Cost-Effectiveness of Hip Protectors in the Prevention of Osteoporosis Related Hip Fractures in Elderly Nursing Home Residents

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ABSTRACT. ***Objective.*** Hip fracture is a common complication of osteoporosis, resulting in significant morbidity and mortality, with a high financial cost to the healthcare system. Hip protectors have been advocated as an effective method to prevent hip fractures in high-risk individuals. This study models the cost-effectiveness of hip protectors in the prevention of osteoporosis related hip fractures in elderly nursing home residents.

Methods. An incremental cost-effectiveness analysis was performed comparing hip protectors to "no treatment" and to "calcium and vitamin D supplements." The study population was a hypothetical cohort of 1000 nursing home residents. A societal perspective, with a lifetime time horizon, was adopted. Data regarding costs, effectiveness, and quality of life measures were collected from the current literature and from Peace Arch Hospital, a community hospital in White Rock, British Columbia, Canada. Sensitivity analysis was performed.

Results. Hip protector use was found to be a dominant strategy compared to no treatment and to calcium and vitamin D supplements. Dominance implies lower cost and higher effect, generating cost-effectiveness ratios less than zero. Dominance with respect to cost and effectiveness of hip protectors in preventing hip fractures persisted when the model was subjected to probabilistic sensitivity analysis.

Conclusion. Cost-effectiveness analysis suggests that hip protectors could save money while preventing hip fractures and improving quality of life in nursing home residents. (J Rheumatol 2004;31:1607–13)

Key Indexing Terms:
COST-EFFECTIVENESS OSTEOPOROSIS HIP PROTECTOR HIP FRACTURE

Hip fracture is a devastating consequence of osteoporosis. Following hip fracture, 50% of patients are unable to walk without aid, 25% will require longterm care placement, and 20% will die within the first year post-fracture[1]. The financial cost of managing the complications of osteoporosis in Canada was estimated at $1.2 billion Canadian per year in 1993[2].

Hip protectors are a relatively new form of treatment to prevent hip fractures. Since 90% of hip fractures are thought to be due to falls[3], hip protectors have been advocated as a promising approach to hip fracture prevention. Widely used among the elderly in Europe, hip protectors have received little attention in North America. There are no published studies assessing the cost-effectiveness of hip protectors in Canada.

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Six randomized placebo-control trials reviewed by the Cochrane Collaboration have assessed the efficacy of hip protectors in preventing hip fractures in elderly nursing home residents[4-9]. Despite low compliance rates (15% to 60%), dramatic efficacy has been reported in all 6 trials, with relative risk of hip fracture in the treatment groups ranging from 20% to 44%. There is good reason to believe that hip protectors would be effective in real-life situations among nursing home residents with hip protector compliance similar to the reported studies.

The cost-effectiveness of hip protectors in the prevention of hip fractures has not been well studied in Canada. Two studies in the USA and one in the United Kingdom have modeled the cost-effectiveness of hip protectors compared to no treatment[10-12]. All 3 studies suggested that hip protectors would be cost-effective, particularly in high-risk elderly nursing home residents. None of these studies compared hip protectors to any active treatment option, used data from real patient populations, or explored the influence of hip fracture incidence on the cost-effectiveness of hip protectors.

The primary objective of this study was to perform an incremental cost-effectiveness analysis, using data from a Canadian nursing home patient population, comparing hip protectors to the 2 most common osteoporosis treatment options for nursing home residents: (1) no treatment or (2) calcium and vitamin D supplements. Our hypothesis was that hip protectors would be cost-effective in the Canadian nursing home setting. The effect of baseline hip fracture incidence on the cost-effectiveness of hip protectors was explored to provide guidance on cost-effective hip protector use in other community settings. With the prevalence of hip fracture in Canada expected to rise in the future[13], there is an urgent need for cost-effective treatments to prevent hip fractures.

