Cost-effectiveness analysis of mammography screening in Hong Kong Chinese using state-transition Markov modelling

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Key Messages

1. We developed a state-transition Markov model to assess the consequences, costs, and cost-effectiveness of biennial mammography screening strategies in Hong Kong Chinese women, and to inform on evidence-based screening policies in Hong Kong, which has a lower breast cancer incidence compared to the West.
2. We adopted a decision analytic framework and a societal perspective. As previously reported, our findings showed a higher incremental cost-effectiveness ratio than in the West and that screening women aged 40 to 69 years was the least costly non-dominated option.
3. Our results suggest that mammography for Hong Kong Chinese women may not be cost-effective based on the threshold of US$50 000 per quality-adjusted life year. However, clinicians must remain vigilant and should periodically revisit the question of population screening.

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Introduction

Mammography screening for early detection of breast cancer has become routine practice in many western countries, and its cost-effectiveness has been established. Nonetheless, it may not be readily applicable to the Hong Kong setting, where breast cancer incidence is much lower and the age profile of cancer incidence differs.

To inform on evidence-based interventions and public health screening policies in Hong Kong, we assessed the consequences, costs and cost-effectiveness of biennial mammography in Hong Kong Chinese women using a state-transition Markov model.

Methods

This study was conducted from August 2005 to July 2007. Data were extracted from local clinical, epidemiological and cost data, the US Surveillance, Epidemiology, and End Results database, results of trial data on western women, and the literature. Cost data were mostly derived from local sources such as the government gazette (public fees and charges) and publications of the Hospital Authority (patient-related group costs). Cost data from the private sector were estimated directly through private providers (eg health maintenance organisations and individual doctors), laboratories and suppliers of consumables. We also benchmarked our derived cost estimates with comparable overseas data to check for internal and external consistencies.

Study instruments and cost-effectiveness analysis

A state-transition Markov model was developed to simulate biennial mammography, breast cancer diagnosis and treatment in a hypothetical population-based cohort of Hong Kong Chinese women aged 40 years or older.[1] The benefit of mammography was modelled by assuming a stage shift, in which cancers were more likely to be diagnosed at an earlier disease stage in screened women. That is, the stage distribution in the non-screened group was specified from local data. The incidence of breast cancer in the screened group was not changed, but the proportion of persons who were initially diagnosed with breast cancer in different stages was changed. The stage shifts were calibrated so that the observed mortality benefits of screening were consistent with the results of randomised controlled trials in western countries.[2]

The structure of the Markov model is presented in Figure 1. The model tracks a cohort of cancer-free 40-year-old women over a 50-year time horizon. Each year they may remain cancer-free (ie alive without breast cancer) or transition to one of the five breast cancer stages, or they could die. The five breast cancer stages included ductal carcinoma in situ (DCIS) and four invasive cancer stages (as designated by the American Joint Committee on Cancer). For the first 10 years, women with a history of DCIS were at an increased risk of developing invasive cancer, compared with healthy women. For women diagnosed with invasive cancer, mortality for the first year was specified. Women diagnosed with

