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TURNing high risk patients: An economic evaluation of repositioning frequency in long-term care

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Speaker Forum		X		X		X		X		X		X
Consultant		X		X		X		X		X		X
Stocks		X		X		X		X		X		X
Royalties		X		X		X		X		X		X
Expert Testimony		X		X		X		X		X		X
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Abstract

Recent evidence suggests that less frequent repositioning of long-term care residents at moderate/high risk of developing pressure ulcers (PrUs) is non-inferior to current repositioning standards in preventing PrUs. However, the long-term health and economic consequences of less frequent repositioning have not been adequately estimated. Our objective is to estimate the cost-effectiveness of different repositioning strategies (2-, 3-, or 4-hour intervals). We conducted a cost-utility analysis using a lifetime horizon based on data from a randomized clinical trial and from the literature. We updated a published PrU decision model with resource utilization, unit costs, and epidemiological estimates from the literature and from a small observational study. The Ontario Ministry of Health and Long-Term Care perspective was taken. We estimated the reduction in costs at 3-hour vs 2- or 4-hour repositioning at CAN\$5,425 (95% Credible Interval (CrI): \$922 – \$12,166), or CAN\$3,296 (95%CrI: -\$483 – \$9,738) per resident across their lifetime respectively. The gain in the expected Quality Adjusted Life Years (QALYs) between 3-hour and 2- or 4-hour repositioning strategies were 0.008, (95% CrI: 0.005 – 0.016) and 0.009 (95%CrI: 0.007 – 0.018) respectively. Repositioning at 3-hour intervals was the dominant strategy with respect to the incremental cost-effectiveness ratio against both 2- and 4-hour strategies. Sensitivity analysis showed a 99% probability that the 3-hourly repositioning was a dominant strategy. We concluded that repositioning at 3-hour intervals for residents at moderate or high risk of PrUs and who were cared for on high-density foam mattresses appeared to be the most cost-effective strategy.

Keywords

economic evaluation; pressure ulcers; reposition frequency

Introduction

Nursing home residents with impaired mobility are at high risk of developing pressure ulcers (PrUs). These complications are caused by prolonged pressure at the interface between bony prominences and support surfaces. In the US and Canada, the prevalence of PrUs is 11–15% among nursing home residents.^{1,2} PrUs can be painful and affect quality of life^{3,4} and are also costly.⁵ However, they can be prevented in most cases through a number of PrU prevention strategies. Such strategies could include educational or nutritional interventions or active skin management such as frequent skin checks, use of pressure redistributing support surfaces (e.g. high-density foam mattresses) and frequent repositioning.

According to current US practice guidelines, nursing home residents should be repositioned as frequently as required by their condition.⁶ Practice guidelines in Canada and the US recommend that patients at high risk of PrUs be repositioned every two hours. Nursing homes in Ontario are required to comply with that recommendation to achieve accreditation standards. However, these recommendations are based on limited scientific evidence.⁷ In addition, recent applications of new technologies in long term care, such as the high density foam mattresses allow for less frequent repositioning without exposing residents to a greater risk of developing PrUs.⁸

The cost implications of PrU prevention can be substantial, as some elements of prevention consume a large amount of human resources. A policy of frequent turning requires that nurses and/or personal support workers (PSWs) devote a large part of each working day to this task. A limited number of recent clinical and economic studies have examined the effectiveness and cost-effectiveness of different repositioning strategies that are less resource-intensive. A Cochrane systematic review examined three clinical RCT studies and one economic study that assessed the effectiveness of repositioning on health.⁹ The systematic review observed a large variation around the effectiveness of repositioning strategies as studies were generally underpowered. An economic evaluation conducted by Moore et al identified that a 3-hour repositioning strategy using a 30° tilt resulted in better effectiveness and fewer costs in comparison to a 6-hour strategy using the 90° lateral rotation.¹⁰

Recent evidence from the TURN randomized control trial suggested that there were no significant differences between 2, 3, and 4 hour repositioning strategies with respect to PrU incidence.⁸ A study that estimated the cost implications of the repositioning strategies from the TURN study concluded that 4-hour repositioning is the least costly strategy.¹¹ However, the long-term implications of a change in PrU incidence were not taken into consideration.¹¹ As noted in the health economic literature, even in the presence of non-inferiority, the estimates of effectiveness from the non-inferiority trial need to be considered in economic evaluations.¹² Considering the above, we conducted a cost-utility analysis to estimate the lifetime health and economic implications associated with repositioning nursing home residents who are at medium or high risk of PrUs using a schedule of 2-hour, 3-hour, or 4-hour intervals.

Methods

Model Structure

This economic evaluation relied on an adaptation of a previously published and validated decision analytic microsimulation model.¹³ The structure and the calibration of the model are presented in Appendix 1 and Appendix 2, respectively. In this model, patients at risk of PrUs can transition progressively at each weekly cycle through PrU stages 1, 2, 3, and 4 and can recover from a PrU of any stage. Patients in stages 2 and 3 are at risk of local infections, while patients in stage 3 and 4 are at risk of systemic infection. The maximum stay in any of the infection states are one and two weeks, respectively. We assumed that patients with systemic infections received treatment in a hospital setting and had an increased risk of mortality due to the infection. The decision analytic model was built using TreeAge Pro 2013 (TreeAge software, Williamstown, Massachusetts).

