Mammographic Screening: Patterns of Use and Estimated Impact on Breast Carcinoma Survival

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Supported by a Dana-Farber/Harvard Cancer Care New Nodal Award in Cancer Disparities.

The authors thank Bruce Chabner, M.D., for his many useful suggestions.

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Received November 4, 2003; revision received April 24, 2004; accepted April 30, 2004.

BACKGROUND. Although many studies support the life-saving potential of screening mammography, the actual utilization of screening and the impact of the actual pattern of screening use on the breast carcinoma death rate, remain incompletely understood. In the current report, the authors describe patterns of screening use among women who were examined at a large screening and diagnostic service and estimate the added mortality associated with missed screening mammograms.

METHODS. Mammography use was assessed in a population of 72,417 women who received a total of 254,818 screening mammograms at the Massachusetts General Hospital (MGH) Avon Comprehensive Breast Center (Boston, MA) between January 1, 1985, and February 19, 2002. A computer simulation of breast carcinoma growth, spread, and detection of breast carcinoma was used to estimate the likely health consequences of various types of screening use.

RESULTS. Both prompt return for annual screening and full use of screening over extended periods of time were rare, and comparison of the MGH population with other populations revealed that the low level of use observed in the MGH population was not atypical. Only 6% of women who received a mammogram in 1992 received all annual mammograms that were available over the next 10 years; the mean number of mammograms received during this period was 5.06, or 51% of the number recommended by the American Cancer Society. Computer simulation results indicate that this underutilization of screening should result in higher mortality levels. Women from traditionally underserved socioeconomic, racial, and ethnic groups, women without insurance, and women who did not speak English had lower levels of use compared with other women. Lower levels of use also were observed among women receiving their first mammogram or who in the past had not returned promptly. Women ages 55–65 years had higher levels of use than did younger or older women. Women who previously had breast carcinoma also had higher levels of screening use. Nonetheless, none of the subpopulations of women stratified by age, race, ethnicity, zip code, income, language, insurance, status, previous screening use, or medical history exhibited a widespread propensity to promptly return for annual screening over an extended period of time.

CONCLUSIONS. By many measures, the current analysis is one of the most detailed descriptions of screening use to date. The authors observed a level of screening use that was disappointingly low, with potentially negative health-related consequences, among women across categories defined by racial, ethnic, socioeconomic, and geographic characteristics; insurance status; language; age; medical history; and previous screening use. Improvements in the promptness with which women return to screening appear to have the potential to lead to considerable reductions in breast carcinoma death. ***Cancer* 2004;101:495–507.**

KEYWORDS: breast carcinoma, mammography, screening, disparity.

DOI 10.1002/cncr.20392
Published online 21 June 2004 in Wiley InterScience (www.interscience.wiley.com).

While a number of studies have shown that prompt annual attendance is important for realizing the life-saving potential of mammographic screening,[1–3] many other studies have indicated that such attendance is not commonly observed.[4–15] For example, we recently reported that at the Massachusetts General Hospital (MGH) Avon Comprehensive Breast Center (Boston, MA), fewer than 10% of women who received a mammogram in 1992 complied with the American Cancer Society's (ACS) recommendation of annual screening by receiving the full complement of 9 mammograms over the next 9 years, whereas more than half had fewer than 5 mammograms during this period.[4] In addition, Ulcickas Yood et al.[6] reported that only 16% of all women who had received a mammogram between 1983 and 1993 at the largest health maintenance organization (HMO) in Michigan received all 5 recommended mammograms over the 5-year period following the index mammogram. Sabogal et al.,[15] using California Medicare data for the period 1992–1998, found that only 30% of non-HMO-enrolled women age ≥ 65 years who participated in screening did so regularly (i.e., without failing to attend in more than 2 consecutive years). Finally, Phillips et al.,[12] using data obtained from a number of sources, reported that although 70% of women ages 50–74 years had received at least 1 mammogram, only 16% had undergone annual screening. These populationwide rates of prompt return for screening are disappointingly low; however, even lower rates of long-term screening use and prompt return have been observed among women in traditionally underserved groups as defined by race, ethnicity, and socioeconomic status.[6,12]

The negative consequences of failing to return promptly for screening have been noted in a number of screening populations. For example, in the MGH screening population, approximately 20% of all invasive breast malignancies detected in women who had received at least 1 screening mammogram before or at the time of detection were discovered by nonmammographic methods more than a year after the previous negative screening mammogram.[4] Malignancies that were not detected by mammographic methods tended to be larger and thus potentially more lethal than screen-detected malignancies.[16] Several observations suggest that the majority of tumors detected by nonmammographic methods in women with a previous negative mammogram would have been detected at screening had patients returned more promptly. First, almost all such tumors were observable on the diagnostic mammograms that were obtained at the time of detection.[4] Second, by back-calculating the likely size of each of these cancers at the time of the negative mammogram, it could be seen that most of these tumors were probably too small to have been reasonable candidates for detection at the time of the previous mammogram. Thus, most of these tumors probably emerged as larger, palpable masses not because a previous mammogram failed to detect them but because too much time had been allowed to pass since the last screening mammogram.[4] Similar findings were documented by Mandelson et al.,[17] who reported that 17% of all malignancies found in an HMO screening population were discovered by nonmammographic methods between 12 and 24 months after a previous negative mammogram, and by Hunt et al.,[3] who noted that breast tumors found in women who received biennial screening were, on average, larger than those found in women who received annual screening.

The negative consequences of failing to return promptly for screening also have been estimated with respect to patient survival. For example, computer simulation studies[18,19] (based on 1) quantitative estimates of the sizes at which invasive malignancies are detected when screening mammography is used versus when it is not used,[20] 2) rates of tumor growth, and 3) the relation between tumor size and survival[16] suggest that each year of delay between screening mammograms decreases the life-sparing potential of screening by approximately one-third. Similar estimates have been reported by Tabar et al.,[2] who used a Markov chain screening model.

This widespread failure to return promptly is likely to be a major component of screening underutilization, as most eligible women in the United States have already received at least one screening mammogram.[12,14,21] The Behavioral Risk Factor Surveillance System telephone survey revealed that by 1997, approximately 80% of women ages 40–49 years and approximately 90% of women ages 50–69 years had received at least 1 mammogram.[21] Similar rates were noted in subpopulations of white, Hispanic, and black women, and only marginally lower rates were noted among women ages 40–49 years, women with median income < \$10,000, and women with < 12 years of education. Even among women without insurance, the subpopulation found to have the lowest rate of screening use in the Behavioral Risk Factor Surveillance System survey, 68% reported having received at least 1 mammogram. Furthermore, because reported screening rates increased over the 8-year period preceding this 1997 survey (from 62% to 80% among women ages 40–49 years and from ~65% to ~90% among women ages 50–69 years), it is likely that the percentage of women who have received at least 1 mammogram is even greater at present than it was at the time of the survey.