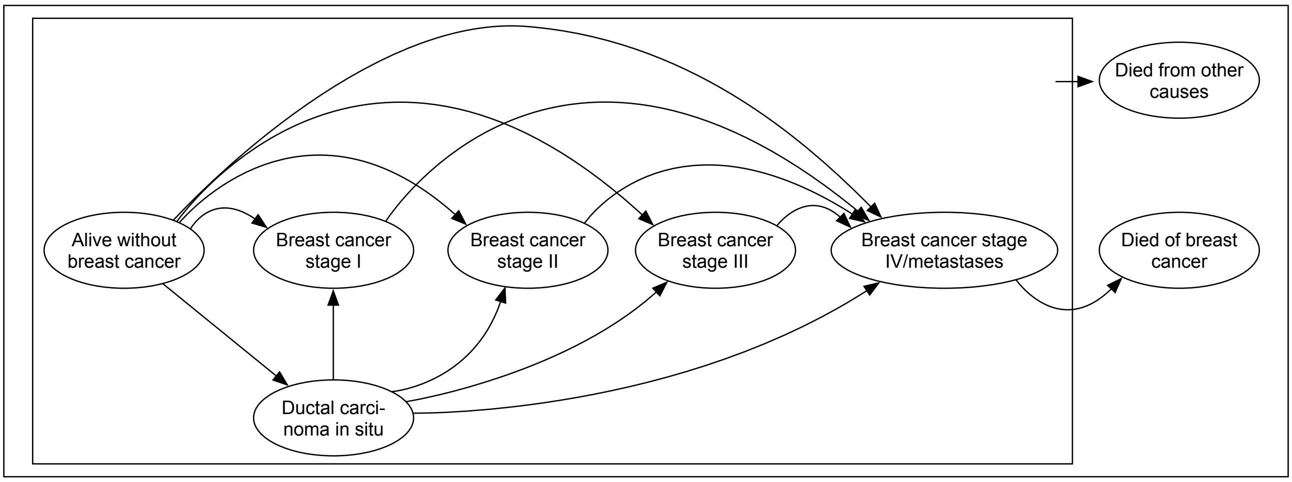

Fig 1. Health states and transitions

stages I to III cancer could subsequently develop metastatic recurrence and transition to the stage IV/metastatic state. Except for treatment-related deaths that occur during the first year after diagnosis, we assumed that breast cancer deaths could only occur among women in the stage IV/metastatic state.

Biennial mammographic screening strategies beginning at age 40 or 50 years and ending at age 69 or 79 years were compared, with a control group having no screening. In our model, women diagnosed with invasive breast cancer were assumed to undergo mammography surveillance every year. All cancer (including DCIS) patients were assumed to undergo prompt treatment on diagnosis.

Four major direct medical costs were considered. They were the cost of screening mammography, the cost of follow-up abnormal screens, the one-time cost of treating invasive cancer and DCIS, and the cost of terminal care during the final 6 months before death. Other major non-health costs were also considered including transportation and time costs. All costs were adjusted to the 2005 level.

Strategies that were less effective and more costly than a competing strategy were eliminated by simple dominance. Comparative performance of the remaining screening strategies was measured by the incremental cost-effectiveness ratio (ICER). Those that were less effective and had a higher ICER than another strategy were ruled out by extended dominance and eliminated, and the ICERs of the remaining strategies were recalculated. All clinical data and parameters have been reported.[1] For the reference case analysis, discounted future costs and health effects were adopted at an annual rate of 3%. All analyses were conducted from a societal perspective.

Sensitivity analysis

We also conducted a probabilistic sensitivity analysis to examine uncertainty in incremental cost-effectiveness analysis. We specified clinical and cost parameters with probabilistic distributions, and cost-effectiveness results associated with selecting values at random from those distributions were employed in a Monte-Carlo simulation of the model with 1000 runs. Based on the simulated results, we constructed a cost-effectiveness acceptability curve to present the uncertainty of the ICER based on different values of the ceiling ratio or acceptable willingness-to-pay threshold.

We further modified our single cohort simulation to multiple cohort simulation on the cost-effectiveness estimates of breast cancer screening programmes by taking into account the age structure of the Hong Kong population that would be affected by the policy decision. We specified the nature of our starting cohort so that it matched the age structure of the local female population. Eight 5-year-interval cohorts were specified between the ages of 40 and 79 years.

Main outcome measures

Model outcomes were life expectancy, quality-adjusted life expectancy and lifetime costs, using a 50-year time horizon. Comparative performance of the remaining screening strategies was measured by the ICER.

Results

Cost-effectiveness

The ICERs associated with different screening strategies are presented in the Table. Compared to no screening, biennial mammography would save between 1590 and 3400 discounted life years per 100 000 women screened, depending on the screening strategy. This is equivalent to a mean increase in life expectancy of 4.3 to 9.3 days per woman. The corresponding cost would be increased by US$117 to $242 million.

