Research article

Breast implants following mastectomy in women with early-stage breast cancer: prevalence and impact on survival

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Abstract

Background Few studies have examined the effect of breast implants after mastectomy on long-term survival in breast cancer patients, despite growing public health concern over potential long-term adverse health effects.

Methods We analyzed data from the Surveillance, Epidemiology and End Results Breast Implant Surveillance Study conducted in San Francisco–Oakland, in Seattle–Puget Sound, and in Iowa. This population-based, retrospective cohort included women younger than 65 years when diagnosed with early or unstaged first primary breast cancer between 1983 and 1989, treated with mastectomy. The women were followed for a median of 12.4 years (n = 4968). Breast implant usage was validated by medical record review. Cox proportional hazards models were used to estimate hazard rate ratios for survival time until death due to breast cancer or other causes for women with and without breast implants, adjusted for relevant patient and tumor characteristics.

Results Twenty percent of cases received postmastectomy breast implants, with silicone gel-filled implants comprising the most common type. Patients with implants were younger and more likely to have in situ disease than patients not receiving implants. Risks of breast cancer mortality (hazard ratio, 0.54; 95% confidence interval, 0.43–0.67) and nonbreast cancer mortality (hazard ratio, 0.59; 95% confidence interval, 0.41–0.85) were lower in patients with implants than in those patients without implants, following adjustment for age and year of diagnosis, race/ethnicity, stage, tumor grade, histology, and radiation therapy. Implant type did not appear to influence long-term survival.

Conclusions In a large, population-representative sample, breast implants following mastectomy do not appear to confer any survival disadvantage following early-stage breast cancer in women younger than 65 years old.

Keywords: breast implants, epidemiology, mastectomy, Surveillance, Epidemiology, and End Results, survival

Introduction

Over the past 30 years, an estimated 1.5–2 million women have received breast implants in the United States [1]. Starting in the 1980s, widespread public health concern arose regarding their potential adverse health effects [2]. Numerous epidemiologic investigations have focused on systemic complications, particularly cancer and connective tissue disease, but have found no significantly increased short-term risk for these diseases [3,4].

Approximately 20% of breast implants are used for reconstruction in breast cancer patients following mastectomy [1]. In this population, however, the use of breast implants, while increasing, has not been well documented [5]. Furthermore, little research has addressed long-term survival, although the few studies conducted suggest that use of implants for breast reconstruction does not impact patient survival [6-9]. However, these studies were limited by comprising clinic-based samples not necessarily representative of all patients, by small sample sizes, by lack of information on type of implant, and by short durations of follow-up.

In 1993, the Surveillance, Epidemiology, and End Results (SEER) program of the National Cancer Institute
implemented the Breast Implant Surveillance Study to document and validate postmastectomy breast implant usage in a population-based series of young, early-stage breast cancer cases. Since the SEER program also monitors patient vital status for life, survival up to 17 years exists in the study cohort. The purpose of the current analysis was to describe the use of breast implants and to examine the impact of breast implants on survival after breast cancer in this cohort.

**Methods**

**Breast Implant Surveillance Study**

The Breast Implant Surveillance Study was conducted during the period 1993–1994 in the United States. Patients were identified through the population-based SEER cancer registries in San Francisco–Oakland, CA, in Seattle–Puget Sound, WA, and in the state of Iowa. Eligible patients included the 5862 females diagnosed younger than age 65 with early-stage or unstaged first primary breast cancer in 1983, 1985, 1987, or 1989 and treated with mastectomy during their first course of therapy.

Participation involved completing a standardized questionnaire inquiring about implant status (right breast only, left breast only, both breasts, no implant, or unknown) and implant type (silicone gel, saline, double lumen [consisting of silicone gel and saline], other, and unknown type), and providing signed consent for release of medical records for validation of implant usage and implant type. Patients in the Seattle–Puget Sound region and the state of Iowa were mailed a self-administered questionnaire, and nonrespondents were contacted for a telephone interview. Women from the San Francisco–Oakland region were administered questionnaires by telephone.

