted hazard ratio 0.58, 95% CI: 0.25, 1.33, $p = 0.198$).

The economic evaluation was undertaken from the health system perspective using data collected alongside the trial, and evaluated the costs and benefits of PUP expressed as both the cost-effectiveness (the incremental cost of preventing an additional case of HAPU or of an additional day free of HAPU) and the cost-benefit (the net monetary benefits associated with the PUPCB). As the duration of the trial was less than one year, discounting was not applied to costs or benefits.

2.2. Cost and resource use data

Data on the cost of administering the PUPCB, including production of brochures, posters and DVD materials and nurse time to deliver the intervention to each patient, were collected for all trial participants. To supplement this, micro-costing data were collected during a 4-week observational period for each site (between September 2014 and February 2015) on a subsample of trial participants, targeting 40 from each site ($n = 320$ total subsample). This sample size reflected 20% of the trial cohort, and was considered sufficient to indicate the mean and distribution of resource use in the cohort. Detailed data on resource use related to PUP were collected by Research Assistants during usual working hours. The data were collected by direct observation of the subsample over an 8-h period, asking participants about events in the

other 16 h of a 24-h period, and auditing medical records. Observation occurred for each participant for a single consecutive period of eight daytime hours sometime between study days 2 and 6. Data from the subsample were used to determine the number of repositioning episodes per participant over the 8-h observation period, number of clinical staff required for each repositioning, and the nurse time required per turn. These data were combined to give the mean nurse time required per patient in the 8-h period, and then extrapolated to a 24-h period using patient self-report data on the number of turns for the other 16 h in the day of observation. The mean nurse turning time and mean number of skin inspections for 24 h for each cluster were extrapolated across all participants for each day in the study. Other resource use related to PUP such as the rate of patients consulting a dietitian was also recorded for the subsample and extrapolated to all trial participants.

Mean values for each hospital cluster from the subsample were applied to each trial participant dependent on their cluster. Thus, subsample data were used alongside PUPCB intervention and duration in the trial to estimate the total resource use and direct healthcare cost related to PUP per participant over the entire study period. Direct costs (inflated to AU\$ 2015 using the Consumer Price Index for Health December 2015 ABS, 2015 where applicable) were allocated to each resource unit using standard costing sources. Table 1 summarises the

resource utilisation data recorded in the main and subsample and the unit costs assigned.

2.3. Cost-effectiveness analysis

For the cost-effectiveness analysis, the primary measure of effectiveness was cases of HAPU prevented; this was aligned with the primary trial outcome (HAPU incidence) and was the outcome specified for the cost-effectiveness analysis in the trial protocol (Chaboyer et al., 2015). In addition, to account for any possible delay in developing a PU that might be associated with the intervention, a secondary analysis also used days remaining free of HAPU as an outcome. This was measured as the days in the study (i.e. from study enrolment until end point).

To provide insight into whether the PUPCB was cost-effective, the following values were assumed as willingness to pay thresholds for an improvement in outcome, from the perspective of the Australian health system. These values were based on an Australian study which estimated the costs of treating a HAPU by stage including the opportunity costs associated with associated LOS (Nguyen et al., 2015), converted to 2015 AU\$:

- (i) AU\$3060 or AU\$11,529.14 per additional HAPU Stage I or II

Table 1
Summary of resource data collection and costing methods.

