Site-specific timing and mode of detection of locoregional recurrence after breast cancer surgery

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Abstract. Locoregional recurrence after breast cancer surgery remains potentially curable; however, current guidelines recommend annual mammography (MMG) alone, and recommend against routine ultrasonography (US) or computed tomography (CT). Despite arising in different anatomic locations, intramammary and regional nodal recurrences are typically analyzed together. The present study aimed to examine when and how locoregional recurrence after surgical treatment was detected under a defined institutional surveillance protocol. Among 61 locoregional recurrences verified at Fukushima Medical University Hospital (Fukushima, Japan) between February 2016 and August 2025, 13 were excluded, leaving 48 patients, each of whom contributed one recurrence. The disease-free interval (DFI), mode of detection and examination that first identified the recurrence were extracted from medical records, and intramammary and regional nodal recurrences were compared. Among the 48 recurrences, 32 were intramammary, 13 involved regional lymph nodes and 3 involved the skin/soft tissue. The median DFI was 156 months for intramammary recurrences and 42 months for regional nodal recurrences (P=0.0009), with 59.4% compared with 15.4% of recurrences being diagnosed >10 years after primary surgery. Overall, US was the most frequent detection modality (47.9%), followed by MMG (18.8%), CT (12.5%), positron emission tomography (PET)-CT (10.4%) and palpation (10.4%). Among intramammary recurrences, 75.0% were detected by US or MMG whereas 9.4% were detected by CT or PET-CT. By contrast, among regional nodal recurrences, 46.2% were detected by CT or PET-CT (P=0.0106). Tumor size at detection did not differ between the recurrence sites. In conclusion, in the present single-center series, intramammary and regional nodal recurrences demonstrated distinct patterns of timing and detection modality. Because the number of examinations performed was unavailable, the findings characterize detection patterns rather than the diagnostic performance of individual examinations. Further validation in larger, multicenter studies is warranted.

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Abbreviations: CT, computed tomography; DFI, disease-free interval; ER, estrogen receptor; HER2, human epidermal growth factor receptor 2; HR, hormone receptor; IQR, interquartile range; MMG, mammography; PET-CT, positron emission tomography-CT; US, ultrasonography

Key words: breast cancer, locoregional recurrence, surveillance, disease-free interval, ultrasonography, mammography

Introduction

Locoregional recurrence occurs in a small number of patients after primary surgery for breast cancer. In a pooled analysis of 3,799 women with node-negative disease who underwent breast-conserving therapy in five National Surgical Adjuvant Breast and Bowel Project trials, 11.0% of patients experienced locoregional failure. Among patients who received adjuvant systemic therapy, the 12-year cumulative incidences of ipsilateral breast tumor recurrence and other locoregional recurrence were 6.6 and 1.8%, respectively (1). Unlike distant metastasis, locoregional recurrence remains potentially curable, and salvage surgery, with or without systemic therapy, can achieve long-term disease control (2). Because successful treatment in that setting depends on complete resection of the recurrent lesion, the extent of disease at diagnosis determines whether curative treatment remains feasible. The clinical value of posttreatment surveillance therefore rests on the premise that earlier detection increases the likelihood of curative treatment. However, that premise has not been directly proved; a meta-analysis of isolated breast recurrences found no clear evidence of a survival benefit associated with earlier detection (3).

Current guidelines recommend a minimum surveillance strategy of periodic history taking, physical examination, and annual mammography (MMG) (4,5). Those recommendations are based largely on two randomized trials conducted in the early 1990s that compared intensive follow-up with clinically directed follow-up and found no difference in overall survival (6,7). A subsequent systematic review reached a

similar conclusion (8). However, those trials evaluated survival in the overall follow-up population and were not designed to determine which examinations detect locoregional recurrence or whether earlier detection improves outcomes. Furthermore, these trials pre-dated contemporary imaging techniques, modern systemic therapies, and the widespread adoption of breast-conserving surgery.

The postsurgical course of breast cancer also depends on tumor biology. In hormone receptor (HR)-positive disease, the risk of recurrence persists for many years after diagnosis (9), such that surveillance strategies evaluated over a five-year period might not reflect the risk profile of patients during subsequent years. Receptor status also influences the imaging characteristics of breast cancer. For example, in cancers positive for the human epidermal growth factor receptor 2 (HER2), calcifications are frequently evident on MMG (10). Furthermore, although intramammary and regional nodal recurrences occur in distinct anatomic compartments, they are generally analyzed together as a single entity despite the possibility that they may differ in their detection modalities and temporal patterns. If their patterns were to differ systematically, a uniform surveillance strategy applied over time may not adequately reflect the distinct risks associated with each recurrence site.

