Continuing Screening Mammography in Women Aged 70 to 79 Years
Impact on Life Expectancy and Cost-effectiveness

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Context Mammography is recommended and is cost-effective for women aged 50 to 69 years, but the value of continuing screening mammography after age 69 years is not known. In particular, older women with low bone mineral density (BMD) have a lower risk of breast cancer and may benefit less from continued screening.

Objective To compare life expectancy and cost-effectiveness of screening mammography in elderly women based on 3 screening strategies.

Design Decision analysis and cost-effectiveness analysis using a Markov model.

Patients General population of women aged 65 years or older.

Interventions The analysis compared 3 strategies: (1) Undergoing biennial mammography from age 65 to 69 years; (2) undergoing biennial mammography from age 65 to 69 years, measurement of distal radial BMD at age 65 years, discontinuing screening at age 69 years in women in the lowest BMD quartile for age, and continuing biennial mammography to age 79 years in those in the top 3 quartiles of distal radius BMD; and (3) undergoing biennial mammography from age 65 to 79 years.

Main Outcome Measures Deaths due to breast cancer averted, life expectancy, and incremental cost-effectiveness ratios.

Results Compared with discontinuing mammography screening at age 69 years, measuring BMD at age 65 years in 10 000 women and continuing mammography to age 79 years only in women with BMD in the top 3 quartiles would prevent 9.4 deaths and add, on average, 2.1 days to life expectancy at an incremental cost of $66 773 per year of life saved. Continuing mammography to age 79 years in all 10 000 elderly women would prevent 1.4 additional breast cancer deaths and add only 7.2 hours to life expectancy at an incremental cost of $117 689 per year of life saved compared with only continuing mammography to age 79 years in women with BMD in the top 3 quartiles.

Conclusions This analysis suggests that continuing mammography screening after age 69 years results in a small gain in life expectancy and is moderately cost-effective in those with high BMD and more costly in those with low BMD. Women's preferences for a small gain in life expectancy and the potential harms of screening mammography should play an important role when elderly women are deciding about screening.

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Organizations recommend screening mammography for women aged 70 years or older despite the lack of evidence of benefit.[1,2] Pooled results from the Swedish randomized controlled trials of screening mammography report no significant reduction in breast cancer mortality for screened women aged 70 years or older[3]; however these trials included too few women to provide meaningful results.

A decision analysis reported that screening mammography saves lives at all ages between 65 and 85 years.[4] For this analysis, the authors assumed that screening results in lower rates of advanced-stage disease and higher rates of early-stage disease and that this results in a reduction in breast cancer mortality among screened elderly women. This decision analysis took a societal perspective and did not consider an elderly woman's preferences for the potential benefits and harms of screening.[4] Two studies that examined the cost-effectiveness of screening mammography among the elderly report a wide range of values from $25 000 to $92 000 per year of life saved for screened women.[5,6] None of these models[4-6] considered discontinuing screening mammog-

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raphy in elderly women at low risk of breast cancer to optimize the cost-effectiveness of screening.

Screening mammography in elderly women may be less beneficial and cost-effective than in women aged 50 to 69 years because older women have a shortened life expectancy, which may reduce the absolute benefit of screening. Second, the absolute benefit of screening may be further reduced in elderly women who have a low incidence of breast cancer, such as those with low bone mineral density (BMD),[7,8] which can be easily and accurately measured and is recommended for all women aged 65 years or older to identify women at high risk of fractures.[9] Third, the incidence of ductal carcinoma in situ (DCIS) increases with age and is higher among screened women. Detecting DCIS on mammography in elderly women is unlikely to affect overall mortality, but all women with DCIS undergo surgery, which increases the overall costs of screening elderly women. Finally, individual elderly women may place more value on the present than on the future, which implies these women have a higher discount rate than is standard for cost-effectiveness analysis from a societal perspective.[10-14] Differences in time preferences or discount rates among elderly women may lead to a different decision about screening than what health care policymakers recommend.