Strategies

We compared the incremental costs and effectiveness, measured in quality-adjusted life years (QALYs) gained, of three repositioning strategies: repositioning every 2 hours, every 3 hours, or every 4 hours.

Cohort

The model followed hypothetical patients similar to those in the TURN study over a life time horizon. The hypothetical cohort of nursing home residents were at moderate or high risk of PrUs according to the Braden Scale and were cared for on high-density foam mattresses combined with guideline-based care and regular skin observations.¹⁴

Economic Assumptions

We conducted the analysis from a public payer perspective. In Ontario, that is the perspective of the Ontario Ministry of Health and Long-term Care. We included only direct healthcare costs borne by the payer. All costs were inflated to 2014 Canadian dollars using the Canadian Consumer Price Index for health and personal care. A discount rate of 5% was applied in both costs and effects, in accordance with guidelines for economic evaluation in Canada.¹⁵

Model inputs

Prevalence of Pressure Ulcers, hospitalization risk, and QoL weights—The model relied on patient level Resident Assessment Instrument–Minimum Data Set (RAI-MDS, version 2.0) data, published literature, and expert opinion. Probabilities related to the prevalence of PrU risk factors among high risk residents, as well as the risk of hospitalization or death and were derived from a population-based cohort (RAI-MDS) and from linked administrative data from the Discharge Abstract Database of the Canadian Institute for Health Information (CIHI-DAD). Quality of life (QoL) weights were estimated by mapping MDS patient level data from population based cohort to Health Utility Index scores using a validated algorithm.^{13,16} Table 1 presents the parameter values, the uncertainty around them, and the distribution assumptions made.

Effectiveness—Effectiveness estimates originated from the TURN study. Briefly the study followed US and Canadian nursing facility residents cared for on high-density foam mattresses who were randomly allocated to one of three repositioning schedules: 2-hour, 3-hour, or 4-hour intervals.⁸ Overall, no significant difference was observed in Stage 2 PrUs incidence between groups after three weeks of follow up (2 hour: 8/321 (2.49%), 3 hour: 2/326 (0.61%), 4 hour: 9/295 (3.05%), *P*-value = 0.07). No Stage 3–4 PrUs were observed during the TURN study.

The published decision model used patient level data from RAI-MDS to estimate the probability of Stage 1–4 PrUs. We used the stage-specific (cumulative) incidence observed in the TURN study to calibrate these stage-specific probabilities of developing PrUs from the decision model. A full description of the calibration analysis can be found in the Appendix.

Resource utilization during repositioning—The findings on the average duration of repositioning from a small observational study conducted alongside the TURN study were used to estimate the average time each personal support worker (PSW) spent during one repositioning (personal communication, Nikhil Padhye, TURN study team¹¹). Based on expert opinion (TURN study team), it was also assumed that 80% of the residents would

require one PSW while 20% of residents would require two PSWs for repositioning. It was further assumed that all repositioning would be carried out by PSWs. Finally, it was assumed based on expert opinion that after a PrU is observed, the resident would be repositioned at 2-hour intervals (personal communication, L. Teague, St Michael's Hospital, Toronto).

Costs—The minimum and maximum hourly cost of employing a PSW in Ontario (as of April 2012, inclusive of salary and benefits) was extracted from the reports of the Ontario-based nursing facilities that participated in the TURN study. The average hourly cost at each nursing facility was assumed to be the midpoint of the minimum and maximum hourly costs. A weighted average of the hourly cost was calculated across all seven nursing facilities. This estimate is commensurate with the findings of a survey of nursing homes in Ontario conducted in 2008, which found that the average cost of employing a PSW at that time was \$16.97 per hour.¹⁷

Base case and sensitivity analysis—The analysis focused on the estimation of the lifetime probability of a PrU, the expected costs, and the expected quality adjusted life-years (QALYs) associated with each repositioning strategy. Incremental costs, QALYs, and cost-effectiveness ratios for each strategy were subsequently estimated. The cost-effectiveness of each strategy relative to the others was estimated using an informal CE threshold of \$50,000/QALY.

A series of analyses were carried out to estimate the sensitivity of the cost-effectiveness estimates on a number of input parameters. Initially one way sensitivity analyses were conducted where the parameters expected to have an impact on the incremental cost-effectiveness estimates (average repositioning time, proportion of residents requiring two PSW during repositioning, average cost of employing a PSW, etc.) were varied across a plausible range (Table 1).

Probabilistic sensitivity analysis (PSA) was conducted to estimate the joint effect of the uncertainty around the model parameters on the final outcomes. We used a Monte Carlo simulation approach to propagate uncertainty from all model input parameter into the final outcomes of the model (total cost and QALYs per strategy, incremental costs and QALYs across strategies). Given the Bayesian nature of this approach, uncertainty around costs and QALYs was summarized using 95% credible intervals, which are analogous to the frequentist notion of confidence intervals.¹⁸ Cost effectiveness acceptability curves were used to summarize the findings of the PSA.