The MGH Avon Comprehensive Breast Center database contains information on more than 80,000 women, accounting for a combined total of more than 300,000 mammograms performed at MGH since 1985. Thus, it represents one of the largest available sets of data on mammographic screening use and its consequences.[4,5,16,19,20,22] We recently reported on general patterns of screening use in this population and on the relation between patterns of use and the sizes at which invasive breast tumors come to medical attention.[4,22] In the current report, we describe in greater detail the patterns of screening use observed in the MGH population as a whole and in subpopulations defined by site of residence, race, ethnicity, previous benign biopsy findings, and pattern of previous screening use. In addition, we report on the use of values obtained in computer simulations[19,20] to calculate expected rates of breast carcinoma–related death in association with the observed screening use patterns.

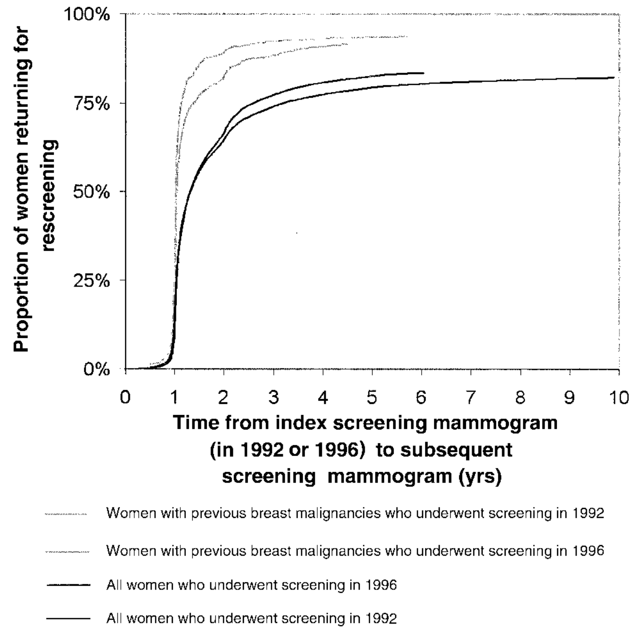

FIGURE 1. Return curves for women who received a screening mammogram in 1992 and women who received a screening mammogram in 1996.

MATERIALS AND METHODS

The MGH Avon Comprehensive Breast Center database contains entries on screening mammography use by 83,511 women, accounting for a combined total of 314,185 mammograms performed at MGH between January 1, 1985, and February 19, 2002. We recently reported on the general features of screening use at MGH[4]; however, in that study, we examined the use of both screening and diagnostic mammography, whereas in the current report, we present a more detailed analysis that is limited to screening mammography use. Our database includes data on the American College of Radiology Breast Imaging Reporting and Data System assessment of disease and on the more detailed MGH assessment; these data make it possible to determine which visits correspond to negative screening mammograms. Furthermore, since 1993, all mammograms have been classified as screening, diagnostic, or procedural measures, and this classification makes it possible to determine which visits correspond to positive screening mammograms and which visits correspond to negative screening mammograms. Of the 314,185 mammograms documented in the database, 254,818 were identified as screening mammograms and were performed for a total of 72,417 patients. Pathologic and survival data allowed the identification of patients with breast carcinoma diagnoses before the time of the study. Demographic data, including name, home address, zip code, and race, were available for all patients who had visited our institution since January 1996. Geographic location was determined by zip code, with the U.S. Census providing median income data for each zip code. Asian and Hispanic patients were identified by analysis of names, the standard method used by tumor registries in the U.S.,[23,24] and data on race were available from MGH's patient demographic database. Among patients who visited our institution between 1996 and 2000, 3.80% had Hispanic names, 2.95% had Asian names, and 93.3% had non-Hispanic, non-Asian names. (Percentages sum to slightly more than 100% because of a small degree of overlap between the Asian and Hispanic name categories.) Of the patients who participated in screening, 82.33% were white, whereas 4.48% were black.

Long-term patterns of screening use were examined in 2 overlapping data sets: 1) a *5-year group*, which consisted of 19,579 women who received a screening mammogram at an MGH screening center in 1996, with these patients' screening use being characterized for the period between the index mammogram and December 31, 2000; and 2) a *10-year group*, which consisted of 15,610 women who had negative findings on screening mammography at an MGH screening center in 1992, with these patients' screening use being characterized for the period between the index mammogram and December 31, 2001. Data on the time to first return after the index mammogram (Figs. 1–3) and on total screening use over the time

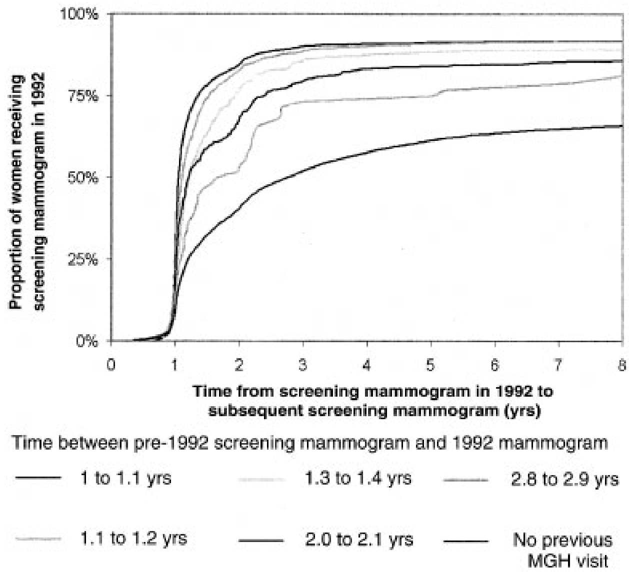

FIGURE 2. Return curves for women who received a screening mammogram in 1992 according to previous screening behavior.

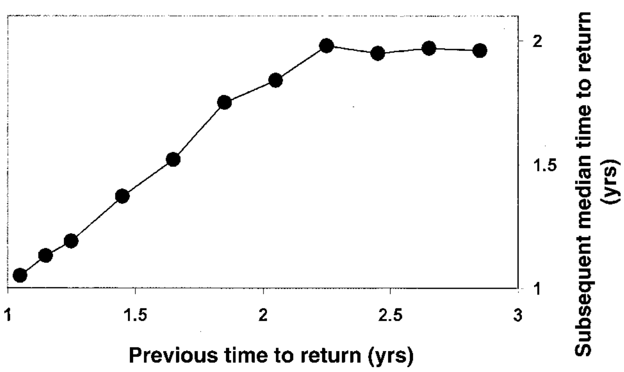

FIGURE 3. Correlation between previous and subsequent times to return to screening. For women who received a mammogram in 1992 and who had received a previous mammogram, median time to return following the 1992 mammogram was calculated according to the time between the pre-1992 mammogram and the 1992 mammogram. See Table 1 for the numeric data used to construct this graph.

periods examined (Table 1) were collected. Findings in the two groups were generally similar, and consequently, most results presented in the current report were derived from the 5-year group.

