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Toronto Health Economics and Technology Assessment Collaborative

The Cost-Effectiveness of Pressure-Redistribution Mattresses for Early Prevention of Pressure Ulcers In Patients Admitted to Hospitals via the Emergency Departments

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December, 2009

THETA Report #005

Contents

Executive Summary

Objectives
To evaluate the cost-effectiveness of pressure-redistribution mattresses (PRMs) compared to standard mattresses (SMs) on emergency room stretchers and beds for the prevention of pressure ulcers (PrUs) in patients admitted to hospitals via emergency departments.

Design
A Markov history model of PrUs was developed. Input data for prevalence of hospital-acquired (H-A) PrUs, health utility and costs were derived from population-based data sources. A cost-utility analysis was conducted according to the Ontario health system perspective and 1-year time horizon.

Setting & Participants
Hypothetical cohort of patients admitted to acute-care hospitals via ERs.

Intervention
PRMs versus SMs on ER stretchers and beds

Measurements
Prevalence of H-A PrUs, incremental quality-adjusted life years, incremental costs, and incremental cost-effectiveness ratios.

Results
Approximately 1 in 6 emergency-admitted patients experienced H-A PrUs. PRMs reduced the prevalence of H-A PrUs by 2.2% (range: 1.7%, 2.6%); on average, 47 patients need to be on PRMs to prevent one H-A PrU. The mean cost saving associated with PRMs was $74 per patient for the 258,000 targeted cases per year in Ontario. PRMs had a 68% chance of improving health while saving costs. The aggregate direct cost saving to hospitals' budgets would be $17 million per year.

Conclusion
The use of PRMs for ER stretchers and beds reduces the incidence of PrUs, alleviates the associated morbidity, saves direct costs to hospitals, and has a modest preventive effect on a large volume of patients at perhaps one of the highest risk periods of their hospital experience.

Background

Pressure ulcers (PrUs) develop in approximately 0.4% to 38% of hospitalized patients.[1] [2] [3] Few studies document the development of PrUs in emergency rooms.[4] In patients with a suspected hip fracture, the incidence of PrUs was reported to be between 8% and 55%.[5] In a prospective study of 3,233 ER-admitted patients aged 65 years or older, Baumgarten et al. reported a 6% incidence of PrUs in the first two days after admission and suggested that a significant proportion of elderly, emergently-admitted hospitalized patients acquire PrUs soon after their admission.[6]

Recent systematic reviews demonstrate that pressure-redistribution mattresses (PRMs) significantly reduce PrU incidence by 64% (95% confidence interval: 0.22, 0.59).[7] [8] yet they are not widely used. In the United States, the national usage estimate of pressure-redistribution devices was approximately 8% in the early 2000's, although the trend has improved recently.[9] Although limited data exists, the use of PRMs in ERs is considered to be substantially less than their use in hospital in-patient wards. Tarpey et al. reported deficiencies in all support surfaces in an audit of an emergency department.[10]

In October 2008, the Ontario Health Technology Assessment Committee (OHTAC) convened an expert panel to review evidence-based options for the prevention and treatment of PrUs.[11] Panel members expressed concern regarding the lack of attention to preventive interventions for patients in the ERs, especially with the large proportion of frail elderly patients seeking care for their urgent conditions. Citing a lack of research data to affect practice changes, the panel requested cost-effectiveness data of targeted interventions to reduce pressure ulcer incidence in acute care hospitals.

Commissioned by OHTAC, the current study evaluated the cost-effectiveness of PRMs on ER stretchers and beds to prevent PrUs in emergency-admitted patients. Our aim was to generate robust cost-effectiveness data to improve the evidence base for policy recommendations, guideline revisions and practice changes.

Methods

Analytic Overview

A cost-utility analysis was conducted from the perspective of the public health system according to the guidelines for economic evaluation of health technologies by the Canadian Agency for Drugs and Technologies in Health.[12] The perspective of the hospitals was also considered. A Markov cohort model was developed to simulate PrU related events in emergency-admitted patients during hospitalization and over a 1-year time horizon post-admission. Input data for prevalence of PrUs, costs and health utilities were largely derived from population-based data sources. Content validation was provided by members of the expert panel convened by OHTAC. The model was calibrated to reproduce the prevalence of hospital-acquired PrUs observed in annual skin assessment surveys conducted in three Toronto hospitals. The main health benefits associated with pressure-redistribution mattresses (PRMs) were measured in terms of differences in the prevalence of hospital-acquired PrUs (and associated number needed-to-treat), incremental quality-adjusted life years (QALYs), incremental costs, and incremental cost-effectiveness ratios. The net monetary benefits of PRMs were also calculated using a willingness-to-pay of $50,000 per QALY. [55] All costs are expressed in 2009 Canadian dollars. We used a 5% discount rate for costs and health outcomes when evaluating alternative time horizons longer than one year.[12]

Target population

The target population included hospitalized patients admitted via emergency departments (Table 1).[13] Emergency-admitted cases were identified from the Discharge Abstract Database at the Ontario Ministry of Health and Long-Term Care (2002-8).[14] On average, approximately 429,000 cases were recorded per year.

Comparators

We compared PRMs to standard mattresses on ER stretchers and ER beds. A recent Cochrane systematic review identified one RCT evaluating PRMs in emergency-admitted patients.[7] Gunningberg et al. examined the PRM effect on 101 patients with a suspected hip fracture.[15] Immediately on arrival to an ER, patients in the study group were placed on a 10 cm thick viscoelastic foam mattress. When transferred to the ward, a 7-cm viscoelastic foam overlay was put on top of a standard mattress. Patients in the control group were placed on routine standard trolleys (5-cm mattress) and on standard hospital mattresses, respectively. In the study group, 12 patients developed PrUs (stage 1, n=8; stage 2, n=4), while 17 patients did so in the control group (stage 1, n=9; stage 2, n=7; stage 4, n=1). The relative risk estimate for any PrUs was 0.78 (95% CI: 0.42, 1.46). Gunningberg et al. concluded that the results partially support the use of PRMs on ER patient support surfaces.[15] However, the Cochrane reviewers interpreted the same results differently; they concluded that PRMs designed for use in ERs had not been adequately evaluated.[16] Although the preventive effect of PRMs has not been confirmed in emergency-admitted patients, the principle that PRMs reduce the risk of PrUs is well established in various systematic reviews of randomized controlled trials involving hospitalized patients.[24,8 11 17] Accordingly, PRMs reduce the risk of PrU by 64% (RR: 0.36; 0.22, 0.59). In the model, the preventive effect of PRMs was considered for the first ER days only; we assumed no different effect due to patient support surfaces once patients were admitted to hospital wards.

Natural history of pressure ulcer

Pressure-ulcer related events in emergency-admitted patients during hospitalization and over a 1-year time horizon post-admission were simulated using a Markov cohort model (Figure 1). The model included 21 mutually exclusive health states according to setting (admitted to hospital or discharged), PrU classification and

related complications (Appendix).[18] PrUs were classified into stages 1-4 according to the National Pressure Ulcer Advisory Panel (NPUAP) classification system (see Figure 1).[19] [20] Increasing tissue damage was represented by progression across stages. As recommended by the NPUAP, we modeled stage-specific healing by a direct transition to skin closure (e.g., stage 2 → stage 0) without intermediate stage regression (e.g. stage 2 → stage 1).[21] [22] Once started, healing was assumed to continue until full skin closure over an average stage-specific healing time.[23] Stage 2-4 PrUs were assumed to be at risk for local infection. In patients with stage 3-4 PrUs, local infection could lead to systemic infection that could, in rare instances, result in a PrU-related death.[24] [25] Locally infected stage 2-4 PrUs were assumed to delay discharge until the infection resolved. Post-discharge, all PrUs were assumed to heal gradually without progression.[23] [26] At any time, patients could die due to causes unrelated to PrUs.

Input data

Pressure-redistribution mattresses

The unit costs of PRMs for ER stretchers and ER beds were obtained from a survey of three manufacturers and distributors in Ontario. The per-patient cost of PRMs on ER stretchers and beds was derived by amortizing their unit costs over their average 2-year warranty and assuming that on average, patients spent approximately 16 hours in ERs, including approximately 4 hours on stretchers (Table 1).

Prevalence and incidence data

We obtained prevalence data from a cohort of 1,398 emergency-admitted patients who participated in the Toronto Tri-Hospital Acute Care Pressure Ulcer Prevalence and Incidence Survey (including two tertiary-care and one community-care hospitals) from 2005 to 2007 (Table 1). On the day of surveillance, all in-patients (except maternity and psychiatric patients and 24-hour-stay patients) who could give consent were assessed to determine whether a PrU was hospital-acquired. The assessment consisted of a head-to-toe inspection, and in PrU cases, clinical bedside audit, full chart review and consensus on ulcer staging. Survey data was collected by skin care nurses using a pre-defined data collection form (Appendix).[27] A one-day surveillance approach was used for prevalence estimates.

In the history model, the daily incidence of developing PrUs was estimated to be highest upon admission, gradually decreasing in subsequent days (Table 1).[28] The time to PrU development was assumed to follow a Weibull distribution such that the cumulative daily incidence over an average length of stay approached the observed prevalence of hospital-acquired PrUs from the survey (Appendix).

The remaining seven day incidence of progression (i.e., stage 1 → 2, 2 → 3, 3 → 4; Figure 1), and healing (each stage 1, 2, 3 or 4 → skin closure) are not simultaneously and directly observable. Their estimates were therefore derived using a calibration approach (Appendix).[29] [30] First, we obtained initial age-specific progression and healing incidence estimates from a long-term care population, for which we had successive quarterly assessment data in the Resident Assessment Instrument - Minimum Data Set (RAI – MDS 2004-2007; 1,088 assessments, Appendix).[18] Next, assuming that the relative risk of transition across age categories was also applicable to PrUs in ER patients, we used seven multipliers to simultaneously adjust the initial age-specific progression and healing profiles until modeled stage-specific prevalence of new PrUs reproduced the corresponding observed prevalence of hospital-acquired PrUs in emergency-admitted patients (Figure 2 and Table 1).

Model validation

We corroborated modeled projections with corresponding estimates from clinical studies (Table 1). The model estimated PrU incidence on the admission day to ER to be 4.2%; it was 6% in the first two days after admission in a prospective study of 3,233 ER-admitted patients

aged 65 years old or older.[6] The model projected that approximately 20% of stage-1 PrUs progressed to stage 2; it was 23% in a study of surgical patients.[28] The projected progression from stage 2 → 3 and 3 → 4 was approximately 4% and 5%, respectively; the progression from stage 2 → 3-4 was reported to be 6% and 18% from two studies of hospitalized patients.[31 32]

Costs attributable to pressure ulcers

From the Ontario Case Costing Initiative, direct in-patient costs included ward care costs, pharmacy costs, overhead costs and capital costs of equipment and infrastructure (Table 1).[33] Using a regression approach, average costs attributable to hospital-acquired stage 2-4 PrUs were estimated as the adjusted cost differences between 1) 3,780 cases identified with post-admission co-morbidity ICD-10-CA codes for PrUs (L890-2, L893-5 and L898); and 2) controls matched to cases by 5-year age groups, gender, most responsible admission diagnosis, and Charlson co-morbidity category (i.e., 0, 1 and ≥ 2; Appendix).[34 35] Stage-2 PrUs were chosen because they represent a break in the skin that is clinically meaningful with greater reliability in reporting than stage-1 PrUs.[36] In the model, the daily attributable costs were derived by allocating the above attributable costs over the average length of stay; this approach under-estimated the PrU burden as on average, it took days to develop severe PrUs.

