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Cost-effectiveness of pressure-relieving devices for the prevention and treatment of pressure ulcers

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Objectives: The cost-effectiveness of alternating pressure-relieving devices, mattress replacements, and mattress overlays compared with a standard hospital (high-specification foam mattress) for the prevention and treatment of pressure ulcers in hospital patients in the United Kingdom was investigated.
Methods: A decision-analytic model was constructed to evaluate different strategies to prevent or treat pressure ulcers. Three scenarios were evaluated: the prevention of pressure ulcers, the treatment of superficial ulcers, and the treatment of severe ulcers. Epidemiological and effectiveness data were obtained from the clinical literature. Expert opinion using a rating scale technique was used to obtain quality of life data. Costs of the devices were obtained from manufacturers, whereas costs of treatment were obtained from the literature. Uncertainty was explored through probabilistic sensitivity analysis.
Results: Using £30,000/QALY (quality-adjusted life year) as the decision-maker's cut off point (the current UK standard), in scenario 1 (prevention), the cost-effective strategy was the mattress overlay at 1, 4, and 12 weeks. In scenarios 2 and 3, the cost-effective strategy was the mattress replacement at 1, 4, and 12 weeks. Standard care was a dominated intervention in all scenarios for values of the decision-maker's ceiling ratio ranging from £5,000 to £100,000/QALY. However, the probabilistic sensitivity analysis results reflected the high uncertainty surrounding the choice of devices.
Conclusions: Current information suggests that alternating pressure mattress overlays may be cost-effective for the prevention of pressure ulcers, whereas alternating pressure mattress replacements appears to be cost-effective for the treatment of superficial and severe pressure ulcers.

Keywords: Pressure ulcer, Beds, Cost-effectiveness, Decision analysis, Stochastic process

Pressure ulcers are areas of localized damage to the skin and underlying tissue due to pressure, shear, or friction. They usually occur over bony prominences and are common in the elderly, the very ill, patients who are neurologically compromised, and in people with conditions that are associated with immobility (38). Prevalence ranges between 5 and 32 percent in UK hospitals (33). Incidence rates may vary greatly according to the setting, as well as to the patient case mix, severity of illness, and other contextual factors (35). Pressure ulcers reduce patients' quality of life and constitute a significant financial burden on the health system (27;28). It has been estimated that the total cost of pressure ulcer care costs may fall between £1.4bn and £2.1bn a year in the United Kingdom (4).

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Several strategies are available for the prevention and treatment of pressure ulcers. However, few of these strategies have been evaluated rigorously, and the evidence available as to the efficacy and cost-effectiveness of these techniques is scant (6;7;19;36;38;42). This study focuses on pressure-relieving devices. Standard care for pressure ulcer prevention and treatment consists of high-specification foam mattresses rather than a standard hospital mattress with no pressure-relieving qualities. There is strong clinical evidence that foam mattresses are more effective than standard hospital mattresses (19;38). In addition, their use is recommended in recent guidelines published by the National Institute of Clinical Excellence (NICE; 38). However, there is little evidence on the effectiveness or cost-effectiveness of the more expensive "high-tech" devices, such as alternating pressure devices, compared with the high-specification foam mattresses. Alternating pressure devices mechanically vary the pressure beneath the patient, thereby reducing the duration of the applied pressure. Such devices are available as mattress replacements (replaces the mattress normally used on the bed) or overlays (placed on top of a normal mattress; 19).

The objective of this study was to model the cost-effectiveness of using alternating pressure mattress replacements (AR) and alternating pressure overlays (AO) compared with the high-specification foam mattress (standard care strategy [SC]) in patients admitted to hospital in the United Kingdom. Three different scenarios were investigated: the prevention of pressure ulcers (scenario 1), the treatment of superficial pressure ulcers (scenario 2), and the treatment of severe pressure ulcers (scenario 3).

METHODS

Decision-Analytic Model

A decision-analytic model was constructed to evaluate different strategies to prevent or treat pressure ulcers in patients admitted to the hospital in the United Kingdom. A common grading system was used to define the severity of pressure (12). Grade 1 (nonreactive erythema) and grade 2 ulcers (superficial break in the skin) are referred to as superficial pressure ulcers, whereas grades 3 (destruction of the skin without cavity) and 4 ulcers (destruction of the skin with cavity involving the underlying tissues) are referred to as severe pressure ulcers.