We address these issues by using decision analysis to determine the impact on life expectancy for women who continue screening mammography after age 69 years compared with those who do not based on their BMD at age 65 years. We also provide estimates of the incremental cost-effectiveness of screening mammography in older women from the societal perspective with updated costs of mammography and treatment of breast cancer including the detection and treatment of DCIS. Lastly, we present results in a format that health practitioners can use to help women make decisions about breast cancer screening by examining a range of discount rates that represent women's values concerning short-term harms and long-term benefits.

METHODS

Model for Reference Case

We developed a Markov model[15-17] that compared life expectancy of 65-year-old women undergoing different breast cancer screening strategies. All women were assumed to be healthy and to have undergone regular screening in the preceding 5 years. At the end of each 1-year cycle, women were in 1 of 6 health states: were healthy, developed DCIS and remained alive, developed invasive breast cancer and remained alive, died of invasive cancer after a diagnosis of DCIS, died of invasive breast cancer after a diagnosis of invasive cancer, or died of another cause. Transition probabilities for the 6 health states were both age- and strategy-dependent (TABLE 1). The reference-case analysis compared 3 strategies: (1) screening mammography biennially from ages 65 to 69 years; (2) screening mammography biennially from ages 65 to 69 years, measure distal radial BMD at age 65 years, discontinue screening mammography for women in the lowest BMD quartile at age 69 years but continue biennial mammography screening to age 79 years among women in

Table 1. Information Used to Calculate Life Expectancy

Variable*	Best Estimate†	Reference
All-cause mortality, y		
65-69	0.01300	18
70-74	0.02030	18
75-79	0.03200	18
80-84	0.05300	18
≥85	0.15000	4
Incidence of invasive breast cancer, y		
65-69	0.004081	19
70-74	0.004568	19
75-79	0.004805	19
80-84	0.004697	19
≥85	0.004000	19
Incidence of DCIS in screened women, y		
65-69	0.001170	20
70-79	0.0009415	20
Incidence of DCIS in unscreened women, y		
70-74	0.0001170	19
75-79	0.0001425	19
80-84	0.0000654	19
≥85	0.0000964	19
Percentage mortality reduction for invasive cancer associated with screening from ages, y		
65-69	27	21
70-79	27	Assumption‡
Percentage breast cancer mortality from invasive disease at 10 years	32	19
Percentage breast cancer mortality from DCIS at 10 years in screened women	1.9	19, 22
Percentage breast cancer mortality from DCIS at 10 years in unscreened women	3.4	19, 22
Percentage incidence reduction for breast cancer associated with lowest quartile distal radius BMD	39	7
Percentage incidence increase for breast cancer associated with highest 3 quartiles distal radius BMD	13	7
Annual discount rate for costs and benefits, %	3	23
Utility of life after treatment	1	Assumption‡
Utility of metastatic breast cancer	1	Assumption‡

*DCIS indicates ductal carcinoma in situ; BMD, bone mineral density.
†Values are for the reference case.
‡Authors assumed mortality reduction from mammography is similar to women aged 65-69 years and the utility associated with life after treatment with breast cancer or living with metastatic breast cancer was 1.

Table 2. Information Used to Calculate Costs*

Variable	Best Estimate† (Reference)
Screening mammogram	$116 (34)
Average cost to work up an abnormal results	$379 (17)
Annual percentage of abnormal screening mammograms for women aged 60-79 y	2.0 (35, 36)
Bone mineral density	$0 (Assumption)‡
Treatment cost for invasive cancer in the screened group	$36 866 (17)
Treatment cost for invasive cancer in the unscreened group	$38 713 (17)
Treatment cost for ductal carcinoma in situ in screened and unscreened groups	$26 267 (37)

*All values are costs in 1998 dollars.
†Values are for reference case.
‡Authors assumed no cost for bone mineral density measurements since it is recommended for other medical reasons than estimating breast cancer risk.

the top 3 quartiles of distal radius BMD (hereafter referred to as the *check BMD* strategy); and (3) screening mammography biennially from ages 65 to 79 years. Distal radial BMD is also measured at age 65 years in strategies 1 and 3 according to recommended guidelines,[9] but the information is not a factor in screening mammography decisions. We calculated the cost-effectiveness of the check BMD strategy by comparing it with the first strategy. To determine the incremental cost-effectiveness of screening all women until age 79 years, we compared the second and third strategies and the first and third strategies. Costs and benefits were discounted at a rate of 3% per year for the reference-case analysis.[13,23,24]