Similarly, average weekly costs attributable to PrU care following hospital discharge were derived in a regression analysis using data from the RAI - Home Care database (Table 1 and Appendix). Cost episodes over a 13-week period were aggregated from individual level client billing records and included charges pertaining to nursing time, personal support, dietetics, social work, and physical, occupational and speech therapy.[26] The average weekly cost attributable to care for stage 2-4 PrUs was estimated adjusting for age, gender, admission diagnosis, and activity of daily living scores. In the model, the mean costs attributable to PrU care were derived by aggregating the average weekly costs over the stage-specific mean healing time.

Cost validation

We validated our estimates of inpatient costs attributable to PrUs with published treatment costs from the United Kingdom (Appendix).[23] After adjusting for purchasing power parity and inflation, the Ontario attributable cost estimate (UK treatment cost) was $11,967 ($10,569), $12,951 ($17,558), and $21,797 ($25,765) attributable to stage 2-4 PU, respectively. These estimates were relatively consistent, particularly in view of the potential for variation in care patterns and costing methods.

Health utility estimates

Health utility data associated with PrUs in hospitalized patients are not available, according to a full literature search of MEDLINE and EMBASE in November 2008.[18] We therefore obtained the proportional utility decrement associated with PrU and applied it to the mean utility scores for hospitalized patients (Table 1). Thein et al. estimated health utility attributable to PrUs using RAI-MDS data.[37] Utility scores were derived using the validated RAI – Health Status Index scale which maps RAI-MDS items to the Health Utilities Index Mark 2 (HUI2). [38 39 40] In a regression analysis, the effect of PrU on overall utility score was estimated adjusting for age, gender and co-morbidity conditions. On average, individuals with stage 2-4 PUs were associated with a health utility decrement of 6.1% compared to individuals with stage 1 or without PrUs (i.e., there were no discernible differences between finer stages within the groupings).[37]

Although utility scores among long-term care residents are relatively low, we assumed that stage 2-4 PrUs would have the same proportional decrement to utility scores among hospitalized patients (Table 1).[37] The mean HUI-based utility for hospitalized patients was obtained from a study of general medicine patients.[41] Post-discharge, the mean HUI-based utility scores of community-dwelling individuals

were estimated from the National Population Health Survey (Appendix).[42] A linear increase in mean inpatient utility to mean community-based utility scores was assumed over the convalescent period of one year.

Pressure ulcer – related infection

Given a lack of alternative data, daily incidence estimates of PrU-related infections given stage 2-4 PUs were estimated using RAI-MDS data from long-term care homes (Table 1). The average clearance duration of local and systemic infection was assumed to be 7 days[43] and 14 days,[44] respectively. The crude mortality among patients with sepsis in Ontario was estimated to be approximately 20%.[25] Using the all-cause mortality estimate of 2.2% for surgical patients, mortality due to PrU-related sepsis was estimated to be approximately 17.8%.

Use of pressure-redistribution mattresses in Emergency Departments

The wound care or infection control nurses of thirty randomly selected Ontario acute care hospitals stratified by five health regions were invited via telephone to participate in a survey regarding the use of PRMs in their emergency departments.[45] Only 17 invitees responded to the invitation and after three telephone follow-ups, only five completed the survey, including one in each region. Among the five responding institutions, two ER departments used PRMs on 100% of their ER stretchers and ER beds whereas three did not use PRMs at all. This suggests that 40% of the estimated 4,727 ER stretchers and ER beds in the province are currently equipped with PRMs.

Sensitivity analysis

Subgroup analyses were conducted for hospitals in which prevalence estimates of hospital-acquired PrUs in emergency-admitted patients ranged from 1 to 35%.[28 46] One-way sensitivity analyses were conducted to assess assumptions and sources of parameter uncertainty used in the base case analysis. We evaluated assumptions related to multiple time horizons and alternative shapes of the Weibull distribution for daily incidence estimates.[28] Sources of uncertainty included relative risk estimate associated with PRMs, time in the ER, PrU-attributable costs, and health utility, among others. A probabilistic sensitivity analysis was conducted to address the joint effect of structural assumptions and parameter uncertainty (n = 50,000 iterations; Appendix).

Results

Clinical effectiveness

Approximately one in six emergency-admitted patients acquired PrUs during their length of stay (Table 1). The model projected that PRMs reduced the overall and stage 2-4 prevalence of hospital-acquired PrUs (Figure 2). The absolute reduction in the overall and stage 2-4 prevalence was 2.2% (1.7%, 2.6%) and 1.5% (1.0%, 2.0%), respectively (Table 2). On average, 47 (68) ER patients would need to be supported by PRMs to prevent one PrU (stage 2-4 PrU).

Cost-utility analysis

In the base case analysis, PRMs were associated with an extremely small improvement in quality-adjusted life expectancy, compared to standard surfaces (Table 2). The associated mean cost saving was $74 per patient, of which $71 was saving from direct inpatient costs to annual hospital budgets. In contrast, the average per-patient cost of PRMs was approximately $0.25 (Table 1).

Expressing all health and monetary outcomes with a single metric, the net monetary benefit (NMB) was also $74, comprised mostly of cost savings and $0.44 worth of health gains (expressed in monetary terms, Appendix). Given the extremely low average per-patient cost of PRMs, the NMB remained positive (i.e., PRMs remained an economically attractive strategy) even in hospitals with a 1% prevalence of hospital-acquired PrUs in emergency-admitted patients; although in these cases, the associated direct cost saving per-patient was minimal (i.e., approximately $3, Figure 3).

In one-way sensitivity analyses, the cost-effectiveness of AFMs varied from a net monetary gain to a net monetary loss (i.e., increased costs and reduced QALY) across their non-significant prevention effect estimate from the original RCT involving ER patients (Figure 3 and Appendix). Had the relative PrU risk of 0.36 (95% CI: 0.22, 0.59, Table 1) associated with PRMs estimated using hospitalized patients been assumed to be generalizeable to emergency-admitted patients, the NMB would have been $221. In the remaining one-way sensitivity analyses, AFMs remained economically attractive across model assumptions and sources of uncertainty (Figure 3). The magnitude of the associated cost saving was however highly influenced by the assumed shape of the Weibull distribution for the daily incidence estimate. Results from the base case analysis remained relatively unchanged with variation in the unit costs of AFMs, ER time, average age of the simulated cohort, and different time horizons, among others. According to the probabilistic sensitivity analysis, PRMs had a 68% probability of both improving QALYs and reducing costs (i.e., AFMs was the dominant choice).

Health system implications for Ontario

We estimated that approximately 40% of the ER patient support surfaces are currently equipped with PRMs. Every year approximately 258,000 ER cases remain at risk for PrUs (Table 2). The expanded use of PRMs to cover the remaining 60% of ER stretchers and ER beds would increase the annual cost of replacing current mattresses by approximately $1 million. The PRMs would prevent approximately 5,500 cases of PrUs per year, and result in a gain of approximately 2.3 QALYs aggregated over the target population. Direct PrU-related costs to the health system would be reduced by approximately $18 million per year. The direct cost saving to hospitals' annual budgets would be $17 million (or equivalently, approximately 275 full-time equivalents of registered nurse time, assuming an annual RN salary of approximately $63,000).[47]

Discussion

The prevention of pressure ulcers in emergency rooms is currently not considered a high priority. However, a high proportion of frail elderly whose emergent conditions put them at a particularly high risk for PrUs during their visit to emergency departments. For these patients, there is increasing recognition that PrU prevention is necessary throughout their entire hospital stay, including their time spent in emergency departments.[10] Our study provides robust cost-effectiveness data in support of early prevention for this patient population. We show the use of PRMs on ER patient support surfaces reduces the incidence of PrUs, alleviates the associated morbidity, saves direct costs to hospitals, and provides a modest preventive effect to a large volume of patients at perhaps one of the highest risk periods of their hospital stay.

Despite evidence that patients may have to wait in the emergency departments for considerable periods on hard surfaces with increasing risk of tissue damage, limited attention has been given to PrU care for patients admitted via the departments.[48] [49] Tarpey et al. audited existing patient support surfaces in an emergency department and reported deficiencies in all of them, including the deterioration of equipments and deficiencies in their design.[10] In the United States, the national estimate of compliance to the use of pressure-redistribution devices has been approximately 8%.[9] Our estimate that 40% of ER surfaces are equipped with PRMs is possibly higher than the actual uptake of these preventive interventions. This was due to a low response rate in our phone survey despite repeated follow-up contacts with the non-responders. These preliminary data suggest ample opportunities for hospitals to improve PrU prevention.

The Centers for Medicare and Medicaid Services (CMS) have recently stopped reimbursing hospitals for the additional cost of treating certain hospital-acquired conditions, including PrUs.[4] [50] This creates a financial incentive for early prevention.[51] Our study provides supporting efficiency evidence that changing the mattresses is a highly logical first step. We however do not intend to suggest that the use of PRMs is sufficient as a sole intervention to prevent PrUs in emergency-admitted patients. Guidelines from the Registered Nurse Association of Ontario emphasize the role of risk assessment and individualized plan of care for PrU prevention.[52] The activity subscale of the Braden or Norton scale should be used to screen for patients at high risk for PrUs.[4] Preliminary data from a recent international consensus paper on prevention and treatment of PrUs also suggest a synergistic effect between the implementation of new PRMs and a training program for clinicians.[20]Additional evidence is needed regarding risk assessment and documentation of PrUs in the ERs.

Our results were similar to those from cost-effectiveness analyses accompanying RCTs evaluating support surfaces for PrU prevention in hospitalized patients. Lower overall costs and greater health benefits were reported for alternating pressure mattresses versus alternating pressure overlays,[53] viscoelastic foam mattresses and seating cushions versus standard surfaces,[54] and air suspension beds versus standard ICU beds.[55] All studies reported qualitatively similar results: the increase in per-patient costs between the experimental and control surfaces was small compared to the cost avoidance associated with the reduction or delay of PrU development.