Next-of-kin were asked about the deceased patient’s implant status and for consent for medical record review. For women reporting breast implants, a medical record review of breast implant usage (including the date and type of implant received, and removal and replacement status) was conducted by trained abstractors for women who reported having a breast implant. Patient and tumor characteristics at diagnosis, including age, race/ethnicity, year, stage, histology, grade, radiation treatment, vital status, and cause of death, were obtained from the SEER database.

Although socioeconomic status (SES) is not routinely collected by SEER, we were able to assign census block group level measures of SES to a subset of subjects (1989 San Francisco Bay Area patients). Using data from the 1990 US Census, we examined the impact of living in census block groups characterized by low education, by poverty, and by occupation (median income, < 20% below poverty versus ≥ 20% below poverty; education, no high school diploma versus high school graduate; and occupation, blue collar versus nonblue collar [10]).

Patients who reported a breast implant were classified as having a particular type of implant if they had a unilateral implant, or if they had bilateral implants of the same type. Nineteen women with bilateral implants and discordant information about implant type were excluded from analyses stratified by the type of implant. An additional 133 women reporting implants but lacking implant information were excluded from all analyses requiring detailed implant information. The vital status (obtained annually through patient contact, death records, motor vehicle departments, voters’ registration records, and Social Security files) was determined from the December 1999 SEER Public Use Tape. The outcome variables were death due to breast cancer and death due to nonbreast cancer causes, as routinely ascertained by SEER and as defined by the International Classification of Disease, Ninth Revision, codes 174.0–174.9 for deaths occurring between 1983 through 1998, and by the International Classification of Disease, 10th Revision, code C509 for deaths occurring in 1999. Survival time was calculated from the date of diagnosis to the earliest date: death, last known to be alive, or 31 December 1999 (study cutoff date).

**Statistical analysis**

For descriptive analyses, women with breast implants were compared with those without implants on characteristics at diagnosis (SEER region of residence, age, year, race/ethnicity, marital status, stage, grade, and histology), using chi-square tests and Fisher’s exact test to assess differences. Two-sided $P < 0.05$ was considered statistically significant.

Of the 5862 patients eligible for the study, 4968 (84.7% of those eligible) patients participated in the study. After restricting the sample to women with primary invasive breast cancer and known survival time, a final sample size of 4385 patients were used for all survival analyses. Survival estimates were computed using the Kaplan–Meier method, and differences in survival were compared using the two-sided log-rank test. To adjust for patient and tumor characteristics, the risks of nonbreast cancer mortality and death due to breast cancer were modeled using Cox proportional hazards regression after censoring deaths from other or unknown causes. The assumption of proportional-ity was tested and met for all covariates used in the Cox analysis. All analyses were performed using SAS Version 8.02 (SAS Institute, Inc., Cary, NC, USA).

**Results**

**Study population**

Eighty-five percent of study-eligible women completed the interview. Responders were slightly older compared with
Table 1
Characteristics of mastectomy-treated breast cancer patients in the Surveillance, Epidemiology, and End Results (SEER) Breast Implant Surveillance Study, 1983–1989

