# Reduction in Breast Cancer Mortality from Organized Service Screening with Mammography: 1. Further Confirmation with Extended Data

**The Swedish Organised Service Screening Evaluation Group**


## Abstract

Background: **In an earlier publication, our evaluation of data from breast cancer screening programs in seven Swedish counties suggested a 40% reduction in incidence-based breast cancer mortality among women actually screened. In the current study, we expand the previous analysis from seven counties to 13 large areas within nine counties, including six of the original counties and seven additional areas, examine a longer period of follow-up (20-44 years), apply new analytic methods for the evaluation of incidence-based breast cancer mortality, and estimate the number needed to screen to save one life.**

Methods: **Data from six of the original counties (one being excluded as it does not yet have 10 years of follow-up after the initiation of screening), with increased follow-up, and seven additional large areas, within three counties, representing ~45% of Swedish women, provide information about age at diagnosis, age at death, and screening history for 542,187 women in the prescreening and 566,423 women in the screening epochs. Regardless of year of diagnosis, there were a total of 6,231 deaths due to breast cancer in the period of study as a whole. Of these, 4,778 were incidence-based deaths in the two epochs, i.e., death among cases diagnosed within either the prescreening or screening period. Data were analyzed using Poisson regression and adjusted, when necessary, for self-selection bias, contemporaneous changes in incidence, and changes in mortality independent of screening.**

Results: **Attendance was uniformly high, averaging 75% in the screening epochs. Recall rates for assessment varied from 4% to 5% at the first round of screening and ~3% at later rounds. Detection rates averaged five breast cancers per 1,000 women screened in the first round, and four breast cancers per 1,000 women screened in subsequent rounds. There was a significant 45% reduction in incidence-based breast cancer mortality among screened women in the screening epoch relative to incidence-based breast cancer mortality in the prescreening epoch (relative risk, 0.55; 95% confidence intervals, 0.51-0.59). After adjusting for self-selection bias, there still was a significant 43% reduction in incidence-based breast cancer mortality associated with screening (relative risk, 0.57; 95% confidence intervals, 0.53-0.62).**

Conclusions: **These results indicate a reduction in breast cancer mortality of between 40% and 45% in association with screening, after adjustment for self-selection bias. These results were obtained with modest human costs: the number needed to screen to save one life was estimated as 472.** (Cancer Epidemiol Biomarkers Prev 2006;15(1):45–51)


## Introduction

Randomized trials of breast cancer screening show that invitation to mammographic screening is associated with a significant reduction in mortality from breast cancer (1-3). Having shown the *efficacy* of breast cancer screening with mammography, today it is equally important to evaluate the *effectiveness* of mammography service screening programs. Comparison of deaths from breast cancer before and after the introduction of screening is a powerful approach but raises various problems of design, analysis, and interpretation. Failure to distinguish breast cancer deaths among women who might have benefited from screening (i.e., incident cases after the introduction of screening) from those who could not have benefited (i.e., incident cases before the introduction of screening) has resulted in very low estimates of the breast cancer mortality reduction as a result of population-based screening (4).

Other changes over an evaluation period also influence breast cancer mortality, such as changes in incidence, improvements in therapy, and increased awareness on the part of women to the first sign of symptoms. In the past, we have addressed the first problem by using incidence-based mortality, i.e., deaths only from tumors diagnosed in the screening epoch are compared with deaths only from tumors diagnosed in the prescreening epoch (5-7). In previous evaluations, to estimate the screening effect independent of other changes, breast cancer mortality among those who did not receive screening in the screening epoch was compared with breast cancer mortality in the prescreening epoch.

Previous research on service screening in Sweden found a range of estimated mortality reductions associated with the policy of offering screening of 9% to 28% depending on the age group and region studied (8-13). Our work on incidence-based mortality indicated that women exposed to mammographic screening (i.e., women actually attending) in the screening epoch had a 40% to 50% reduced breast cancer mortality compared with unexposed women in the prescreening epoch, after adjustment for self-selection for screening (5, 14, 15). The small reduction in mortality of ~15% in unscreened women in the screening epoch indicates that the majority of the 40% to 50% reduction is due to the screening and not to other changes over time (13).