Our analysis has several limitations. The natural history model did not take into account the specific sites of PrUs although some variation in their prognosis across sites is likely. In case of multiple ulcers, the model represented only the highest stage PrU. The model did not take into account the fact that a portion of PrU cases are non-healable. The simplified version of the NPUAP classification used in the model did not include deep tissue injury and unstageable PrUs. There is a potential for inflated cost estimates as severe cases of PrUs are more likely to be observed clinically and over represented in post-discharge diagnosis coding. Substantial uncertainty remained regarding current use of PRMs in emergency departments and related

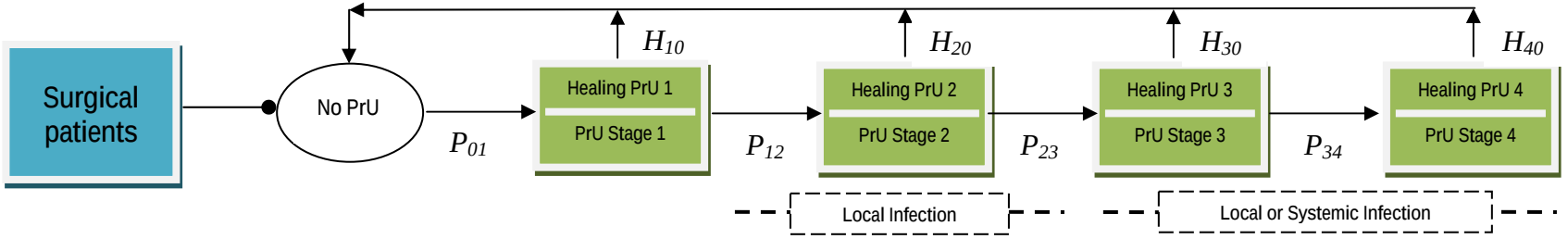
projections due to the low response rate to our patient support surface survey. Last but not least, the prevalence data we derived from three Toronto hospitals may not be representative of the true burden of PrU in other facilities. Our prevalence data were however relatively consistent to recently published prevalence estimates for other hospitals.[56 57]

On the other hand, the current study has significant strengths. First, we used relatively high quality, population-based input data from Ontario data sources. Second, we used sound methodology to derive cost estimates attributable to PrUs, adjusting for patients' characteristics and co-morbidity conditions.[34] Third, our model was built on a biological understanding of PrUs contributed by our expert panel, and calibrated carefully to appropriate natural history data.[35]

Despite the strength of existing evidence, pressure-redistribution support surfaces do not appear to be widely used in emergency departments. On the basis of the data reported here, OHTAC recently recommended using a high quality foam mattress for all persons accessing emergency room care. We believe that the existing clinical and economic evidence strongly supports concerted efforts to deploy PRMs in settings with costs and practice patterns broadly similar to those described in this study.[58]

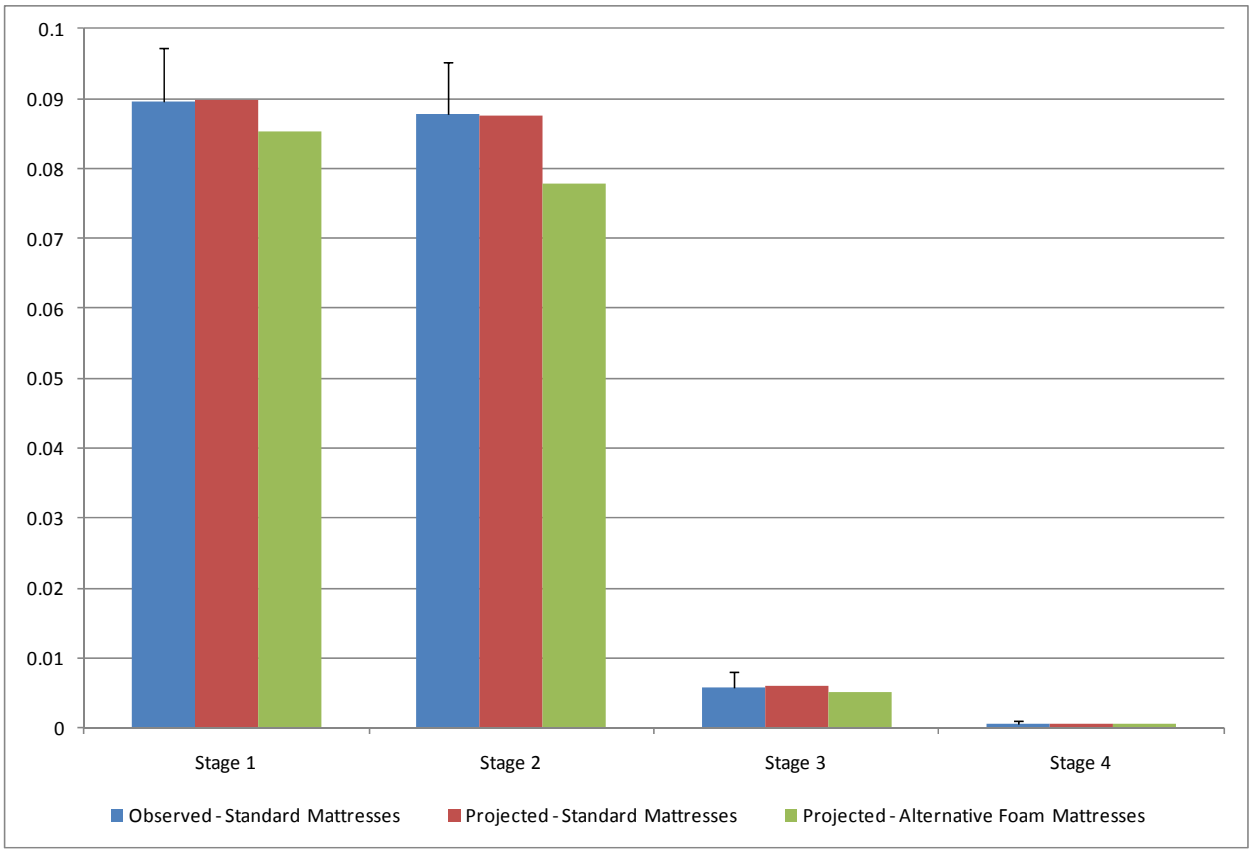
Figures and Tables

Figure 1: Natural history model of pressure ulcers among surgical patients



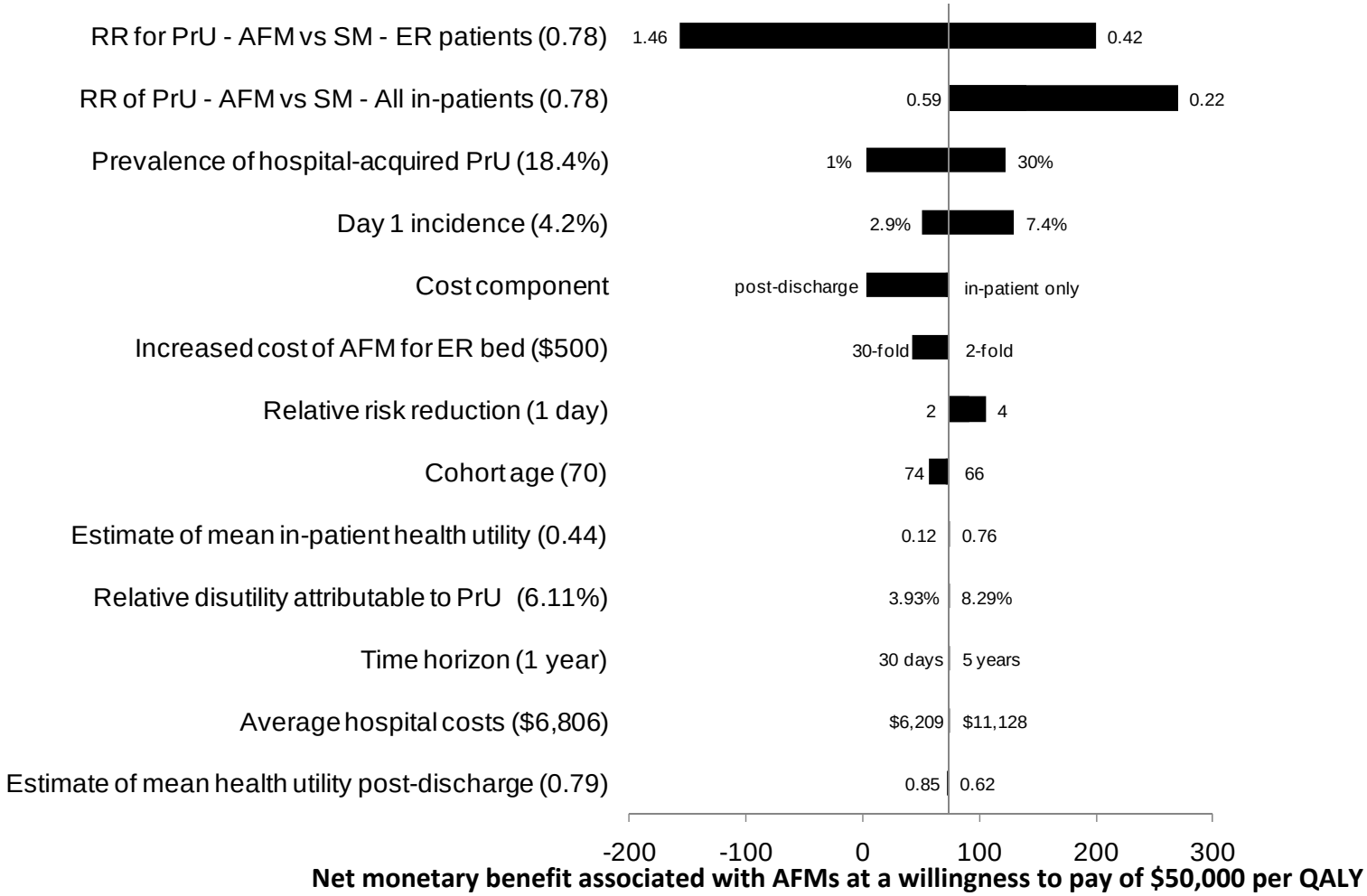
According to the National Pressure Ulcer Advisory Panel (NPUAP) classification system, a stage 1 PrU usually refers to an intact skin with non-blanchable redness of a localized area usually over a bony prominence.[29] Stage 2 refers to a partial thickness loss of dermis presenting as a shallow open ulcer with a red pink wound bed, without slough; stage 3 full thickness tissue loss with subcutaneous fat may be visible but bone, tendon or muscle are not exposed; and stage 4 full thickness tissue loss with exposed bone, tendon or muscle. The daily incidence of developing PrUs P_{01} was estimated to be highest on post-operative day 1 and gradually decreasing in subsequent days, according to a Weibull distribution for time to PrUs development (Table 1 and Appendix).[35] The remaining seven daily incidence estimates of progression P_{12}, P_{23} and P_{34}; and healing H_{10}, H_{20}, H_{30} and H_{40} are not directly available, and were therefore estimated using a calibration approach (Appendix).[36 37]

Figure 2: Observed and projected prevalence of hospital-acquired PrUs given current standard hospital mattresses on ER stretchers and ER beds; and projected prevalence with alternative foam mattresses.



Projected prevalence estimates of hospital-acquired PrUs in patients on standard hospital mattresses on ER stretchers and ER beds (red) reproduced observed stage-specific prevalence (blue) to within sampling error (Pearson's chi-squared test, p-value = 0.99, higher p-value indicating better fit). Projected prevalence with AFMs on ER stretchers and beds was also displayed (green). Bars are standard errors of observed prevalence values, estimates derived assuming binomial distributions.

Figure 3: Variation in net monetary benefits associated with AFMs on ER stretchers and ER beds in one-way sensitivity analysis of model assumptions and uncertainty in input data to the cost-effectiveness analysis.



Black bar represents variation in the net monetary benefit of AFMs. Base-case values are displayed in parentheses. Ranges used in the one-way sensitivity analyses are displayed to the left and right of black bars. The vertical line indicates the expected net monetary benefit of $226 associated with AFMs. The net monetary benefit of AFMs was estimated using a willingness-to-pay threshold of $50,000 per QALY. Abbreviations: RR: relative risk. PrU: pressure ulcer.