We set out to characterize the disease-free interval (DFI) and mode of detection of surgically treated locoregional recurrence in patients followed under a single institutional surveillance protocol. Our primary objective was to compare intramammary and regional nodal recurrences in terms of DFI and modality responsible for detection. The secondary objectives were to describe the overall distribution of detection modalities, the receptor status of the resected recurrent tumors, and tumor size at detection.

Materials and methods

Study design and patients. For this retrospective observational study, we used an institutional database to identify patients who underwent surgery for locoregional breast cancer recurrence at Fukushima Medical University Hospital (Fukushima, Japan) between February 2016 and August 2025. The 68 initially identified surgical records were verified against the corresponding medical records, and seven were excluded as not representing a locoregional recurrence of breast cancer and having been registered in the database in error, leaving 61 verified recurrences. Of those 61, one was excluded because the final diagnosis was angiosarcoma rather than recurrent breast carcinoma. Another four were excluded because the recurrence was detected during community breast cancer screening rather than institutional follow-up; those patients were therefore outside the surveillance protocol described below, meaning that the detection modality could not be attributed to the protocol. Finally, eight were excluded because they represented repeat surgeries in patients who had already contributed an earlier recurrence. Accordingly, only the chronologically first recurrence episode was retained, ensuring that each patient contributed only one episode to the analysis. The final cohort comprised 48 female patients, with a median age of 68 years (age range: 38-88 years), each of whom contributed one locoregional recurrence episode. All included patients had undergone primary surgery for breast cancer and subsequently received follow-up care at the study institution. The study protocol was approved by the General Ethics Committee of Fukushima Medical University (approval no. REC2026-101, dated September 24, 2026), and because of the retrospective design, the requirement for written informed consent was waived, and an opt-out procedure was implemented.

Surveillance protocol. The institutional surveillance protocol remained consistent throughout the study period. During years 1 to 5 after primary surgery, patients underwent physical examinations, blood tests, and breast ultrasonography (US) every three months, whereas computed tomography (CT) and MMG were performed annually. During years 5 to 10, the same assessments were performed every six months, while CT and MMG continued to be performed annually. From year 10 onward, patients underwent annual MMG and US; CT was no longer routinely performed. For patients considered to be at high risk of recurrence, annual bone scintigraphy was additionally performed during the first 10 years after primary surgery. Follow-up continued indefinitely, with no prespecified termination time point.

Definitions and data collection. DFI was defined as the interval, in months, between the date of primary surgery for breast cancer and the date of the locoregional recurrence diagnosis. The mode of detection was extracted from the medical records; recurrences were classified as surveillance-detected if they were identified during a scheduled follow-up visit, or as self-detected if the patient reported a symptom or a palpable mass. The detection modality was recorded as the first examination that identified the lesion: US, MMG, CT, positron emission tomography (PET)-CT, or patient palpation. These classifications were not interchangeable: Of the eight patients who reported a symptom, five had the lesion detected by palpation alone, and the remaining three had a lesion first localized by US during a subsequent clinical visit. Accordingly, these three recurrences were classified as US-detected in the modality analysis. Recurrence sites were classified as intramammary, regional nodal, or skin/soft tissue or chest wall, based on the surgical procedure performed and the corresponding pathology report. Lesions arising in the axilla that were not of nodal origin were assigned to the skin/soft tissue category. Tumor size was defined as the invasive diameter reported in the pathology report for the resected recurrence; noninvasive lesions were assigned a size of 0 cm.

Pathological assessment. The histologic type; invasive diameter; estrogen receptor (ER), progesterone receptor, and HER2 status; and Ki-67 labeling index for each resected recurrence were obtained from the pathology reports routinely issued at the time of surgery. No central re-review was performed. ER and progesterone receptor status were assessed by immunohistochemistry and considered positive when 1% or more of tumor cell nuclei were stained. HER2 status was assessed by immunohistochemistry, in situ hybridization or both. HER2 positivity was defined as an immunohistochemistry score of 3+ or gene amplification on in situ hybridization, applying the American Society of Clinical Oncology/College of American Pathologists criteria in use at the time. When

reported, the Ki-67 labeling index was recorded as the percentage of stained tumor cell nuclei. Tumors were classified into the following surrogate subtypes: HR-positive (ER- or progesterone receptor-positive)/HER2-negative, HR-positive/HER2-positive, HR-negative/HER2-positive, or triple-negative.