Estimates of breast carcinoma–related death rates for the various subsets of women who received a screening mammogram in 1996 were based on values obtained from a computer simulation model.[1,18,19] All studies had appropriate institutional review board approval and were in compliance with the human research study guidelines set forth by the National Institutes of Health.

RESULTS

Underutilization of Screening in the Study Population as a Whole

Few women in the MGH population returned promptly for annual screening (Fig. 1) or took full advantage of screening opportunities over extended periods of time (Table 1). Among women who received a mammogram in either 1992 or 1996, the median time to first return to screening was 1.3 years, and ~25% of these women had not returned within 3 years (Fig. 1). Eighteen percent of women who received a screening mammogram in 1992 or 1996 had no record of returning for screening, although some of these women could have undergone screening elsewhere. In the 5-year group, only 16% of women received 5 subsequent mammograms in compliance with the ACS recommendation of annual mammography, whereas more than 35% received only 1 or 2 mammograms during this period (Table 1). Similarly, only 6% of women who received a screening mammogram in 1992 complied with the ACS recommendation by receiving the full complement of 10 mammograms over the following 10 years, whereas 40% received fewer than 5 mammograms during this period. The mean number of mammograms received over the subsequent 5-year period by women who received a screening mammogram in 1996 was 3.03, or 61% of the ACS-recommended number (Table 1), while the mean number of mammograms received over the subsequent 10-year period by women who received a screening mammogram in 1992 was 5.06, or 51% of the ACS-recommended number.

We do not have information on the fraction of women in the MGH screening population who received mammograms elsewhere. Nonetheless, there are a number of indications that most women remain within the MGH screening system, despite the finding that many do not return promptly. For example, 82% of women who received a screening mammogram in 1992 eventually returned (Fig. 1); in addition, 93% of patients in this population who had undergone screening within 1.1 years before the index (i.e., 1992) visit eventually returned (Fig. 2). Another indication that the majority of women remain within the MGH system, even if they do not return promptly for screening, is our previously published observation that 20% of invasive breast tumors detected in women who received screening between 1991 and 2000 were palpable masses found in patients whose preceding screening mammograms occurred more than a year before detection; this finding suggests that many women remained within the MGH system but stopped receiving regular screening.[4] Ten percent of all malignancies detected by nonmammographic methods were found more than 1.5 years after the preceding negative mammogram, 7% were found more than 2 years after the preceding negative mammogram, and 3% were found more than 5 years after the preceding negative mammogram.[4]

Patterns of screening use in the MGH population were compared with screening use patterns in two other populations,[6,15] and these comparisons revealed remarkably similar results in all three populations (Table 2). Ulcickas Yood et al.[6] examined the screening behavior of women with 5 years of continuous enrollment in Health Alliance Plan, the largest HMO in Michigan (membership, 525,000), after an index screening mammogram in 1989; as in the current 5-year population, the mean number of mammograms subsequently received was 3.03. Similarly, Sabogal et al.,[15] using California Medicare data for the period 1992–1998, found that only 30% of non-HMO-enrolled women age ≥ 65 years who participated in screening did so regularly (i.e., without failing to attend in more than 2 consecutive years); in the MGH population, 26% of women age ≥ 65 years met this criterion (data not shown).

Underutilization of Screening in All Subpopulations Examined

Previous screening behavior

Women who had received at least one previous screening mammogram at MGH were far more likely to return for another mammogram and to return promptly compared with women who had not previously received a mammogram at MGH (Table 1). Only 13% of all women who had received a screening mammogram in 1996 and who had received at least 1 previous screening mammogram did not return for another mammogram in the 5 years following the index year, compared with 39% of all women who had no record of a screening mammogram before 1996 ($P < 0.001$).

For women who had received a mammogram before the index year, the time since that previous mammogram was predictive of future screening behavior (Fig. 2; Table 1). Thus, for women who had received a mammogram < 2 years before the index year, there was a correlation between previous time to return (i.e., time between the visit before the index visit and the index visit itself) and median time to return following the index visit ($R^2 = 0.99$; Fig. 3). In contrast, among women whose previous time to return was > 2 years, the median time to return following the index visit was approximately 2 years; this finding indicates that the extreme degree of tardiness observed in a patient's first return to screening tended not to be fully repeated. Previous screening behavior also had an observable predictive impact on subsequent long-term screening use (Fig. 4). For example, 29% of all women who received a mammogram 1.0–1.1 years before the 1996 index mammogram received all 5 possible screening mammograms over the following 5 years, compared with < 5% of all women who received a mammogram > 2.3 years before the index mammogram ($P < 0.001$).

Race, ethnicity, insurance status, language, site of residence, and income

Race, ethnicity, insurance status, language, site of residence, and income were found to be correlated with screening behavior (Figs. 5, 6; Table 1). Whereas 18% of all non-Asian, non-Hispanic patients and 19% of all white patients received all 5 possible screening mammograms between 1996 and 2000, only 11% of all black patients, 14% of all Asian patients, and 8% of all Hispanic patients did so ($P < 0.01$ for all comparisons; Table 1). In addition, English-speaking women had higher levels of screening use than did non-English-speaking women, and women with health insurance received screening more frequently than did women who were uninsured (Table 1). There also were differences in screening use when women were grouped according to site of residence as indicated by zip code, which was weakly correlated with income as reported on the U.S. Census (Fig. 6; Table 1). For example, only 8% of all women who received a screening mammogram in 1996 and who were residents of Chelsea, MA, a community with a median family income of $30,161, received all 5 mammograms recommended by the ACS, whereas 23% of women residing in Arlington, MA, a community with a median family income of $63,621, received all 5 recommended mammograms ($P < 0.001$) (Table 1). Overall, when the study population was stratified according to site of residence, a modest degree of correlation between screening use and median income was noted ($R^2 = 0.65$; Fig. 6).

