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Lifetime Cost-Effectiveness of Skin Cancer Prevention through Promotion of Daily Sunscreen Use

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ABSTRACT

Objectives: Health-care costs for the treatment of skin cancers are disproportionately high in many white populations, yet they can be reduced through the promotion of sun-protective behaviors. We investigated the lifetime health costs and benefits of sunscreen promotion in the primary prevention of skin cancers, including melanoma. **Methods:** A decision-analytic model with Markov chains was used to integrate data from a central community-based randomized controlled trial conducted in Australia and other epidemiological and published sources. Incremental cost per quality-adjusted life-year was the primary outcome. Extensive one-way and probabilistic sensitivity analyses were performed to test the uncertainty in the base findings with plausible variation to the model parameters. **Results:** Using a combined household and government perspective, the discounted incremental cost per quality-adjusted life-year gained from the sunscreen intervention was AU$40,890. Over the projected lifetime of the intervention cohort, this would prevent 33 melanomas, 168 cutaneous squamous-cell carcinomas, and 4 melanoma-deaths at a cost of approximately AU$808,000. The likelihood that the sunscreen intervention was cost-effective was 64% at a willingness-to-pay threshold of AU$50,000 per quality-adjusted life-year gained. **Conclusions:** Subject to the best-available evidence depicted in our model, the active promotion of routine sunscreen use to white populations residing in sunny settings is likely to be a cost-effective investment for governments and consumers over the long term.

Keywords: cost-effectiveness, health-care costs, melanoma, primary prevention, squamous-cell carcinoma, sunscreen.

Introduction

In predominantly fair-skinned populations living in high sunlight environments, the treatment costs for skin cancers exert a significant financial burden on the health-care system. Cutaneous malignant melanoma is the most deadly skin cancer, causing more than 8000 deaths in the United States [1] and more than 1200 deaths in Australia each year [2]. Although seldom fatal, the sheer quantity of basal-cell carcinoma (BCC) and squamous-cell carcinoma (SCC) in these populations causes disproportionately more resources to be expended on these cancers than on any other [3–5]. In the United States, skin cancer treatments cost an estimated $2 billion each year. In addition are costs of other sun-related skin conditions such as actinic keratoses (AKs), which range in prevalence from 6% to 25% in the United Kingdom and United States [6] to 40% to 60% in Australia [6,7], and are one of the strongest predictors of skin cancer [7]. Management of AKs accounts for an additional $1.2 billion in health-care costs in the United States [8].

The evidence that the vast majority of skin cancers are caused by solar ultraviolet radiation (UVR) exposure is accepted [9]. Both acute and chronic overexposure to the sun, including early in life, are important for the development of skin cancers including melanoma [10] and it is thus expected that their prevention is achievable through the engagement of sun-protective behaviors. On this basis, wearing sun-protective clothing, broad-brimmed hat and sunglasses, and seeking shade is recommended by health authorities in many Western countries [11–13]. The topical application of broad-spectrum sunscreens is also recommended as a safe adjunct measure in protecting human skin from UVR damage and cancer development [14,15].

Australia has the highest reported rates of skin cancer in the world, with two in three Australians being diagnosed with skin cancer in their lifetime and more than 1600 deaths attributed to skin cancer each year [5,16]. Not surprisingly, Australia has led the world in the development of sun-protection messages and promotional campaigns such as Slip Slop Slap and SunSmart and these programs appear to have successfully raised public awareness and improved preventive behaviors [17,18], even slowing melanoma and other skin cancer incidence rates in younger cohorts [19].

It is plausible then that health-care costs could be reduced through interventions promoting sun-protection behaviors. Because many skin cancers are treated in relatively low-cost primary care settings, however, some have suggested that it is more economical to treat these conditions as they arise rather than investing in preventive measures that promote sun protection [20]. Re-

Conflicts of interest: The authors have no conflicts of interest to report.

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futing this with community-based trial data [15], we have shown that a sunscreen intervention provided a practical means of preventing SCCs and produced significant cost-savings for government health providers [21]. The question remained, however, whether these cost-effective benefits could be maintained into the longer term when melanoma, the least prevalent but more often fatal form of skin cancer, was taken into account. Therefore, the purpose of this study was to investigate the potential health costs and benefits of a sunscreen intervention over the longer term (remaining lifetime) with respect to melanoma prevention in addition to the previously demonstrated benefits.

Methods

Description of strategies

The strategies modeled were based on the Nambour Skin Cancer Prevention Trial [22–24] where 1621 residents of Nambour in Queensland, Australia, were randomized to either the sunscreen intervention group or the control group. The intervention group was encouraged to apply a broad-spectrum Sun Protection Factor 15+ sunscreen to their head, neck, arms, and hands every morning ("daily use" group) and received one or more 250-mL bottles of sunscreen free of charge every 3 months at dedicated study clinics. The control group participants were instructed to use sunscreen at their own discretion ("discretionary use" group). All participants received full skin examinations by dermatologists unaware of treatment allocation, at the start (1992), midway (1994), and at the end (1996) of the trial. Any clinically diagnosed skin cancers were confirmed by pathology reports. Participants who withdrew from active trial participation or active follow-up were asked to continue with ongoing "passive" monitoring of skin cancers through their medical records [25]. After the trial ended in 1996, all participants, including those who withdrew from active follow-up, consented to have subsequently diagnosed skin cancers notified to the investigators by regional pathology laboratories in Queensland. Finally, a cross-check for any melanomas diagnosed between 1992 and 2006 in study participants was undertaken through a search of cancer notifications at the Queensland Cancer Registry [26].

