TECHNOLOGY *REPORT*

Issue 15 July 2001

A Population-based Cohort Study of Surveillance Mammography After Treatment of Primary Breast Cancer

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Cite as: Paszat L, Grunfeld E, van Walraven C, Coyle D, Sawka C, Yun J, McGahan L, Noorani H. **A population-based cohort study of surveillance mammography after treatment of primary breast cancer**. Ottawa: Canadian Coordinating Office for Health Technology Assessment; 2001. Technology report no 15.

Legal Deposit - 2001
National Library of Canada
ISBN 1-894620-03-8 (print)
ISBN 1-894620-04-6 (online)
Publications Mail Agreement Number: 40026386

Canadian Coordinating Office for Health Technology Assessment

A Population-based Cohort Study of Surveillance Mammography After Treatment of Primary Breast Cancer

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July 2001

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ACKNOWLEDGEMENTS

Expertise in information science provided by Janet Joyce, MLS, is gratefully acknowledged.

In addition to financial and support in kind from the Canadian Coordinating Office for Health Technology Assessment, this research has been supported in kind by the Institute for Clinical Evaluative Sciences in Ontario, the Radiation Oncology Research Unit (Queen's University at Kingston, Canada), the Ontario Cancer Registry, and Cancer Care Ontario. Dr. Paszat and Dr. Grunfeld are career scientists of the Ontario Ministry of Health. Dr. Grunfeld is a clinician scientist of Cancer Care Ontario.

EXECUTIVE SUMMARY

Annual surveillance mammography after the diagnosis and treatment of operable primary breast cancer has been recommended by the Canadian Steering Committee on Clinical Practice Guidelines for the Care and Treatment of Breast Cancer, and by the American Society of Clinical Oncology. Surveillance mammography refers to routine annual mammography for breast cancer survivors who have no symptoms or clinical findings of breast cancer. This differs from screening mammography which is performed among women who have never had breast cancer at any time in their lives.

The purpose of surveillance mammography is to detect recurrent cancer in the breast after lumpectomy, and to detect contralateral primary breast cancer, before clinical findings appear. The guidelines assumed that surveillance mammography would optimize patient outcomes. However, there has been no evidence of benefit from surveillance mammography. Compliance with this guideline has not been evaluated and the outcomes of surveillance mammography have not been assessed.

This report presents a population-based cohort study of the rates of use of surveillance mammography, and the rates of subsequent breast surgery following surveillance mammography. The study links electronic administrative health services databases from (1) the Ontario Cancer Registry, (2) the Canadian Institute for Health Information, (3) the Radiation Oncology Research Unit at Queen's University at Kingston, (4) the Ontario Health Insurance Plan, and (5) the 1991 Canadian Census. This report is the second of a two-part research project, the first of which was a systematic literature review evaluating the practice of routine surveillance mammography and its impact on disease outcomes published in June 2000.[1]

Although practice guidelines have recommended annual surveillance mammography, we found that the median interval between consecutive surveillance mammograms is more than one year (14.7 months). We found that women diagnosed at age 70 or older, and women treated by lumpectomy without radiation therapy (RT) were less likely to use surveillance mammography compared to other women treated for breast cancer.

The data show long intervals between the date of surveillance mammography and the dates of breast biopsies (median 2.97 months), lumpectomies (median 2.55 months) and mastectomies (median 2.50 months). The reasons for the delay cannot be explained from the data. It is unknown whether the delay is harmful or not.

The data also show two-thirds of subsequent breast surgery performed for women previously treated for breast cancer occur more than four months following surveillance mammography. The reason for this finding is not clear, but suggests a hypothesis that surveillance mammography does not detect all recurrences in the breast, or all new primary contralateral breast cancers. If this hypothesis is true, the effectiveness of surveillance mammography might be less than desired.

The data also suggest a hypothesis that the women at highest risk for subsequent breast surgery are least likely to use surveillance mammography. The data show that the risk of subsequent breast surgery is highest for women diagnosed at age 70 or older, and for women who were treated by lumpectomy without RT. This is ironic, because these are the women who are least likely to undergo surveillance mammography.

Based on these findings, the following indicators should be monitored.

(1) The rates of use of surveillance mammography among the women at highest risk for recurrence of cancer in the breast or for contralateral new primary breast cancer should be monitored, because these are the women who might benefit the most from surveillance mammography but they are least likely to receive it.

(2) The interval between surveillance mammography and subsequent breast surgery should be monitored, because delay between surveillance mammography and surgery may be inappropriate.

(3) The number of women who undergo subsequent lumpectomy or mastectomy, which is apparently precipitated by surveillance mammography within the preceding four months, should be monitored and compared to the number who undergo surgery without surveillance mammography during the previous four months, because this may reflect the relative effectiveness of surveillance mammography.

Monitoring these indicators in each province is feasible, using linked electronic databases of hospital discharge abstracts and billing claims submitted to the provincial health care plans.

Abbreviations

CI	confidence intervals
CIHI	Canadian Institute for Health Information
ICD	international classification of diseases
ICES	Institute for Clinical Evaluative Sciences
OCR	Ontario Cancer Registry
OHIP	Ontario Health Insurance Plan
OR	odds ratio
RORU	Radiation Oncology Research Unit
RPDB	Registered Persons Database
RR	relative risk
RT	radiation therapy

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1. INTRODUCTION

The Canadian Steering Committee on Clinical Practice Guidelines for the Care and Treatment of Breast Cancer recommended annual surveillance mammography after completion of treatment for primary breast cancer.[2] Surveillance mammography would be bilateral for women treated by lumpectomy +/- RT, and unilateral (i.e. contralateral) for women treated by mastectomy. Similar recommendations have been made by other expert panels[3] and by the authors of retrospective, institutionally-based case series studies of the follow-up and results of treatment for primary breast cancer.[4-7] The purpose of surveillance mammography is to detect ipsilateral breast cancer recurrence after breast conserving surgery and to detect contralateral primary breast cancer at the earliest possible time, in an effort to optimize clinical results and patient outcomes.

There is no evidence of benefit from surveillance mammography; however, the effectiveness of surveillance mammography has been extrapolated from data on screening mammography, and from retrospective case series studies. Recurrent tumours detected by surveillance mammography are smaller and have less invasive characteristics than recurrences detected by physical examination.[8] However, the literature containing these observations suffers from lead time, length, referral, and selection biases. There is no direct evidence of (1) the possible survival benefit from early detection of local recurrence in the treated breast; (2) the impact of early detection upon local treatment for local recurrence; (3) the rate of false-negative surveillance mammography; (4) the effect of false positive surveillance mammograms on the quality of life of women with breast cancer; (5) the effect of surveillance mammography on resource utilization in the health care system; or (6) compliance with the recommendation for surveillance mammography. Additionally, mammography is known to have decreased sensitivity in premenopausal women, and reduced sensitivity and specificity in the irradiated breast.

Surveillance mammography is thought to detect contralateral primary breast cancers at an earlier stage than would be detected by clinical examination.[5,6] Inferring from data on screening mammography, reduced mortality would be expected; however, this has never been demonstrated. There are competing hazards of mortality among women whose ipsilateral primary breast cancer was diagnosed at a more advanced stage than the contralateral cancer, so the mortality reduction might not be realized.