Benefits

Elderly women who undergo screening mammography experience a lower rate of more advanced-stage disease and a higher rate of early-stage disease for which treatment is more effective.[20,25] We assumed that screening mammography reduces breast cancer mortality in women aged 65 years or older by 27% as it does in women aged 50 to 69 years.[21] Trials of screening mammography have shown no reduction in breast cancer mortality among screened women aged 50 to 69 years for about 5 years after the initiation of screening.[26-28] We assumed that women had regular screening for the preceding 5 years and a reduction in breast cancer mortality began upon enrollment for all strategies. Also, women continued to experience reduced breast cancer mortality for 5 years after screening stopped.

Pooled results of the efficacy of mammography among women aged 50 years or older do not differ by the length of the screening interval.[21] For the reference-case analysis; therefore, we chose to perform biennial screening because screening more often only increases cost without increasing the benefits of screening.

Utilities

Because there are few data on the utility that women place on life after treatment of breast cancer or the utility placed on living with metastatic cancer, we did not include utilities in the reference-case analysis.

Ductal Carcinoma In Situ

Ductal carcinoma in situ is a breast lesion contained within the milk ducts. Data from the Surveillence Epidemiology and End Results (SEER) program depict a higher than 300% increase in DCIS from 1983 to 1992 for women aged 40 years or older with the greatest number of DCIS cases detected in women aged 50 years or older.[29,30] Since DCIS is primarily diagnosed by screening mammography, the increased use of mammography is the primary explanation for the increased incidence of DCIS.[31] The incidence of DCIS in the 2 groups that continued screening past age 69 years was based on a large population of elderly women undergoing routine screening mammography.[20] For women in the first strategy and in the lowest quartile of BMD in the second strategy who discontinue mammography screening after age 69 years, the incidence of DCIS after age 69 years was based on 1982 data from the SEER program,[19] prior to the widespread use of mammography. Mortality from DCIS detected by mammography is unknown. We assumed that mortality from DCIS in the screened groups would be the same as the mortality rate from DCIS after the widespread use of screening mammography. Based on SEER data from 1984 to 1989, the 10-year mortality rate from invasive breast cancer after detection of DCIS is 1.9%.[19,22] For those who did not continue to undergo screening mammography, we used the 10-year mortality rate (3.5%) from 1978 to 1983, prior to the widespread use of mammography.[19,22] In other words, we assumed a 44% lower mortality for DCIS detected by screening mammography.

Bone Mineral Density

The Study of Osteoporotic Fractures (SOF) demonstrated that women in the lowest quartile of distal radius BMD have a lower incidence of breast cancer than women in the higher BMD quartiles.[7] The relationship between BMD and breast cancer has been confirmed by others using radiographs of the hand to estimate BMD[8] and demonstrate that BMD can be used to predict breast cancer risk. These data are also supported by studies of women with hip or distal forearm fractures reported to be at reduced risk of breast cancer.[32,33] We used updated analyses from SOF, based on additional breast cancer cases (n = 294) and longer follow-up (8 years), to estimate the relationship between BMD and breast cancer risk. For women in the check BMD strategy, we assumed that women in the lowest quartile ($<$0.30 g/cm^2) have a 39% reduction in breast cancer risk and that those in the upper 3 quartiles have a 13% increase in risk (Table 1).

Costs

We included 4 costs related to breast cancer detection and treatment: screening mammography, evaluation of an abnormal mammography result, and treatment of DCIS and invasive breast cancer (TABLE 2). Details on the derivations of costs have been previously published.[17] In brief, the cost of screening mammography was based on the average cost ($91) reported by the National Cancer Institute's National Survey of Mammography Facilities.[34] We