Resource measured	Unit cost (AU\$)	Source for unit cost	Resource data collection, costing approach & assumptions
I. PUPCB Intervention			
Materials			
Photo shoot × 2	528	Commercial provider	Averaged ^a
Poster design	440	Commercial provider	Averaged ^a
Brochure design	690	Commercial provider	Averaged ^a
DVD speaker	50	Commercial provider	Averaged ^a
DVD production	4950	Commercial provider	Averaged ^a
DVD production (edit)	2600	Commercial provider	Averaged ^a
Art work	360	Commercial provider	Averaged ^a
Poster printing × 1000	390	Commercial provider	Averaged ^a
Brochure printing × 1000	390	Commercial provider	Averaged ^a
Time for nurses to receive training in PUPCB (nurse number trained; training duration mins)	45.34/hour	Hospital casual rate for Nurse Grade 5 level 4 (mid-range)	Averaged ^a . Hospital 1: (50;120) Hospital 2: (66;140) Hospital 3: (63;120) Hospital 4: (38;80)
Time to deliver PUPCB materials to patients	45.34/hour	Hospital casual rate for Nurse Grade 5 level 4 (mid-range)	Recorded for all trial participants
II. PUP strategies – nurse time			
Repositioning	45.34/hour	Hospital casual rate for Nurse Grade 5 level 4 (mid-range)	Subsample: number of nurses per turn, turns per patient and time per turn observed over 8-h, extrapolated to trial cohort. ^{b,c}
Skin inspection	45.34/hour	Hospital casual rate for Nurse Grade 5 level 4 (mid-range)	Subsample: number of skin inspections per patient observed over 8-h, extrapolated to trial cohort. ^{b,c} Assumes 5 min nurse time per skin inspection.
III. Other PU prevention			
Bed complements			
(a) Wedge	Per product: (a) 110 (0.33/day)	Hospital cost centre	Recorded for all trial participants. Cost of product annuitized, ^d then applied to number of days product was used, which was recorded for all trial participants.
(b) Elbow/heel bootie	(b) 55 (0.21/day)		
(c) Chair cushion	(c) 45.54 (0.13/day)		
(d) Air mattress/overlay mattress/special bed	(d) 10,000 (6.86/day)		
Nutrition			
(a) Dietitian consult	(a) 48.78 per hour	Hospital casual rate for Dietitian Grade HP3.4 (mid-range).	Subsample: dietitian consults per patient observed over 24-h using patient self-report, extrapolated to trial cohort. ^c Consult assumed to be 30 min.
(b) PUP specific nutritional care plan (high protein diet)	(b) 3 per day for high protein diet	Hospital cost centre	All participants: Number of days under care plan recorded
Skin care	2.40 per tube (100 g)	Pharmacy price of basic skin moisturiser (sorbolene)	One tube for each participant using skin cream, regardless of duration of use.

^a Averaged across all participants receiving PUPCB.

^b Extrapolated to 24-h using patient self-report for the non-observed 16-h (to maximum of 9 reposition episodes in 24 h).

^c Cluster-dependent mean in subsample extrapolated to trial, adjusted for number of days in study.

^d Annuitized, assuming a 1 year (a,b,c) or 5 year (d) life, no residual value, 5% discount rate.

prevented respectively.

- (ii) AU\$109.31 or AU\$110.67 per additional day free of HAPU Stage I or II respectively.

The willingness-to-pay for an outcome was estimated by weighting the thresholds above by the probability of PU stage observed in the clinical study (Chaboyer et al., 2016). In the clinical study, the standard care group experienced 35 more HAPU cases than the PUPCB group, of which 32 cases were stage I and 3 cases were stage II. After this weighting was applied, the willingness-to-pay thresholds used were A\$3786.43 per HAPU case avoided and A\$110.76 per additional day free of HAPU in 2015 dollars.

2.4. Cost-benefit analysis

As an alternative approach to assessing whether the PUPCB was of acceptable cost-effectiveness, a cost-benefit analysis was undertaken using hospital LOS as the outcome measure to reflect the benefits associated with preventing HAPU. The net monetary benefit (NMB) associated with PUPCB compared to standard care was estimated as [(incremental benefit x threshold) – incremental costs]. The threshold (willingness to pay) for a one day reduction in LOS was assumed to be the cost allocated to an additional long stay outlier for a patient with an Australian–Refined Diagnosis Related Group (AR-DRG) code J60-B (skin ulcer without catastrophic complications), which equates to AU \$813.64 per day (2014/5) (Independent Hospital Pricing Authority, 2014). Thus, a NMB of zero would suggest a break-even point (assuming this willingness to pay threshold), a positive NMB would favour the PUPCB, and a negative NMB would favour standard care.

2.5. Evaluation of differences in costs and benefits

Cluster-adjusted T-tests were used to compare costs for distinct resource items between groups. A two-stage cluster-adjusted non-parametric bootstrapping technique was employed (using 10,000 replications with replacement) to compare mean difference in the costs of prevention between groups, and to estimate the incremental cost-effectiveness ratios, along with 95% percentile method confidence intervals (CIs) around the point estimates (Ng et al., 2013). STATA (Version 13, StataCorp, USA) was employed for data analysis.

Table 2
HAPU related prevention costs by group.