MATERIALS AND METHODS

Study design. An incremental cost-effectiveness analysis, using standard methodology, was used to calculate incremental cost-effectiveness ratios (ICER). The ICER that results from this analysis is the additional or incremental cost per effect that would result from instituting hip protectors compared to the standard of care for osteoporosis management in the study population. The standard of care for osteoporosis management in elderly nursing home residents was determined from the medical literature and from a chart review of extended-care residents at Peace Arch Hospital, a community hospital in White Rock, British Columbia, Canada.

Decision analytic modeling was performed to estimate the costs and effects of each treatment option. Two comparisons were performed: (1) hip protectors compared to no treatment and (2) hip protectors compared to calcium and vitamin D supplements. A societal perspective was adopted for this study. The outcomes of interest were hip fracture prevented and quality adjusted life years (QALY) gained. The time horizon for calculating costs of treatment options and the number of hip fractures prevented was 12 months. A lifetime time horizon was adopted for calculating the QALY gained. One-way, 2-way, and probabilistic sensitivity analyses were performed. The Microsoft Excel software program was used for all data analysis.

Study population. Nursing home residents were considered the ideal study subjects to evaluate the cost-effectiveness of hip protectors, as they are known to be at high risk for osteoporosis related hip fracture[14]. A hypothetical cohort of 1000 nursing home residents, average age 85 years, was modeled on the characteristics of a real nursing home population in White Rock, British Columbia.

Description of intervention. The hard-shell hip protectors used in our model consisted of an outer hard shell with a soft inner lining. The protectors are worn inside special girdle-type underwear (Figure 1). During a fall the hard outer shell shunts the energy of impact to the surrounding soft tissue, protecting the femur from the direct impact of the fall. At least 5 models are currently marketed in Canada. The Impact™ hip protector was chosen for our study model because it possessed many desirable features; it is a mid-priced model ($150), comes with 3 pairs of underwear for easier laundering, and is similar in design to the hip protectors used in the hip protector randomized control trials. The Impact™ (High Tech Bodywear Ltd., Auckland, New Zealand) has been tested in biomechanical tests and is expected to last at least one year.

Determination of standard of care for osteoporosis. Despite the high prevalence of osteoporosis in nursing home residents (estimated at 64% for women ages 65–74 years and 86% in women over age 85 years)[15], a sample of 183 nursing home residents in Ontario, Canada, found that only 15% were taking any type of prescription osteoporosis medication and only 25% were taking calcium and vitamin D supplements[16]. A survey of 275 physicians in Ontario found that more than 50% of physicians would not treat osteoporosis in their nursing home residents even if osteoporosis had been clearly documented[17]. The standard of care for osteoporosis management of nursing home residents in Canada appears to be either no treatment or calcium and vitamin D supplements.

Cost analysis. Costs were reported in 2001 Canadian dollars ($1 CAD = 0.73 $US). All costs included in the analysis were direct medical costs. Costs for treatments not covered by the Medical Services Plan of British Columbia were calcium/vitamin D supplements and hip protectors. The cost of treating a hip fracture was estimated from the Finance Department of Peace Arch Hospital and from the relevant literature. Only the cost of the immediate hospitalization for the hip fracture was included. Costs of treatment options were obtained from local retail suppliers and pharmacies. An extra nursing-aid cost to help residents put on the hip protectors was estimated from the Finance Department, Peace Arch Hospital, and was included in the sensitivity analysis. Side effects from treatment options occurred in less than 5% of study subjects in randomized control trials, required no treatment, and were not included in the cost analysis. Costs were calculated for a 12-month time period; therefore discounting was not required.

Figure 1. The Impact™ hip protector.