Statistical analysis. Continuous variables are presented as medians with interquartile ranges (IQRs), and results for the two principal recurrence sites were compared using the Mann-Whitney U test. Categorical variables are presented as frequencies and percentages, and results were compared using the Fisher's exact test. Each analysis involved a comparison between two groups; therefore, no multiple-comparison procedures were applied. No imputation was performed. Each analysis included all patients with interpretable data for the variables under consideration. All analyses were performed using Python (version 3.10.12; Python Software Foundation, Beaverton, OR, USA) with the SciPy library (version 1.15.3). A two-sided $P<0.05$ was considered to indicate a statistically significant difference. Receptor status was summarized descriptively and was not compared between recurrence sites because values were unavailable for a substantial proportion of regional nodal specimens.

Results

Cohort characteristics. The analysis included 48 patients, each contributing one locoregional recurrence episode. Median age at recurrence surgery was 68 years (IQR, 58-79 years; range, 38-88 years), and 16 patients (33.3%) were 75 years of age or older. Recurrences were intramammary in 32 patients (66.7%), regional nodal in 13 (27.1%), and skin/soft tissue in three (6.3%). The median invasive diameter of the resected recurrence was 1.05 cm (IQR, 0.90-1.78 cm), and the median Ki-67 labeling index was 22.5% (IQR, 9.4%-35.0%). Receptor status was available for 42 recurrences: 35 (83.3%) were ER-positive, 26 (61.9%) were progesterone receptor-positive, and eight (19.0%) were HER2-positive. By surrogate subtype, 30 recurrences (71.4%) were HR-positive/HER2-negative, five (11.9%) were HR-positive/HER2-positive, three (7.1%) were HR-negative/HER2-positive, and four (9.5%) were triple-negative. Receptor status was unavailable for five of the 13 regional nodal recurrences and for the single noninvasive intramammary lesion. After recurrence surgery, 31 of 43 evaluable patients (72.1%) received endocrine therapy, 10 (23.3%) received chemotherapy, six (14.0%) received anti-HER2 or other targeted therapy, and seven of 41 (17.1%) received radiotherapy (Table I).

Recurrences were identified during scheduled surveillance in 40 patients (83.3%) and were self-reported by the remaining eight patients (16.7%). The median DFI for the entire cohort was 85 months (IQR, 44-189 months), equivalent to 7.1 years, with a range of seven months to 28.2 years.

DFI according to the recurrence site. The DFI differed significantly between the two principal recurrence sites. The median DFI was 42 months (IQR, 22-83 months; 3.5 years) for regional nodal recurrences and 156 months (IQR, 59-207 months; 13.0 years) for intramammary recurrences, a statistically significant difference (P=0.0009). Only two of the 13 regional nodal recurrences (15.4%), compared with 19 of the 32 intramammary recurrences (59.4%), were diagnosed

Table I. Clinicopathological characteristics of the 48 patients with locoregional recurrence.

Characteristic	Value
Patients, n	48
Median age at recurrence surgery, years (IQR)	68 (58-79)
Aged ≥75 years, n (%)	16 (33.3)
Female sex, n (%)	48 (100)
Disease-free interval	
Median, months (IQR)	85 (44-189)
Median, years	7.1
Range, years	0.6-28.2
Recurrence site, n (%)	
Intramammary	32 (66.7)
Regional nodal	13 (27.1)
Skin or soft tissue	3 (6.3)
Mode of detection, n (%)	
Detected during surveillance	40 (83.3)
Self-detected by the patient	8 (16.7)
Detection modality, n (%)	
Ultrasonography	23 (47.9)
Mammography	9 (18.8)
CT	6 (12.5)
PET-CT	5 (10.4)
Patient palpation	5 (10.4)
Pathological features of the recurrence	
Median invasive diameter, cm (IQR)	1.05 (0.90-1.78)
Median Ki-67 labeling index, % (IQR)[a]	22.5 (9.4-35.0)
Receptor status of the recurrence, n (%)[b]	
ER-positive	35 (83.3)
PgR-positive	26 (61.9)
HER2-positive	8 (19.0)
Surrogate subtype, n (%)[b]	
HR-positive/HER2-negative	30 (71.4)
HR-positive/HER2-positive	5 (11.9)
HR-negative/HER2-positive	3 (7.1)
Triple-negative	4 (9.5)
Treatment after recurrence surgery, n (%)	
Endocrine therapy[c]	31 (72.1)
Chemotherapy[c]	10 (23.3)
Anti-HER2 or other targeted therapy[c]	6 (14.0)
Radiotherapy[d]	7 (17.1)

