Table 3 Response to neoadjuvant chemotherapy, Cox proportional hazards model for disease free survival

Parameter	No. of patients (%)	Hazard ratio (95% CI)
Fisher's classification		
pCR	65 (18)	1.00
pINV	305 (82)	1.07 (0.56–2.73)
Chevallier's classification		
Grade 1	30 (8)	1.00
Grade 2	21 (6)	1.03 (0.18–5.85)
Grade 3	172 (46)	1.00 (0.43–2.26)
Grade 4	147 (40)	1.31 (0.27–5.66)
JBCS classification		
Grade 3	34 (9)	1.00
Grade 2	102 (28)	1.39 (0.54–3.39)
Grade 1b	81 (22)	0.96 (0.36–2.32)
Grade 1a	141 (38)	0.61 (0.21–1.71)
Grade 0	12 (3)	0.50 (0.56–2.73)
Pathological lymph node status		
$n = 0$	174 (47)	1.00
$n = 1$–3	102 (28)	0.78 (0.54–1.10)
$n = 4$–9	57 (15)	1.57* (1.07–2.24)
$n > 10$	37 (10)	2.71* (1.83–3.95)
Clinical stage		
IIA	104 (28)	1.00
IIB	114 (31)	0.68 (0.45–1.01)
IIIA	75 (20)	1.23 (0.86–1.74)
IIIB	77 (21)	1.22 (0.85–1.74)
Clinical response		
CCR + cPR	324 (88)	1.00
CSD + cPD	46 (12)	1.44* (1.10–1.87)

CI, Confidence interval, * $P < .001$

tumors in either breast or lymph node) pathological response. According to the JBCS classification, there were 34 (9%) patients with Grade 3 pathological response (pathologically no residual tumor in the breast). Post-treatment pathological nodal status was negative in 174 (47%), 1–3 positive in 102 (28%), 4–9 positive in 57 (15%), and >10 positive in 37 (10%) patients, respectively. In the Cox proportional hazards model, the classification of pathological lymph node status and clinical response were identified as being independently significantly associated with patient outcomes (Table 3). Pretreatment hormone receptor status was not associated with pathological response or DFS. Inclusion of trastuzumab in NAC was associated with the pathological response in HER2-positive tumors ($P = 0.04$), but there was no statistical difference in the DFS (data not shown).

Figure 1 illustrates the Kaplan–Meier curves of the patient cohort of DFS according to each pathological response classification system (Fisher's, Chevallier's, JBCS). Among these classification systems, Fisher's tended to show a correlation with DFS, however, it did not reach a statistically significant difference ($P = .067$). The five-year DFS rates in Grade 3, Grade 2, Grade 1a, Grade 1b and Grade according to the JBCS system were 77%, 68%, 68%, 58%, and 52%, respectively ($P = .525$). According to Chevallier's system, the five-year DFS rates for Grade 1, Grade 2, Grade 3 and Grade 4 were 83%, 85%, 62% and 65%, respectively ($P = .16$).

The five-year DFS according to the number of post-treatment axillary node metastases was $n = 0$, 86%; $n = 1$–3, 64%; and $n = 4$–9, 25%. Figure 2 shows the DFS according to the pre-treatment cTMN classification, post-treatment pathological nodal status and clinical response to NAC. The pre-treatment clinical stage, clinical response to NAC and post-treatment pathological nodal status were strong predictors of DFS ($P < .0001$, $P = .0005$, $P < .0001$, respectively).

The pathological response results in post-treatment pathological node negative patients are shown in Fig. 3. Pathological node-negative patients accounted for 174 (47%) out of 370 patients. Since the number of Grade 0 patients according to the JBCS system was only two, they were excluded from the analysis. There were no significant relationships between the three pathological response classification systems and the DFS in pathologically node-negative patients. Neither clinical response ($P = .142$) nor pre-treatment clinical stage ($P = .231$) predicted DFS in node-negative patients.