In scenario 1, patients are admitted to the hospital without pressure ulcers and preventive strategies are adopted to avoid the subsequent development of ulcers. In scenarios 2 and 3, patients may be admitted with established ulcers or may develop them in the hospital. Scenario 2 investigates the treatment of superficial ulcers, whereas scenario 3 investigates the treatment of severe ulcers. In all scenarios, patients can develop single or multiple ulcers and superficial or severe ulcers. Ulcers can heal. Patients can remain in the hospital with a pressure ulcer, be discharged with a pressure ulcer, be discharged without a pressure ulcer, or die. The decision tree is shown in Figure 1.

Hypothetical cohorts of 1,000 adult male and female patients admitted to the hospital were modeled. Patients were allocated to health states according to transition probabilities. The majority of patients will be discharged within 1 week, but results were obtained beyond this timeline at 4 weeks and 12 weeks, because patients with pressure ulcers are likely to have extended hospital stays (2;49).

Epidemiology

A literature search on MEDLINE was conducted to identify relevant studies. Seventeen studies were relevant (1;3;5;8;12–15;20;26;32;33;40;41;44;46;49). The studies identified varied in population, setting, inclusion and exclusion criteria, and level of detail in data reporting. To ensure that the variables used in the model offered some consistency, it was decided to use data from Clark (11) as the point estimates each time this was possible (see Box 1). This study offered the most recent data, gave sufficient information for variables to be calculated where necessary, used an appropriate study population, and had a large number of patients (13).

Rates and probabilities were transformed into weekly, 4 weekly, or 12 weekly probabilities when necessary using the appropriate formulae (37). Each estimate was associated with an interval representing a range of possible values for the probabilistic analyses that were obtained from the studies identified in the literature search.

The proportion of patients admitted to the hospital at risk of developing an ulcer was 41 percent (range, 20 to 70 percent), as identified by the use of the Waterlow risk assessment instrument in the study by Clark et al. (13). The risk of developing new ulcers in hospitals per week was 2.9 percent (range, 0 to 5.5 percent; 13). The proportion of patients admitted with established ulcers was 4 percent (range, 0 to 10 percent), and the proportion admitted with ulcers that were superficial was 76 percent (range, 50 to 80 percent). The proportion of patients with new ulcers that were superficial was 88.2 percent (80 to 100 percent), and the proportion with multiple ulcers was 26 percent (range 10 to 60 percent). The proportion of patients who die in a week was 2.1 percent (range, 1 to 3 percent; 13). The proportion of patients discharged at the end of 1 week was 75 percent

Box 1. Study by Clark et al.

The study reported by Clark (11) was a multicenter, prospective nonrandomized cohort study designed to record the occurrences and characteristics of patients vulnerable to or with established pressure ulcers. Two thousand five hundred seven (2,507) UK subjects across four hospitals were recruited between July 1996 and May 1998. Eligible subjects were at least 16 years old, remained in the hospital for at least 2 days, and were not admitted to the following specialty wards: psychiatry, ophthalmology, gynecology, pediatrics, obstetrics, and mental illness (11–13).