Of the four biennial mammographic screening strategies, the least costly non-dominated option was to screen women aged 40 to 69 years, with an ICER of US$64 400 per life year saved. By extending screening until age 79 years, the ICER would increase to $260 300 per life year saved. When

Table. Lifetime discounted costs and benefits of different screening strategies for women in Hong Kong and the US

Screening strategy	Hong Kong				US			
	Discounted lifetime cost (million US$)	Discounted life years	ICER*, cost per life year saved	ICER*, cost per quality-adjusted life year saved‡	Discounted lifetime cost (million US$)	Discounted life years	ICER*, cost per life year saved	ICER*, cost per quality-adjusted life year saved‡
Single cohort model								
No screening	54.14	2 373 740			168.29	2 253 170		
Biennial screening								
50-69 years	170.75	2 375 330	Dominated†	Dominated†	294.65	2 256 590	37 000	33 200
50-79 years	201.99	2 375 450	Dominated†	Dominated†	325.01	2 256 970	Dominated†	Dominated†
40-69 years	265.38	2 377 020	64 400	61 600	396.85	2 258 730	47 800	46 800
40-79 years	296.62	2 377 140	260 300	178 800	427.19	2 259 110	80 200	55 400
Multiple cohort model								
No screening	45.34	1 918 513			165.27	1 793 667		
Biennial screening								
50-69 years	143.20	1 919 827	Dominated†	Dominated†	273.05	1 796 664	36 000	32 300
50-79 years	190.07	1 920 057	Dominated†	Dominated†	321.87	1 797 400	Dominated†	Dominated†
40-69 years	172.98	1 920 411	67 200	63 400	305.42	1 797 426	42 500	Dominated†
40-79 years	219.72	1 920 723	149 500	100 900	353.81	1 798 334	53 300	38 700

* ICER denotes incremental cost effectiveness ratio; all ICERs are rounded to the nearest 100; options are compared with the next least expensive non-dominated strategy

† Strategy that costs more but is less effective than other strategies is known as dominated

‡ Assuming health-related utilities of 0.95, 0.9, 0.8, 0.7 and 0.3 for ductal carcinoma in situ, stage I, stage II, stage III and stage IV invasive cancer for the remaining time spent in the same stage

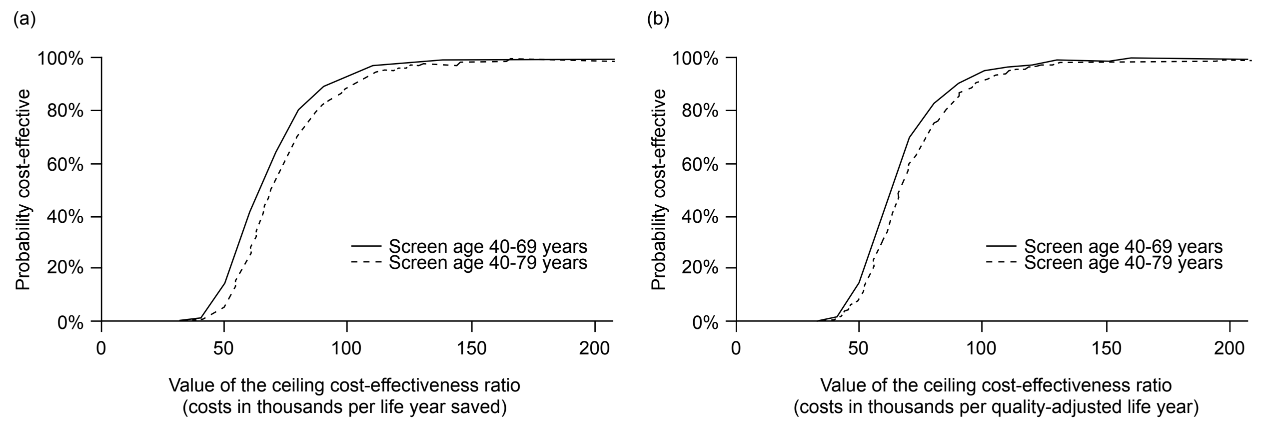

Fig 2. Cost-effectiveness acceptability curves for the non-dominated screening strategies compared with no screening for the (a) cost per life year saved and (b) cost per quality-adjusted life year

health-related quality of life was incorporated, the ICERs were more favourable ($61 600 per quality-adjusted life year saved).