Results

Base case

Table 2 presents the lifetime risk of developing a PrU over their lifetime for our study population, the average time spent with a PrU, as well as a breakdown of total costs between repositioning and non repositioning costs. Over the residents' lifetime (102.7 weeks on average) the risk of developing a PrU was higher for the residents repositioned in 2-hour or 4-hour intervals than those repositioned in 3-hour intervals (37% and 44% higher, respectively). Compared to patients in the 3-hour repositioning strategy, those on the 2- or

the 4-hour strategy spent on average 39% and 51% more of their remaining life with a PrU. Both repositioning and non repositioning-related costs were less in the 3-hour strategy compared to the 2 or 4 hour strategies.

Table 3 reports the results of the base case of the cost-utility analysis along with the 95% credible intervals. The 3-hour repositioning strategy was less costly while achieving incremental QALY gains compared to both 2-hour and 4-hour strategies. Therefore both 2-hour and 4-hour strategies were dominated by the 3-hour strategy.

Sensitivity analysis

The results of the one-way sensitivity analysis for the comparison of 2-hour vs 3-hour repositioning strategies are presented in Table 4. It can be seen that varying the model parameters within the defined range had little effect on the outcomes of the cost-utility analysis, and repositioning every 3-hours remained the dominant strategy. The combined effect of uncertainty around the input parameters examined through the PSA indicated that 3-hour repositioning is the dominant strategy with a probability of >95% at any positive CE threshold.

Discussion

This cost-utility analysis suggests that a switch to a 3-hour repositioning strategy for nursing facility residents at risk of developing PrUs according to the Braden Scale who are cared for on high density foam mattresses combined with guideline-based care and regular skin observations, can yield economic benefits while at the same time resulting in more QALYs gained compared to a 2- or a 4-hour repositioning strategy. The cost savings associated with a 3-hour repositioning strategy largely represents the value of freed up PSW staff time that would have previously been spent repositioning residents. Additionally, a benefit may accrue to residents who are not awakened every two hours and allowed to sleep uninterrupted for longer periods.

Since it is not recommended, nor likely feasible, to employ fewer PSW staff due to high resident-to-staff ratios currently in place in nursing homes,¹⁹ these estimates of economic benefit likely do not represent monetary savings. This PSW time could be spent undertaking other valuable activities instead, such as feeding, toileting, socializing, and mobilizing residents that can improve quality of care.²⁰

Additionally we observed that variation from the base case estimates of the hourly cost of employing a PSW, the average number of PSWs required to reposition each patient and the average time taken to reposition each patient has a significant impact on the magnitude of cost-utility estimates but it does not change the main finding of 3-hour repositioning being the dominant strategy.

The results of the TURN study support less frequent repositioning (e.g., a change from every 2-hour to 3- or 4-hour) for moderate- to high-risk residents on high density foam mattresses. The uptake of this finding should be considered within the following context: 1) provision of a high density foam mattresses to moderate- to high-risk residents according to the Braden

Scale; 2) risk assessment upon admission to nursing facilities; 3) provision of guideline-based care and regular skin observations; and 4) ongoing assessment of resident skin to determine if more frequent repositioning is recommended. Although providing high density foam mattresses to Ontario nursing facility residents at moderate or high risk of developing PrUs has been found to be cost-effective, some nursing facilities in Ontario do not yet provide high density foam mattresses to such residents¹³. The findings of this study provide more evidence to support the argument that for nursing facilities that are not yet equipped with high density foam mattresses, the potential economic benefits of investing in such equipment appear to significantly outweigh the costs (assuming that the cost of a high density foam mattress is approximately \$350). There is currently no evidence to support repositioning residents at intervals of greater than 2 hours in cases where high density foam mattresses are not provided. Finally, the timing of the risk assessment is also important as a previous study has suggested that the majority of PrUs in nursing facilities occur within the first three weeks post admission.^{21–22}

Although the evidence from the TURN study suggests the non-inferiority of 3- and 4-hour interval vs. 2-hour interval repositioning strategies with respect to PrU incidence, a cost-utility instead of a cost-minimization analysis was performed. Our decision was based on the fact that although clinical non-inferiority has been established in the RCT on the basis of the primary outcome (PrU risk), this does not imply that the alternative strategies are equivalent with respect to secondary or other non-clinical outcomes (e.g. quality of life). In addition, a cost-utility approach is more appropriate with respect to incorporating the impact of parameter uncertainty in the economic analysis^{12,23}. According to the results from our cost-utility study and compared to the 2-hour and 4-hour repositioning strategies, the 3-hour repositioning was economically attractive as it improved patient's quality of life and reduced healthcare costs.

Limitations

In the TURN study it has been observed that the reduction of the frequency of repositioning consequently reduced “wet observations”, brief changes, and the use of related supplies. Although this observation might have some clinical and economic implications we decided not to incorporate it in our economic analysis. Firstly, we assumed that the reduction on total costs due to less frequent brief changes would be minimal as the cost of briefs and supplies relative to that of PSW staff time is very small. Additionally, we hypothesized that a reduction of the frequency of brief changes could be linked to a marginal negative clinical consequence and a potential reduction of QoL for which we have no data to control for. These issues represent a limitation in our analysis although their impact on our conclusions is likely to be limited.