[a]Available in 41 patients. [b]Available in 42 patients. [c]Available in 43 patients. [d]Available in 41 patients. ER, estrogen receptor; HER2, human epidermal growth factor receptor 2; HR, hormone receptor; IQR, interquartile range; CT, computed tomography; PET-CT, positron emission tomography-CT; PgR, progesterone receptor.

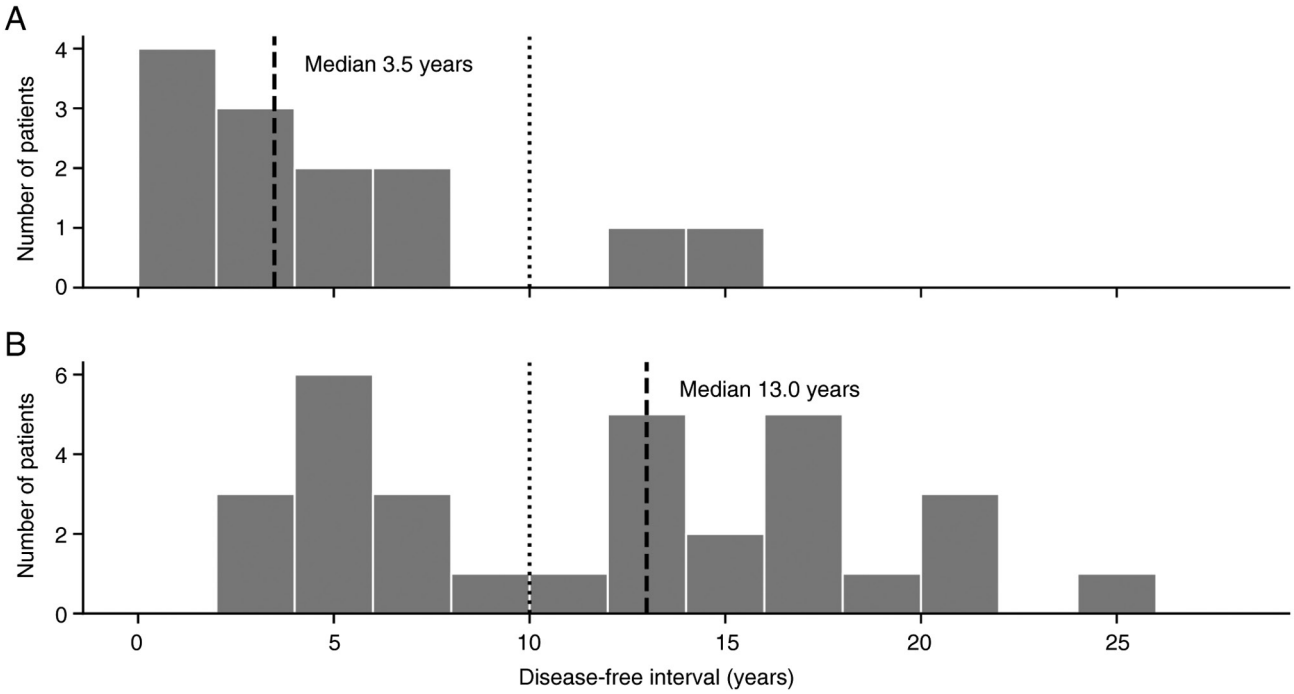


Figure 1. Distribution of the disease-free interval preceding locoregional recurrence by recurrence site. (A) Regional nodal recurrence (n=13). (B) Intramammary recurrence (n=32). Dashed lines indicate the median disease-free interval for each group. Dotted lines mark 10 years after primary surgery, at which point annual computed tomography under the defined surveillance protocol ended.

more than 10 years after primary surgery. The median invasive tumor diameter did not appreciably differ between the two sites (1.15 cm for intramammary and 1.10 cm for regional nodal recurrences; P=0.940) (Fig. 1; Table II).

