A comparison of mammography screening programs: The interaction between mammography sensitivity, specificity, and screening interval on cost effectiveness

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Introduction

Mammography studies and the evaluation of service screening programs have shown different reductions in age-specific breast cancer mortality associated with screening.[1] Explanations for these differences include variable screening intervals and variable program sensitivity. We sought to evaluate the relative contributions of mammography sensitivity, specificity, and screening interval on expected outcomes and costs.

Objective

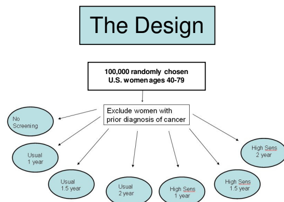
To quantitatively evaluate the relationship between different levels of test sensitivity, the screening interval, and adherence to screening on mortality reductions and costs.

Methods

We used the Archimedes Model of breast cancer screening to evaluate three different screening intervals: 12 months, 18 months, and 24 months. These intervals were compared in (i) a "usual accuracy" program modeled using data from the U.S. Breast Cancer Surveillance Consortium (BCSC),[2] and (ii) a program with higher accuracy, whose sensitivity and specificity is modeled after the British Columbia (BC) Breast Cancer Screening Program.[3] We conducted a virtual trial in which a population of simulated women ages 40-79 at baseline were subjected to 6 different "arms", representing different combinations of screening interval and accuracy, and a no screening arm, and followed each arm for 30 years.

	Type of mammogram	Screening interval in years
0	No screening	
1	Usual Sensitivity*	1
2	Usual Sensitivity*	1.5
3	Usual Sensitivity*	2
4	High Sensitivity**	1
5	High Sensitivity**	1.5
6	High Sensitivity**	2

The Design



Key assumptions/relationships

- **We assume perfect compliance to mammogram screening.**
- **Screening intervals are precise, rather than varying between women in the same arm.**
- **We assume that women start mammographic screening at age 40 and continue until death.**

Modeling Sensitivity

- In order to match the sensitivity of each of the two screening programs, we fit parameters describing the probability of detecting a tumor as a function of size and breast density.
- We model the probability that a mammogram detects a tumor with the equations

$$y = 1 - \exp(-a_d \cdot x^2) \qquad y = 1 - \exp(-a_f \cdot x^2)$$

- x is the diameter of the tumor in mm
- y is the probability that a mammogram will detect it
- a_d is the parameter for breasts with the density of an average 45-year-old
- a_f is the parameter for breasts with the density of an average 65-year-old
- For other breast densities, probability of detection is linearly interpolated from these two equations

Modeling Specificity

- To match the specificity of the two screening programs, we calculate the recall rate among women who do not develop cancer in the following year.
- FP modeled as a function of the woman's age and the length of time since prior mammogram
- We call this the random false positive rate (RFP)

$$RFP = FP \cdot \frac{1}{1 - TP}$$

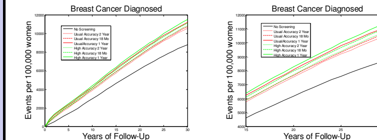
$$FP = (\text{recallRate} - \text{detectionRate})$$

- The recall rate, detection rate, and cancer rate (TP) are taken from the data tables for BCSC and British Columbia
- In addition to detecting true cancers, the radiologists in the model recall women for further testing at the rate RFP

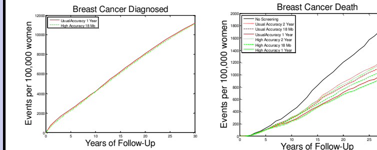
	First Screen	Subsequent Screen
BCSC	12.96%	7.77%
Brit Col	11.57%	5.12%

Results

- Differences in rates of diagnosis between the 6 screening arms are slight compared to the striking difference in rate of diagnosis between no screening and screening (A).
- Zooming in makes it possible to see that more cases of breast cancer are diagnosed as the sensitivity increases and as the screening interval shrinks (B).



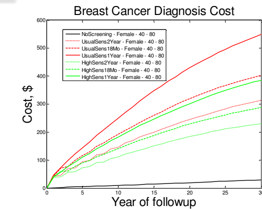
- An 18 month interval with the higher sensitivity has a similar rate of detection as an annual interval with usual sensitivity (A).
- When comparing probability of death from breast cancer, 18 months high sensitivity is similar to 1 year usual sensitivity, and 2 years high sensitivity is comparable to 18 months usual sensitivity (B).



Log-Rank p-values for breast cancer mortality, by pairs of arms:

- Usual accuracy (1 year) vs. high accuracy (18 months): p = 0.2514
- Usual accuracy (18 months) vs. high accuracy (2 years): p = 0.3658

Diagnostic Costs



- Because the higher sensitivity program also has higher specificity, total diagnostic costs (imaging and biopsy) are lower
- The higher sensitivity program with an 18 month interval incurs similar rates of diagnostic procedures as the usual sensitivity program with 2-year screening.
- Thus, cost savings result from a wider screening interval and fewer diagnostic procedures

Conclusions

- Screening mammography done in the United States with an annual screening interval is very effective.
- A mammogram screening program with higher sensitivity and higher specificity and an 18 month interval can achieve the same results in breast cancer detection and mortality reduction as the usual program with 12 month interval.
- The diagnostic costs of the higher sensitivity and specificity mammograms performed every 18 months are the same as our current breast screening performance with 2 year intervals.
- The potential for cost savings and a reduction in the rate of harms should lead policy makers to consider strategies to organize breast cancer screening in order to achieve more uniform quality, and provide incentives to improve and monitor the accuracy of breast imaging.

References:

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2. Coldman A, Phillips N, Warren L, Kan L. Breast cancer mortality after screening mammography in British Columbia women. Int J Cancer 2007;120:1076-80.
3. NCI-funded Breast Cancer Surveillance Consortium co-operative agreement: Performance Measures for 3,603,832 Screening Mammography Examinations from 1996 to 2006 by Age. http://breastscreening.cancer.gov/data/performance/perf_age.html

Disclosures:

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