Age

Women ages 55–65 years tended to have higher levels of screening use than did younger or older women (Fig. 7). Whereas women ages 55–65 years who had an index mammogram in 1996 received 68% of the recommended number of mammograms between 1996 and 2000, women ages 35–45 years, as well as women ages 75–85 years, received approximately 50% of the total number of mammograms recommended by the ACS over that same period ($P < 0.001$). Even lower levels of use were noted among women age > 80 years and women age < 40 years (45% and 40%, respectively, of the total number of mammograms recom-

TABLE 1
Five-Year Screening Use (1996–2000) for Women Who Received a Screening Mammogram in 1996

Characteristic	No. of patients who received a screening mammogram in 1996	Total no. of screening mammograms between 1996 and 2000	Mean no. of mammograms received between 1996 and 2000	% of ACS-recommended mammograms received (95% CI)	Median time to return to screening (yrs)	Median time to return to screening for patients who did return (yrs)	% of patients (95% CI): 1 screening mammogram between 1996 and 2000	2 screening mammograms between 1996 and 2000	3 screening mammograms between 1996 and 2000	4 screening mammograms between 1996 and 2000	5 screening mammograms between 1996 and 2000	Median annual income ($)	Estimated breast carcinoma death rate (%)
Entire population	19,579	59,362	3.03	60 (60–60)	1.31	1.17	18 (17–19)	17 (16–18)	21 (20–22)	26 (25–2750)	16 (15–17)	—	16.01
Previous screening mammogram at MGH													
No	3899	8852	2.27	45 (44–46)	2.53	1.47	39 (38–40)	22 (21–23)	18 (17–19)	15 (14–16)	6 (6–6)	—	19.16
Yes	15,680	50,238	3.2	64 (64–64)	1.21	1.13	13 (13–13)	16 (15–17)	22 (21–23)	29 (28–30)	19 (18–20)	—	15.47
Previous time to return (yrs)													
1.0–1.1	4344	15,782	3.63	72 (71–73)	1.06	1.04	7 (7–7)	11 (11–11)	17 (16–18)	35 (34–36)	29 (28–30)	—	14.29
1.1–1.2	1499	5017	3.35	69 (68–70)	1.16	1.12	10 (10–10)	14 (14–14)	23 (22–24)	31 (30–32)	20 (19–21)	—	14.87
1.2–1.3	887	2836	3.2	63 (62–64)	1.23	1.17	13 (13–13)	14 (14–14)	23 (22–24)	36 (35–37)	13 (13–13)	—	15.44
1.3–1.4	664	2114	3.18	63 (61–65)	1.28	1.21	12 (12–12)	17 (16–18)	26 (25–27)	31 (30–32)	14 (14–14)	—	15.65
1.4–1.5	552	1569	2.84	56 (54–58)	1.34	1.25	13 (13–13)	17 (16–18)	26 (25–27)	32 (31–33)	12 (12–12)	—	15.79
1.5–1.6	422	1213	2.87	57 (55–59)	1.53	4.41	9 (9–9)	18 (17–19)	29 (28–30)	28 (27–29)	9 (9–9)	—	14.52
1.6–1.7	345	994	2.88	57 (55–59)	1.58	1.41	17 (16–18)	21 (20–22)	29 (28–30)	25 (24–26)	8 (8–8)	—	16.58
1.7–1.8	284	849	2.99	59 (56–62)	1.45	1.32	13 (13–13)	21 (20–22)	30 (29–31)	27 (26–28)	10 (10–10)	—	16.21
1.8–1.9	309	915	2.96	59 (57–62)	1.5	1.4	14 (14–14)	19 (18–20)	33 (32–34)	24 (23–25)	10 (10–10)	—	16.16
1.9–2.0	433	1220	2.82	56 (54–58)	1.7	1.36	20 (19–21)	19 (18–20)	26 (25–27)	24 (23–25)	9 (9–9)	—	16.52
2.0–2.1	541	1495	2.76	55 (53–57)	1.89	1.59	19 (18–20)	23 (22–24)	26 (25–27)	25 (24–26)	7 (7–7)	—	16.88
2.1–2.2	274	753	2.75	55 (52–58)	1.89	1.22	20 (19–21)	21 (20–22)	30 (29–31)	22 (21–23)	7 (7–7)	—	16.97
2.2–2.3	191	541	2.83	56 (53–59)	1.76	1.58	16 (15–17)	20 (19–21)	36 (35–37)	20 (19–21)	7 (7–7)	—	16.40
2.3–2.4	181	422	2.33	46 (43–49)	2.3	1.58	34 (33–35)	22 (21–23)	25 (24–26)	15 (14–16)	4 (4–4)	—	18.68
2.4–2.5	141	344	2.44	48 (44–52)	2.12	1.71	25 (24–26)	27 (26–28)	31 (30–32)	13 (13–13)	4 (4–4)	—	17.94
2.5–2.6	105	236	2.25	45 (41–49)	2.09	1.61	29 (28–30)	32 (31–33)	25 (24–26)	14 (14–14)	0 (0–0)	—	18.62
2.6–2.7	111	260	2.34	46 (42–50)	2.24	1.8	28 (27–29)	26 (25–27)	30 (29–31)	16 (15–17)	0 (0–0)	—	18.28
2.7–2.8	113	281	2.49	49 (45–53)	2.08	1.79	20 (19–21)	36 (35–37)	22 (21–23)	17 (16–18)	4 (4–4)	—	17.50
2.8–2.9	99	241	2.43	48 (44–52)	2.09	1.65	26 (25–27)	27 (26–28)	28 (27–29)	13 (13–13)	5 (5–5)	—	17.87
2.9–3.0	93	247	2.66	53 (49–58)	2	1.7	18 (17–19)	28 (27–29)	29 (28–30)	19 (18–200)	5 (5–5)	—	16.96
Negative biopsy in 1995	278	912	3.28	66 (64–69)	1.16	1.09	15 (14–16)	15 (14–16)	20 (19–21)	28 (27–29)	23 (22–24)	—	15.84
Previous breast carcinoma	1088	3915	3.65	73 (72–74)	1.04	1.04	18 (16–21)	17 (15–19)	21 (19–24)	26 (24–29)	16 (14–19)	—	—
Race/ethnicity													
White	15,971	50,745	3.18	64 (64–64)	1.26	1.17	16 (15–16)	16 (16–17)	21 (21–22)	28 (27–29)	18 (17–18)	—	16.78
Black	869	2462	2.83	57 (55–58)	1.56	1.31	21 (21–23)	20 (17–22)	24 (21–27)	24 (21–27)	11 (8–13)	—	17.26
Non-Asian, non-Hispanic	18,268	55,894	3.06	61 (61–61)	1.29	1.15	18 (17–19)	17 (16–18)	21 (20–22)	27 (26–28)	17 (16–18)	—	16.26
Hispanic	744	1894	2.55	51 (49–53)	1.92	1.40	30 (27–33)	22 (19–25)	21 (18–24)	19 (16–22)	8 (6–10)	—	18.08
Asian	578	1677	2.90	58 (56–60)	2.22	1.22	23 (20–26)	18 (15–21)	22 (19–25)	22 (19–25)	14 (11–17)	—	16.85