Table 1: Cohort characteristics (in italics) and input data to the cost-effectiveness analysis

	Estimate	SE, SD or Range	Data Source
Simulated cohort - Characteristics			Tri-Hospital survey
Age (year)	70	18	n=1,398 emergency-
Female*	45.8%	1.4%	admitted patients
Patients with surgical procedures*	19.4%	1.1%	(n=2,958 participants)
Time spent in ER (hour)	15.5	24.2	2005-7 [1]
Patient disposition			Discharge Abstract
Estimated length of stay (day)	6.5	9.7	n=2,575,771
Estimated hospital mortality	7.2%	0.02%	2002-8; [2]
Post-discharge mortality	age-specific	n/a	Statistics Canada [3]
Relative risk of PrU with AFM (95% confidence interval)			
ER patients (Base case analysis)	0.78	0.42, 1.46	Gunningberg et al.[15]
Hospitalized patients (sensitivity analysis)	0.36	0.22, 0.59	McInnes et al.[7]
Natural history of pressure ulcers			
Daily incidence of developing stage 1 PrU			Calibration estimates
Day 1	4.2%	2.9%, 10.7%	[4]
Day 2	2.9%	2.3%, 3.0%	
Day 3	2.6%	1.6%, 2.7%	
Day 4 ... Day 90	Weibull distribution		[4]
Daily progression incidence			Calibration estimates
PrU stage 1 → 2	21.3%	20.2%, 24.9%	[5]
PrU stage 2 → 3	3.5%	2.3%, 3.9%	
PrU stage 3 → 4	5.1%	4.0%, 5.5%	
Daily incidence of initial healing			Calibration estimates
Healing PrU stage 1	2.4%	1.1%, 7.0%	[5]
Healing PrU stage 2	9.4%	7.3%, 11.4%	
Healing PrU stage 3	0.6%	0.3%, 5.1%	
Healing PrU stage 4	0.5%	0.1%, 1.2%	
Observed prevalence of hospital-acquired PrUs			Tri-hospital survey
PrUs – All stages	18.5%	1.0%	n=1,398

	Estimate	SE, SD or Range	Data Source
Stage 1	9.0%	0.8%	2005-7 [1]
Stage 2	8.8%	0.8%	
Stage 3	0.6%	0.2%	
Stage 4	0.05%	0.06%	
Post-discharge mean healing time			Bennett et al.[23]
Stage 1, 2, 3, 4 (week)	4, 13, 18, 22	fixed	
PrU-related complications			
Daily incidence of local infection given stage 2-4	0.14%	0.07%	LTC MDS [6]; n=18,321; 2004-7
Daily incidence of sepsis given stage 3-4	2.22%	0.64%	[6]
Crude mortality among patients with sepsis	20%	0.9%	Tourangeau et al.[25]
Mortality due to PrU-related sepsis	17.80%	0.80%	Calculated
Costs			
AFM costs			
5" x 30" AFM for ER stretchers	$780	$346 - $1000	Survey of
3" foam mattresses for ER stretcher	$300	$300 - $400	3 manufacturers [7]
8" AFM for ER beds	$500	$430 - $4,000	
5" foam mattresses for ER beds	$300	$225 - $400	
Warranty (year)	2	2 – 10	[7]
Average per patient cost difference			
AFM – standard foam mattress	$0.25	$0.15 - $2.60	[7]
In-patient costs			
Additional cost attributable to PrU			OCCI:
Stage 2	$11,967	$3,702	n=3,780 PrU cases;
Stage 3	$12,951	$7,849	2002-7 [8]
Stage 4	$21,797	$12,031	
Mean hospitalization cost	$6,806	$10,745	OCCI: n=370,280 controls; 2002-7 [9]
In-patient physician billings	$445	$728	LTC MDS [10]
Post-discharge costs			
Mean post-discharge cost per wk	$134	$4	MDS-HC [11];
Additional post-discharge cost per week attributable to PrU			n=21,578; 2003-4
Stage 2	$57	$6	Poss et al.[26]

	Estimate	SE, SD or Range	Data Source
Stage 3	$81	$9	
Stage 4	$105	$14	
Weekly MD billings	$0.89		Friedman et al.[59]
Health Utility			LTC; MDS-HSI [12]
Utility decrement of stage 2-4 versus no PrU or stage 1 PrU	6.10%	1.10%	n=16,531; 2004-7
In-patient health utility	0.44	0.32	Hays et al.[41]
Absolute utility decrement of stage 2-4 PrUs versus none or stage 1 PrU	0.0268	0.0048	
Full recovery after 1 year	0.79	0.12	Mittmann et al.[42]

SE: standard error.
SD: standard deviation.
ER: emergency room.
AFM: alternative foam mattress.
PrU: pressure ulcer.
LTC: long-term care.
MDS: Minimum Data Set.
OCCI: Ontario Case Costing Initiative.
HC: home care.
MDS-HSI: Minimum Data Set – Health Status Index.

*Characteristics not directly used as input data to the model.
[1] Toronto Tri-Hospital Acute Care Pressure Ulcer Prevalence and Incidence survey (Appendix).
[2] In the model, the time to discharge or in-hospital death was assumed to follow a Weibull distribution fitted to data from the Discharge Abstract Database, the Health Data Branch, Ontario Ministry of Health and Long-Term Care.
[3] Average mortality according to Statistics Canada 2008.
[4] Time to PrU development was assumed to follow a Weibull distribution fitted to the prevalence of hospital-acquired PrU.
[5] Daily progression and healing incidence estimates were derived via calibration (Appendix).
[6] Resident Assessment Instrument – Minimum Data Set for LTC homes (MDS).[60]
[7] Data from a survey of 3 manufactures in Ontario (Appendix).
[8-9] Ontario Case Costing Initiative data, including PrU cases [8] and matched controls without PrU (Appendix) [9].
[10] MDS for LTC homes linked to Ontario Health Insurance Plan data for physician's billings of hospitalized residents.
[11] MDS – Home Care.
[12] MDS – Health Status Index scale applied to data from the MDS for LTC homes.[39]

Table 2: Clinical effectiveness, cost utility and health system implications of AFMs on ER-stretchers and ER-beds

	AFMs - ER stretchers & beds	Standard surfaces	Difference or Incremental
Clinical effectiveness			
Prevalence of hospital-acquired PrUs			
Estimate for stage 1-4 PrUs[1]	16.3% (16.0%; 16.4%)	18.4% (18.1%; 18.7%)	2.2% (1.7%; 2.6%)
Number needed-to-treat			47 (39; 59)
Estimate for stage 2-4 PrUs[1]	8.0% (7.7%, 8.2%)	9.4% (9.1%, 9.7%)	1.5% (1.0%, 2.0%)
Number needed-to-treat			68 (52; 101)
Cost utility analysis			
Mean QALYs[2]	0.41990 (0.10747; 0.82613)	0.41989 (0.10747; 0.82608)	0.000009 (-0.000003; 0.0001)
Mean direct cost[2]	$6,551 ($133; $38,504)	$6,625 ($226; $38,695)	-$74 (-$598; $238)
Mean direct in-patient cost[2]	$6,529 ($117; $37,965)	$6,600 ($204; $38,142)	-$71 (-$590; $231)
Health system implications			
Current practice			
# ER-admitted patients / yr[3]	429,295	429,295	429,295
Current AFM use in ERs[4]	40%	40%	40%
# cases without AFMs[5]	257,577	257,577	257,577
# hospital-acquired PrU cases[6]	41,856	47,394	-5,538
Aggregated QALYs[7]	108,157	108,154	2.32
Implementation cost of AFMs[8]	$964,308		
Cost avoidance (health system) [9]			-$19,060,698
Cost saving (hospital budget) [10]			-$18,287,967
Net cost avoidance (health system)[11]			-$18,096,390
Net cost saving (hospital budget)[12]			-$17,323,659

AFM: alternative foam mattress. ER: emergency room. PrU: pressure ulcer. QALY: quality-adjusted life year.

[1]Best estimates of hospital-acquired prevalence and ranges from the calibration (Appendix). [2]Estimates were from the base case analysis and 95% credible values (in parentheses) from the probabilistic sensitivity analysis. [3] Average of numbers of emergently admitted patients from 2002 to 2008 from the Discharge Abstract Database. [4]Current AFM use was estimated from a phone survey (see text). [5]The estimate was derived by line 3 times line 4. [6]The estimates were derived by line 1 (stage 1-4 PrUs) times line 5. [7]The estimates were derived by line 2 (mean QALYs) times line 5. [8]Estimated implementation cost based upon a total of 4,727 ER stretchers and beds in Ontario, 60% of the patient support surfaces are without AFMs (n=3,309) and average incremental cost difference of $340 between AFMs for ER stretchers and beds (average cost $640; Table 1) and standard mattresses (average $300). [9]Incremental direct cost times line 5. [10]Incremental hospital direct in-patient cost times line 5. [11] Subtract the line 9 from line 8. [12] Subtract the line 10 from line 8.

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Appendix

Health states in the decision analytic model

Table A1 displays the health states in the pressure ulcer history model.

One-way sensitivity analysis

Table A2 displays the results of the one-way sensitivity analysis.

Probabilistic sensitivity analysis

Table A3 displays the results of the cost-effectiveness plane analysis associated with the probabilistic sensitivity analysis. Plot of cost-effectiveness plane from the probabilistic sensitivity analysis is displayed in Figure A3.

Distribution of length of stay

The time to discharge was assumed to follow a Weibull distribution with small daily probability of discharge early on and highest daily probability of discharge at approximately day 7th. The mean discharge was approximately 6.5 days (Figure A1). The shape of the Weibull distribution for time to discharge was assumed to be larger than one, indicating discharge rate increases with time.

Calibration

The time to stage-1 PrU development was assumed to follow a Weibull distribution assuming that failure rate is higher early on and decreases over time (Figure A2). The daily probability of PrU development was 4.2%, 3.0% and 2.6% for day 1-3, respectively. The daily probability of PrU development decreased in subsequent days in the hospital. At the mean length of stay of approximately 7 days, the cumulative risk of PrU development approaches the prevalence of hospital-acquired PrU of 18.4%. Varied incidence estimates based upon alternative shapes of the distribution were assessed in one-way sensitivity analysis (Table A2).

Daily incidence estimates of progression P_{12} (i.e., stage 1 → 2), P_{23} and P_{34}; and healing H_{10} (stage 1 → 0 – skin closure), H_{20} – H_{40} are not available. They were estimated from the observed stage-specific prevalence of hospital-acquired PrUs via a published calibration approach.[61 62] First, longitudinal data suitable for initial incidence estimates were sought. We derived initial estimates of daily progression and healing incidence using Ontario data from two consecutive quarterly skin assessments of nursing home residents in the Resident Assessment Instrument - Minimum Data Set (RAI-MDS; 2004-2007; 1,088 assessments; Tables A5-A6).[63]

For example, the initial daily incidence estimate of P_{12} in nursing home residents was 0.15%, 0.17% and 0.12% for the age-group 60-69, 70-74 and 75-79, respectively. Next, assuming the age pattern was constant; 7 multipliers were used to simultaneously adjust the initial incidence estimates until modeled stage-specific prevalence of new PrUs reproduced the corresponding observed prevalence (chi-squared test, p-value = 0.99; Figure 2 of the main manuscript). In emergency-admitted patients, the age-specific daily incidence P_{12} was adjusted to 19.8% (calibrated range: 18.7% - 23.1%), 21.3% (20.2%-25.0%) and 14.8% (14.0% - 17.3%) for the three age groups discussed above, respectively (Table A4). Specifically, the calibration proceeded according to the following steps.

Step 1 – Calibration parameters: The seven multipliers were assumed to be uniformly distributed on intervals that were estimated via a series of exploratory sensitivity analyses. For example, the prevalence of hospital-acquired stage-1 PrUs was functionally dependent on the daily incidence of progressing to stage 2, P_{12} and healing H_{10}, given a daily incidence of developing stage-1 PrU (see Figure 1 in the

main manuscript). So the multipliers for P_{12} and H_{10} were jointly varied in a two-way sensitivity analysis to explore as to whether their ranges were wide enough so that projected prevalence estimates for stage-1 PrUs bracketed the corresponding observed prevalence. The initial ranges are displayed in Table A6.