Detection modality according to the recurrence site. Considering the entire cohort, the recurrence detection modality was US in 23 patients (47.9%), MMG in nine (18.8%), CT in six (12.5%), PET-CT in five (10.4%), and patient palpation in five (10.4%). Thus, imaging accounted for the detection in 43 of 48 recurrences (89.6%).

The modality distribution differed by recurrence site. Among intramammary recurrences, 24 of 32 (75.0%) were detected by US or MMG, whereas only three (9.4%) were detected by CT or PET-CT. In contrast, among regional nodal recurrences, was six of 13 (46.2%) were detected by CT or PET-CT and seven (53.8%) were detected by US or MMG. The proportion detected by cross-sectional imaging was significantly higher for regional nodal than for intramammary recurrence (P=0.0106). All five recurrences detected by patient palpation were intramammary; no regional nodal recurrence was self-detected (Fig. 2; Table II).

The three skin/soft tissue recurrences were excluded from the comparison because of the small sample size. All three occurred within five years of primary surgery, with DFIs of seven, 24, and 49 months. Two were detected by CT during scheduled surveillance; the third was reported by the patient and subsequently localized by US.

Discussion

In our cohort of 48 patients who underwent surgery for locoregional breast cancer recurrence under a defined institutional surveillance protocol, intramammary and regional nodal recurrences presented as distinct clinical entities. The median DFIs were 13.0 and 3.5 years, respectively, and cross-sectional imaging accounted for 46.2% of regional nodal recurrences, but only 9.4% of intramammary recurrences. Notably, tumor size at detection did not differ between the sites, suggesting that the principal differences concerned the timing and detection modality rather than the extent of disease at detection.

The timing of intramammary recurrence was particularly noteworthy. Nearly 60% of intramammary recurrences were diagnosed at more than 10 years after primary surgery, with the longest DFI in the series being 28.2 years. That observation is consistent with pooled trial data showing that the risk of recurrence in HR-positive breast cancer remains steady for at least 15 years after the completion of 5 years of endocrine therapy (9). In line with those data, 26 of the 31 intramammary recurrences with available receptor status in our study (83.9%) were ER-positive. Late intramammary events also raise a question about their underlying biology. Ipsilateral breast tumor relapse encompasses two entities: true recurrence of the original tumor, and a new primary carcinoma arising in the preserved breast. Events occurring after a prolonged DFI are disproportionately likely to represent the latter (11). For surveillance, however, this distinction is less consequential: both are detected through breast-directed imaging, and both might be surgically salvageable.

In contrast, regional nodal recurrences were concentrated in the first decade, with 11 of 13 events occurring within 10 years, and were more frequently detected by CT or PET-CT. This pattern is anatomically plausible. Axillary, infraclavicular, and supraclavicular nodes are not adequately assessed by MMG, may not be reliably palpable by patients, and can lie at the margins of or outside the field of standard breast US, whereas

Table II. Comparison of intramammary and regional nodal recurrence.

Variable	Intramammary	Regional nodal	P-value
Patients, n	32	13	
Disease-free interval			
Median, months (IQR)	156 (59-207)	42 (22-83)	0.0009
Median, years	13.0	3.5	
Diagnosed >10 years after surgery, n (%)	19 (59.4)	2 (15.4)	
Median invasive diameter, cm (IQR)	1.15 (0.90-1.67)	1.10 (0.80-2.10)	0.940
Detection modality, n (%)			
Ultrasonography or mammography	24 (75.0)	7 (53.8)	
CT or PET-CT	3 (9.4)	6 (46.2)	0.0106
Patient palpation	5 (15.6)	0 (0)	

Continuous variables were compared using the Mann-Whitney U test and categorical variables using Fisher's exact test. The 3 patients with skin or soft tissue recurrence are not shown. CT, computed tomography; IQR, interquartile range; PET-CT, positron emission tomography-CT.