There are sparse population-based data on compliance with the recommendation for surveillance mammography, and no population-based data on patient outcomes after surveillance mammography. A single-institution-based study in France reported that 68% of cases undergoing frequent follow-up received surveillance mammography during the first year after treatment of primary breast cancer, 80% during the second year, and 68% during the third year.[9] A study of women, aged 65 years and older at diagnosis of breast cancer, showed that 62% of women had a surveillance mammogram in each of the first two years after diagnosis of breast cancer, 23% had one surveillance mammogram during the first two years, and 15% had none.[10]

This document reports the rates of surveillance mammography after the treatment of primary breast cancer in Ontario, and also reports the rates of subsequent breast cancer surgery following surveillance mammography in Ontario. It is the second of a two-part research project, the first of which was a systematic literature review evaluating the practice of routine surveillance mammography and its impact on disease outcomes published in June 2000.[1]

2. OBJECTIVES

1. To describe the rates of use of annual surveillance mammography following the treatment of primary breast cancer in Ontario.
2. To describe the rates of use of subsequent breast surgery following annual surveillance mammography.

3. METHODS

3.1 Data Sources

All women with new cases of invasive breast cancer diagnosed in Ontario between July 1, 1991 and December 31, 1993 were identified from the electronic records of the Ontario Cancer Registry (OCR). None had a previous diagnosis of breast cancer. The methods of case ascertainment by the OCR are described in Clarke et al.[11]

These records were linked to: (1) electronic hospital discharge summaries from the Canadian Institute for Health Information (CIHI) from every hospital in Ontario; (2) every electronic record of radiation therapy from every RT facility in Ontario compiled and processed by the Radiation Oncology Research Unit (RORU) of Queen's University at Kingston, Ontario; (3) electronic billing records from the Ontario Health Insurance Plan (OHIP); (4) median household income data from the 1991 Canadian Census; and (5) the Registered Persons Database (RPDB) held at the Institute for Clinical Evaluative Sciences (ICES) in Toronto, Ontario. Record linkage was based on the unique numeric identifier of the OCR (RORU records), encrypted health card numbers (CIHI, OHIP, and RPDB records), and postal codes (census records).

The OCR records contain the following variables: International Classification of Diseases (ICD-9) cancer diagnosis, date of diagnosis, age at diagnosis, residence at diagnosis (postal code, Ministry of Health residence code, and county code). The OCR records do not contain the stage of breast cancer, the ascertainment of recurrent breast cancer, or the diagnosis of new ipsilateral or contralateral breast cancer.

Regions of Ontario were defined by actual referral patterns of cancer patients to cancer centres. Each case was assigned to a region of the province based on her residential postal code. All analyses were performed with cases assigned to regions of residence even if treatment was performed outside the region.

From the electronic hospital discharge summaries, we identified procedure codes for breast surgery. The validity of coding of breast cancer surgery is described by Holowaty et al;[12] over 97% of procedures coded in the electronic records agreed with the original hospital charts to which they were compared.

We ranked surgical procedure codes according to the extent of surgery on the breast. The maximal surgical procedure was mastectomy, followed by lumpectomy, followed by biopsy or lesser procedures. For each woman, we selected the maximal procedure performed on the breast within four months following the diagnosis of breast cancer. We selected the four months following the date of diagnosis to ensure that we did not exclude any delayed breast surgery intended to be part of the initial treatment from breast cancer, and to ensure that we did exclude any surgery for recurrent breast cancer. The surgical records do not distinguish surgery on the right breast from surgery on the left.

Women having neither mastectomy nor lumpectomy records within four months following diagnosis were not included in the study population, and comprised 15%.

Lumpectomy and mastectomy procedures performed during the years following the diagnosis and treatment of primary breast cancer were also identified.

ICD-9 diagnostic codes for other chronic illnesses recorded during any admissions occurring between one year prior to the diagnosis of breast cancer and four months following the first diagnosis of breast cancer were identified from CIHI records. They are of interest to the study because they represent comorbidity which may influence the health of women diagnosed and treated for breast cancer, and may predict their use of health services following the diagnosis of cancer. The electronic record of the presence of diagnostic codes reflecting other chronic illnesses may be used to compute the Charlson comorbidity score for each case.[13] This score may be used as a descriptive variable to identify women with breast cancer who have other health problems that might explain their rates of use of procedures such as surveillance mammography.

All women having post-lumpectomy RT within twelve months following diagnosis were identified from RORU electronic RT records. The RORU RT records are valid; only 1% of cancer patients had a paper chart record of RT without an electronic record of RT.[14,15]

The records of women in the study population were linked to Ontario provincial medicare (OHIP) billing data by means of unique encrypted health card numbers. Billing records contain the service code and date. The files include all billing records up to December 31, 1998. Outpatient billing records were identified for mammography, breast ultrasound, and breast biopsy following the diagnosis and treatment of primary breast cancer during subsequent years of followup. Outpatient billing records for chemotherapy were also identified. If there was a billing record for chemotherapy within four months after the date of the breast surgery, the woman was identified as receiving adjuvant chemotherapy.

Data on median household income from the 1991 Canadian census were linked to case records via a conversion program relating postal codes and residence codes to census enumeration areas and census subdivisions.

Death ascertainment was by the RPDB which is complete for deaths up to December 31, 1998.

3.2 Study Population and the Treatment of the Primary Breast Cancer

Ontario women newly diagnosed with breast cancer for the first time between July 1, 1991 and December 31, 1993 who underwent mastectomy or lumpectomy within four months following the diagnosis of breast cancer, were followed for: (1) surveillance mammography; (2) subsequent diagnostic procedures on the breast; (3) subsequent breast surgery; and (4) death from any cause, up to December 31, 1998. The study population was described by initial treatment of the primary breast cancer (surgery, RT or adjuvant chemotherapy), by age at diagnosis, Charlson comorbidity score, quintile of median household income, and region of residence at the time of diagnosis. These characteristics have been shown to influence the use of health care services by women with breast cancer.[14-17]

3.3 Survival Analysis of the Study Population

The survival times of the study population were described overall and by population characteristics using life table methods and Cox proportional hazards regression analysis. Survival analysis is conducted to illuminate the study population, and to see if the survival experience of this population is consistent with the expectation of survival in a cohort of women with early stage breast cancer. All analyses of time to death counted deaths from any cause. We conducted survival analysis to help describe the study population. We did not compare the survival experience of women who did or did not use surveillance mammography, because the comparison would be biased. The choice of initial treatment and compliance with surveillance mammography may be related to the physician's and/or patient's perception of the patient's prognosis and life expectancy.

For the same reasons, the rates of use of: (1) surveillance mammography; (2) diagnostic procedures; and (3) subsequent breast surgery during the follow-up annual conditional survival cohorts were NOT included as independent variables in the multivariate survival analyses.

3.4 Operational Definition of Surveillance Mammography

All mammograms in Ontario are performed in public hospitals or in private radiology clinics. No mammography is performed at cancer centres in Ontario. All mammography except screening mammography is billed to OHIP by the radiologist.

The first surveillance mammogram for each woman was defined as the first OHIP mammogram billing record dated six months or later following the diagnosis of primary breast cancer.

Subsequent surveillance mammograms for each woman were identified as billing records for mammograms dated at least 11 months since the most recent previous mammogram, and without a billing record for breast ultrasound, biopsy, lumpectomy or mastectomy within the month preceding the mammogram or on the same date.

All other mammography billing records for each woman were deemed to represent diagnostic mammograms performed because of clinical findings or to follow up mammographic abnormalities.