	PUPCB (per patient)			Standard care (per patient)			P value ^a
	units	Cost (\$) Mean	± SD	units	Cost (\$) Mean	± SD	
(I) PUPCB Intervention							
Materials	NA	13.01	NA	NA	NA	NA	NA
Training Nurses	0.54 h	24.44	± 8.7	NA	NA	NA	NA
Deliver to Patients	0.16 h	7.19	± 4.1	NA	NA	NA	NA
(II) PUP strategies: nurse time (per patient extrapolated across LOS)							
Repositioning episodes	2.44 h	110.69	± 121.04	1.28 h	\$ 58.07	± 41.67	0.343
Skin Inspection	1.60 h	72.47	± 58.97	0.62 h	\$ 28.20	± 24.98	*0.014
(III) PUP strategies: Other PU prevention							
Bed Complements		7.57	± 21.14		6.50	± 15.83	0.711
(a) Wedges	0.37 days	0.12	± 0.37	0.26 days	0.08	± 0.35	0.622
(b) Elbow/heel bootie	0.15 days	0.03	± 0.12	0.10 days	0.02	± 0.11	0.630
(c) Chair cushion	0.43 days	0.06	± 0.21	0.24 days	0.03	± 0.13	0.397
(d) Air mattress	1.07 days	7.37	± 20.99	0.93 days	6.36	± 15.63	0.727
Nutrition		6.39	± 7.56		5.06	± 5.92	0.674
(a) Dietitian consulted	24/799	3.63	± 2.78	21/799	3.12	± 2.71	0.825
(b) Nutrition care plan	0.92 days	2.75	± 6.89	0.65 days	1.94	± 4.49	0.406
Skincare (creams)	2.62 days	1.60	± 1.13	1.47 days	1.16	± 1.20	0.320

NA Not applicable; * p ≤ 0.05.

^a P-value is significance for cluster-adjusted T-test between costs.

2.6. Sensitivity analysis

Hospital LOS may reflect the patient’s underlying condition and not any benefits of PUP, particularly given most PUs observed in the study were Stage I. Therefore, a sensitivity analysis was undertaken excluding long stay outlier participants whose LOS was above or below the mean plus two standard deviations for their intervention group. This assesses the robustness of the findings, assuming that LOS for ‘more complex’ patients is mainly based on their general medical condition and not only the presence of PUs.

3. Results

3.1. Study participants

The main trial enrolled 1600 patients and analysed 1598 (799 to each arm). The characteristics of trial participants have been reported previously (Chaboyer et al., 2016); participants were a median of 71 years old, 52% were female, and 10% had an existing PU at baseline. The sub-study included 317 participants, with between 29 and 46 patients recruited from each site. The subsample had similar characteristics to the overall trial sample with the exception that surgical admission patients were over-represented in the subsample (70%) compared to the full sample (34%).

3.2. HAPU related costs

Table 2 provides a comparison of the resource use and cost per participant, by individual resource type. The largest contributor to prevention costs related to clinical nurse time to reposition the patients or to inspect their skin. The intervention costs also contributed substantially for the PUPCB group. The other PUP strategy products and nutrition contributed relatively little to the costs. There was a significant difference between groups for the costs associated with skin inspection, which were a mean of \$44.27 more costly for PUPCB than for standard care (p = 0.014).

3.3. Differences in costs of prevention and outcomes

Table 3 shows the difference in prevention costs and outcomes. PUPCB is estimated to cost \$144.91 (95%CI \$74.96 to \$246.08) more per patient than standard care. With respect to outcomes, the cluster-adjusted bootstrap did not show a significant difference in the probability of avoiding a PU. However, PUPCB was associated with an

Table 3
Difference in costs and outcomes (two-stage cluster-adjusted bootstrap).

	PUPCB (per patient)	Standard care (per patient)	Difference per patient Mean (SE)		[95% CI]
Costs (per patient)					
Prevention costs	242.91	98.90	144.91	(44.09)	[74.96, 246.08]
Outcomes (per patient)					
Probability of avoiding a PU	0.93	0.89	0.04	(0.03)	[−0.03, 0.12]
Days free of PU	6.35	5.23	1.12	(0.37)	[0.34, 1.82]

increased number of days free of PU per participant (mean difference 1.12 days per patient, 95%CI 0.34–1.82).

3.4. Cost-effectiveness of the PUPCB

Table 4 presents the incremental cost-effectiveness ratio (ICER) estimates for PUPCB compared to standard care. PUPCB is estimated to cost an additional \$3296 per PU case avoided (95%CI dominant to \$144,525) or \$151 per additional day free of PU (95%CI \$57 to \$313) per patient. The point estimate for PU case avoided suggests that PUPCB may be cost-effective when making reasonable assumptions around the willingness to pay thresholds for a PU prevented (\$3786). However, conversely the point estimate for additional day free of PU suggests it may not be cost-effective given the assumed willingness to pay threshold (\$110 per additional day free of PU). Moreover, the estimate of cost-effectiveness is highly uncertain, as shown by the very wide confidence intervals and high proportion of points either side of the assumed willingness to pay threshold in the cost-effectiveness plane (Fig. 1).