The use of incidence-based mortality has been criticized, based on the assertion that use of only deaths from tumors diagnosed in each relevant epoch gives rise to length bias (16, 17). This criticism is mistaken (18) because although length

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bias could artificially increase the number of cases in the screening epoch, it would not affect the observed number of deaths (the numerator of the mortality rate) nor would it affect the person-years in the population as a whole (the denominator). Nevertheless, it is desirable to develop a method of analysis that uses all deaths from all tumors diagnosed throughout the total period of observation. Our companion article addresses this issue (19).

The Swedish Organised Service Screening Evaluation Group aims to draw together evidence from all parts of Sweden on the effect of organized mammographic service screening on breast cancer mortality and other end points. In this article, we report on the effect of the introduction of mammographic screening in 13 large areas within nine counties in Sweden, covering 45% of the Swedish female population, on breast cancer mortality. This analysis includes further follow-up of the six counties included in the earlier report (5), which had at least 10 years of screening activity, plus analysis of data from seven areas which recently joined the Swedish Organised Service Screening Evaluation Group collaboration. The aims of the present study are: (*a*) to compare mortality from breast cancer diagnosed in the prescreening and screening epochs in the 13 areas studied, providing an estimate of the effect of screening on breast cancer mortality when it is offered to the eligible female population; (*b*) to estimate the effect on mortality of actual exposure to screening; (*c*) to make appropriate adjustments for self-selection bias, and for changes occurring contemporaneously with the introduction of screening; and (*d*) to report on the level of screening and diagnostic activity required to produce the benefits in (*a-c*) above.

## Materials and Methods

**Data Available.** We examined prescreening and screening epoch breast cancer mortality data from 13 areas in Sweden, after excluding one county, previously included in our seven-county analysis (5), and two newly participating counties, with <10 years of screening activity. For this purpose Stockholm, the capital city, is treated as five areas, as it has five large populations served by five screening units. The 13 areas are listed in Table 1, with the prescreening and screening epochs for the incidence-based mortality analysis, average populations, and the age ranges invited to screening in the screening epoch. Some counties also offered screening to women ages 70 to 74, but we restricted this analysis to women aged <70. We required an equal follow-up time in each area before and after the start of screening to avoid bias from the nonconstant hazard of breast cancer death by time since diagnosis and from the greater opportunity to develop breast cancer and die from it in the longer period of time (5). This, together with the availability of archived breast cancer data for each county, determined the period of observation specific to each county. Breast cancer diagnoses, including both invasive and ductal carcinoma in situ, were obtained from the Swedish Cancer Registry, backed up by the Regional Oncological Centres. If a woman had more than one breast cancer, the earlier diagnosis was used. Breast cancer deaths were obtained from the National Cause of Death Register, including only those with breast cancer as the underlying cause of death. All reporting of mortality below refers to mortality from breast cancer as the underlying cause.

The size of the female populations by year and county in the age ranges offered screening were provided by Statistics Sweden. The screening centers provided data on the screening exposure for women who died of breast cancer, and of the population, enabling us to calculate deaths and person-years by screening exposure, as well as the epoch of diagnosis. We distinguished being invited to screening from being exposed to screening. Within the first few years of the screening epoch, practically all of the eligible population were invited. Within each area and epoch, the percentage exposed to screening was calculated by determining the percentage of the eligible population who were exposed for each year, and taking the average, weighted by the population for each year, over all years of the epoch. Cancer cases exposed to screening are defined as those attending their last scheduled screening appointment before diagnosis.

The total population studied averaged 542,187 in the prescreening epoch and 566,423 in the screening epoch. There was a total of 6,231 breast cancer deaths available for analysis regardless of epoch of diagnosis. Of these, 4,778 were incidence-based deaths in the two epochs, 2,736 breast cancer deaths in the prescreening epoch from tumors diagnosed in that epoch, and 2,042 from tumors diagnosed in the screening epoch.