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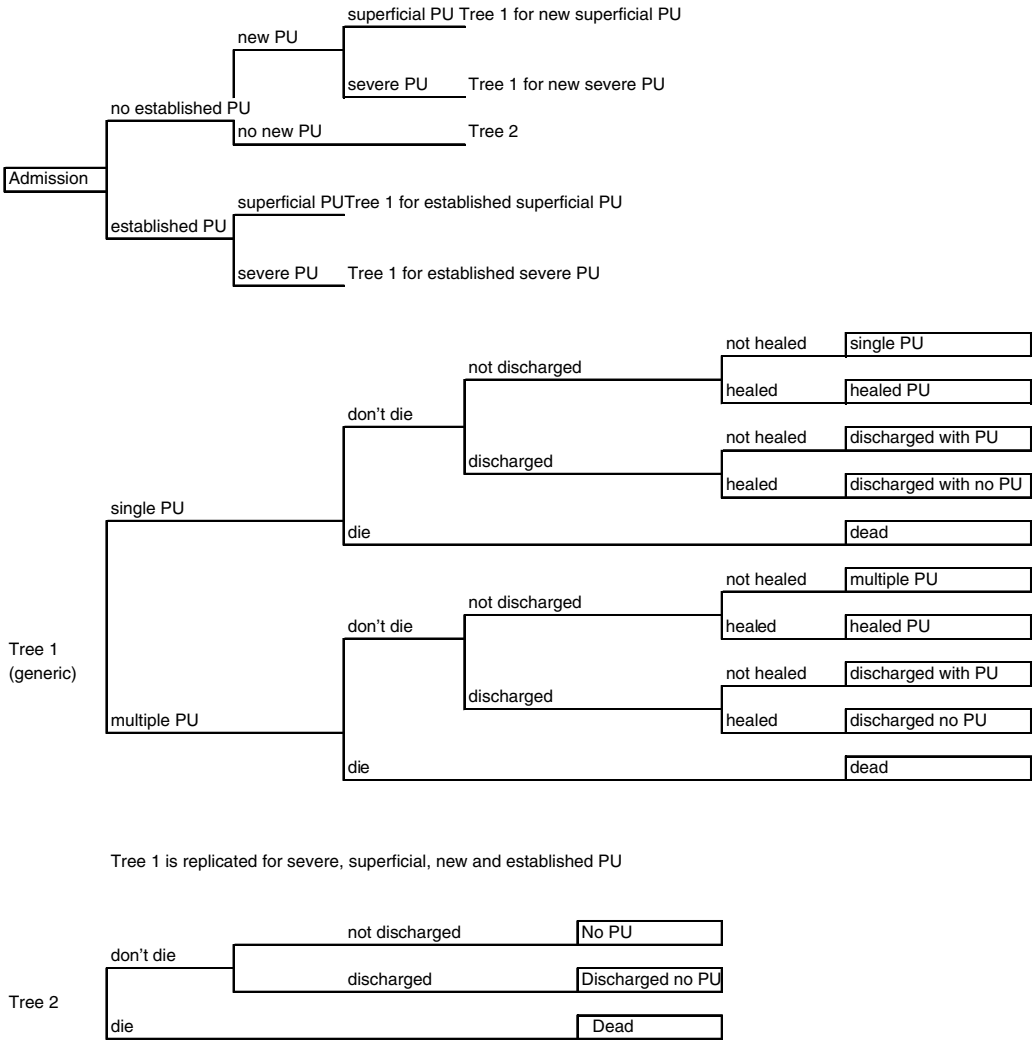

Figure 1. Decision tree.

(range, 70 to 100 percent; 49). The proportion of patients with superficial ulcers that heal in 1 week was 7 percent (range, 2 to 12 percent) and with severe ulcers that heal in 1 week was 2 percent (range, 1.5 to 4 percent; 26).

Effectiveness

A systematic review of the effectiveness of pressure-relieving devices was used (19;38). It concluded that the relative merits of different alternating pressure devices for pressure prevention and treatment were unclear. Despite the lack of evidence, there is a consensus among health professionals that alternating pressure mattresses and overlays are more effective in preventing and treating ulcers than high-specification foam mattresses (38). When no data are available, estimates based on expert opinion can be used (31). The estimates chosen were validated by the expert opinion of a health professional specialist in wound care. For prevention, a relative risk of 0.6 (range, 0.4 to 1.2) for AO compared with SC was used and a relative risk of 0.5 (range, 0.4 to 1.2) was used for AR. For treatment, a factor of 1.5 (range, 0.9 to 2) was used to represent the effectiveness of AO and a factor of 1.7 (range, 0.9 to 2) was used for AR compared with the SC (a larger factor indicates the treatment is more effective). The ranges chosen reflect the possibility that the interventions are equally effective, as they include the value 1.

Costs

The perspective of the costing was the UK National Health Service (NHS). Price year was 2003. Where necessary, prices were adjusted to 2003 values using the Retail Price Index.

There is a dearth of data on the costs of the prevention and treatment of pressure ulcers, and only one relevant study was identified (38). Bennett et al. used a bottom-up methodology based on the daily resources required to deliver protocols of care reflecting good clinical practice (4). Based on the expected cost of healing grade 1, 2, 3, and 4 ulcers per patient (£1,133, £4,686, £7,785, and £11,223, respectively), the following costs were developed: £2,910 per

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superficial ulcer (average of grade 1 and 2) and £9,509 for severe ulcers (average of grade 3 and 4). The cost of treating multiple superficial or severe ulcers was assumed to be 50 percent higher than treating a single ulcer of the same severity, resulting in costs of £4,364 for multiple superficial ulcers and £14,263 for multiple severe ulcers. The cost of prevention was assumed to be the same as treating a grade 1 ulcer, namely £1,133, because standard preventive measures may include similar materials and nursing time than those used for a grade 1 ulcer (10;38).