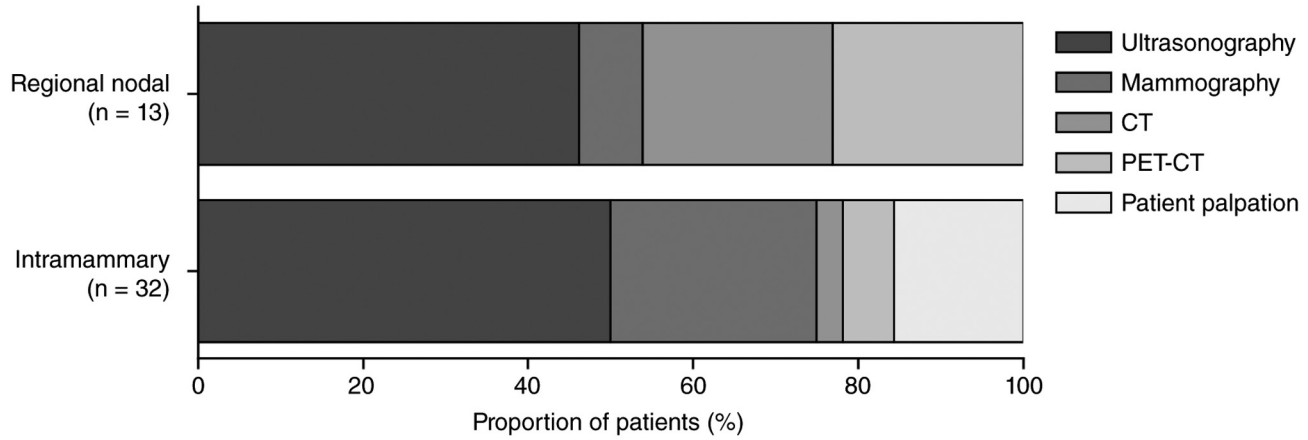


Figure 2. Modality responsible for detection by recurrence site. Bars indicate the proportion of patients for whom each modality first detected the lesion. CT, computed tomography; PET-CT, positron emission tomography-CT.

they are well visualized on cross-sectional imaging. Consistent with this, no regional nodal recurrence in the present series was self-detected; all five recurrences detected by patient palpation were intramammary. The proportion of recurrences identified during scheduled surveillance was higher in our cohort than in those reported elsewhere. In a Swedish two-cohort study, 56% of locoregional recurrences were identified outside scheduled surveillance (12). Similarly, a systematic review of nine studies comprising 613 locoregional recurrences found that 46.3% were detected by patients, 23.3% by MMG, and 14.8% by physical examination (13). Comparable proportions have been reported in other European series (14,15) and a 10-year institutional review (16). In contrast, only eight of the 48 patients in our cohort (16.7%) presented symptomatically, and imaging accounted for 89.6% of detections. The most plausible explanation is the defined follow-up protocol rather than differences in tumor biology: Breast US was performed at every follow-up visit, whereas the surveillance programs in the foregoing studies relied primarily on MMG and clinical examination. Any comparison should therefore be interpreted cautiously because the studies differed in study period, definition of the mode of detection, and completeness of follow-up. None, including the present study, provide the denominator needed to calculate detection yield per examination.

The observed detection patterns should be interpreted in the context of the surveillance strategies used. The American Society of Clinical Oncology and the European Society for Medical Oncology recommend periodic history taking, physical examination, and annual MMG, while recommending against routine laboratory tests, tumor markers, chest radiography, bone scintigraphy, CT, and PET in asymptomatic survivors (4,5). In Japan, clinical practice guidelines published by the Japanese Breast Cancer Society address the use of US, MMG, magnetic resonance imaging, and PET-CT in the post-treatment setting. More intensive surveillance incorporating routine breast US and periodic CT remains common practice (17). The protocol evaluated in the present study belongs to that category, and the detection patterns observed should be understood to be conditioned on it. Routine blood tests were also performed at each visit, and serum lactate dehydrogenase has been investigated as a tumor marker (18). However, every recurrence in our cohort was first identified by imaging or

palpation; whether laboratory abnormalities prompted any of the examinations was not recorded; therefore, the contribution of serum markers to locoregional recurrence detection could not be assessed.

Taken together, our findings suggest that surveillance practice might reasonably be varied with the time since primary surgery rather than remain uniform throughout follow-up. Regional nodal recurrences, which accounted for most recurrences detected by CT or PET-CT, were concentrated in the first decade, whereas intramammary recurrences continued to arise throughout follow-up and were identified by breast-directed imaging. The institutional protocol evaluated in this study, which included annual CT during the first 10 years but discontinued routine CT thereafter while continuing MMG and US indefinitely, is consistent with that recurrence distribution.