Table 3. Health States at Age 85 Years Based on a Cohort of 10 000 Women*

	Alive				Dead						Benefit	
Screening Strategy	No Known Breast Cancer	Alive With Invasive Breast Cancer	Alive With DCIS	Total	No Known Breast Cancer	Other Causes After Diagnosis of Invasive Breast Cancer	Invasive Breast Cancer	Other Causes After Diagnosis of DCIS	Invasive Breast Cancer After Diagnosis of DCIS	Total	Net Deaths Averted	Total Deaths Averted
Screened from ages 65-69 y†	4944	398	41	**5383**	4273	167	148	28	1	**4617**	. . .	. . .
Check BMD‡	4911	405	77	**5393**	4255	171	134	46	1	**4607**	9.4‡§	9.4
Screened from ages 65-79 y‖	4903	407	84	**5394**	4252	172	132	49	1	**4606**	1.4§‖	10.8

*DCIS indicates ductal carcinoma in situ; BMD, bone mineral density; and ellipses, not applicable.
†Reference case is biennial screening for women aged 65 to 69 years.
‡Compared with biennial mammography screening of women aged 65 to 69 years.
§Result expressed to 1 decimal point because rounding overestimates differences between strategies.
‖Compared with check BMD.

assumed that women diagnosed as having breast cancer continued to undergo screening mammography of the opposite breast, at the same cost, after the initial diagnosis of breast cancer.

The cost of evaluating abnormal mammography results was calculated as a weighted average of diagnostic procedures that may follow abnormal mammography. The distribution and types of follow-up procedures were based on those reported by the National Cancer Institute's National Survey of Mammography Facilities.[34] A range of costs for each procedure was based on Medicare, Pennsylvania Blue Cross, Group Health Cooperative, and Kaiser.[17] The percentage of abnormal mammography results was based on obtaining high-quality modern screening mammography (Table 2).[36] The cost of treating DCIS and invasive cancer was based on costs reported for patients in Group Health Cooperative.[37] All costs were inflated to 1998 US dollars using the consumer price index for medical services.

The cost of BMD was specified to be $0 in the reference case since all women are recommended to have BMD measured at age 65 years for other medical reasons than estimating breast cancer risk.[9] We assumed that BMD would be measured at the distal radius.

Other Probabilities

Overall mortality was estimated by using life tables.[18] The incidence of breast cancer was based on 1994 data from SEER.[19] On the basis of 1984 SEER data,[19] the 10-year mortality among women aged 50 years or older with breast cancer was 32%.

Sensitivity Analysis

Data from an Australian study[38] that observed a utility of about 0.8 for life after treatment of breast cancer and a utility of about 0.3 for life with metastatic cancer among women aged 40 to 69 years with and without breast cancer are included in a 1-way sensitivity analysis to determine the extent to which life expectancy and cost per year of life saved (YLS) might differ from quality-adjusted life-year (QALY) saved and cost per QALY saved. We also tested utilities measured among a small group of breast cancer and public health experts[39] and conducted sensitivity analyses over a range of discount rates. The efficacy of screening mammography was varied by 1 SD above and below the median efficacy according to published data (22% and 32%, respectively).[21] The reduction in breast cancer risk associated with the lowest quartile of BMD was varied by 1 SD above and below the median (17% and 56%, respectively). Breast cancer mortality from invasive cancer at 10 years was evaluated at 25%, and the cost of BMD was varied from $25 to $100 in the check BMD strategy.

Individuals' Time Preferences

The Panel on Cost-effectiveness in Health and Medicine, a nongovernmental panel of scientists and scholars with expertise in cost-effective analyses, recommends that a 3% annual discount rate be used for societal cost-effectiveness analyses.[13,23,24] Direct information about individuals' actual discount rate or time preferences is not usually included in cost-effectiveness analyses. Several studies have shown that most individuals, particularly older ones,[14] implicitly discount at a rate significantly higher (10%-20%) than 3%.[10-12,14] We examined the impact of a range of discount rates on our results by calculating the number needed to screen to gain 1 year of life according to BMD. We did this by determining the incremental YLS according to BMD and then by determining the number needed to screen for a woman to gain 1 year of life.