It should be noted that a randomized trial of screening took place in the Stockholm Södersjukhuset area during the nominal prescreening epoch (1981-1986; ref. 20). Also, in Dalarna county, in the last years of the prescreening epoch and the first few years of the screening epoch (1977-1986), a randomized trial of screening was in operation (1), with approximately one third of the population receiving no invitation to screening. After the closure of the trial, screening was offered to the entire population ages 40 to 69. These trials imply considerable screening activity in Stockholm Södersjukhuset in the prescreening epoch and a reduced exposure to screening in the early years of the screening epoch in Dalarna. In addition, there were significant amounts of service screening which occurred in Gävleborg and Västmanland

**Table 1. Prescreening and screening epochs by area, average populations, and age group screened in the screening epoch**

| Area | Prescreening epoch | Average population | Screening epoch | Average population | Age group screened |
|---|---|---|---|---|---|
| Dalarna | 1958-1979 | 51,505 | 1980-2001 | 50,925 | 40-69 |
| Gävleborg | 1968-1984 | 53,074 | 1985-2001 | 52,540 | 40-69 |
| Örebro | 1979-1987* | 47,931 | 1988-1996* | 49,073 | 40-69 |
| Norrbotten | 1976-1988 | 43,989 | 1989-2001 | 48,042 | 40-69 |
| Västernorrland | 1978-1989 | 47,671 | 1990-2001 | 47,595 | 40-69 |
| Södersjukhuset † | 1977-1988 | 49,916 | 1989-2000 | 47,206 | 50-69 |
| Uppsala | 1979-1989 | 39,386 | 1990-2000 | 48,196 | 40-69 |
| Västmanland | 1979-1989 | 45,028 | 1990-2000 | 47,202 | 40-69 |
| Södermanland | 1979-1989 | 43,746 | 1990-2000 | 47,144 | 40-69 |
| Skärholmen † | 1977-1988 | 33,235 | 1989-2000 | 35,795 | 50-69 |
| Danderyd Hospital † | 1977-1988 | 28,540 | 1989-2000 | 32,512 | 50-69 |
| Karolinska Hospital † | 1977-1988 | 25,650 | 1989-2000 | 30,351 | 50-69 |
| Sankt Göran Hospital † | 1979-1989 | 32,516 | 1990-2000 | 29,842 | 50-69 |
| Overall | — | 542,187 | — | 566,423 | — |

*Dates for Örebro refer to epoch of diagnosis. Each epoch had an additional follow-up of 5 years for mortality. For explanation, see Materials and Methods.
†Stockholm centers.

**Table 2. Percentage of attendance, rates of recall for assessment, and detection rates per hundred women screened by area for first round of screening and later rounds**

| Area | First round (start of program) | | | Subsequent rounds (most recent) | | |
|---|---|---|---|---|---|---|
| | Attendance | Recall | Detection | Attendance | Recall | Detection |
| Dalarna | 93 | 5.2 | 0.51 | 85 | 2.4 | 0.40 |
| Gävleborg | 88 | 4.6 | 0.55 | 83 | 1.9 | 0.39 |
| Örebro | 86 | 6.7 | 0.53 | 76 | 3.2 | 0.33 |
| Norrbotten | 89 | 2.1 | 0.41 | 85 | 2.4 | 0.35 |
| Västernorrland | 90 | 1.9 | 0.41 | 88 | 2.5 | 0.36 |
| Södersjukhuset* | 75 | 1.7 | 0.42 | 70 | 2.5 | 0.55 |
| Uppsala | 84 | 4.8 | 0.58 | 82 | 2.6 | 0.40 |
| Västmanland | 90 | 3.1 | 0.46 | 84 | 3.3 | 0.41 |
| Södermanland | 86 | 3.7 | 0.52 | 82 | 2.6 | 0.38 |
| Skärholmen* | 70 | 2.5 | 0.51 | 69 | 2.3 | 0.44 |
| Danderyd Hospital* | 71 | 3.8 | 0.89 | 71 | 3.9 | 0.60 |
| Karolinska Hospital* | 69 | 3.9 | 0.76 | 73 | 3.3 | 0.60 |
| Sankt Göran Hospital* | 63 | 4.8 | 0.77 | 64 | 2.1 | 0.48 |

*Stockholm areas invite women aged 50 to 69, as compared with 40 to 69 in other areas, and hence have higher detection rates on average.

counties in the prescreening epoch. This will tend to dilute the observed effect of offered screening, although this may be partly counterbalanced in the case of Stockholm Södersjukhuset, Gävleborg, and Västmanland by the movement of some tumors to the prescreening epoch as a result of early detection (5).