Fig. 2 shows the cost-effectiveness acceptability curve for PUPCB compared to standard care. There is a 55.01% likelihood that the PUPCB intervention is cost-effective at an assumed willingness-to-pay threshold of A\$3786 per HAPU case prevented. PUPCB is more likely to be cost-effective than standard care at a willingness to pay threshold of \$3360 per PU avoided or above.

3.5. Length of stay (LOS) and cost-benefit of the PUPCB

Whilst the median LOS was 6 days in the PUPCB group compared to 5 days in standard care (cluster-adjusted non-parametric test $p = 0.06$) (Chaboyer et al., 2016), the mean LOS was 2.67 (95%CI 1.22 to 4.70) longer for PUPCB (10.46 days) than for standard care (7.78 days) (Table 5). This translates to an incremental benefit of \$2175 (95%CI \$991 to \$3824) driven by a lower LOS favouring standard care. After considering prevention costs, the NMB for PUPCB compared to standard care is −\$2,319.51 (95%CI −\$3,900.34, −\$1,174.84), suggesting PUPCB is not cost-effective as a PU prevention strategy.

However, 29 (3.63%) participants in PUPCB and 7 (0.88%) in standard care were defined as LOS outliers. When these outliers were excluded, the difference in mean LOS reduced to 1.12 (95%CI 0.39 to 1.91) days and the difference in mean benefit associated with LOS reduced to \$913 (95%CI \$320 to \$1554) favouring standard care. After removing outliers, the NMB for PUPCB compared to standard care is −\$1052.18 (95%CI −\$1,697.35, −\$437.70), which still favours standard care. Thus, based on the cost-benefit analysis, PUPCB was significantly more costly for significantly less benefit, than standard care, suggesting the care bundle is not a cost-effective use of resources.

4. Discussion

This economic study presents to our knowledge one of only two economic evaluations of a care bundle aimed at preventing one of the most burdensome and avoidable adverse events associated with hospital stay: pressure ulcer. The other evaluation was a literature-based modelling study in Denmark (Mathiesen et al., 2013). The care bundle presented in the current evaluation was patient-centred in nature, and the evaluation was undertaken alongside a large pragmatic c-RT

enrolling nearly 1600 patients, making it unique. Whilst the c-RT was equivocal (Chaboyer et al., 2016), it is possible for an intervention to be shown to be cost-effective even if clinical efficacy is not demonstrated (Briggs and O'Brien, 2001). However, this was not the case here. This study was unable to provide consistent, conclusive evidence on the cost-effectiveness of the PUPCB intervention for the prevention of HAPU, possibly due to a lack of power resulting from the small cluster size of the c-RT (8 hospital sites), along with the high variation observed in costs, and the robustness of assumptions (e.g. whether to consider length of stay as a potential benefit). Performing a study of sufficient size and design to provide conclusive evidence is likely to require a prohibitively large research budget.

The conclusion regarding cost-effectiveness of PUPCB in this study is dependent on the method used for analysis, and in particular, on the decision to include LOS costs in the cost-benefit estimate. The findings of the cost-benefit analysis, which consider LOS as a potential benefit of PUP, suggest PUPCB is not cost-effective in preventing PU, even after excluding outliers. The finding of a higher LOS (and therefore negative net benefit) in the PUPCB was unexpected and counter-intuitive to a priori expectations in our study. It might be hypothesised a priori that the PUPCB would be associated with lower rates of PU, and therefore LOS and its associated costs would be lower in the PUPCB group. We can only speculate why we found higher LOS in the PUPCB group. However, we think this is unlikely to be directly associated with the intervention. If we assume the difference in LOS benefits favouring standard care is a random anomaly rather than a systematic finding, then we might pay greater heed to the cost-effectiveness analysis which does not consider LOS, rather than to the cost-benefit analysis. The findings of the cost-effectiveness analysis, which do not consider LOS costs, suggest PUPCB is more likely than not to be cost-effective in preventing PU at the assumed thresholds, but this is not conclusive as there is a high level of uncertainty in the cost-effectiveness estimates.