Discussion

Pathological and biological markers predicting "pCR" in NAC have been evaluated in several studies [6, 7], but there is no consensus on the definition of pathological response. It is particularly unclear whether the classification needs the measurement of the extent of therapeutic effect including the disappearance of tumor cells and decrease of tumor cellularity [1–3, 8, 9]. The frequency distribution of residual tumor size was altered markedly by the inclusion of tumor cellularity, and the accurate pathologic response information may be provided the product of pathologic size and tumor cellularity [10]. The results in our study showed that the evaluation of tumor cellularity and tumor size by both Chevallier's and he JBCS classification systems was not useful for predicting prognosis in both all patients and node-negative patients. This result was in contrast to another study, where the reduction of tumor cellularity significantly correlated with the overall and disease free survival [11]. The negative finding in our study may be due to the small sample size of the study and limited number of events in each category of the

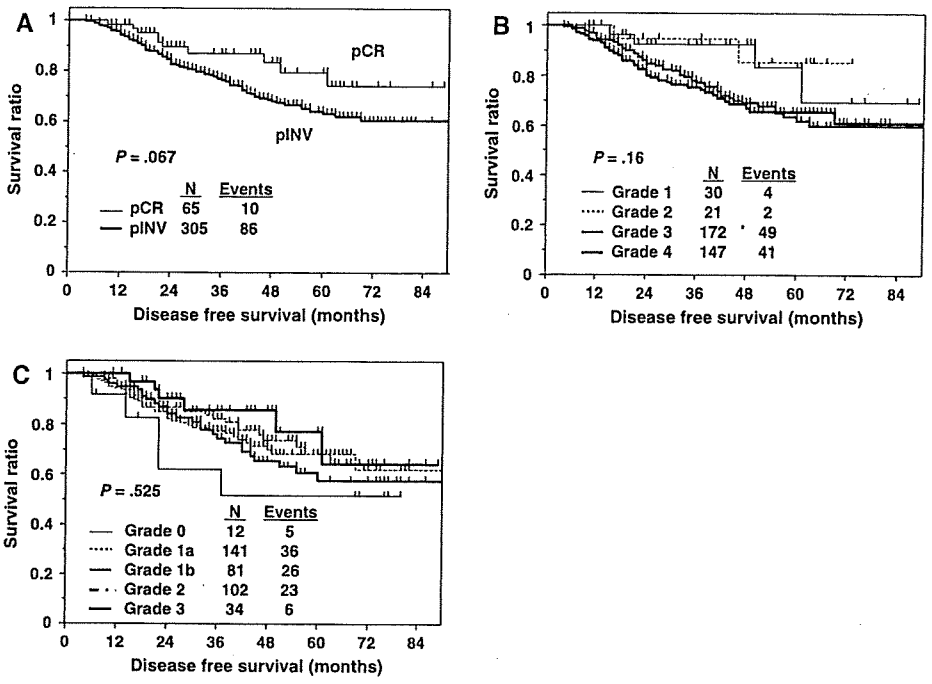

Fig. 1 Kaplan–Meier curves of disease free survival according to pathological response classification systems examined. (a) Fisher's classification; (b) Chevallier's classification; (c) JBCS classification

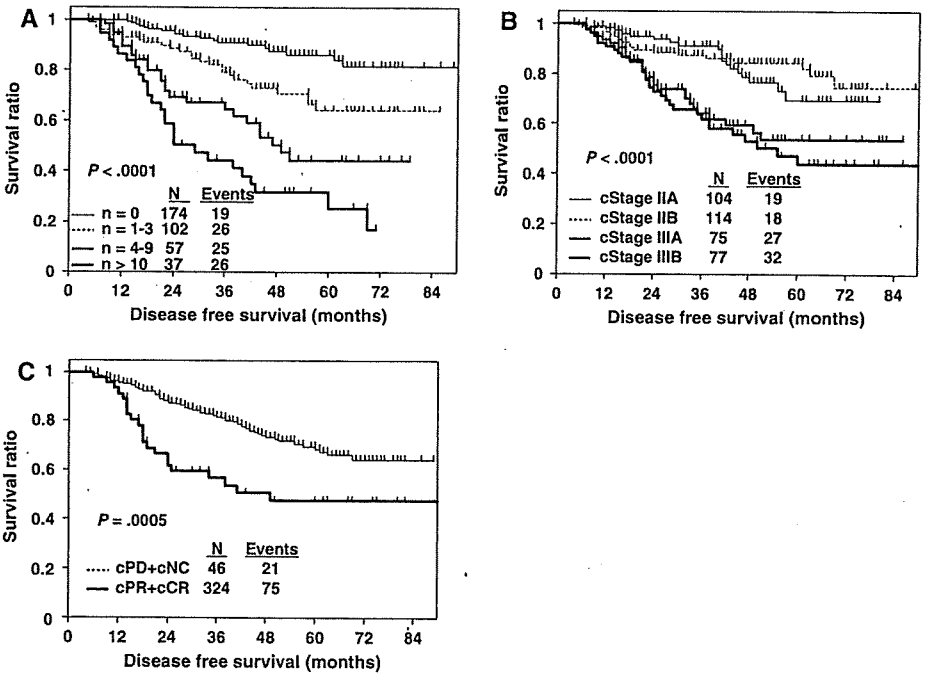

Fig. 2 Kaplan–Meier curves of disease free survival according to (a) Pathologic nodal status; (b) Clinical staging and (c) Clinical response

classification. Moreover the variety of chemotherapy regimens used as NAC may have affected the result. Particularly, trastuzumab was used only in the recent HER2-positive patient cohort.