**Statistical Analysis.** For each county, we used the date of inception of screening and the period of time over which mortality data were available to determine the nominal year that divides the prescreening and screening epochs. Prescreening and screening epoch dates were established based on: (*a*) the importance of equalizing observation times in the two epochs, (*b*) the need to minimize the amount of screening activity in the prescreening epoch and to maximize it in the screening epoch, and (*c*) the desirability of using as much of the available mortality data as possible. The follow-up in the screening epoch is one factor in the choice of the cutoff date. Therefore, for some areas included in our previous evaluation (5), the increased duration of the postscreening epoch meant that a slightly different cutoff date was used for the current evaluation.

Person-years for a given area and epoch were calculated by summing the annual population figures from Statistics Sweden over all years of the epoch. This was stratified by screening exposure where appropriate.

Using Poisson regression (21), we compared the deaths in the prescreening epoch from tumors diagnosed in that epoch with the corresponding deaths in the screening epoch, as in our previous report (5), with the exception of one area, Örebro county. For this area, we needed to reconcile the following observations: first, screening was phased in gradually, in that it started in 1987 but did not reach 70% coverage until 1993; second, we had mortality data from 1979 to 2001. The necessity of equal-length epochs and the use of the full screening mortality data to the end of 2001 would necessitate a nominal division date after 1989, which in turn would mean considerable contamination of the prescreening epoch with exposure to screening. In Örebro, therefore, for the prescreening epoch, we took breast cancer deaths which occurred between 1979 and 1992 but only from tumors diagnosed between 1979 and 1987. The corresponding end point for the screening epoch was the number of breast cancer deaths taking place between 1988 and 2001, but only from tumors diagnosed between 1988 and 1996. This preserved equal diagnostic and follow-up periods during the prescreening and screening epochs, maximized the follow-up periods, and involved minimal exclusion of breast cancer deaths from the analysis.

We also separated the screening deaths and person-years by screening exposure and estimated the change in mortality compared with the prescreening epoch in the screening-exposed and unexposed groups separately. This necessitates correction for self-selection for screening, in that the women exposed in the screening epoch are those who have opted to be screened and the unexposed women are for the most part those who have declined. The former might be expected to be

**Table 3. Percentage exposed to screening, deaths from incident tumors, and person-years by area and epoch**

| Area | Prescreening | | | Screening | | |
|---|---|---|---|---|---|---|
| | % Exposed* | Deaths | Person-years | % Exposed | Deaths | Person-years |
| Dalarna | 4 | 545 | 1,133,119 | 79 | 364 | 1,120,345 |
| Gävleborg | 17 | 370 | 902,258 | 87 | 273 | 893,188 |
| Örebro | 4 | 223 | 671,031 | 59 | 191 | 687,023 |
| Norrbotten | 0 | 163 | 571,857 | 75 | 138 | 624,543 |
| Västernorrland | 0 | 222 | 572,047 | 78 | 148 | 571,135 |
| Södersjukhuset | 36 | 242 | 598,991 | 65 | 152 | 566,473 |
| Uppsala | 3 | 127 | 433,248 | 82 | 119 | 530,158 |
| Västmanland | 20 | 130 | 495,311 | 88 | 99 | 519,222 |
| Södermanland | 1 | 141 | 481,211 | 78 | 116 | 518,587 |
| Skärholmen | 0 | 180 | 398,816 | 63 | 115 | 429,544 |
| Danderyd Hospital | 0 | 143 | 342,476 | 66 | 121 | 390,141 |
| Karolinska Hospital | 0 | 111 | 307,795 | 65 | 101 | 364,214 |
| Sankt Göran Hospital | 0 | 139 | 357,681 | 59 | 105 | 328,260 |
| Overall | 8 | 2,736 | 7,265,841 | 74 | 2,042 | 7,542,833 |

*Although there was only a small amount of exposure to regular organized screening in the prescreening epoch in most areas, there was also some sporadic screening, notably in Gävleborg, which is not counted here if the interval between screens was >3 years.