RESULTS

Effectiveness Analysis

Invasive Cancer. If 10 000 65-year-old women were screened biennially until the age of 69 years and then followed up clinically to age 85 years, 148 would die of breast cancer by age 85 years, while 167 women would die of another cause after the diagnosis of invasive breast cancer (TABLE 3). A total of 4273 women would die of other causes without known breast cancer. Applying the check BMD strategy to this cohort would avert 9.4 deaths; 14 breast cancer deaths would be prevented, but 4.6 of these women would die of other causes by age 85 years. Expanding the mammography screening program to include screening for all women until age 79 years would avert 1.4 additional deaths among the 25% of women in the lowest quartile of BMD; 3 breast cancer deaths would be prevented, but 1.6 of these women would die of other causes by age 85 years.

Ductal Carcinoma in Situ. If 10 000 women are screened biennially from ages 65 to 69 years and followed up clinically to age 85 years, 70 women would be diagnosed as having DCIS and, of these, 1 would die of invasive breast cancer (Table 3). Under the check BMD strategy, another 55 cases of DCIS would be diagnosed for a total of 124 cases and still only 1 of these women would die of invasive breast cancer. Expanding the screening strategy to include all women up to age 79 years would result in an additional 10 cases of DCIS being diagnosed among the 25% of women in the lowest quartile of BMD without averting an additional death from invasive breast cancer.

Life Expectancy. Compared with mammography screening biennially from age 65 to 69 years, the check BMD strategy saved, on average, about 2 days of life per woman screened (TABLE 4). To avert 1 death from invasive breast cancer, 1064 women would have to be enrolled in the check BMD strategy. This would result in approximately 2011 additional mammography examinations per death averted compared with the strategy of screening women until age 69 years only. Screening all women until age 79 years saved an additional 0.3 days of life per woman screened compared with the check BMD strategy. A total of 7143 women would have to be enrolled in the strategy of screening until age 79 years to avert 1 additional death from breast cancer compared with the check BMD strategy, and this would result in 9963 additional mammography examinations.

Cost-effectiveness Analysis

Compared with screening all women through age 69 years, the incremental cost-effectiveness ratio of the check BMD strategy was $66 773 per YLS (TABLE 5). The incremental cost-effectiveness ratio for screening all women until age 79 years compared with the check BMD strategy was $117 689 per YLS and compared with the reference case was $73 855 per YLS.

Table 4. Life Expectancy and Number Needed to Screen for the 3 Screening Strategies*

Screening Strategy	Increase in Life Expectancy, d	Increase in QALY, d†	No. Needed to Screen to Avert 1 Death From Invasive Cancer	No. of Additional Examinations to Avert 1 Death From Invasive Cancer
Screened from ages 65-69, y‡	. . .	. . .	. . .	. . .
Check BMD§	2.1	0.1 to 2.0	1064	2011
Screened from ages 65-79, y‖	0.3	−0.2 to 0.2	7143	9963

*Markov model carried out until all women died.
†Quality-adjusted life-year (QALY) based on utility for life after treatment with breast cancer of 0.8 to 0.9 and life with metastatic breast cancer of 0.3.[38,39]
‡Reference case is biennial screening for women aged 65 to 69 years. Ellipses indicate not applicable.
§Compared with biennial mamography screening of women aged 65 to 69 years.
‖Compared with check bone mineral density (BMD).

Sensitivity Analyses

As the utility placed on life after treatment with breast cancer and life with metastatic breast cancer decreased to 0.8 and 0.3, respectively, the average number of days of life saved per woman for the check BMD strategy becomes very small (Table 4) and the cost per QALY saved becomes very large compared with discontinuing screening mammography at age 69 years (TABLE 6); screening all women to age 79 years results in a loss of QALYs among screened women (Table 4). The low value for QALYs and high cost per QALY are due to the magnitude of the initial expense to treat DCIS, low mortality from DCIS, and large number of women alive with a decreased quality of life after treatment for DCIS. The cost per QALY saved (Table 6) is similar to the reference case when the utility for living with invasive breast cancer and DCIS increases to 0.9 because the large number of women living with a decreased quality of life after treatment for invasive cancer or DCIS is equalized by fewer screened women living with metastatic breast cancer.