(*continued*)

Language spoken													
English	18,096	57,179	3.16	63.2 (63–64)	1.27	1.15	16 (16–17)	17 (16–17)	21 (21–22)	28 (27–28)	17 (17–18)	—	15.89
Other	755	1714	2.27	45.4 (43–48)	2.24	1.53	36 (33–40)	23 (20–26)	22 (19–25)	13 (11–16)	4 (4–6)	—	18.67
Insurance type													
HMO	4562	14,326	3.14	62.8 (62–64)	1.31	1.19	16 (15–17)	17 (16–18)	23 (22–24)	27 (26–28)	16 (15–17)	—	15.93
PPO	1763	5705	3.24	64.7 (63–66)	1.28	1.17	13 (12–15)	17 (15–18)	23 (21–25)	29 (27–31)	17 (16–19)	—	15.56
Indemnity	2126	6209	2.92	58.4 (57–60)	1.35	1.13	23 (22–25)	18 (16–20)	20 (18–21)	22 (20–24)	16 (14–17)	—	16.79
Any private insurance	9195	28,702	3.12	62.4 (62–63)	1.3	1.17	17 (16–18)	17 (16–18)	22 (21–23)	26 (25–27)	16 (16–17)	—	15.91
Medicaid/free	784	1959	2.50	50.0 (48–53)	1.89	1.4	30 (26–33)	23 (20–26)	21 (18–24)	19 (16–22)	6. (5–8)	—	18.02
Site of residence													
Chelsea	804	2170	2.7	54 (53–56)	1.63	1.37	23 (20–26)	21 (18–24)	26 (23–29)	22 (19–25)	8 (6–10)	30,161	17.26
Dorchester	379	1048	2.77	55 (53–57)	1.61	1.22	24 (20–28)	20 (16–24)	23 (19–27)	21 (17–25)	11 (8–14)	35,569	17.12
East Boston	380	1099	2.89	58 (56–60)	1.53	1.25	20 (16–24)	17 (13–21)	21 (17–25)	25 (21–29)	11 (8–14)	31,013	15.79
Somerville	409	1196	2.92	59 (57–61)	1.56	1.81	20 (16–24)	19 (15–23)	23 (19–27)	27 (23–31)	11 (8–14)	44,586	16.71
Malden	370	1117	3.02	60 (58–62)	1.33	1.16	21 (17–25)	15 (11–19)	22 (18–26)	24 (20–28)	16 (12–20)	45,654	16.30
Revere	1400	4236	3.03	61 (60–62)	1.44	1.26	17 (15–19)	18 (16–20)	23 (21–25)	30 (28–32)	12 (10–14)	37,078	16.28
Charles River Park	425	1299	3.06	61 (59–63)	1.33	1.15	19 (15–23)	18 (14–22)	21 (17–25)	25 (21–29)	16 (13–19)	55,678	16.32
Charlestown	504	1548	3.07	61 (59–63)	1.39	1.23	17 (14–20)	18 (15–21)	20 (17–23)	28 (24–32)	15 (12–18)	55,700	15.94
North End	260	800	3.08	62 (59–65)	1.32	1.16	17 (12–22)	19 (14–24)	21 (16–26)	28 (23–33)	15 (11–19)	47,547	16.26
Everett	367	1129	3.08	62 (60–64)	1.39	1.25	16 (12–20)	19 (15–23)	24 (20–28)	27 (22–32)	13 (10–16)	40,661	16.08
Cambridge	616	1905	3.09	62 (60–64)	1.3	1.16	19 (16–22)	15 (12–18)	21 (18–24)	27 (23–31)	16 (13–19)	50,120	16.04
Medford	424	1341	3.16	63 (61–65)	1.29	1.16	15 (12–18)	18 (14–22)	21 (17–25)	28 (24–32)	17 (13–21)	52,512	15.82
Brookline	305	936	3.17	64 (62–66)	1.22	1.14	16 (12–20)	16 (12–20)	20 (16–24)	29 (24–34)	18 (14–22)	46,388	15.81
Quincy	295	936	3.17	64 (62–66)	1.27	1.18	14 (10–18)	17 (13–21)	24 (19–26)	29 (24–34)	15 (11–19)	46,388	15.72
Winthrop	306	980	3.2	64 (62–66)	1.28	1.17	16 (12–20)	17 (13–21)	19 (15–23)	29 (24–34)	17 (13–21)	53,122	15.72
Copley/Back Bay	270	885	3.28	66 (64–69)	1.21	1.12	14 (10–18)	16 (12–20)	19 (14–24)	31 (25–37)	19 (14–24)	60,467	15.54
Arlington	220	733	3.33	67 (64–70)	1.24	1.13	14 (9–19)	15 (10–20)	20 (15–25)	28 (22–34)	23 (17–29)	63,621	15.59
Theoretical 5 yr screening use													
1 mammogram	—	—	1	20	—	—	100	0	0	0	0	—	25.26
5 mammograms	—	—	5	100	—	—	0	0	0	0	100	—	11.97

ACS: American Cancer Society; CI: confidence interval; MGH: Massachusetts General Hospital; HMO: health maintenance organization; PPO: preferred provider organization.

* Median income for all persons residing in the locality of interest according to the U.S. Census.

TABLE 2
Comparison of 5-Year Screening Use (1996–2000) among Women at MGH with 5-Year Screening Use (1983–1993) among Women with 5 Years of Continuous Enrollment in an HMO after an Index Screening Mammogram Performed between 1989 and 1996

Population	No. of patients receiving a screening mammogram in 1996	No. of mammograms received over the 5 yr study period	Mean no. of mammograms received over the 5 yr study period	% of ACS-recommended mammograms received (95% CI)	Median time to return to screening (yrs)	% of patients (95% CI)				
						1 screening mammogram over the 5 yr study period	2 screening mammograms over the 5 yr study period	3 screening mammograms over the 5 yr study period	4 screening mammograms over the 5 yr study period	5 screening mammograms over the 5 yr study period
MGH	19,579	59,362	3.03	60 (60–60)	1.31	18 (17–19)	17 (16–18)	21 (20–22)	26 (25–27)	16 (15–17)
HAP (HMO)[a]	2248	6820	3.03	61 (61–62)	1.48	17 (16–19)	20 (18–22)	21 (19–23)	23 (21–25)	18 (17–20)

MGH: Massachusetts General Hospital; HMO: health maintenance organization; ACS: American Cancer Society; CI: confidence interval; HAP: Health Alliance Plan.
[a] See: Ulcickas Yood M, McCarthy BD, Lee NC, Jacobsen G, Johnson CC. Patterns and characteristics of repeat mammography among women 50 years and older. *Cancer Epidemiol Biomarkers Prev.* 1999;8:595–599.