| Characteristic                          | All eligible patients (n = 5862) | Study responders only (n = 4968) |
|----------------------------------------|---------------------------------|---------------------------------|
|                                        | Nonresponders (n = 894) | Responders (n = 4968) | P value | Women with breast implants (n = 1018) | Women without breast implants (n = 3950) | P value |
|                                        | n | % | n | % | n | % | n | % | n | % |
| SEER region                            |               |               |               |               |               |               |               |               |               |               |
| San Francisco–Oakland                  | 468 | 52.4 | 1853 | 37.3 | 0.0001 | 416 | 40.9 | 1437 | 36.4 | 0.0001 |
| Seattle–Puget Sound                    | 190 | 21.3 | 1663 | 33.5 |          | 374 | 36.7 | 1078 | 27.3 |          |
| Iowa                                   | 236 | 26.4 | 1452 | 29.2 |          | 228 | 22.4 | 1435 | 36.3 |          |
| Year of diagnosis                      |               |               |               |               |               |               |               |               |               |               |
| 1983                                   | 246 | 27.5 | 1102 | 22.2 | 0.0001 | 176 | 17.3 | 926  | 23.4 | 0.0003 |
| 1985                                   | 241 | 27.0 | 1152 | 23.2 |          | 244 | 24.0 | 908  | 23.0 |          |
| 1987                                   | 230 | 25.7 | 1405 | 28.3 |          | 319 | 31.3 | 1086 | 27.5 |          |
| 1989                                   | 177 | 19.8 | 1309 | 26.3 |          | 279 | 27.4 | 1030 | 26.1 |          |
| Age at diagnosis                       |               |               |               |               |               |               |               |               |               |               |
| < 35 years                             | 59  | 6.6  | 175  | 3.5  | 0.0001 | 88  | 8.6  | 87   | 2.2  | 0.0001 |
| 35–44 years                            | 231 | 25.8 | 919  | 18.4 |          | 334 | 32.8 | 585  | 14.8 |          |
| 45–54 years                            | 256 | 28.6 | 1545 | 31.1 |          | 370 | 36.4 | 1175 | 29.8 |          |
| 55–64 years                            | 348 | 38.9 | 2329 | 46.9 |          | 226 | 22.2 | 2103 | 53.2 |          |
| Mean age at diagnosis (years)          | 49.9 | -   | 52.1 | -   | 0.0001 | 46.7 | -   | 53.4 | -   | 0.0001 |
| Race/ethnicity                         |               |               |               |               |               |               |               |               |               |               |
| Non-Hispanic White                     | 670 | 74.9 | 4444 | 89.5 | 0.0001 | 959 | 94.2 | 3485 | 88.2 | 0.0001 |
| Non-Hispanic Black                     | 78  | 8.7  | 150  | 3.0  |          | 13  | 1.3  | 137  | 3.5  |          |
| Hispanic                               | 38  | 4.3  | 131  | 2.6  |          | 20  | 2.0  | 111  | 2.8  |          |
| Asian/Pacific Islander                 | 86  | 9.6  | 179  | 3.6  |          | 16  | 1.6  | 163  | 4.1  |          |
| Other/unknown                          | 22  | 2.5  | 64   | 1.3  |          | 10  | 1.0  | 54   | 1.4  |          |
| Stage at diagnosis                     |               |               |               |               |               |               |               |               |               |               |
| In situ                                | 78  | 8.7  | 567  | 11.4 | 0.04   | 199 | 19.6 | 368  | 9.3  | 0.0001 |
| Localized                              | 562 | 62.9 | 3141 | 63.2 |          | 601 | 59.0 | 2540 | 64.3 |          |
| Regional                               | 241 | 27.0 | 1209 | 24.3 |          | 211 | 20.7 | 998  | 25.3 |          |
| Unstaged                               | 13  | 1.5  | 51   | 1.0  |          | 7   | 0.7  | 44   | 1.1  |          |
| Histology                              |               |               |               |               |               |               |               |               |               |               |
| Infiltrating ductal                    | 687 | 76.9 | 3638 | 73.2 | 0.04   | 695 | 68.3 | 2943 | 74.5 | 0.0001 |
| Lobular                                | 44  | 4.9  | 364  | 7.3  |          | 106 | 10.4 | 258  | 6.5  |          |
| Infiltrating ductal and lobular        | 35  | 3.9  | 195  | 3.9  |          | 54  | 5.3  | 141  | 3.6  |          |
| Not otherwise specified/other          | 128 | 14.3 | 771  | 15.5 |          | 163 | 16.0 | 608  | 15.4 |          |
| Grade                                  |               |               |               |               |               |               |               |               |               |               |
| Well differentiated                    | 17  | 1.9  | 150  | 3.0  | 0.02   | 29  | 2.9  | 121  | 3.1  | 0.91   |
| Moderately differentiated              | 128 | 14.3 | 712  | 14.3 |          | 137 | 13.5 | 575  | 14.6 |          |
| Poorly differentiated                  | 144 | 16.1 | 824  | 6.6  |          | 169 | 16.6 | 655  | 16.6 |          |
| Undifferentiated                      | 17  | 1.9  | 185  | 3.7  |          | 39  | 3.8  | 146  | 3.7  |          |
| Unknown grade                          | 588 | 65.8 | 3097 | 62.3 |          | 644 | 63.3 | 2453 | 62.1 |          |
nonresponders. They also were more often non-Hispanic white, were diagnosed with in situ cancers, were less likely to have more than one primary tumor and were more likely to have lived until the end of the study period (Table 1).