In comparison to previous studies, the costs of prevention alone suggested by this study (AU\$98.90 for standard care and \$242.91 for PUPCB per patient) might be considered to be high. Demarre et al., undertook a systematic review of the cost of prevention or treatment of PUs, and reported the cost of prevention to vary between Euro 2.65 to 87.57 (approximately AU\$3.79 to \$125.18 at 16 Nov16) per patient per day, across all care settings (Demarre et al., 2015a). However, the studies contributing data to this review were mostly based on secondary data. It is possible that the data from our study which included a comparatively large observational microcosting substudy is more accurate. The previous Danish economic model concluded that labour intensive efforts via a care bundle aimed at reducing PUs can be cost-effective (Mathiesen et al., 2013). In fact contrary to our findings, their

Table 4
Cost-effectiveness of PUPCB compared to standard care.

Outcome	ICER (\$ per case prevented)	
	Mean (SE)	[95%CI]
Additional case of PU prevented	3296 (621272)	[−5068,144525]
Days PU prevented	151 (848)	[57,313]

ICER Incremental cost-effectiveness ratio.

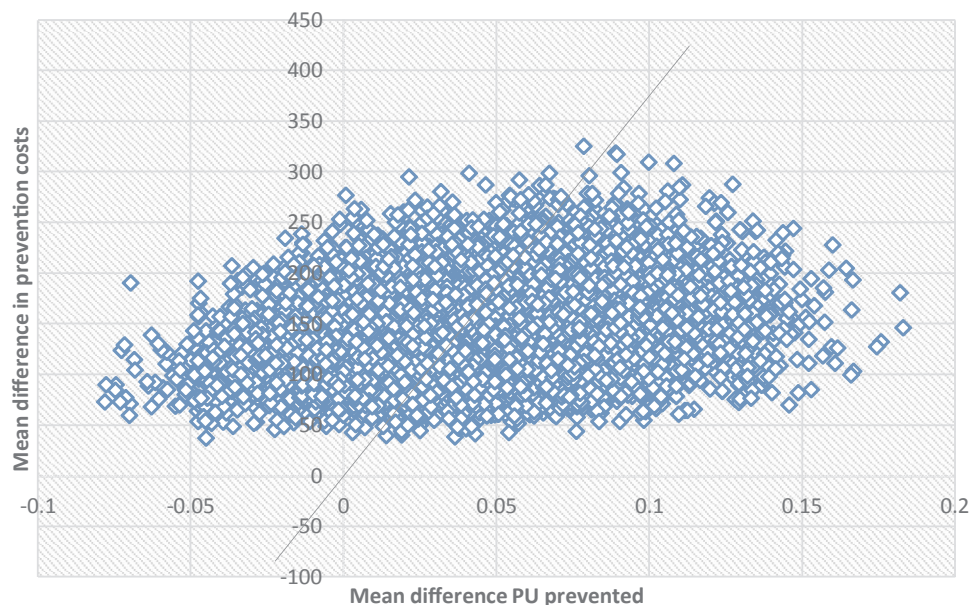


Fig. 1. Cost-effectiveness plane for PUPCB compared to standard care. Line indicates willingness to pay threshold of \$3,786 per HAPU avoided. Points to the right of this line are of acceptable cost-effectiveness at this threshold.

model suggested that the care bundle was likely to be dominant (both cost-saving and more effective at preventing PU than standard care). It could be that the higher apparent costs in our study are driven by our microcosting approach.

So what are the implications of the current study for a health authority that might be considering implementing PUPCB in their tertiary institution? While the main study provides no definitive answers, a decision based solely on the criterion of cost-effectiveness from these data and assuming the willingness to pay thresholds used in this study, would be unlikely to adopt PUPCB into clinical practice. A decision-maker might view the point estimates and considerable uncertainty as unacceptable, and want further evidence before adoption. However, the research costs associated with such a large trial are likely to be prohibitive. Further evidence balancing research costs against the value of implementing PUPCB could be gained by undertaking a value of information analysis (Claxton and Sculpher, 2006). However, this is a technical approach; data would still be based on one trial only, and undertaking such an approach would delay a decision.

Moreover, the implications of the findings are dependent on the choice of analytic approach, with conclusions regarding cost-

effectiveness dependent on the choice of cost-effectiveness analysis or cost-benefit analysis, and the associated decision whether to consider benefits associated with LOS in the analysis. A less risk adverse decision-maker might take the perspective that the intervention is patient-centred, reflects current international guidelines for PUP, might improve clinical practice, offers a low risk of clinical harm and is comparatively low cost for the intervention itself. Any decision would be context specific; however, if implemented, prospective data could be collected to indicate HAPU rates before and after implementation as an indicator of outcome and value for money.