3.5 Analysis of the Rates of Use of Surveillance Mammography

Annual conditional survival cohorts were created in order to report the rates of use of surveillance mammography and other procedures. The first annual conditional survival cohort begins six months following the diagnosis of the primary breast cancer. Each woman alive throughout the following year is assigned to the first annual conditional survival cohort. Women alive throughout each subsequent year are assigned to each of the subsequent annual conditional survival cohorts.

Univariate and bivariate analyses were performed on the proportion of women using surveillance mammography in each conditional survival cohort, by the treatment of the primary breast cancer and by the charateristics of the study population. Multiple logistic regression analysis was performed on the use of surveillance mammography in each conditional survival cohort, with these independent variables: initial treatment of the primary breast cancer, age, Charlson comorbidity score, income quintile and region of residence at diagnosis.

We performed univariate analyses on the interval of time between successive episodes of surveillance mammography.

3.6 Operational Definitions of the Outcomes of Surveillance Mammography: the Rates of Use of Subsequent Breast Surgery Following Surveillance Mammography

We identified billing records for diagnostic mammography, breast ultrasound, breast biopsy, lumpectomy, and mastectomy occurring during the follow-up of the study population. We hypothesized that billing records for these procedures which occurred within four months following surveillance mammography might represent procedures precipitated by the interpretation of the surveillance mammography, and that billing records beyond four months following surveillance mammography would likely not represent procedures on the breast precipitated by the surveillance mammography. We examined the time from surveillance mammography to any of the other procedures on the breast for each woman.

We hypothesized that lumpectomy and mastectomy were reasonable surrogate clinical outcome measures for the treatment of local recurrence of primary breast cancer or new contralateral primary breast cancer. In the group initially treated by mastectomy we assumed the surrogate outcome measures usually represent the treatment of contralateral primary breast cancer. However, among women initially treated by lumpectomy, ipsilateral lumpectomies could not be distinguished from contralateral lumpectomies and mastectomies. Therefore, reasonable hypotheses could not be made about the proportion of women having ipsilateral breast recurrences or contralateral primary breast cancers among the lumpectomy strata.

3.7 Analysis of the Rates of Use of Subsequent Breast Surgery Following Surveillance Mammography

The proportion of women undergoing diagnostic mammography, breast ultrasound, breast biopsy, lumpectomy, or mastectomy within four months following surveillance mammography was described. Univariate analyses of the time interval between surveillance mammography and the dates of diagnostic mammography, breast ultrasound, breast biopsy, lumpectomy and mastectomy were performed.

We also described the proportion of women undergoing diagnostic mammography, breast ultrasound, breast biopsy, lumpectomy or mastectomy without a billing record consistent with surveillance mammography within the preceding four months.

We performed multiple logistic regression analyses of the likelihood of lumpectomy and of mastectomy in each annual conditional survival cohort among those cases having subsequent breast surgery within four months after surveillance mammography, and among those cases for whom the procedures were not preceded by surveillance mammography within four months.

4. RESULTS

4.1 Characteristics of Study Population

The study population consisted of 12,279 women. The mean age at diagnosis for the study population is 60.82 years (standard deviation 13.77 years). The proportion of women with Charlson comorbidity score = 0 compared to >= 1 varied among the age categories ($p<0.0001$), with significantly greater comorbidity among women diagnosed at age 70 and older.

4.2 Treatment for Primary Breast Cancer in the Study Population

Of the study population, 19.6% were initially treated by lumpectomy without RT, 41.7% by lumpectomy plus RT, and 38.7% by mastectomy (Table 1). The percent receiving adjuvant chemotherapy was 9.4% in the lumpectomy without RT stratum, 22.4% in the lumpectomy plus RT stratum, and 26.6% in the mastectomy stratum.

4.3 Variations in Treatment for Primary Breast Cancer in the Study Population

By age:
The initial treatment of the primary breast cancer varied significantly by age. Among women treated by lumpectomy without RT, the mean age was 67.64 years (standard deviation 13.72); for women treated by lumpectomy plus RT, mean = 57.45 years (standard deviation 12.10); for women treated by mastectomy, mean = 61.01 years (standard deviation =14.16). As well, the proportion of women treated by chemotherapy dropped with increasing age ($p<0.001$).

By median household income as a surrogate for socio-economic status:
Women in the lower median household income quintiles were more likely to receive lumpectomy without RT than lumpectomy with RT ($p<0.001$).

By region of residence:
The proportion of women treated by each of the three initial options for treatment of the primary breast cancer varied among the regions of Ontario (in each instance $p<0.0001$), as did the proportion of women treated by adjuvant chemotherapy ($p<0.0001$).

4.4 Survival of the Study Population

In the study population, overall survival at 60 months following diagnosis of breast cancer was 82.7%. Univariate survival analysis stratified by initial treatment of the primary breast cancer did not reveal a survival difference (wilcoxon test $p=0.47$; log-rank test $p=0.37$). However other stratified analyses revealed differences among age groups (wilcoxon test and log-rank test $p<0.0001$, highest survival among youngest), among income quintiles (wilcoxon test and log-rank test $p<0.0001$, highest survival in highest income quintile), among regions of Ontario (wilcoxon test $p=0.0038$; log-rank test $p = 0.003$), and among Charlson score groups 0, 1, 2, and >=3 (wilcoxon test and log-rank test $p<0.0001$, highest survival with score '0').

Multivariate survival analysis using Cox proportional hazards regression analysis was performed with the following independent variables: initial treatment of the primary breast cancer, age, Charlson score, median household income quintile, and region of residence. Those under 70 years old at diagnosis have significantly lower risk of death due to any cause, relative to those 70 years or older (RR <=50 years = 0.63, $p<0.0001$, RR 51-69 years = 0.61, $p<0.0001$). All categories of the Charlson score had a higher relative risk (RR) of death due to any cause, relative to Charlson score = 0 ($p<0.0001$). These results are consistent with the results of the univariate survival analysis.

The lumpectomy plus RT group had significantly lower risk of death due to any cause (RR = 0.53, $p<0.0001$) relative to the reference group (mastectomy); the risk of death due to any cause among the lumpectomy without RT group does not differ from the mastectomy group. This result differs from the univariate analyis and shows that the prognosis among the three initial treatment groups does differ when the comparison is adjusted for age, Charlson score, and the other independent variables.

One region had a significantly lower risk of death due to any cause, relative to the reference region, and the risk of death due to any cause among all other regions does not differ from the reference region. All income quintiles had a significantly higher risk of death due to any cause, relative to the reference group (highest quintile of median household incomes) (RR Q1 = 1.43, $p<0.0001$, RR Q2 = 1.34, $p<0.0001$, RR Q3 = 1.25, $p=0.0006$, RR Q4 = 1.25, $p=0.0009$).

4.5 The Rates of Use of Surveillance Mammography

The mean interval between successive surveillance mammograms is 16.41 months (median =14.70 months).

Table 2 shows the number of women using surveillance mammography in each annual conditional survival cohort, according to their initial treatment group, their age at diagnosis, their comorbidity score, their income quintile, and their region of residence.

The proportion of women using surveillance mammography varied by initial treatment of the primary breast cancer (highest among lumpectomy plus RT, lowest among lumpectomy without RT), the age of the case at diagnosis (lowest among those 70 and older), the Charlson comorbidity score, the median household income quintile (highest use among those living in areas with highest median household incomes), and the region of residence of the case at the time of diagnosis (in each instance, $p<0.001$).