Effectiveness analysis. Baseline risk of hip fracture was derived from the incidence of hip fracture in the nursing home population served by Peace Arch Hospital. The risk of hip fracture when using a hip protector came from an exploratory analysis by the Cochrane Review of the 3 largest randomized control trials of hip protectors[18]. The control groups in each of the 3 trials were similar to our study cohort with respect to age, baseline incidence of hip fracture, and living situation. The incidence of hip fracture in the control groups in the hip protector trials was 46 per 1000 (persons) per year, 58 per 1000 per year, and 38 per 1000 per year, similar to our cohort hip fracture incidence of 43 per 1000 per year. In all the hip protector trials participants were residents living in nursing homes. All the hip protector trials had average ages of 80 to 90 years, similar to our cohort's average age of 85 years. The risk of hip fracture using calcium and vitamin D came from the largest randomized controlled trial of calcium and vitamin D treatment[19]. The control group in the calcium and vitamin D trial was very similar to our cohort with respect to average age (84 yrs vs our average age of 85 yrs), living situation (nursing home), and baseline incidence of hip fracture (47 per 1000/yr compared to our incidence of 43 per 1000/yr).

We obtained utility measures for our study from one of the few available published utility studies that provides data on aged-matched patients with no hip fracture and with hip fracture[20]. This study provided EuroQol-based utility scores for both the first year and the second year post-fracture, and these utility scores were compared to age-matched controls in the general population. Utility scores provided in the 75–84 year age group were used in our study. Utility scores for the third and subsequent years post-fracture were assumed to be the same as the second year post-fracture. Probability of death directly attributable to the hip fracture was estimated from the literature at 10% in the first year post-fracture[21]. Mortality in the second and subsequent years post-fracture was assumed to be the same for those nursing home residents without hip fracture and was based on Canadian Life Tables[22]. The general formula used for the QALY calculations over the lifetime of the resident was:

$$\text{QALY} = \text{Life expectancy} \times \text{Utility weight}$$

In the first year post-fracture the 10% probability of death attributable to the hip fracture was added into the QALY measurements. Discounting of 3% per year for the calculation of QALY measurements over the lifetime of the nursing home resident was performed. Costs were only calculated over the first year of the model and therefore no discounting was performed.

Sensitivity analysis. Standard one-way and 2-way analyses were performed. The variability of the effectiveness measure was explored by using the limits of the 95% confidence interval for the relative risk of hip fracture using a hip protector. Increasing and decreasing the retail cost for hip protectors by one-third and adding additional nursing-aid time made it possible to explore variability of the cost. However, standard sensitivity analyses do not incorporate the distributions of the costs and the effects. Only the best and worst case scenarios are obtained. Probabilistic sensitivity analysis methodology was used to determine the degree of uncertainty surrounding the cost-effectiveness ratios obtained in our analyses[23]. Computer simulation propagated the distributions of 3 variables through the decision model: baseline incidence of hip fracture, cost of hip fracture treatment, and relative risk of hip fracture using a hip protector. The probability that hip protectors are cost-effective, over a broad range of thresholds for cost-effectiveness, was determined from the cost-effectiveness curves generated by our computer simulation. Distributions chosen for the computer simulation took into account the manner in which the point estimator was calculated and the properties inherent to each type of variable (Table 2).

RESULTS

Resident characteristics. A chart review of 335 Extended Care residents at Peace Arch Hospital (average age 85 yrs) found a baseline incidence of hip fracture of 43 hip fractures per 1000 persons per year. Twelve percent of residents were taking prescription medication to treat osteoporosis and 29% were taking calcium and vitamin D supplements. Sixty-nine percent of residents were receiving no treatment for osteoporosis (Table 1). The most common osteoporosis treatments for nursing home residents in our study population were no treatment or calcium and vitamin D supplements (Table 1).

Table 1. Characteristics of nursing home residents at Peace Arch Hospital (n = 335).

	Number (%)
Gender, M/F	247/88 (74/26)
Average age, yrs, mean (SD)	85 (11)
Baseline incidence of hip fracture, /1000/yr	43
Receiving treatment for osteoporosis	
Calcium and vitamin D	99 (30)
Bisphosphonates	27 (8)
Hormones	10 (3)
Calcitonin	2 (0.6)
No specific drug or vitamin	231 (69)

SD: standard deviation.