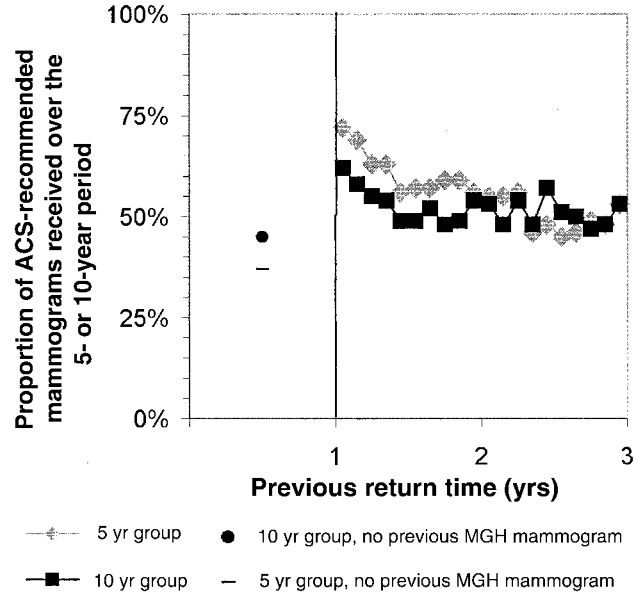

FIGURE 4. Relation between previous and long-term screening use patterns. For women who received a mammogram in 1992 or 1996 and who had received a previous mammogram, the percentage of recommended screening mammograms received over the subsequent years (1992–2001 for patients who received a mammogram in 1992 and 1996–2000 for patients who received a mammogram in 1996) was calculated according to the time between the pre-1992 or pre-1996 mammogram and the index mammogram. See Table 1 for the numeric data used to construct this graph. ACS: American Cancer Society; MGH: Massachusetts General Hospital.

mended by the ACS; $P < 0.001$); however, because women in these categories accounted for only 5% and 3% of the MGH screening population, respectively, and because the ACS screening recommendation applies only to women age ≥ 40 years, the low levels of screening use observed in these groups had little impact on the overall screening population.

Previous negative biopsy findings

There has been concern regarding whether previous false-positive findings could have a negative impact on subsequent screening use, although the available data pertaining to this issue are somewhat contradictory.[25–28] In the MGH population, negative biopsy findings made in the year before screening were not found to have a negative effect on screening use, and in fact, women with such findings tended to have slightly higher levels of long-term use compared with women in the overall population. Among women who received a screening mammogram in 1996, those who had negative biopsy findings in 1995 received 66% of the total number of mammograms recommended by the ACS during the 5-year period that was analyzed,

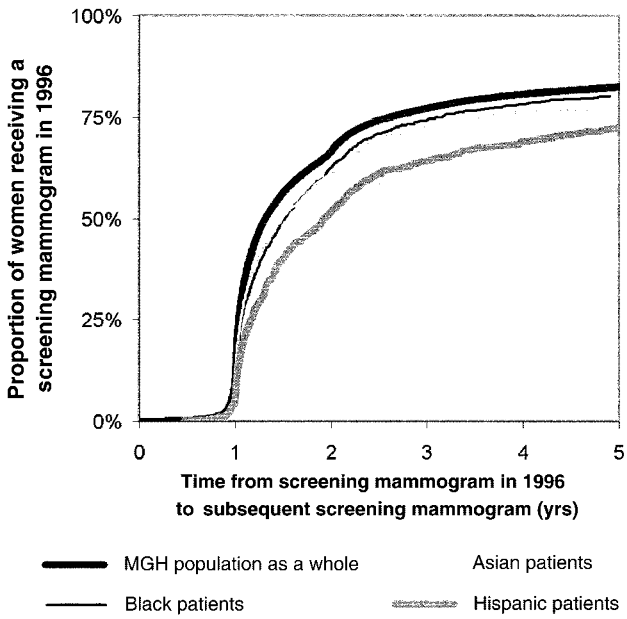

FIGURE 5. Return curves for women who received a screening mammogram in 1996 according to race and ethnicity (as determined by analysis of names). Asian vs. non-Asian, non-Hispanic: $P < 0.05$; Hispanic vs. non-Asian, non-Hispanic: $P < 0.01$; black vs. white: $P < 0.01$. All comparisons were made using the *t* test. MGH: Massachusetts General Hospital.

whereas the overall population received 60% of the recommended number of mammograms during that same period ($P < 0.001$) (Table 1).

Breast carcinoma survivors

Women with previous breast malignancies were found to have especially high levels of screening use. These women had a median time to first return to screening of 1.02 years. In addition, they received 73% of the total number of screening mammograms recommended by the ACS between 1992 and 1996, whereas the overall MGH screening population received 60% of the recommended number of mammograms during that same period ($P < 0.001$) (Fig. 1; Table 1). These calculations were made possible by the fact that 1088 women who received a screening mammogram in 1996 had been diagnosed with breast carcinoma before the index year and were alive throughout the study period. (Women with a previous diagnosis of breast carcinoma who died between 1992 and 1996 were eliminated to avoid bias in the assessment of screening use.)

Estimating the health consequences of various screening use patterns

The goal of screening, of course, is not to meet some specified schedule, but rather to reduce the incidence

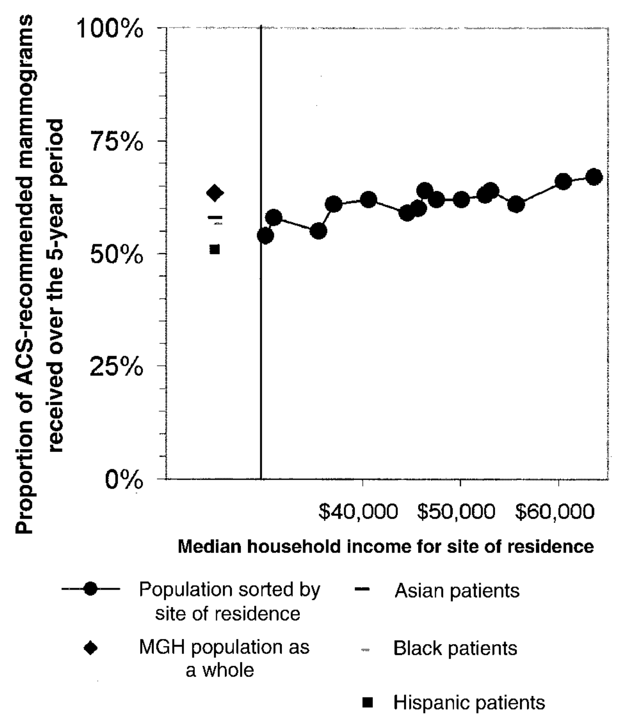

FIGURE 6. Relation between income/site of residence and long-term screening use pattern. For women who received a mammogram in 1996, the percentage of recommended screening mammograms received between 1996 and 2000 was calculated according to the median income in the patients place of residence. See Table 1 for the numeric data used to construct this graph. ACS: American Cancer Society; MGH: Massachusetts General Hospital.