All patients in preventive care and in treatment were assumed to use a pressure-relieving device, so that the total number of devices needed was the number of patients with pressure ulcers plus the number of patients deemed at risk of developing a pressure ulcer. For the high-specification foam mattress, it was assumed that all mattresses were purchased. The equivalent weekly cost of the mattress (the net present value of the stock) is calculated using the price of purchase, the lifetime use of the mattress, and an annuity factor to account for depreciation (23). A one-time cleaning cost per patient was included. The purchase price of a high-specification foam mattress was £200, the cleaning cost per patient was £5, and lifetime of the product was 8 years. Prices were obtained from a Health Technology Assessment (HTA) report and the NICE guideline (19;38). For AO and AR, the model differentiates between purchased and rented mattresses. The number of devices already owned can be set, and the model then evaluates how many are rented. The cost of the device includes the fixed weekly cost of owning the stock (depending on lifetime of mattress, initial purchase price, maintenance contract), a one time cleaning cost per patient, and the additional rental costs of mattresses when the purchased stock is insufficient. By default, the model runs on the assumption that the hospital owns 100 AOs and 100 ARs. Prices for these devices vary considerably. For the model, two specific devices made by Huntleigh Healthcare Products were chosen, the Alpha X-Cell mattress overlay and the Nimbus 111 mattress replacement, because they correspond to equipment used in an ongoing clinical trial in the United Kingdom (39). The purchase cost of the AO was £870 (+VAT), the weekly rental cost £38, the service cost £195 per year, cleaning per patient £20, and lifetime was 2 years. The purchase cost of the AR was £3,604 (+VAT), the weekly rental cost £71.75, the service cost £330 per year, cleaning per patient £20, and lifetime was 8 years. Unit prices for the devices were obtained by telephone from Huntleigh Healthcare Products on April 8, 2003, and from the literature (30;45). Wide ranges (±30 percent of the point estimates) were used to account for the uncertainty surrounding these cost estimates.

Utilities

Little empirical work has been conducted on the health-related quality of life (HRQoL) for patients with pressure ulcers (11). Two studies using an HRQoL instrument (the SF-36) were identified in the literature (11–13;29). Subsequent to this initial literature search, the NICE guidelines reported the results of a systematic review of the literature on quality of life and pressure ulcers in February 2003. None provided sufficient information to derive quantitative estimates of quality of life (38). Due to the lack of empirical data, utility scores for the health states were obtained by developing a simple visual rating scale that was given to health professionals with expertise in wound-care management. A series of six vignettes describing each of the health states used in the model were developed. Respondents were asked to read the vignettes and rate the quality of life of the patient on the provided rating scale. The scale went from 0 (death) to 1 (perfect health). Five health professionals with expertise in wound care completed the exercise. Results were obtained taking the mean of the expert panel responses. Ranges were chosen by the author to reflect wide variation due to the uncertainty surrounding these results. Patients with a single superficial pressure ulcer were estimated to have a quality of life score of 0.68 (range, 0.3 to 1), and patients with multiple superficial pressure ulcers obtained a score of 0.5 (range, 0.1 to 1). The quality of life score for a patient with a single severe pressure ulcer was 0.36 (range, 0.1 to 1) and 0.31 (range 0.1 to 1) for a patient suffering from multiple severe pressure ulcers. The utility score for patients discharged with no pressure ulcers was 0.8 (range, 0.5 to 1).

Analysis

Costs, pressure ulcer-free days, and quality-adjusted life year (QALYs) were obtained for each scenario (prevention, superficial ulcers, and severe ulcers) and for each pressure ulcer-relieving device, for 1 week, 4 weeks, and 12 weeks. The incremental cost per QALY was obtained where appropriate.

Internal validity was established by conducting extreme sensitivity analyses and evaluating the appropriateness of the subsequent results (34). Checks were also done to ensure that the model predicted the same number of ulcers as those reported in the Clark (11) study. External validity was assessed by calculating the predictive cumulative incidence of pressure ulcers.

Probabilistic sensitivity analysis was conducted (22). Each input parameter was assigned an appropriate statistical distribution and an interval, representing a range of plausible values obtained from the literature (9;18). Lognormal distributions were used for cost and effectiveness inputs. Beta distributions were used for pressure ulcer rates and health state utilities. Triangular distributions were used for the lifetime of the pressure-relieving devices. A Monte Carlo simulation was then run to obtain 10,000 iterations of the model. Cost-effectiveness acceptability curves were obtained.(24;25;48).