However, studies including ours indicate the importance of incorporating the pathological nodal status in the prediction of prognosis for patients after NAC [12–15]. Fisher's classification is the most popular classification system using major clinical trials such as NSABP trials, but this classification system is diagnosed simply based on the disappearance of invasive tumor cells, regardless of non-invasive tumor cells, only in the primary tumor. Although Fisher's system is simple, objective and its usefulness as a predictive marker has been validated [1–3, 9, 14], incorporation of the therapeutic effect in axillary lymph nodes may be necessary for more precise outcome prediction.

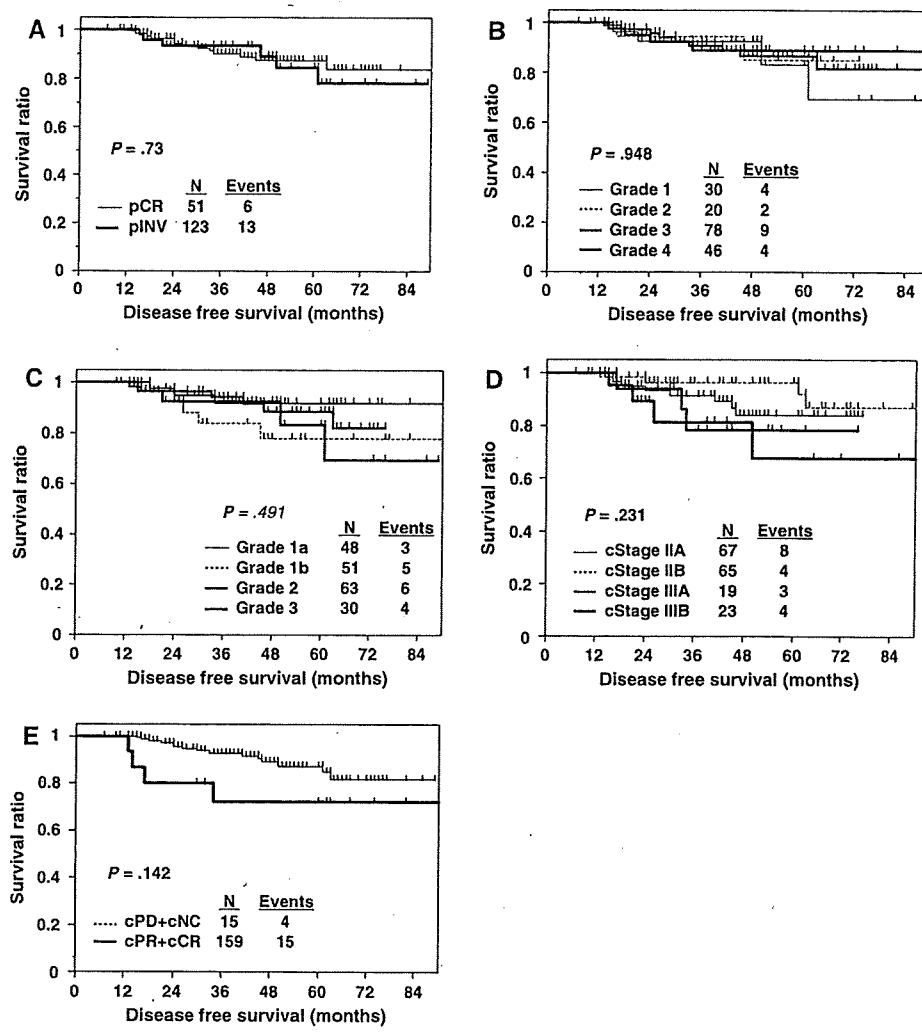

Fig. 3 Kaplan–Meier curves of disease free survival in node negative patients (a) Fisher's classification; (b) Chevallier classification; (c) JBCS classification; (d) Clinical staging; (e) Clinical response

On the other hand, clinical response was the significant predictor of the disease free survival in this study as reported in several other papers [13, 16–19]. Clinical response reflects the activity of chemotherapeutic agents. Clinical responders had a better prognosis compared with non-responders. The pretreatment clinical stage correlated with disease free survival, but there were good responders among the patients with advanced primary lesions and clinically positive axillary lymph nodes. Although pCR significantly correlated with the clinical response, the importance of the clinical response in outcome prediction may remain in patients with residual tumor or pathologically negative axillary lymph node after NAC.