Within each successive annual conditional survival cohort, the proportion of cases using surveillance mammography differs among the initial treatment groups ($p<0.001$), the age groups ($p<0.001$), the level of Charlson comorbidity score ($p<0.001$), the quintiles of median household income ($p<0.001$), and the regions, (in years one to four, $p<0.001$ in each instance and in year five $p=0.007$).

Among women alive in the year five, annual conditional survival cohort (minimum observation period 66 months) the mean number of surveillance mammograms, from year one to year five inclusive, was 3.88 per case (median = 4). Only 10% of these five-year survivors did not have a surveillance mammogram during year five. Stratified by initial treatment of the primary breast cancer, we find among the lumpectomy without RT group that the mean number of surveillance mammograms was 3.24 per case (median = 4). Among the lumpectomy plus RT group the mean was 4.29 per case (median = 4). Among the mastectomy group the mean was 3.64 per case (median = 4). Analysis of variance among these means demonstrated that the means are significantly different ($p<0.05$).

Table 3 shows the results of multiple logistic regression analysis examining the likelihood of using surveillance mammography among each annual conditional survival cohort, including initial treatment of the primary breast cancer, age, Charlson score, median household income quintiles, and region of residence as independent variables.

The analyses showed differences in the odds ratios (OR) for the use of surveillance mammography with non-overlapping 95% confidence intervals (95% C.I.) among each of the three initial treatment groups in all annual cohorts.

The OR for surveillance mammography by age group were consistently higher for those <= 50 years of age and those 51-69 years of age at the time of diagnosis, relative to those >=70 years of age, in all annual cohorts. In most instances, women with a record of comorbid disease at diagnosis (Charlson score >= 1) were less likely to have a surveillance mammogram.

During the first two years, the adjusted OR for surveillance mammography was significantly decreased by women in the lowest median household income group.

4.6 The Rates of Use of Subsequent Breast Surgery Following Surveillance Mammography

The number of women who had further diagnostic (diagnostic mammography, breast ultrasound, or breast biopsy) and/or therapeutic procedures (subsequent breast surgery) within four months of surveillance mammography during each conditional survival cohort is shown in Table 4.

The number of women using surveillance mammography decreases after the first year of follow-up. There is little variation in the proportion of cases having subsequent breast surgery (either lumpectomy or mastectomy) after the first year of follow-up.

In the lumpectomy without RT or the lumpectomy plus RT groups, we cannot distinguish the women undergoing subsequent breast surgery on the same breast in which cancer was first diagnosed, from those undergoing procedures on the opposite breast. However, in the mastectomy group, we consider all women undergoing lumpectomy or mastectomy to be having subsequent breast surgery on the opposite breast.

A small number of the women who had either lumpectomy or mastectomy within four months of surveillance mammography underwent both lumpectomy or mastectomy: 25 women underwent both in year one, 24 in year two, 22 in year three, 21 in year four, and 20 in year five.

Table 5 shows the univariate analysis of time to further diagnostic and/or therapeutic procedures following surveillance mammography among all annual conditional survival cohorts combined. The median time to diagnostic mammography or to breast ultrasound following surveillance is brief; however, the median time to breast biopsy, lumpectomy and mastectomy is between 2.50 and 2.97 months. The mean times are much longer than the median times. The frequency distribution of time to procedures indicates that a large number of subsequent procedures are not preceded by surveillance mammography within four months (see next section 4.7, and table 6).

4.7 Rates of Use of Subsequent Breast Surgery without Surveillance Mammography During the Preceding Four Months

Table 6 shows that the majority of women having diagnostic and/or therapeutic procedures during each conditional survival cohort have not had surveillance mammography within the four months preceding the surgical procedure. Among the women who had either lumpectomy or mastectomy during the year one annual conditional survival cohort, 122 cases underwent both, 119 cases in year two, 109 cases in year three, 98 cases in year four, and 98 cases in year five.

4.8 Multivariate Analysis of the Use of Subsequent Breast Surgery

Table 7 shows the results of multiple logistic regression analyses on the likelihood of lumpectomy and of mastectomy in each annual conditional survival cohort, by initial treatment of the primary breast cancer among the women using surveillance mammography within four months preceding surgery. Results are also present for those women whose surgery was not preceded by surveillance mammography.

In every annual conditional survival cohort, the OR for lumpectomy and the OR for mastectomy are significantly elevated among those women initially treated by lumpectomy without RT relative to those initially treated by mastectomy (the reference group), controlling for age, Charlson comorbidity score, median household income quintile, and region of residence. This was true for women initially treated by lumpectomy without RT, whether or not their subsequent surgery followed surveillance mammography within four months.

Among women whose initial treatment was lumpectomy plus RT, their OR for subsequent lumpectomy was consistently higher than the OR for women whose initial treatment was mastectomy, whether or not the subsequent lumpectomy followed within four months of surveillance mammography.

5. DISCUSSION

5.1 The Appropriateness of the Study Population

The study population was identified on the basis of surgery normally performed only on patients with local or regional stage, operable breast cancer. The study population cannot be described according to stage of breast cancer at diagnosis because this data is absent from the data sources. Nevertheless, the five-year survival experience (82.7%) of the study population is consistent with Stages I and II breast cancer. It may be reasonably assumed that this cohort represents patients initially treated for potentially curable breast cancer. We cannot exclude the possibility of misclassification of some women with advanced breast cancer as operable breast cancer. For example, a women having had an excisional biopsy while presenting with distant metastases, might have been misclassified as having had a lumpectomy. It is unlikely that cases of early breast cancer have been excluded.

5.2 The Rates of Use of Surveillance Mammography

The definitions of surveillance mammography and the outcomes of surveillance mammography were developed after examining the frequency distributions of the procedures over time.

The majority of women used surveillance mammography during each of the five years of follow-up. The results of univariate analysis showed variation in the use of surveillance mammography according to initial treatment, age, Charlson comorbidity score, income, and region. Variation by these factors was previously demonstrated to be associated with variation in the utilization of breast cancer services and variation in patient outcomes.[14-17] However, multivariate analysis showed that initial treatment, age at diagnosis, and Charlson score were all independent influences on the use of mammography.

The lowest use of surveillance mammography is in the group having had lumpectomy without RT as initial treatment of the ipsilateral primary breast cancer. Paradoxically, this is the group of women which has the highest risk of ipsilateral breast recurrence. The highest use of surveillance mammography is by women who had lumpectomy plus RT as initial treatment.

The radiologists' interpretations of surveillance mammography cannot be described in this study, because we have not had access to the mammogram reports. Process outcomes such as the reliability, sensitivity and specificity of surveillance mammography interpretation could not be assessed. This area will require additional research using different study designs and data elements.

We described the frequency of diagnostic mammography, breast ultrasounds, and breast biopsies following surveillance mammography, as well as the interval between surveillance mammography and these subsequent diagnostic procedures. The mean interval between successive surveillance mammograms is 16.41 months (median = 14.70 months), compared to the recommended interval of 12 months. This interval is an important benchmark indicator of the use of surveillance mammography, and the quality of the process, which may be monitored in every province.

5.3 Procedures Following Surveillance Mammography and the Interval Between Surveillance Mammography and Subsequent Procedures

Diagnostic mammography following surveillance mammography may consist of cone magnification views done on the same day as 2-view or 3-view mammography, or on a subsequent date.