**Table 4. Deaths from tumors diagnosed in the screening epoch and the corresponding person-years, by exposure status and area**

| Area | Unexposed to screening | | Exposed to screening | |
|---|---|---|---|---|
| | Deaths | Person-years | Deaths | Person-years |
| Dalarna | 150 | 233,632 | 214 | 886,713 |
| Gävleborg | 66 | 116,907 | 207 | 776,281 |
| Örebro | 102 | 279,317 | 89 | 407,706 |
| Norrbotten | 54 | 158,272 | 84 | 466,271 |
| Västernorrland | 46 | 123,318 | 102 | 447,817 |
| Södersjukhuset | 84 | 197,091 | 68 | 369,382 |
| Uppsala | 39 | 92,059 | 80 | 438,099 |
| Västmanland | 30 | 64,351 | 69 | 454,871 |
| Södermanland | 48 | 112,882 | 68 | 405,705 |
| Skärholmen | 59 | 159,724 | 56 | 269,820 |
| Danderyd Hospital | 64 | 131,237 | 57 | 258,904 |
| Karolinska Hospital | 57 | 125,840 | 44 | 238,374 |
| Sankt Göran Hospital | 61 | 135,891 | 44 | 192,369 |
| Overall | 860 | 1,930,521 | 1,182 | 5,612,312 |

more health-conscious than the latter and therefore less likely to die of breast cancer a priori, as was observed in the randomized trials of screening (22). We corrected for selection bias in the same manner as in the previous seven-county analysis (5), but with two important refinements: first, we estimated the effect of being screened rather than being invited to screening (23), adjusted for self-selection bias; second, we used each area's own relative risk for death among the unexposed group in the screening epoch to adjust for selection bias, instead of the estimated relative risk from the randomized trials. We used estimates of the trends in incidence, fatality, and mortality independent of screening to assess the extent to which observed mortality reductions are attributable to the screening (19). Results from all areas were combined using the inverse variance weighted averages of the relative risks in the logarithmic scale (24).

## Results

Table 2 shows the percentage of attendance, rates of recall for assessment, and cancer detection rates in the 13 areas. Attendance ranged from 70% to 90%. At the first round in the early years of the programs, recall rates varied from 2% to 5%, with an average of ~4%, and cancer detection rates ~0.5%. At recent rounds, recall rates mostly have been in the range of 2% to 3% and detection rates have varied ~0.4%. Table 3 shows the amount of exposure to screening in the prescreening and screening epochs in each area. The proportion exposed is lower on average than the attendance rates, mainly because of the number of women not yet invited in the start-up period of screening. On average, 75% of the unexposed person-years in the screening epoch was due to nonattendance, and 25% was due to the number of eligible women not yet invited. In the prescreening epoch, the vast majority of nonexposure was due to as yet uninvited women. Thus, there is a longer follow-up, in principle, on as yet uninvited women than on nonattenders.

With the exception of Västmanland, where there was a 20% screening exposure due to the need to select a cutoff date during a rather long start-up period, Gävleborg, where some screening took place since 1974, and Stockholm Södersjukhuset, where the Stockholm randomized trial was conducted, very little screening activity was carried out in the prescreening epoch. The figures for exposed refer to attendance at organized programs of regular screening. Average exposure in the screening epoch was 75%. The incidence-based deaths and person-years by epoch and county are shown in Table 4.