We also made the assumption that PrU incidence rate observed within the 3-week follow up of the TURN RCT was informative of the expected incidence rate over the lifetime, for patients cared for with each repositioning strategy. Given the implication of PrU incidence rates on life expectancy and costs we believe that the findings of this study are sensitive to this assumption. We varied the transition rates in sensitivity analysis between the PrU stages

to explore the effect of these parameters on the natural history of the disease, and we did not observe a significant change on inference.

In addition, we did not consider the cost savings/economic benefits that would likely arise should less frequent repositioning reduce the incidence of injuries among nursing staff. There is the belief that personal support workers are at high risk of work-related musculoskeletal injuries due to frequent lifting of heavy loads and working with awkward postures. These injuries are associated with absenteeism from work, compensation claims, and increased healthcare and non-healthcare costs. However, several studies that investigated the cumulative loads associated with a number of daily tasks of nursing staff in long term care concluded that on average repositioning for ulcer prevention probably does not contribute significantly to the increased risk of occupational injury.^{24–26} For that reason we decided to ignore any costs associated with occupational injuries due to repositioning. The analysis is also based on the assumption that PrU progression when left untreated can be characterized using a similar Staging process as for PrU diagnosis. There is debate in clinical practice as to whether this assumption is realistic. Also, we did not consider the challenges associated with implementation of such repositioning strategies within a nursing home (e.g., impact on shifts, reallocation of tasks across PSWs within a nursing unit, etc). Answering such implementation question would need a system-level modeling approach which extends beyond the objective of this study. Therefore, results must be interpreted in light of these assumptions and limitations.

In conclusion, this study identified that, based on the set of assumptions presented above, a switch to a 3-hour repositioning strategy for residents who are at moderate or high risk of PrUs according to the Braden scale, who are cared for on high-density foam mattresses, is likely to yield substantial economic benefits without placing residents at greater risk of developing PrUs. These estimated benefits however are unlikely to result in direct cost-savings to the healthcare system. Instead, these benefits represent the value of staff time that could be spent undertaking other activities that can improve quality of residents' care and/or enhance employee well-being as well as their professional development. We suggest that future research directions should be modeling the implications of implementation of each repositioning strategy on aspects around staff allocation, shift scheduling etc.

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Appendix 1

Schematic representation of the natural history model for patients at high risk of developing a pressure ulcer (PrU)

Appendix 2

Model Calibration Process

The incidence of stage-2 PrUs reported in the TURN trial is summarized in Table A1. We calibrated the predicted incidence from the decision model against the reported incidence to determine the weekly transition rates of developing stage-1 PrUs- p_{01} , weekly transition probability from a stage-1 PrU to a stage-2 PrU – p_{12} , and weekly healing of a stage-1 PrUs- p_{10} . Estimates of the transition probability vector (p_{01} , p_{12} , p_{10}) were derived for each repositioning frequency in the TURN trial in order to project the health and cost consequences associated with the repositioning frequencies evaluated in the cost-effectiveness analysis.

The calibration process described below was conducted according to the seven-step approach to the calibration of decision analytic models proposed by Vanni et al. 2011.^{1,2}

Step 1: Which inputs should be varied in the calibration process?

First, we assigned uniform distribution over the plausible range for each of the transition probabilities (p_{01} , p_{12} , p_{10}). We then drew random values from their distribution for use in the calibration.

$$p_{01} \sim \text{Uniform}(0, 22.88\%)$$

$$p_{12} \sim \text{Uni}(3.57\%, 16.02\%)$$

$$p_{10} \sim \text{Uniform}(9.18\%, 23.59\%)$$

The ranges were estimated using data from RCTs evaluating repositioning frequencies (Table A2). These RCTs were selected because they included participants who were reasonably similar to the patient population in the TURN trial. Specifically, the included participants were at moderate to high risk of developing PrUs. They were mainly supported by high-density foam mattresses and were subjected to different repositioning frequencies. Table A2 also displays the weekly transition probability estimates from these trials, including their 95% confidence intervals.

Plausible ranges of the transition probabilities were determined according to the lower and upper bounds of the confidence intervals. Specifically, the plausible range of the weekly incidence of developing stage-1 pressure ulcer was estimated to be from 0% to 22.88% according to the confidence intervals from the RCTs by Defloor et al. 2005 and Moore et al. 2013. The plausible range for the weekly transition probability from stage-1 to stage-2 was estimated to be from 3.57% to 16.02%, according to the confidence intervals from the RCT by Vanderwee et al. 2007. This RCT included participants with stage-1 PrU and followed them up for possible development of stage-2 or higher-stage PrUs. The plausible range for the weekly healing probability of stage-1 PrUs was derived from a cost-effectiveness analysis of pressure ulcer prevention in long-term care. It was estimated to be from 9.18% to 23.59%.

Step 2: Which calibration targets should be used?

The calibration target was the cumulative incidence of stage-2 PrUs over three weeks, reported in Table A1.