Median intervals from surveillance mammography to diagnostic mammography and to breast ultrasound examination are very short, but the median interval to breast biopsy is 2.97 months. There appear to be untimely delays between the date of surveillance mammography and the dates of breast biopsies, lumpectomies and mastectomies among the annual conditional survival cohorts. These observations are skewed, reflecting a proportion of procedures closely related in time to surveillance mammography, and a proportion temporally remote from surveillance mammography. These intervals are important benchmark indicators of the outcomes of surveillance mammography, and the quality of the process, and may be monitored in every province.

5.4 The Rates of Subsequent Breast Surgery Following Surveillance Mammography

The limitations to lumpectomy and mastectomy as surrogate outcome measures are the lack of laterality designation to distinguish ipsilateral from contralateral procedures and the lack of histologic confirmation of cancer in the resection specimens. Further research is needed in this area, using different study designs, and different data elements.

About one third of lumpectomies and mastectomies performed during the five years of follow-up appeared to be associated with surveillance mammography less than four months prior to the surgical procedure. This suggests that the remainder of lumpectomies and mastectomies were performed after the detection of clinical abnormalities and/or symptoms, rather than by surveillance mammography.

The decrease in the use of surveillance mammography after the first annual conditional survival cohort is not justified, because the proportion of surviving women undergoing lumpectomy or mastectomy among the second through fifth year annual consecutive survival cohorts does not decrease.

These proportions are important benchmark indicators of the outcomes of surveillance mammography, and the quality of the process, and may be monitored in every province.

5.5 Rates of Subsequent Breast Surgery Without Surveillance Mammography During the Preceding Four Months

Subsequent breast surgery has not been preceded by surveillance mammography within the preceding four months, for the majority of women who have subsequent breast surgery. This is consistent with hypotheses that: (1) surveillance mammography cannot identify the majority of women who need subsequent breast surgery; or (2) that the women most likely to need subsequent breast surgery are the least likely to use surveillance mammography.

The proportion of women who undergo lumpectomy or mastectomy not preceded by surveillance mammography is an important benchmark indicator of the use and effectiveness of surveillance mammography, and may be monitored in every province.

5.6 Benefits of Surveillance Mammography

Among the five consecutive annual conditional survival cohorts, between 24.0% and 36.9% of cases undergoing lumpectomy procedures, and between 20.1% and 36.6% of cases undergoing mastectomy procedures, follow surveillance mammography within four months. We hypothesize that these represent the percentage of ipsilateral breast recurrences and new contralateral primary breast cancers detected by surveillance mammography in the absence of clinical findings, and that this may be the best available measure of the effectiveness of surveillance mammography.

We cannot assess the presence or absence of mortality reduction due to surveillance mammography without information on the stage of disease: (1) at the time of initial diagnosis of the ipsilateral primary breast cancer; and (2) at the time of diagnosis of contralateral primary breast cancer, as well as information on the extent of disease at the time of ipsilateral breast recurrence.

Further research using different study designs and different data sources are necessary to determine: (1) the possibility of survival benefit from the detection of local recurrence in the treated breast by surveillance mammography; (2) the impact of detection by surveillance mammography upon local treatment for local recurrence; (3) the impact of detection by surveillance mammography on the size and aggressiveness of local recurrences and contralateral primary breast cancers; (4) the rate of false-negative surveillance mammography; (5) the effect of false positive surveillance mammograms on the quality of life of women with breast cancer; (6) the effect of surveillance mammography on resource utilization in the health care system; and (7) the reasons for compliance or noncompliance with the recommendation for surveillance mammography.

5.7 Opportunities for Improvement

A non-randomized study cannot establish causation between surveillance mammography and improved clinical outcomes.

Surveillance mammography appeared to have precipitated about one-third of subsequent lumpectomies and mastectomies. There is an obvious opportunity to increase the use of surveillance mammography by focusing on women who were initially treated for ipsilateral

primary breast cancer by lumpectomy without RT, because the proportion of these women who have subsequent breast surgery is higher than the women who initially had lumpectomy plus RT or mastectomy, while their use of surveillance mammography is lower.

5.8 Generalizability of Study Results

It is unclear if this population-based study of surveillance mammography in Ontario is generalizable to the rest of Canada, because of increasing dissimilarities in the organization of health care systems and payment systems among the provinces in Canada.

6. CONCLUSIONS

The use of surveillance mammography following the diagnosis and treatment of ipsilateral primary breast cancer in Ontario varied according to the initial treatment received by women with breast cancer, and by their age and comorbidity profile.

There appeared to be lengthy delays between the date of surveillance mammography and the dates of breast biopsies, lumpectomies and mastectomies during the five years of follow-up.

This study demonstrates that two-thirds of subsequent breast surgery appears to be precipitated by women's symptoms or doctor's clinical findings, rather than by surveillance mammography, during the five years following the treatment of primary breast cancer. This observation suggests several hypotheses: (1) compliance with surveillance mammography may be lower among those at highest risk for ipsilateral breast cancer recurrence or contralateral primary breast cancer; and (2) the effectiveness of surveillance mammography may be decreased among those at highest risk for ipsilateral breast cancer recurrence or metachronous primary contralateral breast cancer.

Based on these findings, the following indicators should be monitored:

- the rates of the use of surveillance mammography among the women at highest risk for recurrence of cancer in the breast or for contralateral new primary breast cancer should be monitored, because these are the women who might benefit the most from surveillance mammography but they are least likely to receive it;
- the interval between surveillance mammography and subsequent breast surgery should be monitored, because delay between surveillance mammography and surgery may be inappropriate; and
- the number of women who undergo subsequent lumpectomy or mastectomy, which is apparently precipitated by surveillance mammography within the preceding four months, should be monitored and compared to the number who undergo surgery without surveillance mammography during the previous four months, because this may reflect the relative effectiveness of surveillance mammography.

Monitoring these indicators in each province is feasible using linked electronic databases of hospital discharge abstracts and billing claims to the provincial health care plans.