Step 2 – Calibration targets: The cross-sectional stage-specific prevalence observed in the Tri-Hospital survey was used as the calibration target. In order to reproduce the calibration target using a cohort model, we surveyed the PrU history model according to three time points along the length of stay distribution: days 4, 7, and 11 post-operation (Figure A1). Beside the mean LOS of 7 days, day 4 was selected to capture PrU prevalence in early discharged patients (17.4% of the target population) and day 11 in patients who remained in the hospital for a relatively long time (14.1%). The projected stage-specific prevalence was derived as weighted estimates of prevalence observed on days 4, 11 and 20.

The Pearson's goodness-of-fit statistic was used to compare the observed and projected stage-specific prevalence. A candidate model defined via a set of multiplier values was considered a good-fit model if 1) the fit statistic was ≤ 9.5 (i.e., the 95% quantile of a chi-squared distribution with 4 degrees of freedom) and 2) healing incidences decreased with increasing PrU stages.

Step 3 – Sampling: Latin-hypercube sampling was used to produce stratified random samples of the 7 multipliers from their uniform distributions. The stratification was done to ensure even distribution across ranges of the multipliers. In the first pass, random multiplier-sets were generated to provide broad coverage of the 7-dimensional space (n=5,000 samples) for the search of multiplier-sets fulfilled good-fit criteria in step 2. In the second pass, sampling was done taking into account the correlation structure of multiplier-sets that corresponding to good-fit models identified in the first pass (n=10,000 samples for the second pass). Latin-hypercube samples were generated using the freeware DAKOTA from Sandia National Laboratory.[64]

Step 4 - Model evaluation: using combinations of random parameter-sets and input variables, candidate models were defined and evaluated according to step 2. Projected stage-specific prevalence estimates were obtained using the method of expected value calculation. For example, prevalence estimates of stages 0-4 were obtained via five separate rewards in the TreeAge model, each recorded the presence of a stage-specific PrU according to the survey scheme of the PrU history model in step 2. A roll-back operation was then used to calculate the related expected values to obtain the projected stage-specific prevalence of PrUs.

The first pass of 5,000 samples yielded 21 good-fit models. The second pass of 10,000 correlated samples yielded 72 good-fit models. The best-fit model was used for the estimated incidence reported in Figure 1 and calibrated prevalence in Figure 2 of the main manuscript. In the probabilistic sensitivity analysis, the correlated multiplier samples from the 72 good-fit models were re-sampled according a weighted distribution derived from the reciprocal of the fit-statistics, including a re-scaling the reciprocal values by its total (see the probabilistic sensitivity analysis section).

Inpatient costs attributable to pressure ulcers

The average stage-specific costs attributable to pressure ulcers were estimated using the following steps:

1) cases were identified with post-admission comorbid ICD-10-CA codes for pressure ulcers (i.e., hospital-acquired),

2) controls who were matched to cases by the most responsible diagnosis, age (5-year age groups), gender, and Charlson's co-morbidity score (i.e., 0, 1 and ≥ 2),

3) direct costs for all cases were obtained from the OCCI data,

4) the mean and standard deviation of direct costs for the matched controls were also obtained from the OCCI data.

The cost difference between the cost for each case and the mean cost of corresponding matched controls was derived. Cases in which hospital costs exceeded the mean cost of their matched controls by 3 standard deviations were excluded from the analysis (they were considered with specific conditions un-adjustable even with the availability of the Charlson's co-morbidity scores).

A weighted average of the cost differences across all cases was computed. The last step was conducted using a multiple linear regression that correlated hospital costs (log-transformed) with age, sex, major diagnosis and Charlson's score (Table A7). The weighted average estimates was obtained from the fitted model (R^2=0.87) via a least mean squared estimate (Table A8). Here, the estimated costs attributable to pressure ulcer care accounted for tangible costs related to pressure ulcers (e.g., nursing time, dressing supplies) as well as related but intangible costs (e.g., longer length of stay). The detection and recording of stage 1 pressure ulcer in the OCCI data is highly uncertain; as such, costs of stages 2-4 were contrasted with stages 0 (no pressure ulcer) and stage 1 in the weighted average estimates.

Average costs attributable to PrUs after discharge

Direct costs pertaining to nursing, personal support, dietetics, social work as well as physical, occupational and speech therapies were included. These costs were estimated by applying a case-control approach to data from a costing dataset used to validate the Resource Utilization Groups for Home Care (RUG-III/HC).[65] In brief, cost episodes over a 13-week period were aggregated from individual level client billing records and matched to assessment information collected using the Resident Assessment Instrument for Home Care (RAI-HC February 2003 – November 2004 data; n=21,578).[65]

The stage-specific costs of nursing care for pressure ulcers were estimated using the following steps:

1) cases were clients with pressure ulcer(s) as recorded in the Skin Condition of the RAI-HC (pressure ulcer stage ≥ 1; section N),

2) controls matched to cases by 28 disease diagnoses (section J: Disease Diagnoses; RAI-HC), age, gender, and activity of daily living – self performance (section H: Physical Functioning; RAI-HC),

3) direct costs for all cases and their matched controls were obtained from the costing dataset.
The cost difference between the cost of each case and the mean cost of corresponding matched controls was derived. A weighted average of the cost differences across all cases was computed. The last step was conducted using a multiple linear regression that correlated the direct costs with age, sex, disease diagnosis and activity of daily living score. The weighted average estimates were obtained from the fitted model via a least mean squared estimate (R^2= 0.22; Table A9).

Probabilistic sensitivity analysis - Distribution

Distributions used in the PSA are displayed in Table A10.

Health utility

Estimates of health utility HUI-Mark III scores in individuals living in the community with selected chronic conditions are displayed in Table A11.[66] A full manuscript regarding the health utility estimate attributable to stage 2-4 PrU is available from the corresponding author

(Thein et al., 2009; In press at Quality of Life Research).

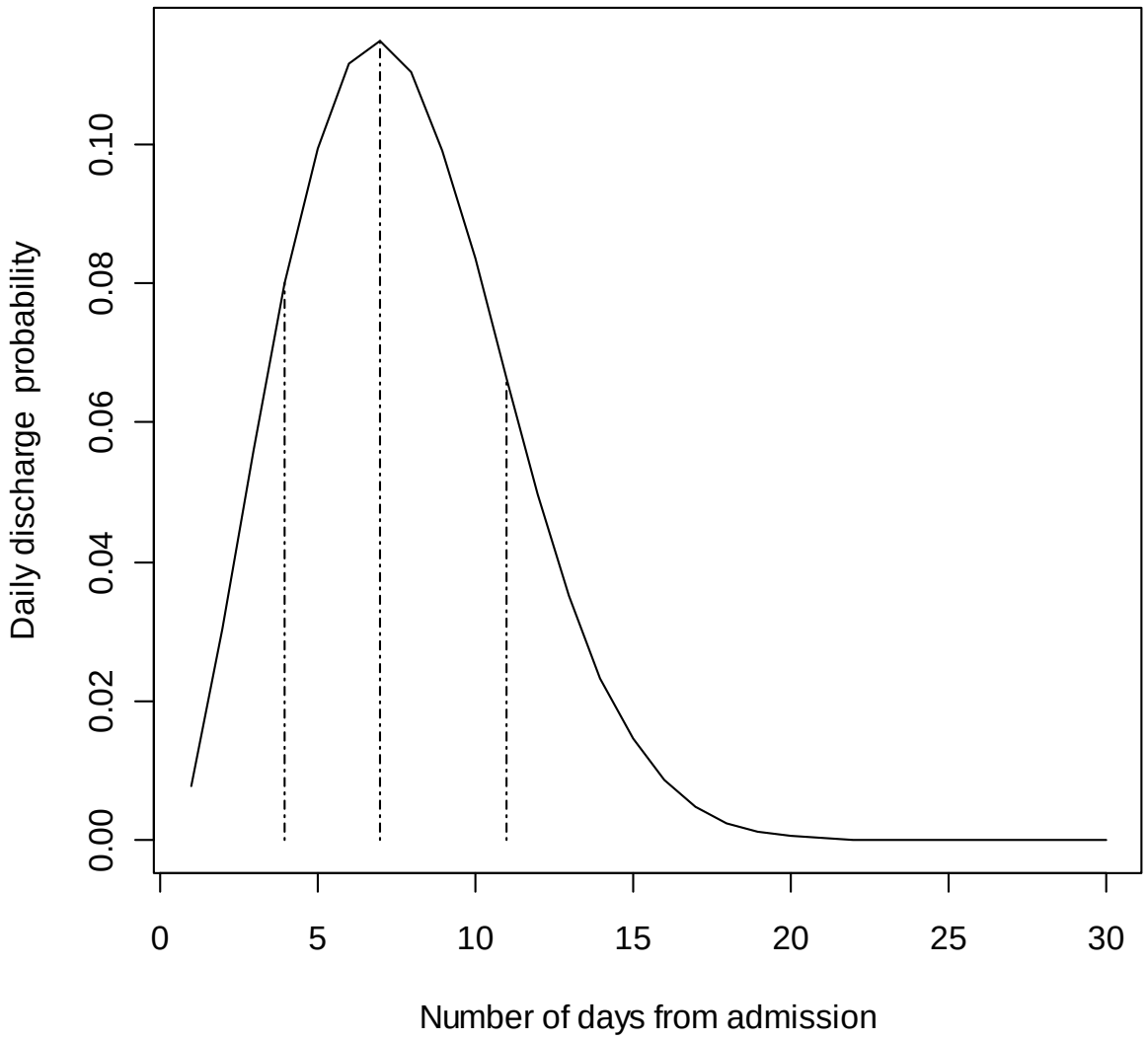
Tri-Hospital Survey

The data collection form for the Tri-Hospital Survey is enclosed in Table A12.