Step 3: What measure of goodness-of-fit (GOF) should be used?

Let $I_{\text{predicted}}$ be the predicted incidence corresponding to the reported incidence I_{observed} of stage-2 PrUs in Table A1. We calculated the lack-of-fit (LOF) value

$$C = \left(\frac{I_{\text{observed}} - I_{\text{predicted}}}{\text{SE}(I_{\text{observed}})} \right)^2, \text{ with } \text{SE}(I_{\text{observed}}) = \sqrt{\frac{I_{\text{observed}} * (1 - I_{\text{observed}})}{n}} \text{ where } n$$

denotes the number of participants in each of the turning frequency.

Step 4: What parameter search strategy should be used?

We used a random search strategy to obtain random values of the transition probabilities (p_{01} , p_{12} , p_{10}). The search was aimed to identify transition probabilities for which modeled predictions replicate the reported incidence of stage-2 PrUs from the TURN trial.

Step 5: What determines acceptable GOF parameter sets?

We accepted random values of the transition probabilities that resulted in the predicted incidence of stage-2 PrUs falling within the 95% confidence intervals of the calibration targets in step 2.

Step 6: What determines the termination of the calibration process?

The calibration was conducted with a fixed sample size of 100,000 random values generated from the initial distributions of the transition probabilities (p_{01} , p_{12} , p_{10}) in step 1. These values were used as inputs to the decision model in order to generate the corresponding predicted incidence estimates. The predicted incidence estimates were evaluated against the reported incidence for each of the repositioning frequencies in Table A1, using the acceptable criteria in step 5.

The calibration resulted in 66,963 good-fit transition probability values for the 2-hour repositioning frequency, 37,558 good-fit values for the 3-hour repositioning frequency and 66,228 good-fit values for the 4-hour repositioning frequency. Within these good-fit transition probability values, some are better fit than others, as indicated by the low value of LOF C in step 3. We have selected to use only the 1000 best-fit values identified in step 5 for each of the TURN repositioning frequencies.

Step 7: How should the model calibration results and economic parameters be integrated?

We calculated the p-values of the LOF C statistic values for each of the good-fit estimates from step 6, assuming that the C-statistic is chi-squared distributed with 1 degree of freedom. Here, larger p-values indicate better agreement between the predicted and observed incidence when the corresponding triple vectors of good-fit transition probabilities (p_{01} , p_{12} , p_{10}) were used into the decision model. This allows for the integration of the calibration results into the cost-effectiveness analysis.

Figure A1–A3 displays the distributions of the weighted cumulative incidence of stage-2 PrUs for the repositioning frequency of every 2 hours, 3 hours and 4 hours, respectively.

Results

The calibrated estimates of the weekly incidence of developing a stage-1 PrU, weekly transition probability from a stage-1 PrU to stage-2 PrU and weekly healing probability of a stage-1 PrU are displayed in Table A3.

Figure A1.

Reported cumulative incidence of stage-2 pressure ulcers over three weeks according to the results of the Bergstrom et al. trial (green line) and corresponding predicted incidence from the pressure ulcer decision model (blue line) for the 2-hour repositioning group

Figure A2.

Reported cumulative incidence of stage-2 pressure ulcers over three weeks according to the results of the Bergstrom et al. trial (green line) and corresponding predicted incidence from the pressure ulcer decision model (blue line) for the 3-hour repositioning group

Figure A3.

Reported cumulative incidence of stage-2 pressure ulcers over three weeks according to the results of the Bergstrom et al. trial (green line) and corresponding predicted incidence from the pressure ulcer decision model (blue line) for the 4-hour repositioning group

Table A1

Incidence of stage-2 pressure ulcers among participants in the TURN trial who were repositioned every 2 hours, 3 hours and 4 hours {Bergstrom}

	2-hour turning	3-hour turning	4-hour turning
# participants developing stage-2 pressure ulcers */# total number of participants	8/321	2/326	9/295

	2-hour turning	3-hour turning	4-hour turning
Reported incidence $I_{observed}$ (standard error)	2.5% (0.9%)	0.6% (0.4%)	3.1% (1.0%)

* The cumulative incidence was reported for a follow-up duration of 3 weeks.

Table A2

Transition probability estimates from randomized controlled trials evaluating repositioning frequencies