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8. TABLES

Table 1: Description of population treated for primary breast cancer

Variable	Lumpectomy		Lumpectomy + RT		Mastectomy		Row Totals	
No. at cohort inception	2,412	(19.6%)	5,119	(41.7%)	4,748	(38.7%)	12,279	(100%)
Adjuvant chemotherapy	226/2,412	(9.4%)	1,146/5,119	(22.4%)	1,261/4,748	(26.6%)	2,633/12,279	(21.4%)
Age at diagnosis								
<=50	292	(12.1%)	1,461	(28.5%)	1,181	(24.9%)	2,934	(23.9%)
51-69	909	(37.7%)	2,739	(53.5%)	2,081	(43.8%)	5,729	(46.7%)
>=70	1,211	(50.2%)	919	(18.0%)	1,486	(31.3%)	3,616	(29.4%)
Total	2,412	(100%)	5,119	(100%)	4,748	(100%)	12,279	(100%)
Charlson score								
0	1,942	(81.4%)	4,745	(93.6%)	4,089	(86.8%)	10,776	(87.8%)
1	245	(10.3%)	227	(4.5%)	397	(8.4%)	869	(7.1%)
2	78	(3.3%)	41	(0.8%)	88	(1.9%)	207	(1.7%)
>=3	121	(5.0%)	57	(1.1%)	138	(2.9%)	316	(2.6%)
missing	26	(1.1%)	49	(1.0%)	36	(0.8%)	111	(0.8%)
Total	2,412	(100%)	5,119	(100%)	4,748	(100%)	12,279	(100%)
Income quintiles								
1 (lowest)	539	(22.3%)	984	(19.2%)	974	(20.5%)	2,497	(20.3%)
2	558	(23.1%)	1,019	(19.9%)	1,001	(21.1%)	2,578	(21.0%)
3	528	(21.9%)	1,098	(21.5%)	1,052	(22.2%)	2,678	(21.8%)
4	444	(18.4%)	1,026	(20.1%)	869	(18.3%)	2,339	(19.1%)
5 (highest)	329	(13.6%)	943	(18.4%)	810	(17.1%)	2,082	(17.0%)
Missing values	14	(0.7%)	49	(0.9%)	42	(0.8%)	105	(0.8%)
Total	2,412	(100%)	5,119	(100%)	4,748	(100%)	12,279	(100%)
Region								
Hamilton	413	(17.2%)	809	(15.8%)	603	(12.7%)	1,825	(14.9%)
Kingston	170	(7.0%)	404	(7.9%)	425	(9.0%)	999	(8.1%)
London	400	(16.6%)	674	(13.2%)	914	(19.3%)	1,988	(16.2%)
Northeast	137	(5.7%)	288	(5.6%)	320	(6.7%)	745	(6.1%)
Northwest	39	(1.6%)	105	(2.1%)	126	(2.7%)	270	(2.2%)
Ottawa	201	(8.3%)	578	(11.3%)	477	(10.1%)	1,256	(10.2%)
Toronto	981	(40.7%)	1,996	(39.0%)	1,659	(34.9%)	4,636	(37.8%)
Windsor	54	(2.2%)	211	(4.1%)	178	(3.8%)	443	(3.6%)
Missing values	17	(0.7%)	54	(1.0%)	46	(0.8%)	117	(0.9%)
Total	2,412	(100%)	5,119	(100%)	4,748	(100%)	12,279	(100%)

Table 2: Utilization of surveillance mammography by conditional survival cohorts

	Year 1	Year 2	Year 3	Year 4	Year 5
Initial treatment					
Lump no RT	1,415/2,222 **(63.7%)**	1,008/2,053 **(49.1%)**	979/1,912 **(51.2%)**	850/1,772 **(48.0%)**	782/1,663 **(47.0%)**
Lump + RT	4,537/5,038 **(90.1%)**	3,188/4,876 **(65.4%)**	3,380/4,711 **(71.8%)**	3,265/4,553 **(71.7%)**	2,973/4,402 **(67.5%)**
Mastectomy	3,206/4,512 **(71.1%)**	2,386/4,168 **(57.3%)**	2,229/3,887 **(57.3%)**	2,106/3,649 **(57.7%)**	1,853/3,432 **(54.0%)**
Age at diagnosis					
<=50	2,375/2,855 **(83.2%)**	1,670/2,707 **(61.7%)**	1,668/2,578 **(64.7%)**	1,596/2,470 **(64.6%)**	1,450/2,396 **(60.5%)**
51-69	4,693/5,538 **(84.7%)**	3,363/5,289 **(63.6%)**	3,489/5,061 **(68.9%)**	3,309/4,864 **(68.0%)**	3,034/4,658 **(65.1%)**
>=70	2,090/3,379 **(61.9%)**	1,549/3,101 **(50.0%)**	1,431/2,871 **(49.8%)**	1,316/2,640 **(49.9%)**	1,124/2,443 **(46.0%)**
Charlson score					
0	8335/10430 **(79.9%)**	6016/9922 **(60.6%)**	6034/9451 **(63.8%)**	5722/9019 **(63.4%)**	5182/8616 **(60.1%)**
1	508/794 **(64.0%)**	346/718 **(48.2%)**	352/654 **(53.8%)**	322/599 **(53.8%)**	264/552 **(47.8%)**
2	110/188 **(58.5%)**	78/157 **(49.7%)**	62/143 **(43.4%)**	54/123 **(43.9%)**	47/109 **(43.1%)**
>=3	140/253 **(55.3%)**	93/203 **(45.8%)**	93/173 **(53.8%)**	80/150 **(53.3%)**	72/141 **(51.1%)**
Income quintile					
1 (lowest)	1,764/2,370 **(74.4%)**	1,232/2,196 **(56.1%)**	1,272/2,083 **(61.1%)**	1,163/1,959 **(59.4%)**	1,032/1,846 **(55.9%)**
2	1,872/2,460 **(76.1%)**	1,319 **(57.0%)**	1,324/2,192 **(60.4%)**	1,242/2,062 **(60.2%)**	1,134/1,957 **(58.0%)**
3	2,020/2,568 **(78.5%)**	1,487/2,427 **(61.3%)**	1,463/2,275 **(64.3%)**	1,390/2,158 **(64.4%)**	1,243/2,061 **(60.3%)**
4	1,764/2,248 **(78.5%)**	1,297/2,132 **(60.6%)**	1,287/2,007 **(64.1%)**	1,236/1,913 **(64.6%)**	1,125/1,824 **(61.7%)**
5 (highest)	1,662/2,024 **(82.1%)**	1,201/1,930 **(62.2%)**	1,206/1,854 **(65.1%)**	1,160/1,783 **(65.1%)**	1,056/1,710 **(61.8%)**
Missing values	102	99	99	99	99
Region					
Hamilton	1,373/1,744 **(78.7%)**	1,032/1,641 **(62.9%)**	1,027/1,548 **(66.3%)**	945/1,475 **(64.1%)**	862/1,412 **(61.1%)**
Kingston	693/946 **(73.3%)**	490/895 **(54.8%)**	518/852 **(60.8%)**	486/812 **(60.0%)**	420/763 **(55.1%)**
London	1,470/1,905 **(77.2%)**	1,047/1,800 **(58.2%)**	1,032/1,700 **(60.7%)**	959/1,597 **(60.1%)**	908/1,509 **(60.2%)**
Northeast	505/719 **(70.3%)**	368/661 **(55.7%)**	385/619 **(62.2%)**	361/587 **(61.5%)**	320/562 **(56.9%)**
Northwest	187/258 **(72.5%)**	139/238 **(58.4%)**	132/229 **(57.6%)**	126/222 **(56.8%)**	108/211 **(51.2%)**
Ottawa	941/1,212 **(77.6%)**	644/1,147 **(56.2%)**	653/1,095 **(59.6%)**	654/1,040 **(62.9%)**	577/997 **(57.9%)**
Toronto	3,580/4,443 **(80.6%)**	2,549/4,201 **(60.7%)**	2,558/3,978 **(64.3%)**	2,405/3,768 **(63.8%)**	2,164/3,591 **(60.3%)**
Windsor	312/423 **(73.8%)**	254/392 **(64.8%)**	231/367 **(62.9%)**	239/352 **(67.9%)**	215/332 **(64.8%)**
Missing values	122	122	122	121	120

Table 3: Odds ratios (95% confidence intervals) for surveillance mammography
(from multiple logistic regression models for each annual conditional survival cohort)