Any conclusions regarding implementation of PUPCB should also consider that several elements that might be relevant for a decision were not included in the analysis. First, we used the PU stage observed in the c-RT with short term follow up (maximum of 28 days) on which to base our cost and benefit estimates. Once patients developed a PU (which was a study endpoint), they exited the study and were not followed up. While the main trial did not test the proposition that the PUPCB decreases the likelihood of Stage I/II progressing to Stage III/IV it is plausible that some of the Stage I and II HAPUs observed in the clinical trial may be anticipated to progress to higher stage PUs with

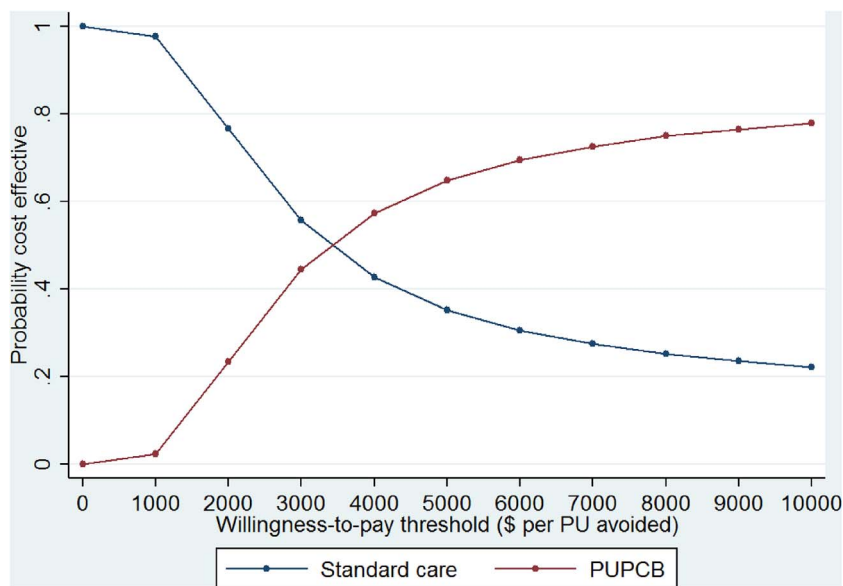


Fig. 2. Cost-effectiveness acceptability curve for PUPCB compared to standard care. The graph shows the probability PUPCB is cost-effective (y axis) for each of a range of different willingness-to-pay thresholds per HAPU avoided (x axis).

Table 5
Length of stay characteristics.

	PUPCB (per patient)	Standard care (per patient)	Difference per patient Mean (SE)	[95% CI]
LOS (days)	10.46	7.78	2.67 (0.96)	[1.22, 4.70]
LOS– excluding outliers (days)	8.54	7.41	1.12 (0.00)	[0.39, 1.91]
LOS benefit (\$)	–8507.07	–6331.93	–2175.14 (-4.13)	[–991.29, –3823.65]
LOS benefit – excluding outliers (\$)	–6944.47	–6031.42	–913.06 (0.50)	[–320.45, –1554.15]

LOS Hospital length of stay. LOS Outlier is defined to be an individual whose LOS is ≥ 2 standard deviations above or below the mean.

time. The cost of managing a stage III or IV PU (A\$17,442 or \$22,467 respectively (Nguyen et al., 2015)) is substantially higher than stages I or II. Moreover, to promote quality of care, some health authorities implement fines for the occurrence of HAPU in their facilities. For example in one Australian state, the Government fines facilities AU \$30,000 for each stage III and AU\$50,000 for stage IV HAPU (Queensland Health, 2012). US Medicaid does not reimburse hospitals for PUs, and in the UK the safety thermometer is used and hospitals are rewarded if their PUs lessen (Rosenthal, 2007; Power et al., 2012). As the analysis in this evaluation was undertaken from a health system perspective, this was not included in the estimate. Nevertheless, it would likely be a consideration for the acceptability of implementing PUPCB from an individual hospital perspective. Secondly, the higher costs in the PUPCB arm were associated in part with the increased nursing time required to turn patients and for skin inspection – which are considered to be components of good nursing practice. These may have benefits in addition to PUP such as providing an opportunity for the nurse to engage with the patient, providing education, and reinforcing participation in PUP. Finally, given the follow-up of patients was to hospital discharge or 28 days it was not feasible to record any changes in HRQOL for patients in the trial and it was considered unlikely to observe a HRQOL change in such a short time period. Nevertheless, any possible benefits in HRQOL have not been considered in the assessment of cost-effectiveness.