Among the responders, 20% received a breast implant (Table 1). Their mean age at diagnosis was 47 years, and they were younger, on average, than women without implants. Somewhat higher proportions of women with implants were of non-Hispanic white race/ethnicity, resided in the San Francisco–Oakland region, were diagnosed in the late 1980s, and had tumors of lobular histology than women without implants. The percentage of women with in situ breast cancer was twice as high in women with breast implants as in nonimplanted women. In addition, women with implants were less likely to receive radiation therapy or to be diagnosed with more than one primary tumor.

**Implant characteristics and usage**
Implant information was obtained for 866 women; these women were slightly older and more likely to be living than women with unknown implant information. Among the 1143 breast implants received (Table 2), the most common types were silicone gel and double lumen. The majority of women (67%) received a unilateral implant a median of 9.6 months after breast cancer diagnosis. Approximately one-third of the women had an implant removed; the majority of these women chose to have the implant replaced. Silicone-filled implants were removed for 48% of women, although saline-filled tissue expanders (temporary implants) may be incorrectly included in this category. Fifty-four percent of women with ‘other’ implants had them removed, and 49% had them replaced.

**Survival**
At the end of the follow-up period, 231 (5.3%) patients did not have complete follow-up. Twenty-eight percent of all patients died, with nearly two-thirds of these deaths due to breast cancer (Table 3). Women with implants had a similar distribution of causes of death to those without implants (Table 3), except for a significantly larger proportion of deaths due to suicide – although this was based on a small number of deaths (0.4% versus 0.03% of all patients, respectively; $P = 0.02$). Among the 4385 patients with invasive breast cancer and known survival time, the 817 (19%) receiving a breast implant experienced better survival than women without implants, after adjustment for age at diagnosis (Fig. 1).

The multivariate Cox proportional hazards model showed that implant status was a significant factor associated with improved survival for deaths due to breast cancer and for nonbreast cancer mortality (Table 4). Risk of breast cancer death in women with implants was approximately one-half of that for women without implants, after adjustment for multiple clinical and sociodemographic factors. Age at diagnosis, stage, grade, histology, and radiation therapy were significant predictors of breast cancer death in this cohort, as they were for women without implants. With the exception of age, results were similar when modeled for nonbreast cancer mortality, although hazard rate ratios for women with implants were slightly higher overall. Among women with implants, the type of breast implant did not significantly impact survival, although women receiving saline implants had marginally lower risks than women receiving silicone gel implants.

For the subsample of 384 San Francisco Bay Area study subjects for whom we were able to assign census-level SES indicators, risk of death among women with breast implants compared with that among women without implants continued to be reduced (hazard ratio, 0.50; 95% confidence interval, 0.20–1.25) after adjustment for census block-group level SES variables.
Discussion

In this large population-based study of breast cancer patients treated with mastectomy, risks of breast cancer death and nonbreast cancer mortality were lower in women with implants than in women without implants, after adjustment for potential confounders. Postmastectomy breast implants were used by one-fifth of patients who were slightly younger at diagnosis and were more likely to be of white race/ethnicity and to have in situ disease than women without implants. The silicone gel-filled implant was the most common type of implant received.

Although breast reconstruction has been shown to provide psychosocial benefits to breast cancer survivors [11-13], concerns have been raised that breast implants may increase the risk of local complications and systemic diseases, including certain cancers and autoimmune diseases [2,3,14,15]. Breast implants have been suggested to interfere with mammography, thereby facilitating delayed detection of breast tumors, and, consequently, decreased survival [16]. Despite recent Institute of Medicine recommendations to continue monitoring women with breast implants and to evaluate the potential long-term health effects [1], few research studies have addressed long-term health outcomes in this group. Moreover, these studies were often conducted on small, nonrepresentative samples without detailed information on implant type and history of use.