	Year 1		Year 2		Year 3		Year 4		Year 5	
Initial treatment										
Lump no RT	**0.84**	**(0.74, 0.94)**	**0.76**	**0.69, 0.85)**	**0.83**	**(0.74, 0.94**	**0.73**	**(0.65, 0.83)**	**0.81**	**(0.72, 0.92**
Lump + RT	**3.24**	**(2.88, 3.64)**	**1.30**	**(1.19, 1.42)**	**1.73**	**(1.58, 1.90**	**1.74**	**(1.58, 1.91)**	**1.66**	**(1.51, 1.82**
Mastectomy	1.00		1.00		1.00		1.00		1.00	
Age at diagnosis										
<=50	**2.19**	**(1.92, 2.50)**	**1.33**	**(1.19, 1.48)**	**1.51**	**(1.34, 1.69**	**1.48**	**(1.31, 1.67)**	**1.47**	**(1.30, 1.66**
51-69	**2.71**	**(2.43, 3.02)**	**1.53**	**(1.39, 1.68)**	**1.88**	**(1.70, 2.08**	**1.80**	**(1.62, 1.99)**	**1.89**	**(1.70, 2.09**
>=70	1.00		1.00		1.00		1.00		1.00	
Charlson score										
0	1.00		1.00		1.00		1.00		1.00	
1	**0.64**	**(0.54, 0.76)**	**0.68**	**(0.59, 0.80)**	**0.80**	**(0.68, 0.94**	**0.82**	**(0.69, 0.97)**	**0.71**	**(0.59, 0.85**
2	**0.58**	**(0.43, 0.80)**	0.78	(0.56, 1.08)	**0.57**	**(0.40, 0.81**	**0.59**	**(0.41, 0.86)**	**0.61**	**(0.41, 0.91**
>=3	**0.38**	**(0.29, 0.50)**	**0.60**	**(0.45, 0.80)**	0.74	(0.54, 1.02	0.75	(0.53, 1.04)	0.78	(0.55, 1.10
Income quintile										
1 (lowest)	**0.83**	**(0.71, 0.98)**	**0.86**	**(0.75, 0.99)**	0.94	(0.81, 1.08	0.88	(0.76, 1.01)	0.87	(0.75, 1.00
2	0.86	(0.73, 1.02)	0.90	(0.79, 1.03)	0.89	(0.78, 1.03	0.91	(0.79, 1.04)	0.94	(0.81, 1.08
3	0.94	(0.80, 1.11)	1.25	(0.90, 1.17)	1.03	(0.90, 1.19	1.07	(0.93, 1.23)	1.01	(0.88, 1.16
4	0.85	(0.72, 1.00)	0.97	(0.84, 1.10)	0.99	(0.86, 1.14	1.03	(0.90, 1.19)	1.02	(0.90, 1.19
5 (highest)	1.00		1.00		1.00		1.00		1.00	
Region										
Hamilton	**1.50**	**(1.15, 1.95)**	0.95	(0.76, 1.21)	1.21	(0.95, 1.55	0.86	(0.67, 1.11)	0.87	(0.67, 1.13
Kingston	1.20	(0.91, 1.60)	**0.72**	**(0.56, 0.92)**	1.03	(0.79, 1.34	0.79	(0.60, 1.05)	**0.74**	**(0.56, 0.97**
London	**1.63**	**(1.25, 2.12)**	0.81	(0.64, 1.02)	1.04	(0.82, 1.33	0.79	(0.61, 1.02)	0.92	(0.71, 1.18
Northeast	**0.67**	**(0.53, 0.84)**	1.00	(0.82, 1.22)	1.13	(0.91, 1.40	0.98	(0.79, 1.22)	1.01	(0.81, 1.25
Northwest	1.18	(0.81, 1.72)	0.80	(0.57, 1.12)	0.88	(0.62, 1.27	**0.64**	**(0.45, 0.92)**	**0.61**	**(0.42, 0.87**
Ottawa	**1.42**	**(1.08, 1.87)**	**0.73**	**(0.57, 0.93)**	0.91	(0.71, 1.18	0.83	(0.64, 1.09)	0.78	(0.60, 1.01
Toronto	**1.71**	**(1.33, 2.18)**	0.86	(0.69, 1.08)	1.13	(0.90, 1.41	0.87	(0.68, 1.10)	0.85	(0.67, 1.09
Windsor	1.00		1.00		1.00		1.00		1.00	

Table 4: Outcomes of surveillance mammography

Annual conditional survival cohorts	Cases		Initial treatment: lumpectomy without RT		Initial treatment: lumpectomy + RT		Initial treatment: mastectomy	
Year one cases:								
Alive	11,772		2,222		5,038		4,512	
Surveillance mammogram	9,158	(77.8%)	1,415	(63.7%)	4,537	(90.1%)	3,206	(71.1%)
Diagnostic mammogram	1,958	(21.4%)	393	(27.8%)	848	(18.7%)	717	(22.4%)
Breast ultrasound	522	(5.7%)	103	(7.3%)	231	(5.1%)	188	(5.9%)
Breast biopsy	255	(2.8%)	56	(4.0%)	123	(2.7%)	76	(2.4%)
Lumpectomy	177	(1.9%)	46	(3.3%)	78	(1.7%)	53	(1.7%)
Mastectomy	118	(1.3%)	40	(2.8%)	30	(0.7%)	38	(1.2%)
Year two cases:								
Alive	11,097		2,053		4,876		4,168	
Surveillance mammogram	6,582	(59.3%)	1,008	(49.1%)	3,188	(65.4%)	2,386	(57.3%)
Diagnostic mammogram	1,865	(28.2%)	376	(37.3%)	814	(25.5%)	675	(28.3%)
Breast ultrasound	503	(7.6%)	97	(9.6%)	226	(7.1%)	180	(7.5%)
Breast biopsy	275	(4.2%)	55	(5.5%)	147	(4.6%)	73	(3.1%)
Lumpectomy	171	(2.6%)	45	(4.5%)	76	(2.4%)	50	(2.1%)
Mastectomy	100	(1.5%)	36	(3.6%)	28	(0.9%)	36	(1.5%)
Year three cases:								
Alive	10,510		1,912		4,711		3,887	
Surveillance mammogram	6,588	(62.7%)	979	(51.2%)	3,380	(71.8%)	2,229	(57.3%)
Diagnostic mammogram	1,780	(27.0%)	364	(37.2%)	776	(23.0%)	640	(28.7%)
Breast ultrasound	478	(7.3%)	95	(9.7%)	216	(6.4%)	167	(7.5%)
Breast biopsy	262	(4.0%)	51	(5.2%)	142	(4.2%)	69	(3.1%)
Lumpectomy	163	(2.5%)	45	(4.6%)	73	(2.2%)	45	(2.0%)
Mastectomy	92	(1.4%)	33	(3.4%)	25	(0.7%)	34	(1.5%)
Year four cases:								
Alive	9,954		1,772		4,533		3,649	
Surveillance mammogram	6,221	(62.5%)	850	(48.0%)	3,265	(71.7%)	2,106	(57.7%)
Diagnostic mammogram	1638	(26.3%)	288	(33.9%)	750	(23.0%)	600	(28.5%)
Breast ultrasound	452	(7.3%)	89	(10.5%)	205	(6.3%)	158	(7.5%)
Breast biopsy	250	(4.0%)	50	(5.9%)	136	(4.2%)	64	(3.0%)
Lumpectomy	156	(2.5%)	44	(5.2%)	69	(2.1%)	43	(2.0%)
Mastectomy	87	(1.4%)	31	(3.7%)	23	(0.7%)	33	(1.6%)
Year five cases:								
Alive	9,497		1,663		4,402		3,432	
Surveillance mammogram	5,608	(59.1%)	782	(47.0%)	2,973	(67.5%)	1,853	(54.0%)
Diagnostic mammogram	1609	(28.7%)	324	(41.4%)	721	(24.3%)	564	(30.4%)
Breast ultrasound	424	(7.6%)	77	(9.9%)	196	(6.6%)	151	(8.2%)
Breast biopsy	242	(4.3%)	46	(5.9%)	136	(4.6%)	60	(3.2%)
Lumpectomy	148	(2.6%)	41	(5.2%)	67	(2.3%)	40	(2.2%)
Mastectomy	78	(1.4%)	26	(3.3%)	21	(0.7%)	31	(1.7%)