Figure 1A shows the result of comparing the incidence-based breast cancer mortality among the screening-exposed women in the screening epoch with all women in the prescreening epoch. Overall, there was a 45% reduction in breast cancer mortality in the screened women [relative risk (RR), 0.55; 95% confidence interval (CI), 0.51-0.59] with a range of 36% to 54%. However, the magnitude of this estimate is partly due to self-selection bias because Fig. 1B shows that the unscreened women in the screening epoch had a 17% increased risk of death from breast cancer compared with the unscreened women in the prescreening epoch (RR, 1.17; 95% CI, 1.08-1.26), suggesting that the screened women are a group less likely to die of breast cancer independently of screening. Adjusting for this bias reduces the mortality reduction by 2%, to a 43% reduction in incidence-based breast cancer mortality associated with screening (RR, 0.57; 95% CI, 0.53-0.62) as shown in Fig. 2.

In our companion article, we found an increase in the incidence of just under 1% per annum, in the combined unexposed population prescreening (19). This was almost exactly balanced by a 1% reduction in fatality per annum. This suggests that most of the 43% mortality reduction in the screened women is due to the effect of screening, and that without the other changes in therapy and awareness, there would have been an ~10% increase in mortality.

Figure 3 shows the relative risks for all women, screened and unscreened in the screening epoch compared with the

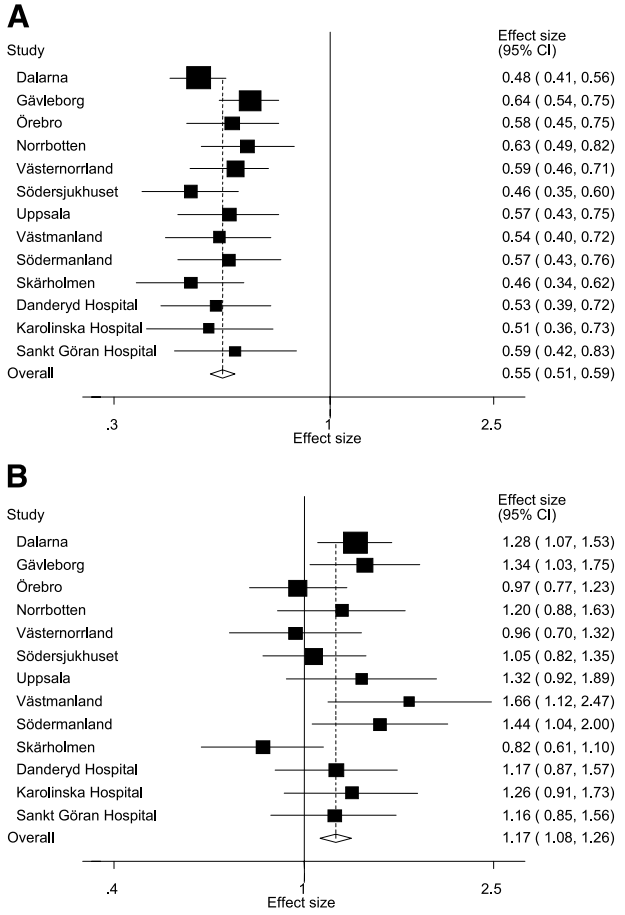


**Figure 1. A.** Relative risk of incidence-based breast cancer mortality for screened women in the screening epoch compared with the prescreening epoch. **B.** Relative risk of incidence-based breast cancer mortality for unscreened women in the screening epoch compared with the prescreening epoch.

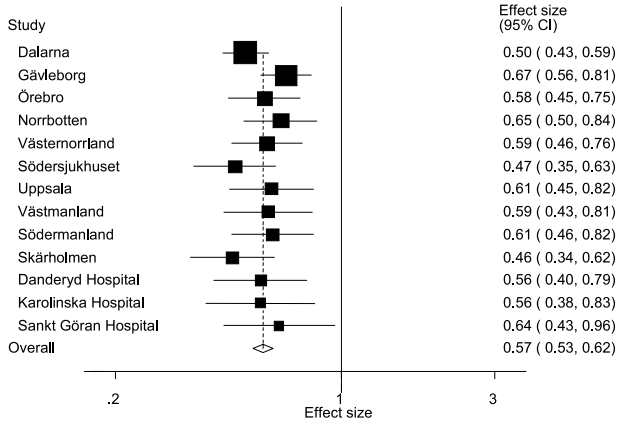


**Figure 2.** Relative risk of incidence-based breast cancer mortality for screened women in the screening epoch compared with the prescreening epoch, adjusted for self-selection bias.

prescreening. This shows a 27% reduction in mortality in the screening epoch (RR, 0.73; 95% CI, 0.69-0.77) compared with the prescreening.