Overview of model structure

A decision-analytic model with Markov chains was constructed in TreeAge Pro 2009 software (TreeAge Software, Inc., Williamstown, MA) (Fig. 1). The model tracked multiple hypothetical cohorts separately to examine the health and cost outcomes of individuals with different profiles. Male, female, or mixed-sex cohorts with a mean starting age of 49 years (i.e., the mean age of participants at commencement of the Nambour Skin Cancer Trial) were modeled until age 100 years or death. Key measures in the model included time since diagnosis, costs, number of melanomas, quality-adjusted life-years (QALYs) and life-years lived. Guidelines for best-practice procedures for economic modeling were adhered to during our study [27].

Health states and transition probabilities

The model consists of seven health states—no melanoma; melanoma (in situ); melanoma (stage I); melanoma (stage II); melanoma (stage III); melanoma (stage IV); and dead—with staging defined by the American Joint Committee on Cancer categories [28]. All cohort members begin the model without a melanoma. Individuals will either continue to live without a melanoma or be diagnosed with a melanoma (and treated accordingly based on their American Joint Committee on Cancer stage). Following treatment, individuals diagnosed with melanoma face stage-specific risks of remaining in remission, having a recurrence, a diagnosis of additional tumors, distant metastases, or death. In all health states, individuals also face an age-specific all-cause mortality risk. Time-dependent probabilities have been built into the model to ensure that the risk of cancer progression, recurrence, or death is dependent on the duration since diagnosis.

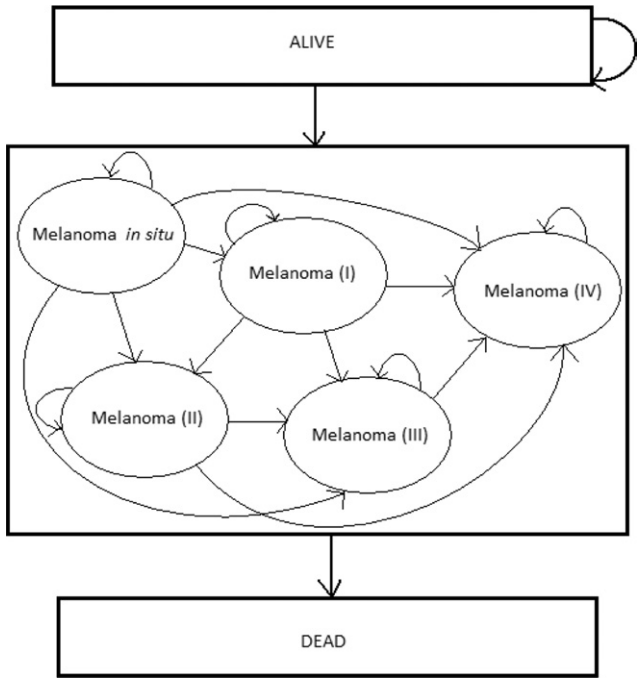

Fig. 1 – Schematic of melanoma-only model. Note: Patients diagnosed with a melanoma of a specific stage may be diagnosed with additional melanomas of the same or later stage. Transition to a higher stage may be disease progression or additional melanoma. Death may be melanoma related or from any cause.

Melanoma stage and incidence rates are the average of the latest three years of Australian melanoma incidence data by age and gender [29] (Table 1). An age-specific risk of melanoma was used in the model, and a constant hazard ratio from sunscreen use applied to this risk. Therefore, the absolute risk reduction (risk difference) is age dependent.

Evidence for the effectiveness of daily sunscreen use in preventing melanoma was sourced from the Nambour study [26] where Cox proportional-hazards regression was performed to estimate the hazard ratio for melanoma development in relation to daily sunscreen use compared with discretionary use. Intention-to-treat analysis was carried out for all reviewed and histologically confirmed melanomas between 1993 and 2006 [26]. The protective effect from sunscreen was statistically significant for invasive melanoma (0.27; 95% confidence interval [CI] 0.08–0.97) [26]. There were no significant differences in sun-protection behaviors (time spent outdoors on the weekend and weekdays, seeking of shade, and hat wearing) other than sunscreen use between the intervention and control groups before and after the intervention.

Estimates of survival rates for melanoma patients were transformed into progression rates to late-stage cancer and subsequent mortality [31]. The annual progression rates to stage IV melanoma from stages I and II were steady at 2% and 7%, respectively. Stage III melanomas had a first-year progression rate of 45%, but it fell by a third each year thereafter. Mortality risk in year 1 of a stage IV diagnosis was 42%, and it fell by approximately one-fifth each year since diagnosis. Additional melanoma diagnoses were assumed to