Table 5: Interval between surveillance mammography and subsequent diagnostic and/or therapeutic procedures within eleven months following surveillance mammography

	Mean (+ standard deviation)	Median	Interquartile range
Diagnostic mammogram	2.10 months (3.47)	0 months	3.97 months
Breast ultrasound	2.48 months (3.22)	0.62 months	4.71 months
Breast biopsy	3.66 months (3.11)	2.97 months	5.06 months
Lumpectomy	3.83 months (3.23)	2.55 months	5.72 months
Mastectomy	3.89 months (3.20)	2.50 months	5.45 months

Table 6: Breast procedures as outcomes of surveillance mammography compared to breast procedures not following surveillance mammography

Annual conditional survival cohorts	Outcomes of surveillance mammography: breast procedures within four months		Breast procedures not following surveillance mammography		Total breast procedures: following surveillance mammography or not	
Year one cases: Alive	11,772		11,772		11,772	
Surveillance mammogram	9,158	(77.8%)				
Diagnostic mammogram	1,958	(16.6%)	1,757	(14.9%)	3,715	(31.6%)
Breast ultrasound	522	(4.4%)	1,407	(12.0%)	1,929	(16.4%)
Breast biopsy	255	(1.9%)	1,089	(9.3%)	1,344	(11.4%)
Lumpectomy	177	(1.5%)	414	(3.5%)	591	(5.0%)
Mastectomy	118	(1.0%)	271	(2.3%)	389	(3.3%)
Year two cases: Alive	11,097		11,097		11,097	
Surveillance mammogram	6,582	(59.3%)				
Diagnostic mammogram	1,865	(16.8%)	1,711	(15.4%)	3,576	(32.2%)
Breast ultrasound	503	(4.5%)	1,390	(12.5%)	1,893	(17.1%)
Breast biopsy	275	(2.5%)	1,067	(9.6%)	1,342	(12.1%)
Lumpectomy	171	(1.5%)	396	(3.6%)	567	(5.1%)
Mastectomy	100	(0.9%)	260	(2.3%)	360	(3.2%)
Year three cases: Alive	10,510		10,510		10,510	
Surveillance mammogram	6,588	(62.7%)				
Diagnostic mammogram	1,780	(16.9%)	1,654	(15.7%)	3,434	(32.7%)
Breast ultrasound	478	(4.5%)	1,369	(13.0%)	1,847	(17.6%)
Breast biopsy	262	(2.5%)	1,027	(9.8%)	1,289	(12.3%)
Lumpectomy	163	(1.6%)	369	(3.5%)	532	(5.1%)
Mastectomy	92	(0.8%)	235	(2.2%)	327	(3.1%)
Year four cases: Alive	9,954		9,954		9,954	
Surveillance mammogram	6,221	(62.5%)				
Diagnostic mammogram	1638	(16.5%)	1,585	(15.9%)	3,223	(32.4%)
Breast ultrasound	452	(4.5%)	1,341	(13.5%)	1,793	(18.0%)
Breast biopsy	250	(2.5%)	986	(9.9%)	1,236	(12.4%)
Lumpectomy	156	(1.6%)	345	(3.5%)	501	(5.0%)
Mastectomy	87	(0.9%)	223	(2.2%)	310	(3.1%)
Year five cases: Alive	9,497		9,497		9,497	
Surveillance mammogram	5,608	(59.1%)				
Diagnostic mammogram	1609	(16.9%)	1,511	(15.9%)	3,120	(32.9%)
Breast ultrasound	424	(4.5%)	1,305	(13.7%)	1,729	(18.2%)
Breast biopsy	242	(2.5%)	950	(10.0%)	1,192	(12.6%)
Lumpectomy	148	(1.6%)	318	(3.3%)	466	(4.9%)
Mastectomy	78	(0.8%)	184	(1.9%)	262	(2.6%)

Table 7: Odds ratios (95% confidence intervals) for lumpectomy and for mastectomy, by annual conditional survival cohorts* +

	Surveillance mammography within four months precedeing surgery			No surveillance mammography within four months precedeing surgery		
Initial treatment	**Lumpectomy without RT**	**Lumpectomy + RT**	**Mastectomy**	**Lumpectomy without RT**	**Lumpectomy + RT**	**Mastectomy**
Year one						
Lumpectomy	**2.40 (1.52, 3.81)**	**1.62 (1.07, 2.45)**	1.00	**2.30 (1.80, 2.94)**	**1.95 (1.59, 2.39)**	1.00
Mastectomy	**1.83 (1.38, 2.44)**	1.16 (0.91, 1.49)	1.00	**1.73 (1.46, 2.04)**	**1.52 (1.33, 1.74)**	1.00
Year two						
Lumpectomy	**2.57 (1.59, 4.13)**	**1.70 (1.10, 2.62)**	1.00	**2.31 (1.80, 2.96)**	**1.91 (1.55, 2.36)**	1.00
Mastectomy	**1.88 (1.40, 2.52)**	1.13 (0.88, 1.47)	1.00	**1.71 (1.44, 2.02)**	**1.48 (1.30, 1.70)**	1.00
Year three						
Lumpectomy	**2.63 (1.60, 4.31)**	**1.78 (1.14, 2.79)**	1.00	**2.38 (1.84, 3.07)**	**1.93 (1.56, 2.39)**	1.00
Mastectomy	**1.92 (1.42, 2.61)**	1.15 (0.88, 1.49)	1.00	**1.68 (1.41, 2.01)**	**1.49 (1.29, 1.71)**	1.00
Year four						
Lumpectomy	**2.60 (1.55, 4.39)**	**1.79 (1.12, 2.87)**	1.00	**2.15 (1.65, 2.81)**	**1.89 (1.52, 2.35)**	1.00
Mastectomy	**1.90 (1.39, 2.61)**	1.14 (0.87, 1.50)	1.00	**1.65 (1.37, 1.98)**	**1.47 (1.28, 1.70)**	1.00
Year five						
Lumpectomy	**2.31 (1.35, 3.95)**	**1.69 (1.06, 2.72)**	1.00	**2.08 (1.59, 2.74)**	**1.84 (1.48, 2.30)**	1.00
Mastectomy	**1.73 (1.24, 2.41)**	1.12 (0.84, 1.49)	1.00	**1.61 (1.34, 1.95)**	**1.44 (1.25, 1.66)**	1.00

* from multiple logistic regression analyses, controlling for age, Charlson comorbidity score, median household income quintiles, and region of residence

\+ separate analysis performed for each procedure in each year among cases in the stratum with surveillance mammography within four months preceding surgery, and separately in the stratum of cases who did not.