Study	Reposition	Mattress	FU Wks	Baseline	Outcome	d	n	Incidence	Low	High	Weekly transition	Low	High
Bergstrom 2013	2-hr	PRM	3	No PrUs	Stage-2 PrUs	8	321	0.0249	0.0079	0.0420	0.0084	0.0026	0.0143
	3-hr	PRM	3	No PrUs	Stage-2 PrUs	2	326	0.0061	0.0000	0.0146	0.0021	0.0000	0.0049
	4-hr	PRM	3	No PrUs	Stage-2 PrUs	9	295	0.0305	0.0109	0.0501	0.0103	0.0036	0.0171
Defloor 2005	2-h	STD	4	No PrUs	Stage-1 PrUs	30	63	0.4762	0.3529	0.5995	0.1617	0.1088	0.2288
	3-h	STD	4	No PrUs	Stage-1 PrUs	26	58	0.4483	0.3203	0.5763	0.1487	0.0965	0.2147
	4-h	PRM	4	No PrUs	Stage-1 PrUs	28	66	0.4242	0.3050	0.5435	0.1380	0.0910	0.1960
	6-h	PRM	4	No PrUs	Stage-1 PrUs	29	63	0.4603	0.3372	0.5834	0.1542	0.1028	0.2189
Moore 2011	3-hr	PRM	4	No PrUs	Stage-1 PrUs	1	99	0.0101	0.0000	0.0298	0.0025	0.0000	0.0076
	6-hr	PRM	4	No PrUs	Stage-1 PrUs	6	114	0.0526	0.0116	0.0936	0.0135	0.0029	0.0246
Vanderwee 2007	2-hr 4-hr	PRM	2.27	Stage-1 PrUs	Stage-2 PrUs	17	122	0.1393	0.0779	0.2008	0.0661	0.0357	0.0988
	4-hr	PRM	1.94	Stage-1 PrUs	Stage-2 PrUs	22	113	0.1947	0.1217	0.2677	0.1114	0.0667	0.1602

PRM: pressure-redistribution mattress. STD: standard mattress.

With a 30 degree tilt for the repositioning procedure.

With a 90 degree lateral.

Alternately 2- hour lateral and 4-hour supine.

Usual practice.

“d” number of pressure ulcers. “n” number of participants.

Table A3

Calibrated values for the transition probabilities

2-hr	P ₀₁	P ₁₂	P ₁₀
Best estimate	0.0883	0.1333	0.1735
Min	0.0663	0.0492	0.0918
Max	0.2187	0.1602	0.2358
3-hr			
Best estimate	0.0391	0.0721	0.1797
Min	0.0165	0.0357	0.0924
Max	0.0837	0.1600	0.2359
4-hr			
Best estimate	0.1675	0.0969	0.2354
Min	0.0813	0.0606	0.0919
Max	0.2189	0.1601	0.2357

References

1. Stout NK, Knudsen AB, Kong CY, McMahon PM, Gazelle GS. Calibration methods used in cancer simulation models and suggested reporting guidelines. *Pharmacoeconomics*. 2009; 27(7):533–545. [PubMed: 19663525]
2. Vanni T, Karnon J, Madan J, et al. Calibrating models in economic evaluation: A seven-step approach. *Pharmacoeconomics*. 2011; 29(1):35–49. [PubMed: 21142277]

References

1. Van Gilder C, Stephanie A, Harisson P., et al. [Accessed December 10, 2014] 2010 International Pressure Ulcer Prevalence™ Survey: Canadian Results. Symp Adv Ski Wound Care. 2011. Available at: <https://library.hill-rom.com/Global/CRC/Library/US - EN/Pressure Ulcer Management/VanGilder.Results of the 2010 International Pressure Ulcer Prevalence Survey.pdf>
2. Park-Lee E, Caffrey C. [Accessed January 31, 2014] Pressure ulcers among nursing home residents: United States, 2004; NCHS Data Brief. 2009. 1–8. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19389326>
3. Thein H-H, Gomes T, Krahn MD, et al. Health status utilities and the impact of pressure ulcers in long-term care residents in Ontario. *Qual Life Res*. 2010; 19(1):81–9. DOI: 10.1007/s11136-009-9563-2 [PubMed: 20033300]
4. Gorecki C, Brown JM, Nelson EA, et al. Impact of pressure ulcers on quality of life in older patients: a systematic review. *J Am Geriatr Soc*. 2009; 57(7):1175–83. DOI: 10.1111/j.1532-5415.2009.02307.x [PubMed: 19486198]
5. Chan BC, Nanwa N, Mittmann N, et al. The average cost of pressure ulcer management in a community dwelling spinal cord injury population. *Int Wound J*. 2013; 10(4):431–40. DOI: 10.1111/j.1742-481X.2012.01002.x [PubMed: 22715990]
6. Emily Haesler, editor 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. Cambridge Media; Osborne Park, Western Australia: 2014. Accessed from <http://www.epuap.org/wp-content/uploads/2016/10/quick-reference-guide-digital-npuap-epuap-pppia-jan2016.pdf>
7. Chou R, Dana T, Bougatsos C, et al. Pressure ulcer risk assessment and prevention: a systematic comparative effectiveness review. *Ann Intern Med*. 2013; 159(1):28–38. DOI: 10.7326/0003-4819-159-1-201307020-00006 [PubMed: 23817702]
8. Bergstrom N, Horn SD, Rapp MP, et al. Turning for Ulcer Reduction: a multisite randomized clinical trial in nursing homes. *J Am Geriatr Soc*. 2013; 61(10):1705–13. DOI: 10.1111/jgs.12440 [PubMed: 24050454]
9. Gillespie BM, Chaboyer WP, McInnes E, et al. Repositioning for pressure ulcer prevention in adults. *Cochrane database Syst Rev*. 2014; 4 CD009958. doi: 10.1002/14651858.CD009958.pub2
10. Moore Z, Cowman S, Posnett J. An economic analysis of repositioning for the prevention of pressure ulcers. *J Clin Nurs*. 2013; 22(15–16):2354–60. DOI: 10.1111/j.1365-2702.2012.04310.x [PubMed: 23829408]
11. Paulden M, Bergstrom N, Horn SD, et al. Turning for ulcer reduction (TURN) study: an economic analysis. *Ontario health technology assessment series*. 2014; 14(12):1.
12. Briggs AH, O'Brien BJ. The death of cost-minimization analysis? *Health economics*. 2001 Mar 1; 10(2):179–84. <https://www.ncbi.nlm.nih.gov/pubmed/11252048>. [PubMed: 11252048]
13. Pham B, Stern A, Chen W, et al. Preventing pressure ulcers in long-term care: a cost-effectiveness analysis. *Arch Intern Med*. 2011; 171(20):1839–47. DOI: 10.1001/archinternmed.2011.473 [PubMed: 21949031]
14. Bergstrom N, Braden BJ, Laguzza A, et al. The Braden Scale for Predicting Pressure Sore Risk. *Nurs Res*. 36(4):205–10. [Accessed December 10, 2014] Available at: <http://www.ncbi.nlm.nih.gov/pubmed/3299278>.
15. Canadian Agency for Drugs and Technologies in Health. Guidelines for the economic evaluation of health technologies: Canada. 3. Ottawa, Canada: 2006. 46