## Discussion

Our results showed a significant 45% reduction (RR, 0.55; 95% CI, 0.51-0.59) in incidence-based mortality from breast cancer in screened women compared with the prescreening epoch. After adjustment for self-selection bias, the mortality reduction for women actually screened was 43% (RR, 0.57; 95% CI, 0.53-0.62). This relative risk corresponds to the causal estimate of Baker et al. of absolute risk difference (25). This is consistent with our previous results, showing a 39% reduction after adjustment for self-selection bias (5).

It could be argued that our correction for self-selection is inaccurate because it uses the relative risk in the unexposed in the screening epoch compared with the prescreening, and is hence confounded with other changes over time. However, the temporal increase in incidence and the decrease in fatality, both independent of screening, are of almost exactly the same relative magnitude and therefore balance each other (19). A corresponding correction to the relative risk estimate from contemporaneous comparison in the randomized trials would be considerably larger (22), but arguably inappropriate for the populations studied here. The advantage of the relative risk being specific to the populations studied probably outweighs the disadvantage of the relative risk being noncontemporaneous. There is room for further methodologic development to estimate temporal effects and selection bias effects simultaneously and mutually adjusted.

Overall, there was a 27% reduction in incidence-based mortality in the screening epoch compared with the prescreening epoch for the population as a whole, i.e., including women who attended and who did not attend screening combined. Thus, our results are consistent with just under a 30% reduction in breast cancer mortality associated with a policy of offering screening and a 40% to 45% reduction associated with actually being screened. The estimate of the benefit associated with actually being screened is the more appropriate estimate to communicate to women, whereas the effect of the invitation is more appropriate to policy decisions. Consideration of Table 2 indicates that the mortality reduction was achieved with rates of recall for assessment of ~4% during first round and 2% to 3% at later rounds. Detection rates were typically five breast cancers per thousand at first round and four per thousand subsequently. The programs had interscreening intervals of ~2 years.

We can use the data on the exposed women in Table 3 and the results in Fig. 2 to estimate the number needed to screen to save a single life from breast cancer. These estimates are shown in Table 5. During the screening epoch, 886 breast cancer deaths were prevented by screening 418,532 women. The overall estimate of the number needed to screen to save one life is 472, which is consistent with our findings from a randomized trial of mammographic screening (26). This estimate is lower than previous estimates in the literature, which are usually based on the number invited to screening and not on the number actually screened, and which either use a follow-up time which is too short to observe the full benefit of screening or which confuse the period of delivery of screening with period of follow-up (27, 28). Naturally, the number needed to screen will be lower than the number needed to invite due to the fact that a number of women refuse screening. It also should be noted that the number needed to screen is dependent on the absolute number of deaths prevented, which in turn depends on how long the screening has been in place. In Table 5, there is a significant negative correlation between the number needed to screen and the length of follow-up screening. For those counties with ≥13 years of screening, the estimated number needed to screen was ~430, whereas for those with <13 years, the estimate was ~650. The high long-term survival rates from breast cancer in recent years provide the reason why longer follow-up is necessary to measure the full benefit of breast cancer screening.

In relation to this, it should be noted that the evaluation above, despite the very long screening epochs in two of the areas studied, Dalarna and Gävleborg, still relates largely to the early period of screening delivery. In the screening epoch, in Södermanland and Uppsala, for example, with 11 years of follow-up, 64% and 71% of the incidence-based deaths were from cancers diagnosed in the first 5 years of the screening epoch. Even in Dalarna and Gävleborg, with 22 and 17 years of screening, respectively, the figures were 37% and 43%. Thus, the absolute benefits, and probably the relative benefits, estimated here are likely to underestimate the full benefit of screening.

We cannot exclude the possibility that there are differential effects of therapy, particularly adjuvant endocrine and cytotoxic chemotherapy, between women unexposed and women exposed to screening. It may be that there are synergistic effects of combining early detection with systemic adjuvant treatment in individuals with otherwise negative prognostic features. This issue, however, is beyond the scope of this study.