Cost-effectiveness analysis. Values used in the cost-effectiveness analysis are presented in Table 2. The decision analytic model (Figure 2) was used to generate the cost and effectiveness measures for each treatment option. The base-case analysis demonstrated negative cost-effectiveness ratios, suggesting that hip protectors save money while preventing hip fractures and gaining QALY compared to no treatment and to calcium and vitamin D. Cost savings were in the range of $10,000 per hip fracture prevented and $17,000 per QALY gained (Table 3). The base-case analysis comparing hip protectors to no treatment was robust to one-way and 2-way sensitivity analysis generating mostly negative cost-effectiveness ratios. The maximum cost per fracture prevented was $240 and the maximum cost per QALY gained for females was $364 (Table 4). Similar cost per QALY results were obtained for men. Probabilistic sensitivity analysis generated a cost-acceptability curve suggesting there is a 99% probability that the cost per hip fracture prevented is less than $4000 and a 92% probability that the cost is less than zero dollars (Figure 3). Similar results were obtained for the cost per QALY gained, with a 99% probability that the cost is less than $4500 and a 98% probability that the cost is less than zero dollars (data not shown).

The base-case analysis comparing hip protectors to calcium and vitamin D was less robust to sensitivity analysis. The maximum cost per fracture prevented was $18,727 and the maximum cost per QALY was $28,326 for women (Table 4). Similar costs per QALY were obtained for men. Probabilistic sensitivity analysis generated a cost-acceptability curve suggesting that there is a 95% probability that the cost per hip fracture prevented is less than $20,000. There is a 96% probability that the cost is less than zero dollars if no extra nursing time is required to use the hip protector, and the hip protector cost stays below $150. Similar results were obtained for the cost per QALY gained, with a 96% probability that the cost is less than $21,000 and a 97% probability that the cost is less than zero dollars if no extra nursing time is required and the cost of the hip protector is less than $150 (data not shown).

Cost-effectiveness of hip protectors varied significantly as the baseline incidence of hip fracture in the study population changed. Hip protectors compared to no treatment remained a cost-saving strategy until the hip fracture incidence dropped below 12 per 1000 persons (Figure 4).

DISCUSSION

Our study generated negative cost-effectiveness ratios, suggesting that hip protectors are a dominant cost-effective strategy compared to the option of no treatment in elderly nursing home residents. Dominance implies that hip protectors save money while preventing hip fractures and gaining quality adjusted life years over a one-year treatment period. We recognize that the magnitude of negative cost-effectiveness ratios cannot be easily compared[24].

Table 2. Costs (in Canadian dollars), probabilities, and values used in the decision model.

	Costs, $ Base Case	Range Upper	Range Lower	Distribution
Cost Variable				
Hip protector	150	200	100	
Calcium/vitamin D	56			
Acute hospital treatment of hip fracture	16,250	18,854	14,508	Gamma
Additional nursing aid time: 2.5 full-time/1000 residents	112,000			
Probabilities				
RR of hip fracture — no treatment	1.00			
RR of hip fracture — calcium/vitamin D	0.73			
RR of hip fracture — hip protector	0.37	0.56	0.24	Lognormal
Values				
Baseline incidence of hip fracture, /1000/yr	43	69	26	Beta
QALY measurements at age 75–84 yrs:				
No fracture	0.63			
1 yr post fracture	0.43			
2 yrs post fracture	0.53			
3 yrs and all subsequent yrs post fracture	0.53			

RR: relative risk; QALY: quality adjusted life year.