Georgiade and colleagues found that the survival time for 101 women undergoing breast reconstruction with breast implants was nonsignificantly better than that for 377 women without reconstruction, after adjustment for tumor grade, histology, lymph node involvement, and age at diagnosis, and after a median of 3 years of follow-up [6]. With a median of 13 years of follow-up, Petit and colleagues found that the risk of breast cancer death was marginally lower in 146 women who underwent breast reconstruction with silicone gel-filled implants than in a matched group without implants (relative risk, 0.6; 95% confidence interval, 0.3–1.1) [7]. Vandeweyer and colleagues compared 49 women who received saline-filled breast implants following mastectomy with a matched group of women who did not. They found no difference in the number of breast cancer deaths between the two groups [8]. In a matched analysis of 176 women with a mean of almost 6 years of follow-up, Park and colleagues found that women with breast implants after mastectomy had approximately a 70% reduced risk of death compared with women without implants (relative risk, 0.33; 95% confidence interval, 0.11–0.92) [9].

Our finding of better survival in women with breast implants is consistent with most of this research [6-8]. However, our study has the substantial advantages of being population-based, being large, having a long follow-up (median, 12.4 years), and including information on implant type and the implant removal and replacement. It is thus well suited to address public health concerns regarding the long-term survival and use of breast implants in women with early-stage, mastectomy-treated breast cancer. Such concerns have recently been re-evaluated in conjunction with the Food and Drug Administration hearings regarding the safety of silicone gel breast implants and their availability for the general market [17,18].

One explanation for our finding of reduced mortality in patients with breast implants may relate to self-selection rather than to a causal role of implants. Although most women who receive mastectomy are eligible to receive breast implants as part of breast reconstruction, surgeons may not recommend this surgery to women with health conditions such as obesity or a recent history of smoking that may contribute to postoperative complications, and may thus impact on survival [19,20]. In our data, the possibility of self-selection based on smoking is supported by the

| Table 2  | Characteristics of breast implants in mastectomy-treated breast cancer patients in the Surveillance, Epidemiology, and End Results Breast Implant Surveillance Study, 1983–1989 (n = 866)a |
|----------|---------------------------------------------------------------------------------------------------|
|          | Silicone gel (n = 333) | Saline (n = 149) | Double lumen (n = 314) | Other (n = 33) | Unknown (n = 37) | P value |
|          | n | % | n | % | n | % | n | % | n | % |
| Prevalence of type | 38.4 | 17.2 | 36.3 | 3.8 | 4.3 |
| Implant removal status | | | | | | | | | |
| No known removal | 244 | 73.3 | 77 | 51.7 | 216 | 64.9 | 15 | 45.5 | 25 | 67.6 | 0.0001 |
| Removed | 89 | 26.7 | 72 | 48.3 | 98 | 31.2 | 18 | 54.5 | 12 | 32.4 |
| Implant replacement status | | | | | | | | | |
| No known replacement | 262 | 78.7 | 87 | 58.4 | 237 | 75.4 | 17 | 51.5 | 26 | 70.3 | 0.0001 |
| Replaced | 71 | 21.3 | 62 | 41.6 | 77 | 24.5 | 16 | 48.5 | 11 | 29.7 |

aExcludes 133 patients with missing implant information and 19 patients with bilateral implants of disordant types
higher proportions of deaths from respiratory cancers and chronic obstructive pulmonary diseases in women without breast implants (Table 3). Further investigation is warranted for lifestyle factors (e.g. smoking, diet) and for comorbidities that may account for the survival advantage seen in women with breast implants.

In the present study, women with breast implants had a significant excess proportion of deaths due to suicide compared with women without implants. This finding, albeit based on small numbers, is consistent with observations from studies conducted in cosmetic breast implant patients [21,22] and suggests psychiatric consultation should also be considered for breast cancer patients seeking reconstructive surgery with breast implants. In any case, future studies with larger sample sizes are needed to confirm this finding in the breast reconstruction population.