Cost validation

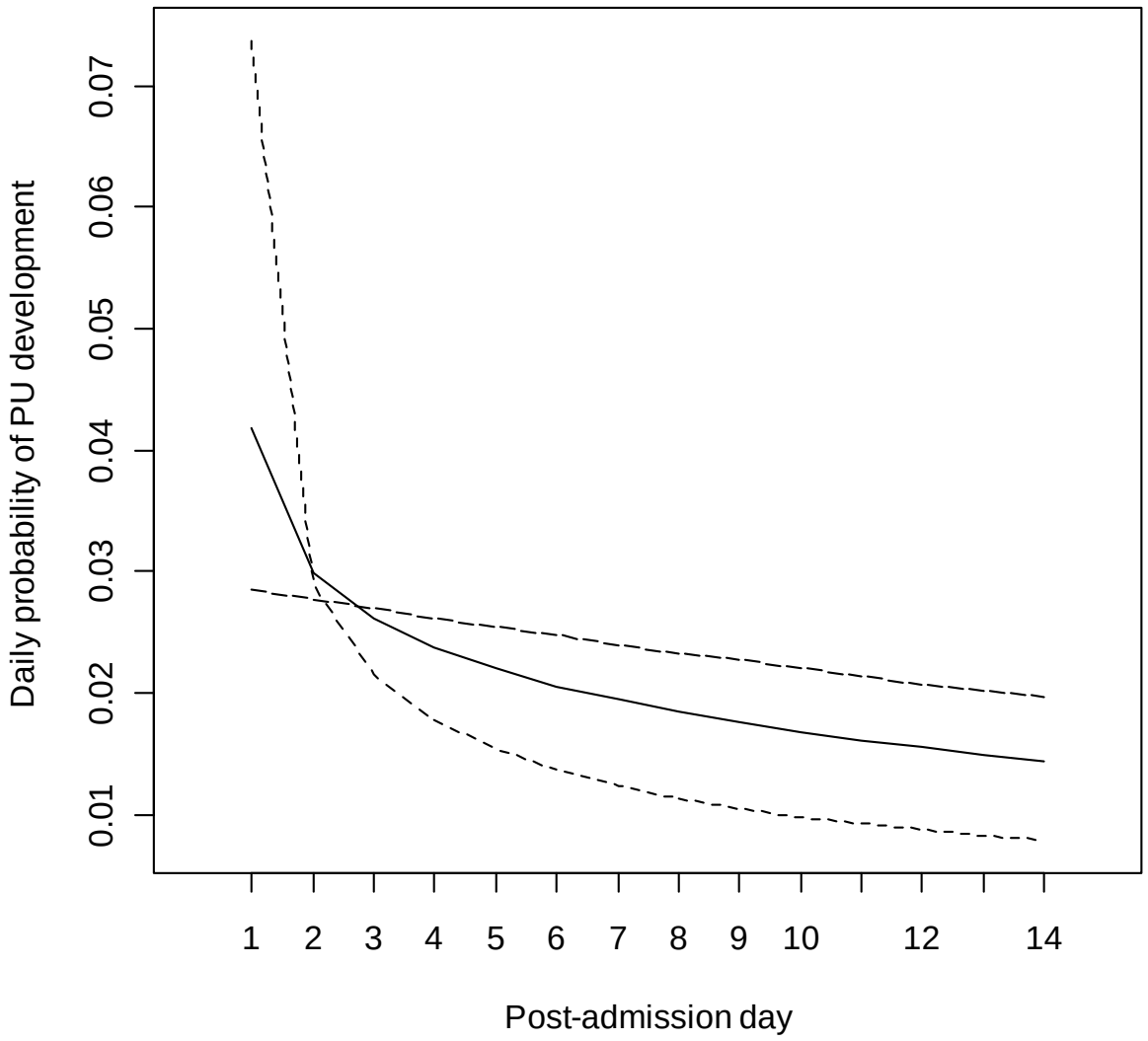
The stage-specific treatment costs from the United Kingdom reported in 2000 pounds were converted to 2000 Canadian dollar adjusting for purchasing power parities for gross domestic product published by the Organization for Economic Co-Operation and Development (http://stats.oecd.org/Index.aspx?datasetcode=SNA_TABLE4, accessed October 2, 2009; $1 U.S. was equivalent to $1.29 Canadian and £0.63 U.K.). The costs in 2000 Canadian dollar was converted to 2009 Canadian dollar adjusting for inflation using the health and personal care component of the Consumer Price Index (http://www.statcan.gc.ca/subjects-sujets/cpi-ipc/t091016a1-eng.htm, accessed October 2, 2009; $1 in 2000 is equivalent to $1.17 in 2009). The stage-specific treatment costs from the U.K. are displayed in Table 1 of the main manuscript.

Figure A1: Distribution of time to discharge



The time to discharge was assumed to follow a Weibull distribution with shape 2.3 and scale 1/0.1218136. Vertical lines denote Day 4, 7 and 11 where the modeled PrU history was sampled to obtain the projected stage-specific prevalence distribution from the modeled cohort in order to reproduce the corresponding observed prevalence from the cross-sectional Tri-hospital survey.

Figure A2: Distribution of time to pressure ulcer development



The time to PU development was assumed to follow a Weibull distribution with shape < 1, indicating that failure was more likely to be early on. Solid line denotes a Weibull distribution with shape 0.8, broken line with high decreasing from Day 1 a Weibull distribution with shape 0.5, and flat broken line an exponential distribution with constant failure rate. The base case analysis used a Weibull distribution with shape 0.8 (middle line).

Figure A3: Plot of cost-effectiveness plane – Results from probabilistic sensitivity analysis

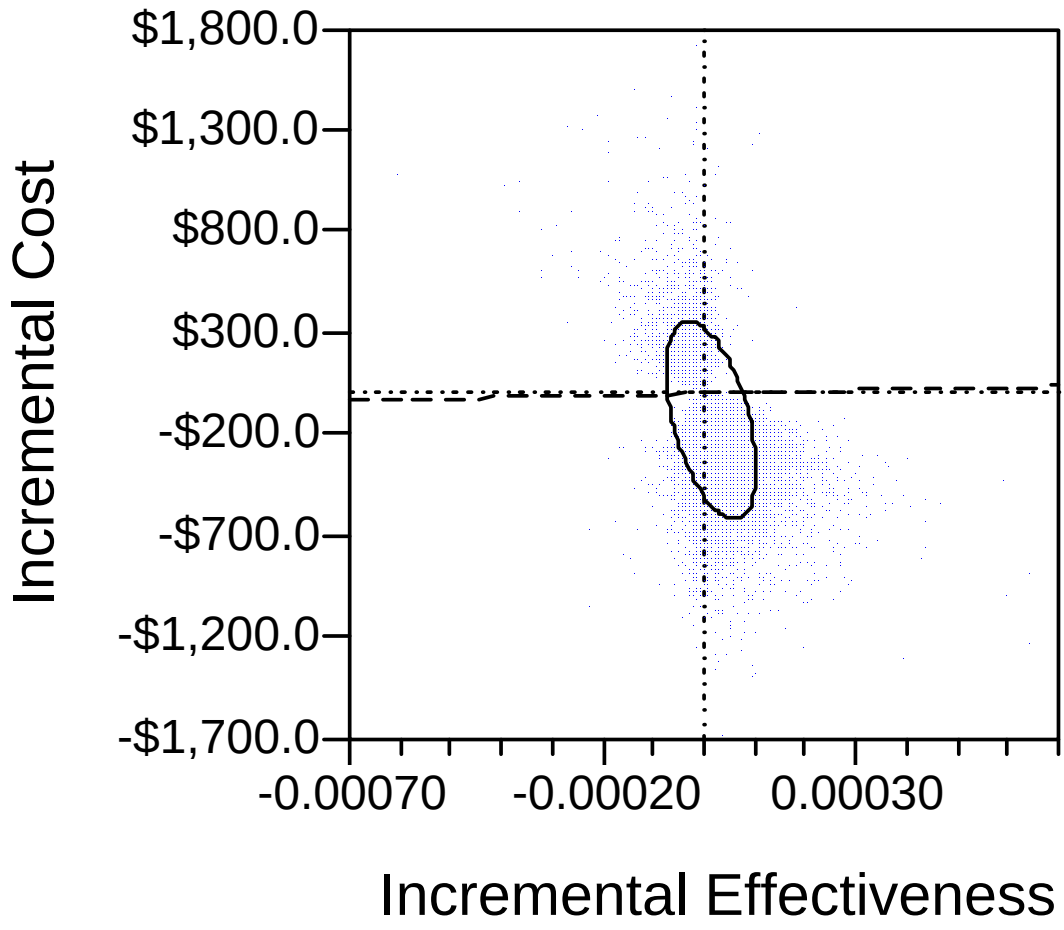


Table A1: Health States in the decision analytic model

Health state	Description
Inpatient – At risk	In-patients without PU but at risk for PrU
Inpatient – PU 1	In-patients with stage 1 PrU
Inpatient – Healing PU 1	In-patients with healing stage 1 PrU. No worsening of PrU during the stage-specific means healing time.
Inpatient – PU 2	In-patients with stage 2 PrU
Inpatient – Healing PU 2	In-patients with healing stage 2 PrU. No worsening of PrU condition during the stage-specific means healing time.
Inpatient – PU 2 – Local infection	In-patients with stage 2 PrU and related local infection. Healing is not possible until clearance of infection.
Inpatient – PU 3	In-patients with stage 3 PrU
Inpatient – Healing PU 3	In-patients with healing stage 3 PrU. No worsening of PrU condition during the stage-specific means healing time.
Inpatient – PU 3 – Local infection	In-patients with stage 3 PrU and related local infection. Healing is not possible until clearance of infection.
Inpatient – PU 3 – Systemic infection	In-patients with stage 3 PrU and related local infection. Systemic infection was assumed to be the results with untreated or not well managed local infection. Healing is not possible until clearance of infection.
Inpatient – PU 4	In-patients with stage 4 PrU
Inpatient – Healing PU 4	In-patients with healing stage 4 PrU. No worsening of PrU condition during the stage-specific means healing time.
Inpatient – PU 4 – Local infection	In-patients with stage 3 PrU and related local infection. Healing is not possible until clearance of infection.
Inpatient – PU 4 – Systemic infection	In-patients with stage 3 PrU and related local infection. Systemic infection was assumed to be the results with untreated or not well managed local infection. Healing is not possible until clearance of infection.
Discharged – no support servicers	Discharged from hospital after the resolution of the most responsible diagnosis without any PrU
Discharge – PU 1 – no support services	Discharged from hospital after the resolution of the most responsible diagnosis with stage-1 PrUs, no support services.
Discharge – PU 2 – with support services	Discharged from hospital after the resolution of the most responsible diagnosis with stage-2 PrUs, with support services.
Discharge – PU 3 – with support services	Discharged from hospital after the resolution of the most responsible diagnosis with stage-3 PrUs, with support services.
Discharge – PU 4 – with support services	Discharged from hospital after the resolution of the most responsible diagnosis with stage-4 PrUs, with support services.
PU-related death	Death due to sepsis in patients with PrU-related systemic infection
Other deaths - hospital	Death in hospital due to other causes.

Table A2: One-way sensitivity analysis

	Value (Base)	Cost		Health outcomes		Incremental		
		AFM	Std	AFM	Std	Cost	QALY	NHB
QALY	Base case	$6,551	$6,625	0.419900796	0.419891323	-$73.9700	0.0000094730	74.44
Life year	LY (QALY)	$6,551	$6,625	0.95143785	0.951437675	-$74	0.0000001750	73.98
Cohort age	66 (70)	$6,526	$6,596	0.421264988	0.421256	-$70	0.0000089920	70.58
	74 (70)	$6,440	$6,497	0.417566195	0.417559	-$57	0.0000072590	57.24
Time horizon	30 days (1 year)	$6,551	$6,625	0.036652025	0.036642653	-$74	0.0000093720	74.38
	2 years (1 year)	$6,551	$6,625	1.121591919	1.121582312	-$74	0.0000096070	74.45
	3 years (1 year)	$6,551	$6,625	1.773802825	1.773793095	-$74	0.0000097300	74.46
	4 years (1 year)	$6,551	$6,625	2.380140433	2.380130588	-$74	0.0000098450	74.46
	5 years (1 year)	$6,551	$6,625	2.943722634	2.943712683	-$74	0.0000099510	74.47
Day 1 incidence	7.4% (4.2%)	$6,728	$6,857	0.41987927	0.419862879	-$129	0.0000163910	129.54
	6.1% (4.2%)	$6,660	$6,767	0.419887503	0.419873825	-$107	0.0000136780	107.94
	5.1% (4.2%)	$6,602	$6,691	0.419894626	0.419883233	-$89	0.0000113930	89.74
	3.5% (4.2%)	$6,508	$6,569	0.419906152	0.419898284	-$61	0.0000078680	61.63
	2.9% (4.2%)	$6,470	$6,521	0.419910809	0.419904284	-$51	0.0000065250	50.94
Hospital-acquired prevalence								
	1% (18.4%)	$6,108	$6,111	0.419961369	0.419960848	-$3	0.0000005210	3.03
	2% (18.4%)	$6,133	$6,140	0.419957852	0.419956811	-$7	0.0000010410	7.14
	5% (18.4%)	$6,210	$6,229	0.419947326	0.419944728	-$19	0.0000025980	19.47
	10% (18.4%)	$6,338	$6,377	0.419929855	0.419924674	-$40	0.0000051810	40.03
	15% (18.4%)	$6,465	$6,526	0.419912451	0.419904699	-$60	0.0000077520	60.61
	20% (18.4%)	$6,593	$6,674	0.419895086	0.419884769	-$81	0.0000103170	81.25
	25% (18.4%)	$6,722	$6,823	0.419877727	0.419864848	-$101	0.0000128790	101.97
	30% (18.4%)	$6,852	$6,974	0.419860337	0.419844893	-$122	0.0000154440	122.86
Average hospital costs								
Genitourinary system (ICD-10)	$6,209 ($6,806)	$5,957	$6,031	0.419900796	0.419891323	-$74	0.0000094730	74.43
Endocrine & metabolic disorder	$7,102 ($6,806)	$6,846	$6,920	0.419900796	0.419891323	-$74	0.0000094730	74.44
Nervous system	$11,128 ($6,806)	$10,850	$10,924	0.419900796	0.419891323	-$74	0.0000094730	74.49