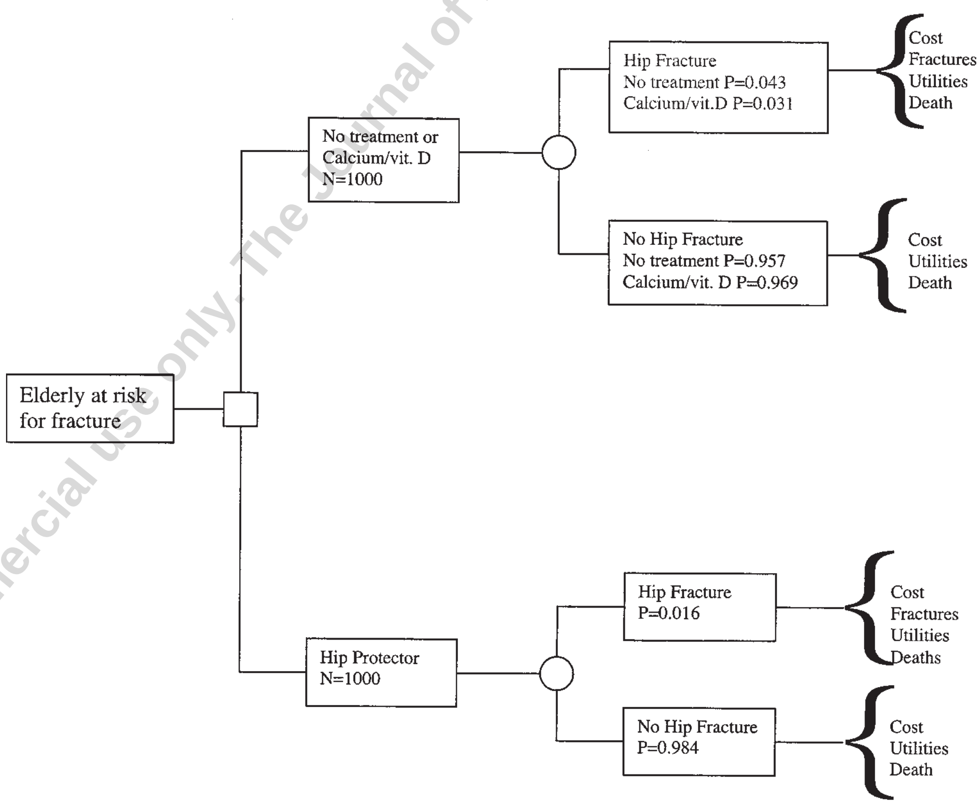

Figure 2. The decision analytic model was used to generate the cost and effectiveness measures for each treatment option.

Table 3. Base analysis: Incremental cost-effectiveness.

	Cost per Hip Fracture Prevented, $	Cost per QALY Gained, Female	Cost per QALY Gained, Male
Hip protector vs no treatment	(–10,713)	(–16,204)	(–18,272)
Hip protector vs calcium/vitamin D	(–10,198)	(–15,426)	(–17,394)

We predicted that the use of hip protectors in 1000 nursing home residents for one year would prevent 27 hip fractures. With savings of about $10,000 per hip fracture prevented, this translates into cost savings of $270,000. Our study suggests that hip protectors are a cost-effective, but not dominant, strategy compared to calcium and vitamin D, with a 96% probability of a cost per QALY of less than $21,000.

Will hip protectors be cost-effective outside the nursing home environment where the incidence of hip fracture is much lower? In the general Canadian population over 75 years of age, the incidence of hip fracture is estimated at 5 per 1000[25]. At this incidence rate, hip protectors were less cost-effective, compared to no treatment, with a cost per hip fracture prevented of $13,500 (Figure 4) and a cost per QALY gained of $47,500 (data not shown). The cost per hip fracture prevented drops below zero at a hip fracture incidence of 12 per 1000 (Figure 4). The cost per QALY gained drops below $20,000 at a hip fracture incidence of 8 per 1000 (data not shown). In selected high-risk elderly people living in the community, hip protectors may still be very cost-effective compared to no treatment.