An important bias of common concern in retrospective cohort studies is loss to follow-up. A total 231 (5.3%) of the 4385 patients included in the survival analysis did not have complete follow-up at the end of the study period. However, because of the relatively small percentage of patients lost to follow-up, we know that bias due to loss to follow-up has little impact on our survival findings since we found no substantial change in hazards ratios when we assumed the worst-case scenario that all patients lost to follow-up had all died or assumed that all patients lost to follow-up all lived until the end of the study period.

Figure 1
Age-adjusted breast cancer survival curve by breast implant status, 1983–1989.

![Survival Probability by Breast Implant Status](image)

Additional unmeasured confounders related to the increased medical care of women with breast implants could explain the protective association of breast implants with cancer survival. Because women with breast implants may be more closely followed in their medical care, they may have recurrences diagnosed and treated earlier; thus they may experience better survival than women without implants. Although our study lacked information on breast cancer recurrence, we were able to examine the impact of subsequently diagnosed primary breast tumors. We observed that the proportion of women with two or more primary breast tumors was lower in women with breast implants than in women without (15% and 21%, respectively).

To address the possibility that a higher incidence of subsequently diagnosed primary breast tumors impacted survival in women without breast implants, we limited survival analyses to women with only one primary tumor ($n = 3535$) and found a consistently reduced risk of breast cancer death associated with breast implant usage (hazard ratio, 0.54; 95% confidence interval, 0.42–0.68), after adjusting for similar prognostic factors. Our findings also are consistent
with results from studies showing a reduced risk of death in augmentation mammoplasty patients with at least 10 years of follow-up compared with the general population [26-29]. Furthermore, psychological factors underlying a woman's decision to obtain breast implants [30,31], including body image concerns and self-esteem, may play a role in lifestyle behaviors relevant to survival, although the extent to which they directly impact survival is unclear.

Several biological mechanisms have been proposed to explain how breast implants may influence survival outcomes [16,26,32,33]. Breast implants may stimulate a local immune response in which cancer cells are more likely to be destroyed [34]. Breast implants may compress breast tissue, reducing the flow of blood and thereby slowing the rate of cell or tumor growth. Breast implants may decrease the temperature of the breast by separating the breast tis-

### Table 3

|                         | Women with breast implants (n = 817) | Women without breast implants (n = 3568) | Total (n = 4385) | P value\(a\) |
|-------------------------|-------------------------------------|----------------------------------------|-----------------|--------------|
|                         | n        | %       | n        | %       | n        | %       |               |              |
| **Alive**               |          |         |          |         |          |         |               |              |
| Total                   | 676      | 82.3    | 2498     | 70.0    | 3174     | 72.4    |              | < 0.0001     |
| **Deceased**            |          |         |          |         |          |         |               |              |
| All malignant cancers   |          |         |          |         |          |         |               |              |
| Digestive system        | 2        | 0.2     | 32       | 0.9     | 34       | 0.8     |              | 0.08         |
| Respiratory             | 3        | 0.4     | 51       | 1.4     | 54       | 1.2     |              | 0.01         |
| Breast                  | 101      | 12.4    | 703      | 19.7    | 804      | 18.3    |              | < 0.0001     |
| Female genital          | 4        | 0.5     | 20       | 0.6     | 24       | 0.5     |              | 0.80         |
| Kidney                  | -        | -       | 2        | 0.1     | 2        | 0.2     |              | -            |
| Brain                   | -        | -       | 7        | 0.2     | 7        | 0.2     |              | -            |
| Melanoma                | 1        | 0.1     | 2        | 0.1     | 3        | 0.1     |              | 0.46         |
| Multiple myeloma        | -        | -       | 3        | 0.1     | 3        | 0.1     |              | -            |
| Non-Hodgkin's lymphoma  | -        | -       | 3        | 0.1     | 3        | 0.1     |              | -            |
| Leukemia                | 2        | 0.2     | 2        | 0.1     | 4        | 0.1     |              | 0.16         |
| Diabetes mellitus       | 2        | 0.2     | 13       | 0.4     | 15       | 0.3     |              | 0.60         |
| Circulatory system      |          |         |          |         |          |         |               |              |
| Heart disease           | 4        | 0.5     | 65       | 1.8     | 69       | 1.6     |              | 0.01         |
| Cerebrovascular disease | 2        | 0.2     | 14       | 0.4     | 16       | 0.4     |              | 0.75         |
| Atherosclerosis         | -        | -       | 3        | 0.1     | 3        | 0.1     |              | -            |
| Respiratory disease     |          |         |          |         |          |         |               |              |
| Pneumonia/influenza     | 1        | 0.1     | 10       | 0.3     | 11       | 0.3     |              | -            |
| Chronic obstructive pulmonar y disease | 2 | 0.2 | 23 | 0.6 | 25 | 0.6 |              | 0.21         |
| Digestive system disease |          |         |          |         |          |         |               |              |
| Stomach/duodenal ulcers | -        | -       | 3        | 0.1     | 3        | 0.1     |              | -            |
| Chronic liver disease   | 1        | 0.1     | 7        | 0.2     | 8        | 0.2     |              | -            |
| Nephritis               | -        | -       | 7        | 0.2     | 7        | 0.2     |              | -            |
| All external causes     |          |         |          |         |          |         |               |              |
| Accidents               | -        | -       | 4        | 0.1     | 4        | 0.3     |              | -            |
| Suicides                | 3        | 0.4     | 1        | 0.03    | 4        | 0.3     |              | 0.02         |
| Other cause of death    | 5        | 0.6     | 38       | 1.1     | 43       | 3.6     |              | 0.26         |
| Unknown cause of death  | 7        | 0.9     | 32       | 0.9     | 39       | 3.2     |              | 0.91         |