	Value (Base)	Cost		Health outcomes		Incremental		
		AFM	Std	AFM	Std	Cost	QALY	NHB
Relative risk for PrU - AFMs vs SMs - ER patients								
Low 95% CI	0.42 (0.78)	$6,427	$6,625	0.419916521	0.419891323	-$198	0.0000251980	199.75
High 95% CI	1.46 (0.78)	$6,781	$6,625	0.419871743	0.419891323	$156	-0.0000195800	-157.28
Relative risk for PrU - AFMs vs SMs - Hospitalized patients	0.36 (0.78)	$6,406	$6,625	0.419919161	0.419891323	-$219	0.0000278380	220.77
Low 95% CI	0.22 (0.78)	$6,357	$6,625	0.419925343	0.419891323	-$268	0.0000340200	270.01
High 95% CI	0.59 (0.78)	$6,486	$6,625	0.419909076	0.419891323	-$140	0.0000177530	140.44
RR reduction extends to 2 days	2 days (1 day)	$6,535	$6,625	0.419903198	0.419891323	-$90	0.0000118750	90.71
RR reduction extends to 3 days	3 days (1 day)	$6,526	$6,625	0.419904743	0.419891323	-$100	0.0000134200	100.29
RR reduction extends to 4 days	4 days (1 day)	$6,520	$6,625	0.419905699	0.419891323	-$105	0.0000143760	105.71
Increased cost of AFM for ER bed	2-fold ($500)	$6,552	$6,625	0.419900796	0.419891323	-$73	0.0000094730	73.35
Increased cost of AFM for ER bed	5-fold ($500)	$6,556	$6,625	0.419900796	0.419891323	-$70	0.0000094730	70.10
Increased cost of AFM for ER bed	10-fold ($500)	$6,561	$6,625	0.419900796	0.419891323	-$64	0.0000094730	64.67
Increased cost of AFM for ER bed	20-fold ($500)	$6,572	$6,625	0.419900796	0.419891323	-$53	0.0000094730	53.80
Increased cost of AFM for ER bed	30-fold ($500)	$6,583	$6,625	0.419900796	0.419891323	-$42	0.0000094730	42.94
In-patient cost attributable to pressure ulcers only	$0 (stage-specific)	$6,529	$6,600	0.419900796	0.419891323	-$71	0.0000094730	71.46
Nursing cost attributable to PrU care post-discharged only	$0 (stage-specific)	$22	$25	0.419900796	0.419891323	-$3	0.0000094730	3.45
Relative disutility attributable to PU								
Low 95% CI	3.93% (6.11%)	$6,551	$6,625	0.419931411	0.419926219	-$74	0.0000051920	74.23
High 95% CI	8.29% (6.11%)	$6,551	$6,625	0.419870182	0.419856426	-$74	0.0000137560	74.66
Estimate of mean in-patient health utility								
Lower bound	0.12 (0.44)	$6,551	$6,625	0.11590409	0.115903285	-$74	0.0000008050	74.01
Upper bound	0.76 (0.44)	$6,551	$6,625	0.723897503	0.72387936	-$74	0.0000181430	74.88
Estimate of mean health utility post discharge								
Lower bound	0.62 (0.79)	$6,551	$6,625	0.419687311	0.419677837	-$73.97000	0.0008348575	115.71
Upper bound	0.85 (0.79)	$6,551	$6,625	0.419976144	0.41996667	-$73.97000	0.0008348637	115.71

	Value (Base)	Cost		Health outcomes		Incremental		
		AFM	Std	AFM	Std	Cost	QALY	NHB
Discount	3% (5%)	$6,553	$6,627	0.423930741	0.423921261	-$74	0.0000094800	74.47

Table A3: Probabilistic sensitivity analysis

Component	Quadrant	Incr. Eff.	Incr. Cost	ICER	# Points	Percent
C1	IV	IE>0	IC<0	Dominant	33899	67.80%
C2	I	IE>0	IC>0	<50000	1	0%
C3	III	IE<0	IC<0	>50000	7151	14.30%
C4	I	IE>0	IC>0	>50000	1682	3.36%
C5	III	IE<0	IC<0	<50000	0	0%
C6	II	IE<0	IC>0	Dominated	7267	14.53%
Indiff	origin	IE=0	IC=0	0/0	0	0%

Quadrants in Figure A3 above begin at "I" in the upper right, and increment counterclockwise to "IV" in the lower right.

To identify cost-effective points, a different component labeling system is used.
Cost-effective points for "ER beds or trolleys with AFMs" lie below the WTP line,
in components 1-3.

Component 1 (C1) is where the comparator is dominant.
Component 2 (C2) is where the comparator is more costly, but lies below the WTP.
Component 3 (C3) is where the comparator is less costly, but lies below the WTP.

Component 4 (C4) is where the comparator is more costly, and lies above the WTP.
Component 5 (C5) is where the comparator is less costly, and lies above the WTP.
Component 6 (C6) is where the comparator is dominated.

Table A4: Calibrated progression incidence

Progression		MDS	Calibrated		MDS	Calibrated		MDS	Calibrated
Transition	n	1 → 2+	1 → 2	n	2 → 3+	2 → 3	n	3 → 4+	3 → 4
Age		%	%		%	%		%	%
		High	0.230933			0.053015			0.039975
60-69	59	0.0015	0.19758	79	0.0008	0.047325	14	0.0003998	0.037173
		Low	0.187151			0.030868			0.028766
			0.249453			0.039395			0.055304
70-74	131	0.0017	0.213426	112	0.0006	0.035167	44	0.0005531	0.051428
			0.20216			0.022937			0.039798
			0.172725			0.050801			0.090778
75-79	233	0.0012	0.14778	248	0.0008	0.045349	68	0.0009079	0.084416
			0.139979			0.029579			0.065325

Table A5: Calibrated healing incidence

Healing		MDS	Calibrated		MDS	Calibrated		MDS	Calibrated		MDS	Calibrated
Transition	n	1 → 0	1 → 0	n	2 → 0	2 → 0	n	3 → 0	3 → 0	n	4 → 0	4 → 0
Age		%	%		%	%		%	%		%	%
		Low	0.126297			0.071705			0.043848			0.005318
60-69	59	0.0102	0.105205	79	0.0065	0.024514	14	0.0022	0.005402	16	0.0003	0.002061
		High	0.008132			0.011506			0.002887			0.000396
			0.113888			0.069898			0.050599			0.012362
70-74	131	0.0100	0.094868	112	0.0059	0.023896	44	0.0025	0.006234	31	0.0007	0.00479
			0.007333			0.011216			0.003331			0.00092
			0.127877			0.071615			0.056779			0.025136
75-79	233	0.0102	0.106522	248	0.0066	0.024483	68	0.0029	0.006996	53	0.0013	0.009739
			0.008233			0.011492			0.003738			0.001871

Table A6: Ranges of uniform distributions for the multipliers used in the calibration

Multipliers							
Uniform distribution	**1 →2**	**2 →3**	**3 →4**	**1 →0**	**2 →0**	**3 →0**	**4 →0**
Min	100	10	10	1	1	1	1
Max	150	100	100	20	20	20	20

Table A7: Regression analysis of direct inpatient costs

From cases and matched controls adjusting for age, sex, major diagnosis, Charlson'scores and PrU stage (log scale).

Source	DF	Type III SS	Mean Square	F Value	Pr > F
diag_mrdx	325	17186.919	52.883	21.04	< 0.0001
age	1	36.319	36.319	14.45	0.0002
Sex	1	6.828	6.828	2.72	0.0996
Charlson_Scores	2	4480.596	2240.298	891.14	< 0.0001
pu_stage	4	182.431	45.608	18.14	< 0.0001

Table A8: Attributable direct costs by PU stage

Label	Estimate	Standard Error	t Value	Pr > |t|	LSMEANS	Factor	Mean cost	Attributable cost
PU stage 0, 1					8.923	1.000	7,505	
PU stage 2	0.953	0.186	5.13	<.0001	9.877	2.594	19,472	11,967
PU stage 3	1.003	0.354	2.83	0.0048	9.926	2.726	20,457	12,951
PU stage 4	1.362	0.376	3.63	0.0003	10.285	3.904	29,303	21,797
PU (no stage specified)	1.085	0.203	5.34	<.0001	10.008	2.960	22,213	

Table A9: Regression analysis of home care costs

From cases and matched controls adjusting for age, sex, major diagnosis, Activities of Daily Living scores and PrU stage

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	35	109390256	3125436	273.57	<.0001
Error	33974	388136839	11425		
Corrected Total	34009	497527095			

Root MSE	106.88557	R-Square	0.2199
Dependent Mean	112.68222	Adj R-Sq	0.2191
Coeff Var	94.85576		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	133.70034	3.76094	35.55	<.0001
approx_age	1	-0.78658	0.04765	-16.44	<.0001
sex	1	-0.32425	1.35126	-0.24	0.8104
n2a_1	1	42.16106	3.51141	12.01	<.0001
n2a_2	1	56.52474	5.66066	9.99	<.0001
n2a_3	1	80.93724	9.19949	8.80	<.0001
n2a_4	1	105.30385	13.74612	7.66	<.0001
j1a	1	0.93391	1.28433	0.73	0.4671
j1b	1	4.16845	1.41807	2.94	0.0033
j1c	1	-1.76389	1.16573	-1.51	0.1303
j1d	1	-1.39523	0.99894	-1.40	0.1625
j1e	1	4.81046	1.71729	2.80	0.0051
j1f	1	10.87855	1.67013	6.51	<.0001
j1g	1	16.00663	1.74900	9.15	<.0001
j1h	1	6.12891	1.66496	3.68	0.0002
j1i	1	4.11374	3.47445	1.18	0.2364
j1j	1	0.21093	2.59759	0.08	0.9353
j1k	1	7.00146	2.47492	2.83	0.0047
j1l	1	-0.43212	2.19267	-0.20	0.8438
j1m	1	-0.40642	1.01557	-0.40	0.6890
j1n	1	1.01756	2.27771	0.45	0.6551
j1o	1	6.70913	1.62737	4.12	<.0001
j1p	1	-2.22832	1.27345	-1.75	0.0802
j1q	1	-1.10113	1.43843	-0.77	0.4440
j1r	1	4.23309	2.14534	1.97	0.0485
j1s	1	-1.91359	1.49218	-1.28	0.1997
j1t	1	13.05371	15.05319	0.87	0.3859
j1u	1	9.64149	2.80820	3.43	0.0006
j1v	1	0.27344	13.14943	0.02	0.9834
j1w	1	8.06541	2.42865	3.33	0.0009
j1x	1	16.10242	1.27374	12.64	<.0001
j1y	1	8.84215	1.13203	7.81	<.0001
j1z	1	1.87192	1.28981	1.45	0.1467
j1aa	1	10.37868	2.31796	4.48	<.0001
j1ab	1	-1.30542	1.54999	-0.84	0.3997
ADL_long_hc2	1	8.31389	0.10943	75.96	<.0001