Varying the discount rate had a large impact on the cost-effectiveness ratios while varying the mortality reduction from screening mammography and breast cancer mortality from invasive cancer only had a moderate impact on the results (Table 6). When breast cancer risk reduction associated with low BMD was decreased to 17% or the cost of BMD increased to $50 for the check BMD strategy, the difference between the cost-effectiveness ratios for the check BMD strategy vs mammography screen-

Table 5. Costs and Benefits of the 3 Strategies Applied to a Cohort of 10 000 Women*

Screening Strategy	Cost in Millions, $: Screening	Follow-up	Treatment	Total	Incremental Difference	Benefit: Total Life Years	Life-Years Saved	Cost-Effectiveness Cost per Year of Life Saved
Screened from ages 65-69 y†	2.66	0.18	24.70	27.54	. . .	146 591	. . .	. . .
Check BMD‡	5.43	0.36	25.66	31.45	3.9‡	146 649	58.6‡	66 773‡
Screened from ages 65-79 y§	6.37	0.42	25.74	32.53	1.1§	146 658	9.1§	117 689§
Screened from ages 65-79 y‡	6.37	0.42	25.74	32.53	5.0‡	146 658	67.7‡	73 855‡

*Markov model carried out until all women died. Costs are based on 1998 US dollars. Ellipses indicate not applicable.
†Reference case is biennial screening mammography for women aged 65 to 69 years.
‡Compared with biennial mammography screening of women aged 65 to 69 years.
§Compared with check bone mineral density (BMD).

ing for all women to age 79 years strategy was small (Table 6). If the cost of BMD was $100 for the check BMD strategy and the breast cancer risk reduction associated with low BMD decreased to 17%, the cost-effectiveness ratio for the strategy of screening all women to age 79 years was lower ($73 645 per YLS) than the check BMD strategy ($96 724 YLS) compared with discontinuing screening at age 69 years. It is unlikely that the breast cancer risk reduction associated with low BMD would be as low as 17% given that 2 studies have reported much higher risk reductions of 39%[7] and 70%.[8] It is also unlikely that the cost of BMD would be $100 or, if it were, the full cost would be attributable to mammography screening given that BMD is used primarily for other medical reasons.

Effect of Individual Discount Rate

Clinicians and women may have difficulty appreciating the value of small gains in "average" life expectancy. Therefore, we calculated the number needed to screen to extend a woman's life by 1 year based on her discount rate and BMD. For a woman who discounts at 15% and is in the lowest quartile of BMD, such that, her chance of developing breast cancer is low, the number needed to screen to gain 1 year of life is 9091 (TABLE 7). This woman has a 1 in 9091 chance that biennial screening mammography from age 69 to 79 years, compared with discontinuing screening at age 69 years, will extend her life expectancy by 1 year. For a woman who values the future as much as the present, such that she does not discount and is in the highest quartile of BMD, the number needed to screen is 146. This woman has a 1 in 146 chance that biennial screening mammography from age 69 to 79 years, compared with discontinuing mammography screening at age 69 years, will extend her life expectancy by 1 year.

Table 6. One-Way Sensitivity Analyses*

Variable	Check BMD	Screened From Ages 65-79 Years
	Cost per Quality-Adjusted Life-Year Saved$†	
Utilities		
0.8/0.3‡	1.2 million	. . .
0.9/0.3§	70 478	191 110
	Cost per Year of Life Saved$†	
Discount rate, %		
0	41 524	78 240
5	89 191	151 331
10	172 378	268 631
15	312 797	450 073
Mortality reduction from mammography, %		
22	80 621	150 211
32	56 993	96 757
10-Year breast cancer mortality, %		
25	85 534	150 304
Breast cancer risk reduction associated with low BMD, %		
56	61 155	236 737
17	73 588	73 867
BMD cost, $		
25	71 037	90 358
50	75 302	73 465‖
100	83 832	73 465‖

*Markov model carried out until all women died. All costs are based on 1998 US dollars. Ellipses indicate not applicable.
†Check bone mineral density (BMD) are compared with biennial mammography screening in women aged 65 to 69 years. Screened from ages 65-79 years are compared with the check BMD.
‡Based on utility for life after treatment with breast cancer of 0.8 and life with metastatic breast cancer of 0.3[38]
§Based on utility for life after treatment with breast cancer of 0.9 and life with metastatic breast cancer of 0.3.[39]
‖Compared with biennial mammography screening from ages 65 to 69 years.