Sum of deaths will not add to overall total since data are only shown for causes with at least two deaths in either group of women.

\(a\) P value for chi-square test or, where appropriate, Fisher’s Exact Test.
**Table 4**

Proportional hazards regression model: hazard ratio and 95% confidence interval (CI) for mastectomy-treated breast cancer patients in the Surveillance, Epidemiology, and End Results (SEER) Breast Implant Surveillance Study, 1983–1989 (n = 4385)\(^a\)

| Covariate | Distribution of sample | Breast cancer mortality | Non-breast cancer mortality |
|-----------|------------------------|-------------------------|-----------------------------|
|           | \(n\) | % | Hazard ratio | 95% confidence interval | Hazard ratio | 95% confidence interval |
| Implant status | | | | | | |
| No (referent) | 3568 | 81.4 | 1.00 | - | 1.00 | - |
| Yes | 817 | 18.6 | 0.54 | 0.43–0.67 | 0.59 | 0.41–0.85 |
| Age at diagnosis | | | | | | |
| \(< 35\) years | 163 | 3.7 | 1.95 | 1.42–2.69 | 0.24 | 0.09–0.66 |
| 35–44 years | 805 | 18.4 | 1.29 | 1.07–1.56 | 0.19 | 0.12–0.30 |
| 45–54 years | 1332 | 30.4 | 1.02 | 0.86–1.20 | 0.35 | 0.26–0.46 |
| 55–64 years (referent) | 2085 | 47.6 | 1.00 | - | - | - |
| Race/ethnicity | | | | | | |
| Non-Hispanic White (referent) | 3915 | 89.3 | 1.00 | - | 1.00 | - |
| Non-Hispanic Black | 131 | 3.0 | 0.90 | 0.58–1.39 | 1.58 | 0.93–2.68 |
| Hispanic | 120 | 2.7 | 1.37 | 0.93–2.04 | 1.22 | 0.64–2.33 |
| Non-Hispanic Asian | 160 | 3.7 | 0.86 | 0.57–1.31 | 0.68 | 0.33–1.39 |
| Other/unknown | 59 | 1.4 | 0.75 | 0.37–1.50 | 1.36 | 0.60–3.07 |
| Stage at diagnosis | | | | | | |
| Local (referent) | 3126 | 71.3 | 1.00 | - | 1.00 | - |
| Regional | 1208 | 27.6 | 2.28 | 1.97–2.63 | 1.86 | 1.65–2.09 |
| Unstaged | 51 | 1.2 | 3.80 | 2.41–5.99 | 3.35 | 2.28–4.92 |
| SEER region | | | | | | |
| San Francisco–Oakland (referent) | 1624 | 37.0 | 1.00 | - | 1.00 | - |
| Seattle–Puget Sound | 1423 | 34.1 | 1.10 | 0.91–1.32 | 1.17 | 0.91–1.51 |
| Iowa | 1268 | 28.9 | 1.15 | 0.96–1.38 | 0.86 | 0.66–1.13 |
| Year of diagnosis | | | | | | |
| 1983 (referent) | 1037 | 23.7 | 1.00 | - | 1.00 | - |
| 1985 | 1003 | 22.9 | 1.06 | 0.88–1.29 | 0.96 | 0.73–1.27 |
| 1987 | 1232 | 28.1 | 0.97 | 0.80–1.18 | 1.05 | 0.78–1.40 |
| 1989 | 1113 | 25.4 | 0.84 | 0.68–1.04 | 1.12 | 0.80–1.56 |
| Grade | | | | | | |
| Well differentiated (referent) | 142 | 3.2 | 1.00 | - | 1.00 | - |
| Moderately differentiated | 695 | 15.9 | 2.16 | 1.13–4.13 | 0.75 | 0.42–1.34 |
| Poorly differentiated | 817 | 18.6 | 3.45 | 1.82–6.53 | 0.79 | 0.44–1.40 |