16. Wodchis WP, Hirdes JP, Feeny DH. Health-related quality of life measure based on the minimum data set. *Int J Technol Assess Health Care*. 2003; 19(3):490–506. [Accessed December 10, 2014] Available at: <http://www.ncbi.nlm.nih.gov/pubmed/12962335>. [PubMed: 12962335]
17. THETA Collaborative Report. The cost-effectiveness of prevention strategies for pressure ulcers in long-term care homes in Ontario: Projections of the Ontario Pressure Ulcer Model. Toronto ON: 2008. Available at: <http://theta.utoronto.ca/content.php?pid=411861&sid=3717152#13455553>
18. Huck SW. *Statistical Misconceptions: Classic Edition*. Routledge: 2015 Nov 19.
19. People Caring For People. Impacting the quality of life and care of residents of long-term care homes: A Report of the Independent Review of Staffing and Care Standards for Long-Term Care Homes in Ontario. Markham ON: 2008. 84 Available at: http://tools.hhr-rhs.ca/index.php?option=com_mtree&task=att_download&link_id=5987&cf_id=68&lang=en
20. Long-Term Care Task Force. Resident Care and Safety. Ontario: 2012. 106 Available at: <http://longtermcaretaskforce.ca/images/uploads/LTCFTRReportEnglish.pdf>
21. Bergstrom N, Braden B. A prospective study of pressure sore risk among institutionalized elderly. *J Am Geriatr Soc*. 1992; 40:747–58. [PubMed: 1634717]
22. Lyder CH, Ayello EA. Pressure Ulcers: A Patient Safety Issue. In: Hughes RG, editor *Patient Safety and Quality: An Evidence-Based Handbook for Nurses*. Vol. Chapter 12. Rockville (MD): Agency for Healthcare Research and Quality (US); 2008 Apr.
23. Dakin H, Wordsworth S. Cost-minimisation analysis versus cost-effectiveness analysis, revisited. *Health Econ*. 2013; 22(1):22–34. DOI: 10.1002/hec.1812 [PubMed: 22109960]
24. Gagnon M, Chehade A, Kemp F, et al. Lumbo-sacral loads and selected muscle activity while turning patients in bed. *Ergonomics*. 1987; 30:1013–32. [PubMed: 3678194]
25. Garg A, Owen B. Reducing back stress to nursing personnel: an ergonomic intervention in a nursing home. *Ergonomics*. 1992; 35:1353–75. [PubMed: 1425566]
26. Garg A, Owen B, Beller D, et al. A biomechanical and ergonomic evaluation of patient transferring tasks: wheelchair to shower chair and shower chair to wheelchair. *Ergonomics*. 1991; 34:407–19. [PubMed: 1860461]

Table 1

Baseline probabilities, HRQL weights, and costs for the repositioning strategy

PrU risk and prognosis	Value	SE/Range	Distribution	Source
<i>Weekly incidence of a stage 1 PrU (%)[*]</i>				
2-hour repositioning	0.09	0.07,0.22	Resampling	Calibrated
3-hour repositioning	0.04	0.02,0.08	Resampling	Calibrated
4-hour repositioning	0.17	0.08, 0.22	Resampling	Calibrated
<i>Weekly transition probabilities (%)</i>				
Stage 1 to 2 [*]				
2-hour repositioning	0.13	0.05,0.16	Resampling	Calibrated
3-hour repositioning	0.07	0.04,0.16	Resampling	Calibrated
4-hour repositioning	0.10	0.06,0.16	Resampling	Calibrated
Stage 1 to healing [*]				
2-hour repositioning	0.17	0.09,0.24	Resampling	Calibrated
3-hour repositioning	0.18	0.09,0.24	Resampling	Calibrated
4-hour repositioning	0.24	0.09,0.24	Resampling	Calibrated
Stage 2 to 3	0.12	0.05,0.33	Age-specific	RAI-MDS
Stage 3 to 4	0.71	0.19,1.18	Age-specific	RAI-MDS
Stage 2 to healing	1.34	0.37,1.54	Age-specific	RAI-MDS
Stage 3 to healing	0.73	0.14,1.11	Age-specific	RAI-MDS
Stage 4 to healing	0.23	0.09,0.58	Age-specific	RAI-MDS
<i>Weekly incidence rates of PrU-related infections (%)</i>				
Local infection given stage 2–4	1.21	0.47	Beta	RAI-MDS
Sepsis given infection in stage 3–4	1.28	0.43	Beta	RAI-MDS
<i>Hospitalization, mortality, & repositioning</i>				
Weekly hospitalization percentage	1.46	0.14	Age-specific	CIHI-DAD
Mean length of hospital stay (days)	6.8	Not varied		CIHI-DAD
Inpatient mortality (%)	16.63	4.94	Age-specific	CIHI-DAD