COMMENT

We found that continuing mammography screening after age 69 years results in a small gain in life expectancy, is moderately cost-effective in those with high BMD, and more costly in those with low BMD.

Cumulative exposure to endogenous estrogen has been associated with an elevated risk of breast cancer. Women with early age at menarche (before age 12 years) and late age at menopause (after age 55 years) are at greater risk of breast cancer.[40] Bone mineral density is a marker of lifetime exposure to estrogen that has been shown to be strong predictor of breast cancer risk.[7,8] We have demonstrated that use of BMD to assess breast cancer risk before deciding to continue screening mammography after age 69 years is a more cost-effective clinical practice than screening all women to age 79 years. In many cases, women aged 65 years and older will undergo BMD measurements to assess risk of fractures.[9] These measurements may be used—at no additional cost—to assist with decision making about continuing screening mammography. We assumed that distal radial BMD would be used because it is inexpensive and the most common test used to screen for osteoporosis. Other sites of BMD measurement, including hip BMD, by dual-energy or single-energy x-ray absorptiometry, have a very similar relationship to risk of breast cancer.[7] Therefore, if a woman has a BMD measurement available, this information can be used to help make a decision about mammography screening.

Table 7. Number Needed to Screen With Mammography for 10 Years to Extend a Woman's Life by 1 Year According to Her Individualized Discount Rate and Bone Mineral Density Quartile

Discount Rate, %	No. Needed to Screen: Quartile 1 (<0.30 g/cm²)	Quartiles 2 and 3 (0.30-0.42 g/cm²)	Quartile 4 (>0.42 g/cm²)
0	505	176	146
3	980	342	282
5	1471	521	420
10	3704	1333	1042
15	9091	3125	2273

Our results are consistent with those of a decision analysis of the value of screening elderly women for breast cancer that modeled SEER data for women age 65 to 85 years and reported that, on average, life expectancy would be extended about 2 days for women age 65 to 74 years and 1 day for women age 75 to 85 years who underwent routine screening mammography.[4] Life expectancy was attenuated for women whose breast cancer was detected by screening mammography and who also had heart failure with increases in life expectancy of 1 day and less than 1 day for women age 65 to 74 years and 75 years or more, respectively.[4] Our results extend these analyses to show that screening elderly women with low BMD has very little benefit. In general, gains from preventive measures targeted at average-risk persons that result in an increase on the order of a month of life expectancy can be considered large.[41] Based on this scale, the gains in life expectancy from mammography screening in elderly women are small indeed.

Preventive health interventions that cost less than \$50 000 per YLS (or per QALY saved) are generally viewed favorably, those between \$50 000 and \$100 000 per YLS are borderline, and interventions that cost more than \$100 000 per YLS are generally not considered cost-effective.[42] Given this, we found continuing screening mammography to age 79 years is moderately cost-effective only if those with higher BMD ($\geq$0.30 g/cm^2) are screened. Our cost-effectiveness ratios are slightly higher than 2 earlier published studies.[5,6] Both of these cost-effectiveness analyses used low estimates for the cost of mammography, costs based on earlier years (1984 and 1990 US dollars), and did not take into account the detection and treatment of DCIS.[5,6] However, consistent with our results, both previous analyses showed that the cost per YLS is higher among elderly women than those in their 50s and 60s.[5,6] Routine screening mammography is cost-effective (\$21 400 YLS) for women aged 50 to 69 years since breast cancer is the leading cause of death in these women even among a screened population.[17] In contrast, among elderly women, cardiovascular disease is the leading cause of death with more women dying of other causes after detection of breast cancer whether or not they undergo screening mammography (Table 3). In addition to competing risks for death, a decreased life expectancy of older women reduces the cost-effectiveness of mammography screening in these women.[6]