Table A10: Distributions used in the probabilistic sensitivity analysis

Name	Description	Parameters/Info
d_logN_RR_AFM	Distribution for relative risk of ER AFM	Log-Normal, u (mean of logs) = -0.298461359, sigma (std dev of logs) = 0.317841072; Expected value: 0.780399052
d_LOS	Distribution of LOS for ER-admitted patients	Gamma, alpha = 0.518110881, lambda = 0.07401584; Expected value: 7.000000014
d_gamma_cost_factor_PU2	Distribution of factor used to adjust for attributable cost, estimated from regression analysis	Gamma, alpha = 26.27630981, lambda = 27.56102539; Expected value: 0.95338651
d_gamma_cost_factor_PU3	Distribution of factor used to adjust for attributable cost, estimated from regression analysis	Gamma, alpha = 8.002038232, lambda = 7.980447292; Expected value: 1.00270548
d_gamma_cost_factor_PU4	Distribution of factor used to adjust for attributable cost, estimated from regression analysis	Gamma, alpha = 13.14343338, lambda = 9.649636487; Expected value: 1.36206513
d_Gam_base_utility_hospital	Distribution of inpatient health utility	Gamma, alpha = 1.890625, lambda = 4.296875; Expected value: 0.44
d_Beta_relative_disutility	Distribution of relative utility decrement associated with severe PU	Beta, Real-numbered parameters, alpha = 28.27244498, beta = 434.4516954; Expected value: 0.0611
d_Gam_base_utility_community	Average health utility for individuals living in the community with typical chronic conditions	Gamma, alpha = 47.19092628, lambda = 59.73534972; Expected value: 0.79
d_cost_gamma_afm_stretcher	Cost of AFM on ER stretcher	Gamma, alpha = 7.386273962, lambda = 0.009469582; Expected value: 780.000000211
t_index_Weibull_incidence	Distribution of index to table of different Weibull scales for daily prob from PU 0 to 1	Uniform, Integer parameters only, Low Value = 1, High Value = 10; Expected value: 5.5
d_cost_MD_visit	Distribution of cost of MD visits for inpatient	Gamma, alpha = 0.373403499, lambda = 0.000839024; Expected value: 445.045074992
d_local_infection_PU24	Distribution for daily local infection given severe PU	Beta, Real-numbered parameters, alpha = 4.60943513, beta = 3174.277046; Expected value: 0.001450016
d_base_hospitalization_cost	Distribution of base cost for hospitalization of surgical patients - Need to adjust for PU cost later	Gamma, alpha = 0.401209354, lambda = 5.89494E-05; Expected value: 6805.995548725
d_systemic_infection_PU34	Distribution of daily prob of systemic infection given PU 34	Beta, Real-numbered parameters, alpha = 8.628089439, beta = 4697.326472; Expected value: 0.001833441
d_cost_hc_PU2	Distribution of attributable cost post discharge	Gamma, alpha = 85.8508573, lambda = 1.51894652; Expected value: 56.519999993
d_cost_hc_PU3	Distribution of attributable cost post discharge	Gamma, alpha = 66.30612245, lambda = 0.81920092; Expected value: 80.939999982
d_cost_hc_PU4	Distribution of attributable cost post discharge	Gamma, alpha = 50.34877871, lambda = 0.478146047; Expected value: 105.299999918
t_ER_goodfit_index_table	Table distribution for weighted sampling of good-fit models after calibration	Sample from table "t_ER_goodfit_index_prob_sampling"; Expected value: 28.801101318

Name	Description	Parameters/Info
d_death_due_to_sepsis_PU34	Distribution of daily death due to sepsis related to PU 34	Beta, Real-numbered parameters, alpha = 362.7091484, beta = 25724.89769; Expected value: 0.013903504
d_healing_time_PU1	Distribution of full healing time for PU stage 1	Exponential, lambda = 0.25; Expected value: 4
d_healing_time_PU2	Distribution of full skin closure for PU stage 2	Exponential, lambda = 1/13; Expected value: 13
d_healing_time_PU3	Distribution of full skin closure for PU stage 3	Exponential, lambda = 1/18; Expected value: 18
d_healing_time_PU4	Distribution of full skin closure for PU stage 4	Exponential, lambda = 1/22; Expected value: 22
d_cost_gamma_afm_er_bed	Cost of AFM on ER beds	Gamma, alpha = 0.060014197, lambda = 0.000120028; Expected value: 500.001641284

Table A11: Estimates of health utility HUI-Mark III scores

In individuals living in the community with selected chronic conditions.

	Age 60-69 (e.g.	Age 60-69 (e.g. OR)
	HUI Mean	Prevalence (%)
Alzheimer's disease	0.62	0.3
Arthritis/rheumatism	0.79	34.8
Asthma	0.76	5.5
Back pain	0.79	19.5
Bronchitis/emphysema	0.75	6.4
Cancer	0.85	3.8
Cataracts	0.77	5.7
Diabetes	0.81	8
Epilepsy	0.74	0.6
Glaucoma	0.76	2.3
Heart	0.8	11.5
High blood pressure	0.83	25.7
Migraine	0.75	5.3
Sinusitis	0.8	6.7
Stroke	0.72	2.6
Stomach/intestinal ulcer	0.78	5.3
Urinary incontinence	0.71	3
Weighted estimate	0.79 (0.62,	
Source: Mittmann et al. 1999[6]		

Table A12: Toronto Tri-Hospital Survey - Data collection form

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Toronto Tri-Hospital Acute Care Pressure Ulcer Prevalence and Incidence Survey Tool

Subject ID - for Office only

Study Type
☐ Prevalence
☐ Incidence

Date of Observation (DD/MMM/YY): ____ / ____ / ____ **Hospital** ____ **Site** ____ **Unit Name** ____

PATIENT INFORMATION ☐ Declined

Patient Encounter Number ____ **Age** ____

Gender
☐ Male
☐ Female

Height (cm) ☐ Unable to obtain

Weight (kg) ☐ Unable to obtain

Date of Admission:
____ / ____ / ____
DD / MMM / YY

Pressure Ulcer Risk Assessment Tool:
☒ Braden ☐ Norton ☐ Other ☐ None

PRESSURE ULCER SCREEN

ULCER IDENTIFICATION TABLE

☐ **No pressure ulcers present**

Ulcer #	Location Code	Stage (select one box)	Length cm	Width cm
1	☐ Left ☐ Right	DTI ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ unstageable ☐		
2	☐ Left ☐ Right	DTI ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ unstageable ☐		
3	☐ Left ☐ Right	DTI ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ unstageable ☐		
4	☐ Left ☐ Right	DTI ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ unstageable ☐		
5	☐ Left ☐ Right	DTI ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ unstageable ☐		
6	☐ Left ☐ Right	DTI ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ unstageable ☐		
7	☐ Left ☐ Right	DTI ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ unstageable ☐		
8	☐ Left ☐ Right	DTI ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ unstageable ☐		
9	☐ Left ☐ Right	DTI ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ unstageable ☐		
10	☐ Left ☐ Right	DTI ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ unstageable ☐		

Ulcer Code Table

Occiput	OCC
Ear	EAR
Shoulder	SHO
Scapula	SCA
Elbow	ELB
Spine	SPI
Sacrum/Coccyx	SAC
Ischium	ISC
Buttocks	BUT
Hip	HIP
Thigh	THI
Knee	KNE
Ankle	ANK
Heel	HEE
Foot	FOO
Other	OTH

If more than 10 ulcers are present, please complete an additional form and fill in same Subject ID

Is the patient bedbound or on bed rest? ☐ Yes ☐ No
Turning and Repositioning? ☐ Yes ☐ No ☐ Independent
Heel Offloading Devices? ☐ Yes ☐ No If Yes, type: ____ ☐ Left foot ☐ Right foot

Is the patient chairfast? ☐ Yes ☐ No If Yes, Seating Cushion? ☐ Yes ☐ No If Yes, ☐ Gel ☐ Foam ☐ Air

Management of Pressure:
Current Mattress (shade one only): ☐ Pressure Redistribution ☐ Non Pressure Redistribution
Type of Mattress (shade one only): ☐ Air ☐ Fluid/Gel ☐ Foam ☐ Other
Is mattress motorized? ☐ Yes ☐ No

Management of:
Moisture: ☐ Yes ☐ No ☐ N/I
Friction/Shear: ☐ Yes ☐ No ☐ N/I
Nutrition: ☐ Yes ☐ No ☐ N/I

Pressure Ulcer P and I : 14 September 2007, v. 23

5308502946

Subject ID - for Office only

ADMITTING DIAGNOSIS (select one box only):

☐ Cardiovascular	☐ Musculoskeletal	☐ Skin/Wound
☐ Gastrointestinal	☐ Neuro	☐ Trauma
☐ Genito/Urinary	☐ Oncology	☐ Other _____
☐ Infectious Disease	☐ Respiratory	

Does the patient have Diabetes? ☐ Yes ☐ No

Is the patient receiving Dialysis? ☐ Yes ☐ No

Location of the patient over the last 48 hours (select all that apply):

☐ No Change	☐ Home	☐ Long-Term Care
☐ Another Hospital	☐ Homeless	☐ OR
☐ Diagnostic Test	☐ Critical Care Unit	
☐ ER	☐ Rehab	

Skin assessment completed on admission: ☐ Yes ☐ No

Were pressure ulcer(s) documented on admission? ☐ Yes ☐ No ☐ N/I

Number of hours spent in the ER prior to admission to unit: ☐ N/A

Pressure Ulcer Risk Assessment Tool Documented within 24 hours of admission? ☐ Yes ☐ No

If Yes, admission score ____

Has the patient been admitted to a critical care unit during this admission? ☐ Yes ☐ No

Has the patient had surgery during this admission? ☐ Yes ☐ No

If yes, how many? ____

Document the length of time of each surgery

- ☐ OR 1 time in hours ____
- ☐ OR 2 time in hours ____
- ☐ OR 3 time in hours ____
- ☐ OR 4 time in hours ____
- ☐ 5 or more ORs time in hours (add remaining OR times) ____

Date of most current pressure ulcer risk assessment score within the last 7 days:

____ / ____ / ____

DD / MMM / YY

Current Score: ____

CONTRIBUTING FACTORS

	Yes	No
Hemoglobin in last 4 weeks?	☐	☐
If yes, is most recent Hg less than 100 g/L?	☐	☐

	Yes	No
Albumin in last 4 weeks?	☐	☐
If yes, is most recent Albumin less than 35 g/L?	☐	☐

	Yes	No	U/D
NPO x3 days within last 7 days?	☐	☐	
Parenteral/Enteral Feeding	☐	☐	
Involuntary Weight Loss	☐	☐	☐
Sensory Impairment	☐	☐	☐
Peripheral Arterial Disease	☐	☐	☐
Immobility	☐	☐	
Contracted	☐	☐	
Agitation	☐	☐	
Fragile Skin	☐	☐	
Immunosuppressive Drugs/ Cancer Therapy	☐	☐	

	Yes	No
Urinary Incontinence	☐	☐
Fecal Incontinence	☐	☐
Diarrhea	☐	☐
Diaphoresis	☐	☐
Anasarca (Total Body Edema)	☐	☐
Acute/Chronic Pain	☐	☐
Is pain interferring with ADLs?	☐	☐
Critical Care Only:		
Neuromuscular Blockers	☐	☐
Sedation	☐	☐
Hemodynamic Instability (Critical Care only)	☐	☐

Pressure Ulcer P and I : 14 September 2007, v. 23

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