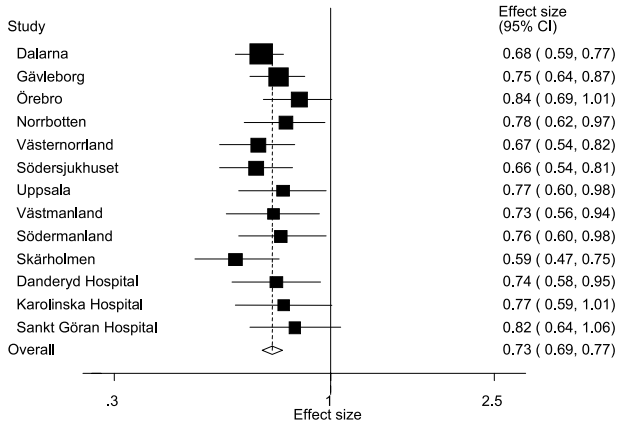


**Figure 3.** Relative risk of incidence-based breast cancer mortality for all women in the screening epoch compared with the prescreening epoch.

**Table 5. Deaths avoided in the screened women, screening epoch, and estimated numbers needed to screen to save one life**

| Area | Observed deaths | Expected deaths* | Deaths avoided | Average number screened | Numbers needed to screen to save one life (95% CI) | Years of follow-up |
|---|---|---|---|---|---|---|
| Dalarna | 214 | 428 | 214 | 40,305 | 188 (158-234) | 22 |
| Gävleborg | 207 | 309 | 102 | 45,664 | 448 (309-812) | 17 |
| Örebro | 89 | 153 | 64 | 29,122 | 455 (313-832) | 14 |
| Norrbotten | 84 | 129 | 45 | 35,867 | 797 (500-1,954) | 13 |
| Västernorrland | 102 | 173 | 71 | 37,318 | 526 (357-994) | 12 |
| Södersjukhuset | 68 | 145 | 77 | 30,782 | 400 (287-655) | 12 |
| Uppsala | 80 | 131 | 51 | 39,827 | 781 (475-2,184) | 11 |
| Västmanland | 69 | 117 | 48 | 41,352 | 862 (533-2,235) | 11 |
| Södermanland | 68 | 111 | 43 | 36,882 | 858 (555-1,883) | 11 |
| Skärholmen | 56 | 122 | 66 | 22,485 | 341 (251-529) | 12 |
| Danderyd Hospital | 57 | 102 | 45 | 21,575 | 479 (302-1,155) | 12 |
| Karolinska Hospital | 44 | 79 | 34 | 19,865 | 584 (344-1,920) | 12 |
| Sankt Göran Hospital | 44 | 69 | 25 | 17,488 | 700 (368-6,949) | 11 |
| Overall | 1,182 | 2,068 | 886 | 418,532 | 472 (418-544) | 13 |

*Calculated on the basis of the relative risks in Fig. 2.

Some of the variation between areas in the mortality reduction is due to prescreening variability in the force of mortality (Table 3). The overall range of incidence-based mortality rates in the prescreening epoch was ~3/10,000 (from 3.4/10,000 to 6.4/10,000), whereas the range for the screening epoch was ~1.3/10,000 (from 1.9/10,000 to 3.2/10,000). This illustrates another positive effect of the introduction of screening, that of regionwide and possibly nationwide introduction of an evidence-based chain of assessment and treatment. As a more general point, there is impressive consistency in the screening epoch from area to area in recall, detection, and mortality rates.

In conclusion, our results show a significant and substantial reduction in breast cancer mortality as a result of service screening with mammography in 13 Swedish counties. In the women screened, the reduction in mortality was from 40% to 45%. This is consistent with previous results. This was achieved with screening intervals typically of 2 years, and comparatively low rates of recall for assessment of radiologically suspicious features. In an average follow-up period of 13 years, approximately one life is saved for every 472 women screened. For longer follow-up periods, the number needed to screen is smaller. This indicates that the Swedish breast screening program is achieving valuable results.

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