In conclusion, we think that all three classifications analyzed in this study were not adequate as a prognostic marker of long-term outcome after NAC. The evaluation of the therapeutic effect in primary tumors warrants further study, especially in pathologically node-negative patients after NAC. Given the suggestion that the benefit of certain chemotherapy regimens might be different depending on the biological tumor characteristics (e.g. hormone responsive, HER2, triple negative), the validity of pCR as a prognostic marker might better be tested independently in each biological subset. Moreover, the validity of pCR with NAC including biologically targeted drugs such as trastuzumab should also be revisited.

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Clinicopathological Features of Tumors as Predictors of the Efficacy of Primary Neoadjuvant Chemotherapy for Operable Breast Cancer

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Abstract
Background Neoadjuvant chemotherapy (NC) is standard therapy for patients with locally advanced breast cancer and is increasingly used for early-stage operable disease.. Clinical and pathological responses are important prognostic parameters for NC, which aims to achieve a pathological complete response or tumor reduction to reduce the volume of subsequent breast resection. Clinicopathological markers that predict patient response to NC are needed to individualize treatment.
Methods From 1998 to 2006, 368 patients with primary breast cancer underwent curative surgical treatment after NC (anthracycline and/or taxane without trastuzumab). We retrospectively evaluated the clinicopathological features and classification of the tumors using computed tomography (CT) before NC and analyzed the correlation with the pathological complete response (pCR) and reduction of tumor size after treatment.
Results The overall response and pCR rates in these patients were 86% and 17%, respectively. In multivariate analysis, classification as a scirrhous-type tumor was an independent predictor of reduced likelihood of pCR ($p = 0.0115$; odds ratio 0.21). For tumor reduction, histological grade 3 ($p = 0.0002$; odds ratio 3.3) and localized tumors identified by using CT imaging ($p = 0.0126$; odds ratio 2.4) were independent predictors in multivariate analysis.
Conclusions In this study, NC often did not result in pCR for breast cancers classified as scirrhous. Furthermore, tumor type classification using CT imaging and histological grading was effective to predict tumor reduction in response to NC that included an anthracycline and/or a taxane.

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Introduction

Neoadjuvant chemotherapy (NC) is used to reduce the size of locally advanced breast cancer tumors, and hence, the area to be resected, or to enable breast conservation for cases in which it was otherwise not possible. In clinical practice, because currently available anticancer drugs are extremely effective, these goals are achieved in many patients and the primary tumors completely disappear (i.e., pathological complete response (pCR)) in some patients by the end of NC. Data from large-scale studies have revealed that the patients who achieved pCR after preoperative administration of anticancer drugs have significantly better prognoses than other patients. These preoperative chemotherapy regimens primarily consist of an anthracycline. A

taxane may be added for some patients and additionally, trastuzumab is included for HER-2-positive patients. Indeed, the percentage of patients who experienced pCR increased when an anthracycline was added to their treatment regimens, and further increased with the addition of a taxane [1, 2]. With NC, limited surgery is assumed to be performed after the volume of the advanced breast cancer tumor is reduced, whereas NC is designed to extend the survival of patients by causing tumors to disappear solely by using anticancer drugs. Therefore, even those patients with breast cancer who have relatively small tumors close to their early-stage are currently treated first with anticancer drugs. Although preoperative chemotherapy has been used in wider range of cases, there are no practical criteria for its indications in terms of the results from clinicopathological examinations. Clinically, some patients show excellent responses to anticancer drugs and NC should be performed proactively, whereas other patients do not significantly benefit from these drugs and NC may not be necessary. Thus, individually predicting the efficacy of NC used for different purposes and deciding whether it should be performed is a current clinical goal.