There are a number of limitations to this study. The use of data from several different sources increases potential measurement errors. Our analysis did not include costs of rehabilitation after acute fracture or costs of increased level of nursing care after hip fracture. Therefore, we may have underestimated the cost of hip fracture treatment. The cost savings of hip protector use may be greater than we have reported. The analysis did not take into account the cost of caring for a nursing home resident who does not die from a hip fracture or the cost of treating side effects, as little information was available on these issues. These costs would tend to decrease the cost-effectiveness of hip protectors. We included the cost of increased nursing-aid time in our sensitivity analysis but were unable to adjust for the effect of these nursing aids on compliance with use of hip protectors. The utilities chosen for the study were measured in the general population 75–84 years of age and may not apply to the nursing home population. However, the incremental QALY differences between patients with or without a hip fracture are likely to be very similar in the nursing home population even if the absolute QALY measures may be different. We did not assess the effect of wearing a hip protector on quality of life measures as little information was available.

Hip protector effectiveness was based on the assumption that compliance in real life would be similar to compliance in the randomized control trials chosen (24–48%). Observational studies in Europe, with up to 12 months of

Table 4. One-way and 2-way sensitivity analysis: hip protectors versus no treatment or calcium/vitamin D following one year treatment.

	Incremental Cost Effectiveness Cost/Hip Fracture Prevented, $		Incremental Cost Utility Cost/QALY-Female, $	
	No Treatment	Calcium/Vitamin D	No Treatment	Calcium/Vitamin D
One-way sensitivity analysis				
Increase cost of protector by 1/3	< 0 (-8867)	< 0 (-6968)	< 0 (-13,413)	< 0 (-10,540)
Decrease cost of protector by 1/3	< 0 (-12,559)	< 0 (-13,428)		
Add cost of 2.5 nursing aid	< 0 (-6578)	< 0 (-2963)	< 0 (-9950)	< 0 (-4482)
Add both increased cost protector by 1/3 and cost of nursing aid	< 0 (-4733)	299	< 0 (-7159)	403
RR = 0.24 (95% CI)	< 0 (-11,660)	< 0 (-11,804)	< 0 (-17,637)	< 0 (-17,854)
RR = 0.56 (95% CI)	< 0 (-8322)	< 0 (-3435)	< 0 (-12,588)	< 0 (-5195)
Two-way sensitivity analysis — 1/3 increase cost of protector				
RR = 0.24	< 0 (-10,130)	< 0 (-9431)	< 0 (-15,323)	< 0 (-14,265)
RR = 0.56	< 0 (-5679)	< 0 (3405)	< 0 (-8590)	5150
Two-way sensitivity analysis — add 2.5 nursing aid				
RR = 0.24	< 0 (-8233)	< 0 (-6488)	< 0 (-12,453)	< 0 (-9814)
RR = 0.56	< 0 (-2402)	11,887	< 0 (-3633)	17, 980
Two-way sensitivity analysis — add 1/3 increase cost of protector and 2.5 nursing aid				
RR = 0.24	< 0 (-6703)	< 0 (4091)	< 0 (10,139)	< 0 (-6224)
RR = 0.56	240	18,727	364	28,326

RR: relative risk; CI: confidence interval.