The goal of screening for breast cancer is to prevent deaths from breast cancer at a reasonable cost and, at the same time, to minimize the harms of screening healthy women. Given the small benefit and moderate cost of mammography screening after age 69 years, 1 reason to consider discontinuing screening after age 69 years is the potential harms associated with mammography.[36,43,44] Screening mammography tends to discover early cancers that may never have produced symptoms or have shortened life expectancy. For example, the incidence of DCIS increases with age with 25% of cancers detected by mammography being DCIS among elderly women.[20,36] Identifying and treating DCIS lesions in elderly women is unlikely to affect life expectancy since the risk of death from DCIS progressing to invasive breast cancer is very low.[19,22] For every 10 000 women aged 70 years and older screened for 10 years, 65 cases of DCIS will be detected and surgically treated with mastectomy or lumpectomy and only 1 death from invasive breast cancer averted. Thus, early detection will likely increase the rate of surgical treatment of clinically insignificant lesions with little hope of impacting overall mortality given elderly women's short life expectancy and high risk of death from cardiovascular disease. In addition, up to 8% of women aged 70 years and older who undergo mammography will have an abnormal result.[36,44] Although 85% to 92% of women who have an abnormal result do not have cancer, all women who have an abnormal result have additional diagnostic procedures, plus the worry and anxiety of wondering if they have cancer.

Health policymakers may establish screening recommendations for society based on the decision analysis and cost-effectiveness results presented herein that used a 3% discount rate. However, the choice that a woman makes depends on how she views preventive care. All preventive measures require patients to invest something (time, possibly money, risk of a false-positive result) in the present for the possibility of a future benefit. The extent to which people are willing to invest in the present to benefit the future varies and can be at least partially captured in the discount rate. Elderly women who are bothered by medical tests, visits to physicians, and the discomfort of undergoing mammography, or who experience significant anxiety waiting for test results, and who are willing to accept a very small incremental risk of death from breast cancer, may rationally decline screening. These women would have a high discount rate since they value the present more and are less willing to risk the quality of present time for a chance at benefiting from screening in the future. In contrast, women who easily tolerate the additional tests that are recommended following an abnormal screening result, want to decrease the chance of death from breast cancer at any cost, could live with the knowledge they have breast cancer, and could easily tolerate life after treatment for breast cancer without it affecting their quality of life, would have a low discount rate since they place a high value on the future. For healthy, elderly women interested in continuing mammography screening after age 69 years, physicians should assist them with determining their utility for undergoing screening mammography and the potential harms of screening (discount rate), may estimate their breast cancer risk according to their BMD, and then inform them of the chance their life will be extended 1 year (Table 7) if they undergo routine screening. Women with low BMD and/or high discount rates are unlikely to benefit from routine screening mammography after age 69 years.

The main limitation of our study is that the efficacy of mammography in older women is unknown. If there is no benefit to screening older women, then continuing screening after age 69 years will only incur costs and significant harms for elderly women. We did not consider the benefit of reassurance associated with a normal mammography result or that some screened women may benefit psychologically from less disfiguring procedures available to treat earlier stage disease. On the cost side, we did not consider the harm, such as the low quality of life caused by false-positive test results[45] or the additional medical costs (eg, to treat heart disease) incurred by women saved by screening mammography. We also did not consider interventions that may be started among women with low BMD that may influence breast cancer risk. For example, women with low BMD who choose to take raloxifene hydrochloride would probably benefit very little from ongoing screening mammography after age 69 years since raloxifene should further decrease the risk of breast cancer.[46] In contrast, women with low BMD who choose to start estrogen therapy may have a similar risk of breast cancer as the higher BMD groups after 10 years of therapy since long-term use of estrogen has been shown to increase breast cancer risk by 25%.[47] Finally, the BMD data from the SOF was obtained from white women and may not be generalizable to women of other races.

In conclusion, screening mammography is minimally beneficial among women aged 69 years and older because of a shortened life expectancy and competing risks of death. To prevent 1 death, clinicians need to screen 1064 women with high BMD routinely from ages 69 to 79 years. On the other hand, clinicians need to screen 7143 women with low BMD routinely from ages 69 to 79 years to prevent 1 death. Given these results, it is more costly to offer biennial screening mammography to all elderly women than to use BMD to identify women who will benefit the most by continued screening. Of women with high BMD, continuing biennial mammography screening is most beneficial in those elderly women who value the future more than the present. Women's preferences for a small gain in life expectancy and the potential harms of screening should play an important role when elderly women are deciding about screening.

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