RESULTS

The prevalence at 1 week of superficial or severe pressure ulcers predicted by the model was 5 percent and 1 percent,

Table 1. Costs (£, 2003), Pressure Ulcer-Free days and QALYs per 1,000 Patients Admitted for the Prevention and Treatment of Pressure Ulcers Using Alternating Pressure-Relieving Devices

	Costs	Pressure ulcer-free days	QALYs	Incremental cost per QALY gained
Scenario 1: prevention				
1 week				
SC	£581,886	6760	15.71	Dominated intervention
AO	£558,429	6798	15.74	NA
AR	£560,158	6807	15.74	£262,927
4 weeks				
SC	£829,982	26269	62.29	Dominated intervention
AO	£766,247	26714	62.61	NA
AR	£786,773	26828	62.69	£253,367
Scenario 2: superficial ulcers				
1 week				
SC	£149,995	6655	15.59	Dominated intervention
AO	£121,569	6687	15.61	Dominated intervention
AR	£114,415	6695	15.61	Dominates
4 weeks				
SC	£285,754	26125	62.20	Dominated intervention
AO	£205,511	26495	62.42	Dominated intervention
AR	£185,276	26590	62.47	Dominates
Scenario 3: severe ulcers				
1 week				
SC	£105,114	6808	15.70	Dominated intervention
AO	£92,513	6813	15.71	Dominated intervention
AR	£89,491	6814	15.71	Dominates
4 weeks				
SC	£213,920	27118	62.67	Dominated intervention
AO	£168,580	27185	62.76	Dominated intervention
AR	£157,805	27202	62.78	Dominates

AO, alternating pressure mattress overlay; AR, alternating pressure mattress replacement; NA, not applicable; QALYs, quality-adjusted life year; SC, standard care.

respectively. At 4 weeks, the prevalence was 9 percent and 2 percent, respectively. This finding was within the range reported in the literature (33).

Table 1 presents the costs, pressure ulcer-free days, and QALYs per 1,000 patients admitted at 1 and 4 weeks (12-week results are not reported in the table). Dominated interventions are interventions that are less effective and more costly than the comparator(s). In scenario 1 (prevention), the cost-effective strategy (using £30,000/QALY as the decision-maker's cut off point, the UK standard), is AO, at 1, 4, and 12 weeks. In scenarios 2 and 3, the cost-effective strategy is AR at 1, 4, and 12 weeks (43). Moreover, for values of the decision-maker's ceiling ratio ranging from £5,000/QALY to £100,000/QALY, the optimal strategy remained AR in scenarios 2 and 3. In scenario 1, at a ceiling ratio of £5,000/QALY, the optimal strategy was SC. Beyond this value, it switches to AO.

Cost-effectiveness acceptability curves represent the uncertainty surrounding the treatment decision and can be used to inform the decision whether to acquire further information through research to inform service provision in the future (25). Cost-effectiveness acceptability curves for scenario 1 (prevention) at 1 and 4 weeks are shown in Figure 2. In Table 2, the probability that the strategy is cost-effective is reported at 1, 4, and 12 weeks for all three scenarios. For example, in the prevention scenario, at 1 week, there is between 42 percent and 43 percent probability that the replacement is more cost-effective than AO, across a wide range

Table 2. Probability Intervention Is Cost-Effective for Values of Decision-Maker's Ceiling Ratio Ranging from £5,000 to £100,000, by Intervention at 1 Week, 4 Weeks, and 12 Weeks[a]

	SC	AR	AO
Prevention (scenario 1)			
1 week	12% to 13%	42% to 43%	45%
4 weeks	12% to 17%	36% to 40%	47% to 48%
12 weeks	23% to 43%	19% to 32%	38% to 45%
Superficial (scenario 2)			
1 week	0%	64%	36%
4 weeks	0%	64%	36%
12 weeks	1% to 3%	59% to 60%	38% to 40%
Severe (scenario 3)			
1 week	1%	61%	38%
4 weeks	1%	61% to 62%	39% to 40%
12 weeks	0% to 1%	59% to 61%	39% to 40%

[a] Percentages are rounded up.
AO, alternating pressure mattress overlay; AR, alternating pressure mattress replacement; SC, standard care.