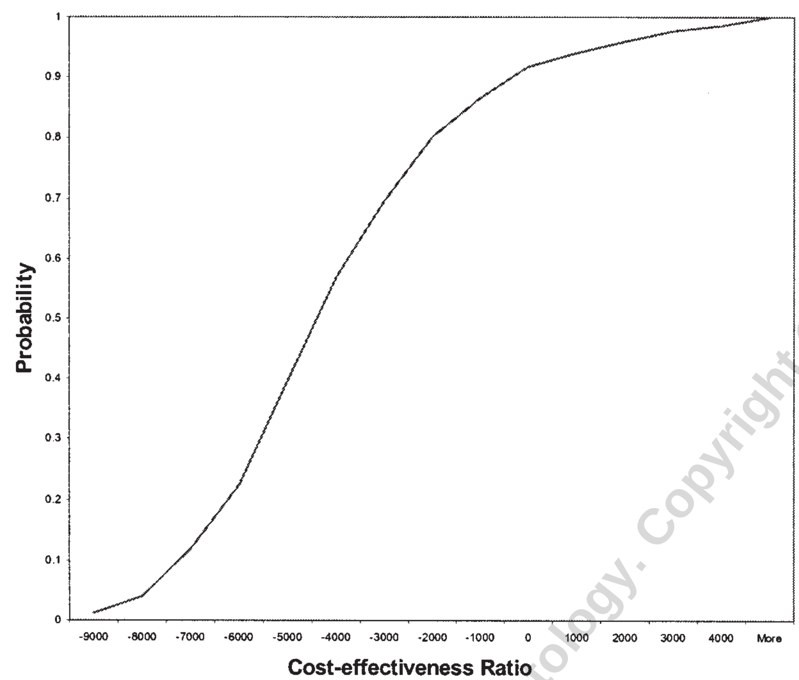

Figure 3. Cost per hip fracture prevented. Hip protector versus no treatment. Cost-effectiveness ratio.

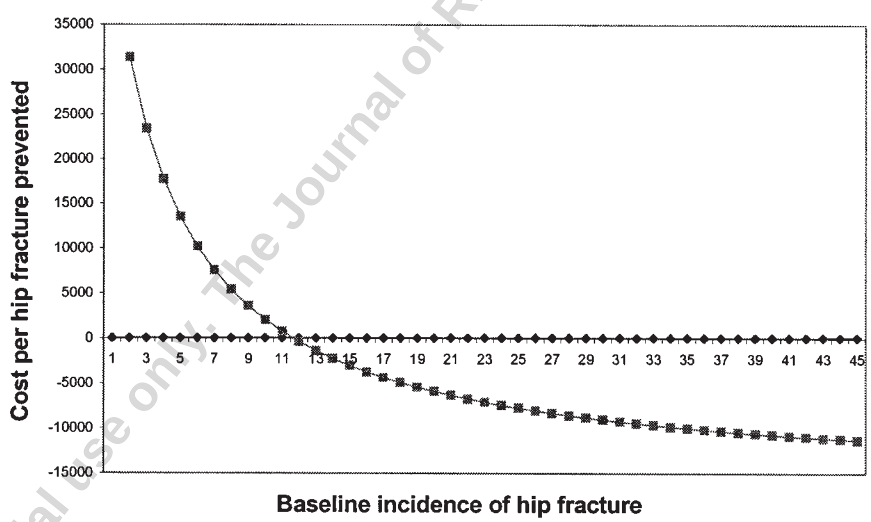

Figure 4. Cost per hip fracture prevented. Hip protector versus no treatment. Baseline incidence of hip fracture.

followup, have found compliance with hip protector use to range from 30% to 40% in real-life nursing home settings[26–28]. Compliance may be very similar in Canadian nursing home settings. The methodology used to measure compliance was different in each of the hip protector trials used in our model. Compliance was poorly documented and was not reliably correlated with effectiveness. Therefore, it was not possible to confidently predict cost-effectiveness based on compliance from existing studies.

This is the first study suggesting that hip protectors are cost-effective compared to both no treatment and calcium and vitamin D supplements in the Canadian healthcare setting. Our results add to the small body of information supporting the use of hip protectors as an important and cost-effective strategy in preventing hip fractures in high-risk individuals. Promotion of hip protectors at an institutional, rather than at the individual level may dramatically improve compliance in nursing homes. Further improve-

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ments in the comfort and ease of application of hip protectors may improve compliance. Just as bicycle helmets have become widely accepted for prevention of head injuries, hip protectors may become the accepted method for prevention of hip fractures in nursing home residents and in high-risk elderly living in the community.

In summary, hip protectors appear to be an exciting, cost-effective treatment option to prevent hip fractures in elderly nursing home residents in Canada. With the low unit cost of $150, hip protectors may save money while preventing fractures, prolonging life, and improving quality of life. Use of hip protectors at an institutional level and further improvements in the design of hip protectors may improve compliance.

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