Our interpretation of the findings of this study are also based on an assumed willingness to pay threshold for PU prevention (\$3786.43 per PU prevented), which was equated to PU treatment costs reported in the literature, from a health system perspective. The treatment cost adopted from the literature was based on an Australian cost-of-illness study by Nguyen et al. (Nguyen et al., 2015) which adopted selected data from a UK study by Dealey et al. (Dealey et al., 2012) and included direct health system costs (in hospital and in the community) to heal a PU. These costs related to nursing time for risk assessment, monitoring and repositioning, skin dressings, moisturiser, antibiotics, analgesics, supporting surfaces, wound debridement, the management of complications in a small proportion (2.5 to 5%) of those with Stage II PU, and for the indirect opportunity costs of any associated increase in length of stay. Thus, the willingness to pay threshold used to interpret the study is an estimate only, and takes no account of the value patients might place on preventing a PU and its consequences, which could include reduced quality of life, increased stay in hospital, negative impacts on productivity, and informal care costs, particularly with higher stages of PU. A more holistic value for PU prevention could be assessed directly from patients and the public more widely using stated preference methods such as discrete choice experiments or contingent valuation.

4.1. Limitations

As already indicated, the main limitation of this study is its inadequate power to give definitive guidance on cost-effectiveness, driven by an inadequate sample size and/or cluster size, the comparatively small and unproven clinical benefit, the considerable patient heterogeneity, and the short follow up. Sample size calculations were not performed based on economic outcomes before conducting the economic evaluation. The equivocal findings of this economic

evaluation highlight the need to consider the potential role of large administrative datasets alongside trial data to estimate the costs and benefits associated with interventions for the prevention of events such as HAPU, where costs are highly variable and the highest cost events (Stages II to IV) are comparatively rare. The current analysis also assumed that resource use measured for the subsample on selected days applied to the whole trial cohort across the time they were enrolled in the study. However, measuring these resources for all patients was not feasible for logistic reasons.

5. Conclusion

Overall, this study suggests a PUPCB consisting of multicomponent nurse training and patient education strategies may encourage good nursing practice but may not be cost-effective in preventing HAPU. If PUPCB were to be implemented into practice in adult tertiary acute care institutions, consideration should be given to collecting further evidence alongside implementation to indicate real world costs and outcomes, and to confirm any impact on LOS.

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Ethical approval

This study was approved by the following Human Research Ethics Committees: Gold Coast Health HREC/13/QGC/192, The Alfred Hospital 202/14, St Vincent's Private Hospital (Sydney) 14/109 LNR SSA AU/7/8748115, Cabrini 14-12-05-14, Eastern Health HREC/13/QGC/192, Griffith University 2014/196, University of the Sunshine Coast A/14/628, University of Queensland 2014001380. Participants gave informed consent prior to participating in the study.

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References

- Australian Bureau of Statistics (ABS), 6401.0 – Consumer Price Index, Australia, December 2015 [Table 7] Canberra : ABS, December 2015.
- Allman, R.M., Goode, P.S., Burst, N., Bartolucci, A.A., Thomas, D.R., 1999. Pressure ulcers, hospital complications, and disease severity: impact on hospital costs and length of stay. *Adv. Wound Care* 12 (1), 22–30.
- Australian Commission on Safety and Quality in Health Care, 2011. National Safety and Quality Health Service Standards. ACSQHC, Sydney.
- Boyd, S., Aggarwal, I., Davey, P., Logan, M., Nathwani, D., 2011. Peripheral intravenous catheters: the road to quality improvement and safer patient care. *J. Hosp. Infect.* 77 (1), 37–41.
- Briggs, A.H., O'Brien, B.J., 2001. The death of cost-minimization analysis? *Health Econ.* 10 (2), 179–184.
- Chaboyer, W., Bucknall, T., Webster, J., McInnes, E., Banks, M., Wallis, M., et al., 2015. Introducing A Care bundle To prevent pressure injury (INTACT) in at-risk patients: a protocol for a cluster randomised trial. *Int. J. Nurs. Stud.* 52 (11), 1659–1668.
- Chaboyer, W., Bucknall, T., Webster, J., McInnes, E., Gillespie, B.M., Banks, M., et al.,