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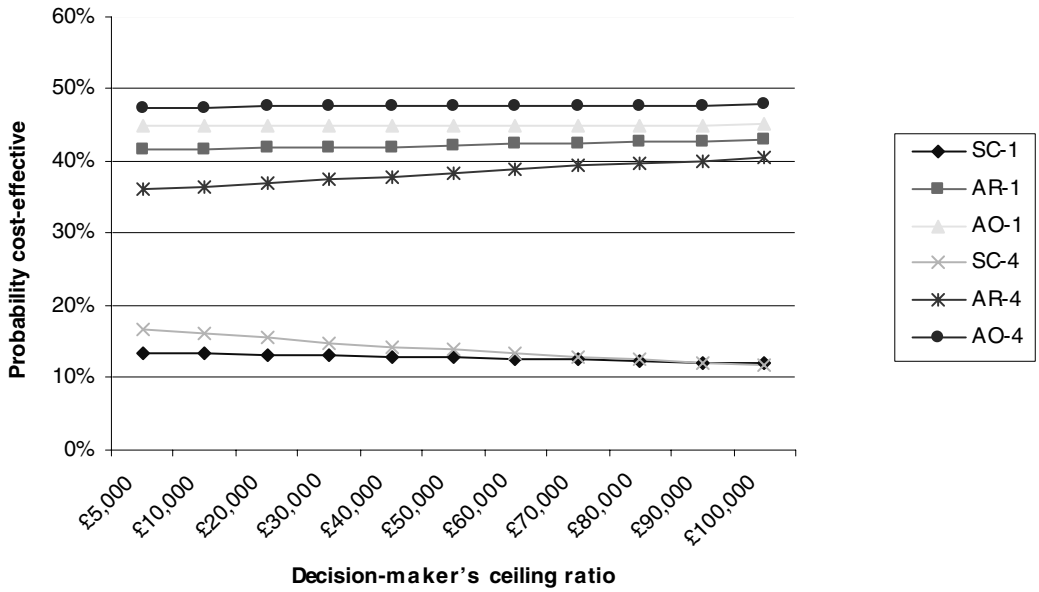

Figure 2. Cost-effectiveness acceptability curve for scenario 1 (prevention) at 1 and 4 weeks. SC-1, standard care in 1 week; AR-1, mattress replacement in 1 week; AO-1, mattress overlay in 1 week; SC-4, standard care in 4 weeks; AR-4, mattress replacement in 4 weeks; AO-4, mattress overlay in 4 weeks.

of the decision-maker's ceiling ratios (from £5,000/QALY to £100,000/QALY), whereas the probability that the AO is cost-effective is approximately 45 percent (standard care has a probability of being cost-effective between 12 and 13 percent).

By default the model assumes that the hospital has purchased 100 AOs and 100 ARs. To investigate this assumption, the model was run with the assumption that the hospital owned no mattress replacements or overlays (and rented all necessary equipment) and then with the assumption that the hospital owned 500 of each type of device.

Figure 3 shows the total costs per 1,000 patients per strategy according to the number of pressure-relieving devices owned at 1 week in scenario 1. Results showed that it was less expensive for the hospital to own devices than to rent them, as the total costs decrease with the increase in ownership.

DISCUSSION

The findings of this study suggest that, based on current evidence, alternating pressure mattress overlays may be cost-effective for the prevention of pressure ulcers, whereas alternating pressure mattress replacements appear to be cost-effective for the treatment of superficial and severe pressure ulcers. The probabilistic sensitivity analysis shows that the uncertainty surrounding the choice between AO and AR is high. The lack of robust information on several parameters populating the model, represented by wide intervals, is the source of this decision uncertainty. Indeed, the lack of good quality data is widespread for all the parameters that were needed to develop the cost-effectiveness model. Decision-analytic models can combine the available evidence in a rational framework to aid decision making (16).

There are several limitations to the present study. First, several simplifying assumptions surrounding the disease process and treatment were necessary to construct the model. For example, the model could not account for a precise number of multiple ulcers, only for more than one. Moreover, the model did not allow for switches in treatment strategies, although in practice it is possible that different types of pressure-relieving devices will be used throughout the treatment of the same patient if the health-care team decides this strategy is necessary. In scenario 1 (prevention), the patients at risk were assumed to be identified through the use of a pressure ulcer risk assessment instrument. However, it is likely that, in practice, the decision process will be more complex and the proportion of patients receiving preventive measures may be different from that predicted by instruments alone (for example, it may depend on the site of the ulcer). Finally, most patients with pressure ulcers will be treated in the hospital for other conditions. Ideally, a case-mix analysis of the patient population should be conducted to account for comorbidities. This investigation was beyond the scope of the present study.