When we used the US all-cause mortality, age-specific cancer incidence and costs as our input parameters, the least costly non-dominated options were to screen women aged 50 to 69 years ($37 000 per life year saved), followed by women aged 40 to 69 years ($47 800 per life year saved) and women aged 40 to 79 years ($80 200 per life year saved). This change in the ranking can be explained by the different age distribution of cancer incidence between the two populations in that cancer rates increase substantially in US women after age 40 years, in contrast to a much slower rising plateau in Hong Kong women.

Sensitivity analysis

When taking different age structures into account at the beginning of the simulation in the multiple cohort approach, both costs and effects were lower than with a single cohort of women at the same starting age in the base case. This is because the mean age of persons starting the multiple cohort simulation is higher than that in the single cohort simulation, whereas older age-groups have fewer screening years remaining and thus accumulate lower costs and benefits from screening. But this adjustment did not change our cost-effectiveness rankings (Table).

Figure 2 shows cost-effectiveness acceptability curves based on different values of the ceiling cost-effectiveness ratio. They reflect the uncertainty that is potentially present in the costs and life-expectancy or quality-adjusted life years saved. For example, the probability of the ICER being below the threshold of US$50 000 per quality-adjusted life year saved was less than 15.3% (14.6%) for the least costly non-dominated option.

Discussion

There have been widespread suggestions and unqualified recommendations for whole-population screening, and the aggressive promotion of mammographic examination in Chinese women. There is no systematic screening programme for breast cancer in Hong Kong. Instead, opportunistic mammography screening services are available in both the private and public sectors. An important consideration is the low breast cancer incidence, and hence its low prevalence at screening in Hong Kong compared with western populations. This implies a lower positive predictive value and many false-positive results. The present analyses give us insights into the cost-effectiveness of mammography screening in Chinese and other East Asian women with a low baseline risk for breast cancer. It appears that population-based mammography screening might be an inefficient way to allocate scarce public health care resources.

The state-transition Markov model is probably the most appropriate modelling technique in the context of Hong Kong, owing to the logistic and pragmatic difficulty inherent in the running of a local randomised control trial. This difficulty likely stems from concerns about the costs of a trial because of large sample size requirements (given the much-attenuated degree of absolute benefit associated with a low cancer incidence). Moreover, the long follow-up needed for such a trial (to monitor at least 10 years of cancer-related mortality), and cross contamination between the intervention and control arms would pose other challenges.

Of the five screening strategies, biennial mammography for women aged 40 to 69 years appears the least costly non-dominated screening option. The respective incremental cost (compared to no screening) of US$61 600 (HK$480 480) per quality-adjusted life year is much larger than corresponding costs in the West. This figure also seems slightly greater than the typical threshold of US50 000 (HK$390 000) per quality-adjusted life year used for new technology adoption by many advanced economies.

An important potential limitation was that we did not have aggregate local stage-specific treatment costs for invasive breast cancer, and instead relied on individual itemised cost data. Thus the results were not sensitive to treatment costs on a one-way sensitivity testing. Second, we did not evaluate newer technologies to detect breast lesions (magnetic resonance imaging, ultrasound, full-field digital mammography or computer-aided detection techniques). A recent systematic review suggested that there was insufficient evidence to support the use of any of these four methods for screening.[3]

Our analysis has illustrated the potential threat of adopting screening guidelines based on research in western populations, without careful economic appraisal. In a developed and established economy like Hong Kong, population-based mammography screening is likely an inefficient use of scarce public health resources at this time.

Acknowledgement

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