PrU risk and prognosis		Value	SE/Range	Distribution	Source
Annual LTC mortality (%)		13.78	2.32	Age-specific	RAI-MDS
Duration of repositioning (minutes)		7.14	1.52,12.65	Gamma	TURN data
Repositioning requiring two PSWs (%)		20	0, 40	Uniform	Expert opinion
Number of hours in bed per day		16	12–24	Uniform	Assumption
<i>Mean HRQL weights</i>					
QoL weight with intact skin		0.36	0.17	Gamma	Thein et al.
QoL decrement with PrU stage 2–4		0.022	0.004	Gamma	Thein et al.
<i>Cost inputs</i> (LTC cost)($\text{\$}$)					
Personal Support Worker (hourly rate)		18.78	`	Gamma	RNAO
Nursing and personal care cost (week)		557.2	Not varied		OMHLTC
Other weekly costs (e.g., food, accommodations)		430.2	Not varied		OMHLTC

* Parameters calibrated to match the observed probability of Stage 2 and Stage 3 in the TURN trial (details provided in Appendix 2).

◆ Resampling from a set of 1000 best-fit estimates from the calibration process (Appendix 2)

PrU: Pressure Ulcer, HRQL: Health-Related Quality of Life, LTC: Long-Term Care, SE: Standard Error, RAI-MDS: Resident Assessment Instrument-Minimum Dataset, OMHLTC: Ontario Ministry of Health and Long-Term Care, CIHI-DAD: Canadian Institute of Health Information-Discharge Abstract Database, RNAO: Registered Nurses' Association of Ontario.

Table 2

Predicted lifetime risk of developing a PrU, average time spent with PrU and predicted costs

Parameter	Repositioning Strategy		
	2-hour	3-hour	4-hour
Lifetime risk of developing a PrU (%)	68.70	50.18	72.48
Average time with PrU (weeks) *	59.52	42.79	64.78
Repositioning costs (2014 CAD)			
While PrU free	\$5 972	\$5 758	\$2 692
After having developed a PrU	\$8 099	\$5 435	\$8 688
Other costs	\$94 076	\$91 529	\$94 639

PrU: Pressure Ulcer.

* Average time estimated among simulated patients who developed PrU over the lifetime.

Table 3

Results of the full incremental cost effectiveness analysis

Strategy	Total Cost (\$)	QALYs	vs. Strategy	Incremental Cost (\$) (95% CrI)	Incremental QALY (95% CrI)	ICER
3-hour	102,272 (90,228 – 126,673)	0.636 (0.118 – 1.172)	-	-	-	
4-hour	106,018 (94,884 – 126,673)	0.627 (0.106 – 1.158)	3-hour	3,296 (-483 – 9,738)	-0.009 (-0.018 – -0.007)	Dominated
2-hour	108,147 (95,530 – 132,120)	0.629 (0.107 – 1.16)	3-hour	5,425 (922 – 12,166)	-0.008 (-0.016 – -0.005)	Dominated

QALY: Quality Adjusted Life Year, ICER: Incremental Cost Effectiveness Ratio, CI: Credible interval

Table 4

Results of the one-way sensitivity analysis for the comparison of 2- vs 3-hour strategy

Parameter	Range	Incremental Cost (\$)	Incremental QALY	ICER
Weekly transition rate stage 2–3	0.0005	5,409	–0.0075	3-hour repositioning is the dominant strategy
	0.0033	5,439	–0.0076	
QoL decrement with PrU stage 2–4	0.015	5,424	–0.0049	
	0.03	5,424	–0.0102	
Repositioning requiring two PSWs (%)	1	4,945	–0.0076	
	1.4	5,905		
Number of hours in bed (per day)	12	4,705	–0.0076	
	24	6,864		
PSW hourly rate(\$)	10	4,079	–0.0076	
	25	6,378		
Duration of repositioning (minutes)	1.52	3,160	–0.0076	
	12.65	7,646		
Hospitalization rate (week)	0.0003	5,950	–0.0084	
	0.0009	4,860	–0.0066	

PrU: Pressure Ulcer, QoL: Quality of Life, LTC: Long-Term Care, PSW: Personal Support Worker.