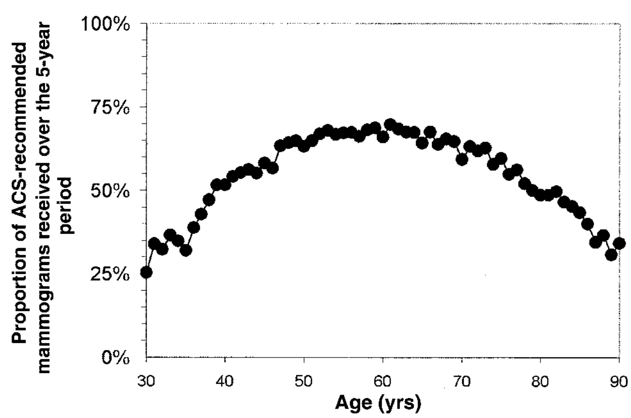

FIGURE 7. Relation between age and long-term screening use pattern for women who received a mammogram in 1996. ACS: American Cancer Society.

of breast carcinoma–related death. It was possible to translate the various screening use patterns described above into expected rates of breast carcinoma–related death using a computer simulation model[18,19] based on 1) quantitative estimates of the sizes at which invasive malignancies are detected in the presence and absence of screening,[18,19] 2) rates of tumor growth,[5]

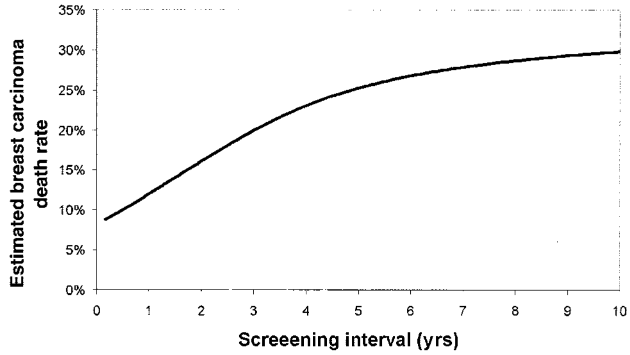

FIGURE 8. Computer simulation estimates of the relation between screening interval and breast carcinoma death rate in a population of women ages 40–85 years. See Michaelson et al., 2000[1]; Michaelson et al., 1999[18]; and Michaelson, 2001[19] for further information.

and 3) the relation between tumor size and survival.[16] These simulations indicate that among women diagnosed with invasive breast carcinoma, those who attend screening every year have an expected breast carcinoma–related death rate of 11.97%, whereas women who are screened only once every 5 years have an expected death rate that is nearly twice as large (25.26%) (Fig. 8). The expected breast carcinoma–related death rate associated with the screening use pattern observed in the MGH population as a whole lies between these two extremes (16.01%) (Fig. 9; Table 1). We were surprised to find that none of the subpopulations defined by race, ethnicity, zip code, previous screening use, or medical history approached either of the extreme patterns of screening use (i.e., prompt annual screening or screening only once every 5 years). For example, excluding breast carcinoma survivors, women screened 1.0–1.1 years before the index screening mammogram had the highest levels of screening use and thus the lowest expected death rate of any subpopulation (14.29%), but this death rate still was markedly higher than the rate that was associated with prompt annual screening (11.97%). Furthermore, women who had not previously been screened had the lowest levels of screening use and thus the highest expected breast carcinoma–related death rate of any subpopulation (19.16%), but this rate still was considerably lower than the expected rate associated with the use of screening only once every 5 years (25.26%). Differences in screening use according to zip code, income, race, and ethnicity, while significant, were relatively small, and no subgroup approached the recommended level of screening use over an extended period of time (Fig. 9B). Nonetheless, the disappointing finding that no subgroup used screening at the recommended level was balanced by the finding that no subgroup used screening at a completely unsatisfactory level; in fact, all subgroups examined appeared to have derived some amount of benefit from the use of screening mammography (Fig. 9).