Our observations should not be interpreted as evidence that intensive imaging surveillance improves clinical outcomes. The randomized trials underpinning current surveillance recommendations compared intensive with clinically directed follow-up and found no difference in survival (6,7). The present study lacked a comparison group and survival data and therefore cannot address the question. In a program involving routine US and CT, those examinations were the first to identify most locoregional recurrences; as a first modality, MMG identified fewer than one in five. Because the number of examinations of each type was unavailable, we can describe only the pattern of detection under the defined protocol and not the relative diagnostic performance of the examinations. Whether earlier detection translates into a clinical benefit is being investigated prospectively in the JCOG1204 (INSPIRE) trial, which is reexamining whether intensive surveillance improves overall survival in patients at high risk of recurrence (19). However, the intensive arm includes bone scintigraphy, chest and abdominal CT, brain imaging, and frequent tumor marker measurements, with annual MMG in both arms. The trial therefore focuses primarily on distant metastasis and will not establish the optimal approach for detecting locoregional recurrence.

Our study has limitations. First, it included detected recurrences without a denominator: the number of patients undergoing surveillance and the number of examinations performed were unavailable. No estimate of sensitivity, specificity, positive predictive value, or yield per examination could therefore be derived, and the modalities could not be compared on diagnostic performance. For the same reason, a receiver operating characteristic analysis could not be performed given that patients without recurrence and examination-level data would be required. The observed distribution of modalities therefore reflects both the detection capabilities and the frequency with which they were used under the protocol. Second, survival and subsequent recurrence data were unavailable, and so the clinical implications of the mode of detection could not be assessed. Third, this was a retrospective single-center analysis of 48 patients, limiting its statistical power. Although the differences in DFI and detection modality between sites were statistically significant, the absence of a difference in tumor size might reflect insufficient power rather than true equivalence, and estimates for small subgroups, such as the three skin/soft tissue recurrences, are imprecise. Those findings therefore require validation in larger, multicenter cohorts. Fourth, the analysis was restricted to surgically treated recurrences and excluded patients with unresectable locoregional disease, synchronous distant metastasis, or recurrences detected during community screening. Patients with unresectable or synchronous metastatic disease are likely to differ in tumor biology, and because synchronous distant disease is often identified through cross-sectional imaging, their exclusion might have led to an underestimation of the proportion of early recurrences and of the contributions of CT and PET-CT. Our observations therefore apply to resectable locoregional recurrences and might not be representative of all locoregional recurrences. Fifth, recurrence sites and detection modalities were obtained retrospectively. When multiple examinations were performed during the same visit, the attribution of detection to a single modality might have been imprecise. Furthermore, receptor status was unavailable for several regional nodal specimens. Finally, adherence to the defined surveillance protocol was not verified for individual patients.

In conclusion, in this single-center series, intramammary and regional nodal recurrence after surgery for breast cancer differed in timing and detection modality, whereas tumor size at detection was comparable. Regional nodal recurrences predominantly occurred early and were identified on cross-sectional imaging. In contrast, intramammary recurrences continued to occur throughout follow-up, often more than 10 years, and were detected by breast-directed imaging. Those patterns suggest that posttreatment surveillance could potentially be tailored to the time elapsed since primary surgery. They also suggest the value of continuing breast imaging beyond a fixed follow-up period. As the study lacked examination-level denominators, survival data, and a multicenter sample, the resulting observations require validation in larger, prospective studies before they can inform surveillance recommendations.

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Availability of data and materials

The data generated in the present study are not publicly available because of restrictions related to patient privacy but may be requested from the corresponding author.

Authors' contributions

KT and TO conceived and designed the study. MN, NH, SA, MH, TT, AI and MO were involved in the clinical management and surveillance of the patients, acquired and verified the clinical data, contributed to the interpretation of the results and critically revised the manuscript for important intellectual content. KT analyzed and interpreted the data, and prepared the figures and tables. KT drafted the manuscript and TO critically revised it for important intellectual content. KT and MN

confirm the authenticity of all raw data. All authors read and approved the final version of the manuscript.

Ethics approval and consent to participate

The present study was approved by the General Ethics Committee of Fukushima Medical University (Fukushima, Japan; approval no. REC2026-101) and was conducted in accordance with The Declaration of Helsinki. Given the retrospective design, the committee waived the requirement for individual written informed consent. Information about the study was made publicly available, and in accordance with the approved protocol, patients were given the opportunity to opt out.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Use of artificial intelligence tools

During the preparation of this work, AI tools (Claude; Anthropic, PBC) were used to improve the readability and language of the manuscript, and subsequently, the authors revised and edited the content produced by the AI tools as necessary, taking full responsibility for the ultimate content of the present manuscript.

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