| Undifferentiated | 182 | 4.2 | 4.97 | 2.52–9.78 | 1.23 | 0.60–2.52 |
| Unknown | 2549 | 58.1 | 2.41 | 1.28–4.52 | 0.85 | 0.50–1.45 |
| Histology | | | | | | |
| Ductal (referent) | 3253 | 74.2 | 1.00 | - | 1.00 | - |
| Lobular | 279 | 6.4 | 1.09 | 0.82–1.44 | 1.26 | 0.88–1.81 |
| Mixed ductal and lobular | 167 | 3.8 | 1.06 | 0.74–1.53 | 0.66 | 0.32–1.33 |
| Other | 686 | 15.6 | 0.71 | 0.57–0.89 | 1.01 | 0.76–1.34 |
Table 4 (Continued)

Proportional hazards regression model: hazard ratio and 95% confidence interval (CI) for mastectomy-treated breast cancer patients in the Surveillance, Epidemiology, and End Results (SEER) Breast Implant Surveillance Study, 1983–1989 (n = 4385)\(^a\)

| Radiation therapy | Type of breast implant\(^b\) | Hazard ratio (95% CI) | \(P\) value |
|-------------------|-----------------------------|-----------------------|-------------|
| No (ref)          | Silicone gel (referent)      | 1.00                  | -           |
| Yes               | 1.43                        | 1.15–1.78             | 0.84        |
| Unknown           | 4.68                        | 1.74–12.60            | -           |
|                   | Saline                      | 1.01                  | -           |
|                   | 0.44–2.34                   | 1.75                  | 0.29–10.39  |
|                   | Double lumen                | 1.49                  | -           |
|                   | 0.83–2.70                   | 3.13                  | 0.91–10.78  |
|                   | Other                       | 1.11                  | -           |
|                   | 0.24–5.03                   | -                     | -           |
|                   | Unknown                     | 2.03                  | -           |
|                   | 0.71–5.79                   | 6.59                  | 1.17–37.06  |

\(^a\)Adjusted for age, year, stage at diagnosis, race/ethnicity, SEER region, tumor grade, histology, and radiation therapy. 
\(^b\)Model (n = 689) restricted to women with implant-specific information and concordant bilateral implants.

The author(s) declare that they have no competing interests.

**Authors’ contributions**

SLG, DWW, JLS, and CFL implemented the study and acquired the data. GML, SLG, and CDO participated in the design and conceptualization of the study. GML performed the statistical analysis and drafted the manuscript. GML, SLG, CDO, and THMK participated in the analysis and interpretation of the data. All authors read and approved the final manuscript.

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