Second, several parameters used for the model were extrapolated to the population and setting of the model. Extrapolations were kept to a minimum by using the Clark (11) study whenever possible. Until more data become available, these were necessary extrapolations and the uncertainty surrounding these estimates was accounted for by using large intervals in the probabilistic sensitivity analysis.

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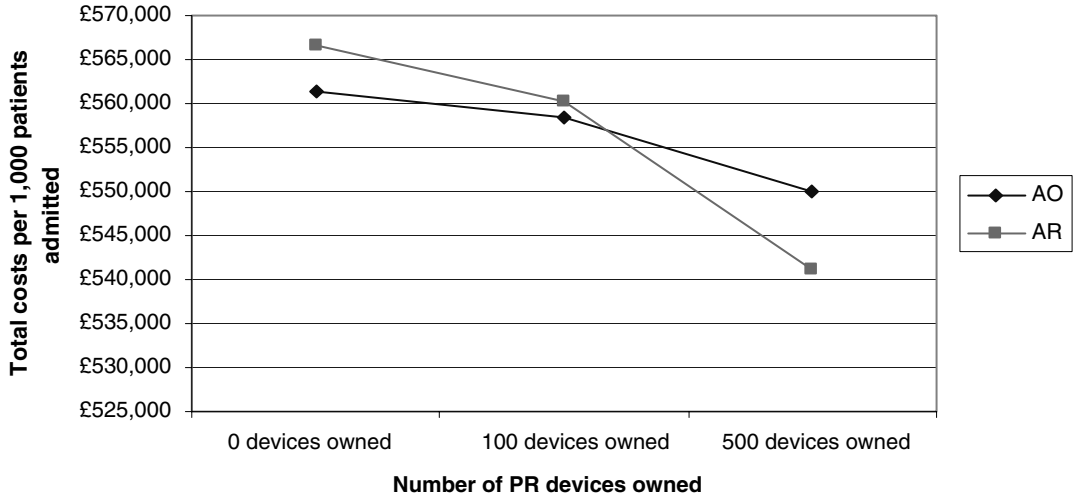

Figure 3. Total costs per 1,000 patients in 1 week, according to stock ownership for the prevention scenario. PR, pressure-relieving.

Third, there was a dearth of data for the effectiveness, costs, and quality of life associated with pressure ulcers. Several assumptions and use of expert opinion were necessary. The small empirical study that was conducted has several limitations. In particular, the visual analogue scale may not be the best method to elicit such information, and the number of respondents was small. However, in the absence of data, this was a necessary exercise.

There has been little work conducted in the economic evaluation of pressure ulcer treatment and prevention. Three economic evaluations of pressure-relieving devices for the prevention of pressure ulcers were identified in a systematic review of the literature reported in the NICE guidelines (38). None of these studies compared alternating pressure devices or alternating pressure devices with a high-specification foam alternative.

POLICY IMPLICATIONS

This study has highlighted a potentially important role in the prevention and treatment of pressure ulcers for strategies involving alternating pressure mattress overlays and replacements. In the United Kingdom, approximately 1.7 million hospital admissions for patients over 50 at risk of developing pressure ulcers will occur annually (12;13;21). The overall cost implications for the NHS of providing pressure-relieving devices such as mattress overlays or mattress replacements to this population are considerable. This finding is particularly true if such devices were to be systematically provided to the large numbers of patients who were only at risk of developing pressure ulcers, rather than just to patients with established pressure ulcers.

This study also has highlighted several implications for research policy. The uncertainty surrounding several of the input parameters used in the model is high, and this uncertainty makes them good candidates for further research. For example, in addition to data on effectiveness, costs, and quality of life relating to interventions available for the prevention and treatment of pressure ulcers, data on the current availability of pressure-relieving devices in hospitals and how these devices are being financed are also likely to be important in informing policy decisions. However, the scarcity of research funds available requires priority setting in research. Recently, frameworks for investigating the cost-effectiveness of research have been proposed (17;47). Decision-analytic models such as the one described in this study can be used to investigate which are the areas where further research would be most valuable.

CONTACT INFORMATION

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