2016. The effect of a patient centred care bundle intervention on pressure ulcer incidence (INTACT): A cluster randomised trial. *Int. J. Nurs. Stud.* 64, 63–71.
- Claxton, K.P., Sculpher, M.J., 2006. Using value of information analysis to prioritise health research: some lessons from recent UK experience. *Pharmacoeconomics* 24 (11), 1055–1068.
- Dealey, C., Posnett, J., Walker, A., 2012. The cost of pressure ulcers in the United Kingdom. *J. Wound Care* 21 (6), 261–262 (4, 6).
- Demarre, L., Van Lancker, A., Van Hecke, A., Verhaeghe, S., Grypdonck, M., Lemey, J., et al., 2015a. The cost of prevention and treatment of pressure ulcers: a systematic review. *Int. J. Nurs. Stud.* 52 (11), 1754–1774.
- Demarre, L., Verhaeghe, S., Annemans, L., Van Hecke, A., Grypdonck, M., Beeckman, D., 2015b. The cost of pressure ulcer prevention and treatment in hospitals and nursing homes in Flanders: a cost-of-illness study. *Int. J. Nurs. Stud.* 52 (7), 1166–1179.
- van Gaal, B.G., Schoonhoven, L., Mintjes, J.A., Borm, G.F., Hulscher, M.E., Defloor, T., et al., 2011. Fewer adverse events as a result of the SAFE or SORRY? programme in hospitals and nursing homes. part i: primary outcome of a cluster randomised trial. *Int. J. Nurs. Stud.* 48 (9), 1040–1048.
- Gillespie, B.M., Chaboyer, W.P., McInnes, E., Kent, B., Whitty, J.A., Thalib, L., 2014. Repositioning for pressure ulcer prevention in adults. *Cochrane Database Syst. Rev.* 4, CD009958.
- Gorecki, C., Brown, J.M., Nelson, E.A., Briggs, M., Schoonhoven, L., Dealey, C., et al., 2009. Impact of pressure ulcers on quality of life in older patients: a systematic review. *J. Am. Geriatr. Soc.* 57 (7), 1175–1183.
- Graves, N., Birrell, F., Whitby, M., 2005. Effect of pressure ulcers on length of hospital stay. *Infect. Control Hosp. Epidemiol.* 26 (3), 293–297.
- National Pressure Ulcer Advisory Panel, European Pressure Ulcer Advisory Panel and Pan Pacific Pressure Injury Alliance. Prevention and Treatment of Pressure Ulcers: Quick Reference Guide. In: Haesler, E. (Ed.), Cambridge Media, Osborne Park, Australia.
- Hengstermann, S., Fischer, A., Steinhagen-Thiessen, E., Schulz, R.J., 2007. Nutrition status and pressure ulcer: what we need for nutrition screening. *J. Parenter Enter Nutr.* 31 (4), 288–294.
- Independent Hospital Pricing Authority, 2014. Nationally Efficient Price Determination 2014-15. Independent Hospital Pricing Authority, Darlinghurst NSW.
- Jackson, S.S., 2011. Incidence of hospital-acquired pressure ulcers in acute care using two different risk assessment scales: results of a retrospective study. *Ostomy Wound Manage.* 57 (5), 20–.
- Mathiesen, A.S., Norgaard, K., Andersen, M.F., Moller, K.M., Ehlers, L.H., 2013. Are labour-intensive efforts to prevent pressure ulcers cost-effective? *J. Med. Econ.* 16 (10), 1238–1245.
- Ng, E.S.-W., Grieve, R., Carpenter, J.R., 2013. Two-stage nonparametric bootstrap sampling with shrinkage correction for clustered data. *STATA J.* 13 (1), 141–164.
- Nguyen, K.H., Chaboyer, W., Whitty, J.A., 2015. Pressure injury in Australian public hospitals: a cost-of-illness study. *Aust. Health Rev.* 39 (3), 329–336.
- Power, M., Stewart, K., Brotherton, A., 2012. What is the NHS safety thermometer? *Clin. Risk* 18 (5), 163–169.
- Queensland Health, 2012. Metro North 2012-13 Service Agreement. Queensland Government, Brisbane, Australia.
- Reddy, M., Gill, S.S., Rochon, P.A., 2006. Preventing pressure ulcers: a systematic review. *JAMA* 296 (8), 974–984.
- Rosenthal, M.B., 2007. Nonpayment for performance? Medicare's new reimbursement rule. *N. Engl. J. Med.* 357 (16), 1573–1575.
- Sebba Tosta de Souza, D.M., Veiga, D.F., Santos, I.D., Abla, L.E., Juliano, Y., Ferreira, L.M., 2015. Health-related quality of life in elderly patients with pressure ulcers in different care settings. *J. Wound. Ostomy Continence Nurs.* 42 (4), 352–359.
- Vetrano, D.L., Landi, F., De Buysier, S.L., Carfi, A., Zuccala, G., Petrovic, M., et al., 2014. Predictors of length of hospital stay among older adults admitted to acute care wards: a multicentre observational study. *Eur. J. Intern. Med.* 25 (1), 56–62.