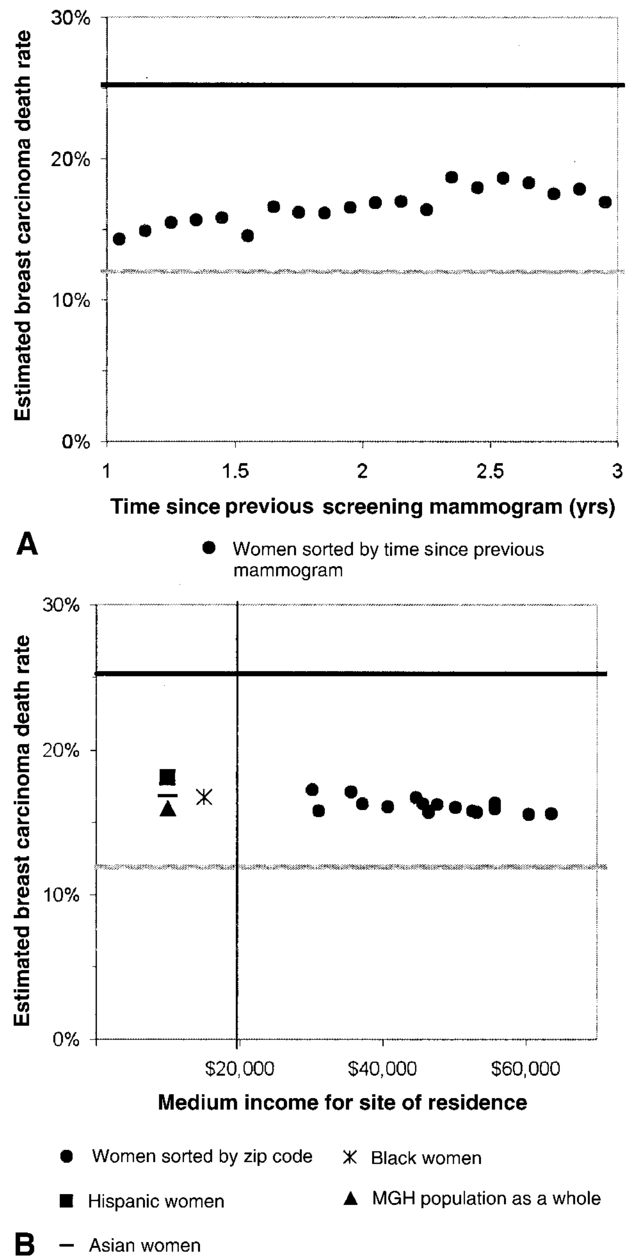

FIGURE 9. Expected breast carcinoma death rates (calculated using values generated by the computer simulation model) associated with long-term screening use patterns in patients sorted by (A) time between preindex mammogram and index mammogram and (B) median income for the patient's site of residence. See Table 1 for the numeric data used to construct this graph. Black horizontal line: expected death rate associated with use of screening once every 5 years; gray horizontal line: expected death rate associated with yearly screening use. MGH: Massachusetts General Hospital.

DISCUSSION

The MGH Avon Comprehensive Breast Center screening population is one of the largest and most completely described screening populations in existence.[4,5,16,19,20] As a result, the current report provides one of the most detailed descriptions of screening use to date. Because it is a large, urban tertiary care facility, MGH probably is not representative of most screening centers in the U.S. Nonetheless, we found that the overall pattern of use in the MGH population was remarkably similar to the patterns of use observed in other cohorts reported on in the literature.[6,15] For this reason, we believe that many of the lessons learned from the MGH population may be applicable to a wide variety of settings.

MGH, which vigorously advocates prompt annual screening for women age ≥ 40 years, has an aggressive reminder program. Three to 6 hours are spent each day calling women to remind them of their upcoming examinations. As a result, approximately 90% of all women who make appointments at MGH actually keep them (unpublished data); this rate is quite high compared with published attendance rates in other screening populations.[29,30] Nonetheless, the current report reveals that overall screening use in the MGH population is far from ideal and that the observed levels of screening use may have unfavorable health-related consequences. In the MGH population as a whole, screening use falls far short of what is recommended by the ACS, with women receiving only approximately 50–60% of the total number of mammograms recommended by the ACS over an extended period of time.

We previously examined the negative consequences of failing to return promptly for screening by investigating the appearance of lesions detected by nonmammographic methods. Such lesions are larger and thus more likely to be lethal[16] compared with mammographically detected lesions, and they begin to appear at a regular rate approximately 1 year after negative findings are made on mammography.[5,22] In the current study, we determined the expected health consequences associated with various screening intervals using a simulation model that was based on 1) quantitative estimates of the sizes at which invasive tumors are detected in the presence and absence of screening,[18,19] 2) rates of tumor growth,[5] and 3) the relation between tumor size and survival.[16] The results of these computer simulation studies suggest that women can reduce breast carcinoma–related death rates to as low as 11.97% by adhering to the ACS guidelines regarding prompt annual screening; however, only approximately 1 of every 7 patients in the MGH population complied with the ACS recommendation. For the MGH screening population considered as a whole, simulation analysis yields an expected breast carcinoma–related death rate of 16.01%, which is approximately one-third greater than the expected rate for women who are screened regularly. Approximately 1 of every 5 patients who attended screening did so only once every 5 (or more) years, and the simulation model indicated that these women had a far higher expected rate of breast carcinoma–related death (25.26% or greater).

As expected, the observed levels of screening use varied among the subsets of women within the MGH population. It was not surprising that lower levels of screening use were noted among historically underserved (i.e., Hispanic, Asian, and black) women and among women who lived in lower-income communities. Although the ultimate goal would be to increase levels of use across the entire screening population, these findings indicate that additional attention and resources should be focused on equalizing disparities within the population.

We were surprised to find that no subset of women in the MGH population approached the recommended level of screening use. The highest level of long-term use was noted among breast carcinoma survivors, and even this subpopulation of women with an obvious motivation to undergo screening received only 73% of the total number of mammographic examinations recommended by the ACS over the 5-year study period. The next highest level of long-term use was observed among women who had been screened 1.0–1.1 years before the index examination, and these women, for whom there was evidence of previous prompt screening use, received only 72% of the ACS-recommended number of examinations over the 5-year period following the index mammogram. This pattern of use was associated with an expected breast carcinoma–related death rate of 14.29%, which is approximately one-fifth greater than the expected rate of 11.97% for women who are screened promptly each year. Women from Arlington (median family income, $63,621), the most affluent community served by MGH, received only 67% of the total number of recommended mammograms over the 5-year period that was analyzed; this use pattern was associated with an expected breast carcinoma–related death rate of 15.59%, which is approximately one-third higher than the expected death rate for women who are screened promptly each year.

The data reported here reveal that the widespread failure of many women to attend screening regularly occurs to a degree that is likely to reduce the life-sparing potential of screening. Many psychologic, sociologic, and economic factors contribute to a woman's tendency to receive prompt screening;[6,9,10,12,13,15,31] nonetheless, we are impressed by the simple importance of appointment making and keeping[29,30] and by the finding (made in more than 100 studies) that postal and telephone reminders enhance the likelihood of screening attendance.[32–34] Reminders are a somewhat unglamorous and neglected aspect of breast screening, but we believe that their use can have an enormous impact on breast carcinoma death rates.

We propose that there are two types of determinants, which we shall call *systematic* and *individual* determinants, that affect return to screening. Systematic determinants are those factors governing appointment-making and appointment-keeping behaviors that are independent of each woman's specific characteristics. In contrast, individual determinants are factors that distinguish one patient's return behavior from another patient's return behavior. Although the development of a statistical model will be necessary for quantitative isolation of the relative contribution made by each type of determinant and for assessment of the nature of these determinants (the data assembled should form the basis for such a model), a general idea of the relative importance of these two types of factors can be obtained from the raw data. For example, the finding that a very large fraction of women who received consecutive screening mammograms separated by only 1.0–1.1 years (89% of such women who received a screening mammogram in 1992) did not continue to return promptly for annual examinations over longer periods of time suggests that prompt return in the past does not invariably predict subsequent prompt return. Likewise, the finding that a significant proportion (~5%) of women who previously allowed 2.9–3.0 years to pass between consecutive screening examinations returned promptly for annual examinations over the 5-year period that was investigated indicates that past failure to be screened promptly is not invariably repeated in the future. We believe that such observations point to the central role of systematic factors in determining levels of screening use. In this sense we suggest that the challenge ahead is an operations-research challenge,[35] not unlike the challenge posed by the efficient management of any large enterprise, but a challenge whose solution has the potential to save enormous numbers of lives.

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