In recent translational research, the efficacy of anticancer or hormone drugs were predicted by immunologically examining the sensitivity of the patients to these drugs [3]. As the indications of NC continue to expand, it is necessary to precisely select therapeutic methods, including the type of anticancer drugs, based on small tissue samples and laboratory test results that are available before surgeries. In the present study, we retrospectively examined cases treated at our clinic to determine whether it is possible to predict the efficacy of NC used for different purposes based on pretreatment tissue samples and the tumor shape observed using pretreatment CT imaging.

Methods

Patients and treatments

All patients diagnosed with operable breast cancer and treated between May 1998 and July 2006 at the National Cancer Center Hospital (NCCH; Tokyo, Japan) with NC, including an anthracycline and a taxane, were included this retrospective study. NC was indicated for clinical stage II tumors and tumors >3 cm or stage III breast cancer tumors. Core-needle biopsy was performed before NC to allow a pathological diagnosis. Doxorubicin (DOX, 50 mg/m^2) and docetaxel (DOC, 60 mg/m^2) (AT regimen) were administered in four cycles every 3 weeks before surgery. Additional adjuvant treatment with DOX/DTX was given if the patients achieved complete or partial remission after preoperative chemotherapy or were otherwise treated with four cycles of intravenous cyclophosphamide, methotrexate, and 5-fluorouracil. FECT treatment was four cycles of 5-fluorouracil (500 mg/m^2)/epirubicin (100 mg/m^2)/cyclophosphamide (500 mg/m^2) plus 12 weekly cycles of paclitaxel (80 mg/m^2) followed by surgery. The ACT regimen was 4 cycles of doxorubicin (60 mg/m^2)/cyclophosphamide (600 mg/m^2) plus 12 weekly cycles of paclitaxel (80 mg/m^2) followed by surgery. The T regimen was 12 weekly cycles of paclitaxel (80 mg/m^2) followed by surgery. Recently, patients with breast cancer that showed an HER-2 overexpression phenotype have received trastuzumab as PST. However, in this study we excluded these patients because we have only recently begun to use trastuzumab, and many HER-2–positive patients did not receive this treatment. Tamoxifen (20 mg/day) or anastrozole (10 mg/day) was administered for 5 years when pretreatment biopsy specimens or surgical postchemotherapy specimens were positive for estrogen receptor (ER) or progesterone receptor (PgR). The surgical treatment employed was mastectomy or breast-conserving surgery with axillary lymph node dissection (level 2) and that was decided from both of preoperative general diagnosis (palpation, MMG, US, and MDCT findings) and intraoperative pathological findings.

Evaluation of pathological factors

Pretreatment diagnoses were established by our pathologists using a core-needle biopsy or a surgical resection. The expression levels of hormone receptors and HER-2 were determined by using immunohistological examinations. Surgical specimens were sectioned to an approximately 7–10-mm thickness and pathologically classified by pathologists. Pathologic features were noted and invasive ductal carcinomas (IDCs) were classified as one of three subtypes (papillotubular, solid-tubular, and scirrhous) according to the General and Pathological Recording of Breast Cancer guideline established by the Japanese Breast Cancer Society [4]. The diagnosis of invasive lobular carcinoma was based on tumor histology showing the absence of E-cadherin by immunohistological examination on the pretreatment specimens. The criteria for histological grading of IDCs were based on a modification of those recommended by the World Health Organization [5, 6]. The response criteria used in this study include Fisher's system [7]; pCR means no histological evidence of invasive tumor cells (specimens with only noninvasive cells were included), whereas pINV indicated the presence of invasive tumor cells. The criterion for ER- and PgR-positive samples was specific signals in more than 10% of the cancer cell nuclei, regardless of intensity. HER-2 positivity was defined as 3+ , i.e., markedly positive in more than 10% of the cancer cells.

Clinical responses to preoperative chemotherapy were reflected by the two greatest perpendicular diameters (before each chemotherapy treatment and before surgery) of tumors in the breast and an axillary lymph node. No clinical evidence of palpable tumor in the breast and axillary lymph nodes was defined as a clinical complete response (cCR). Reduction in the total tumor size by 30% or more was graded as a clinical partial response (cPR). An increase in the total tumor size of more than 20% or appearance of new suspicious ipsilateral axillary adenopathy was considered progressive disease (cPD). Tumors that did not meet any of the criteria for response or progression were considered unchanged (cNC).

CT imaging

CT examinations were performed with the patient in the supine position using a helical CT scanner (X-Vigor; Toshiba Medical Systems, Japan) between January and June 2000 or using an MDCT scanner (Aquilion, Toshiba) beginning in July 2000. The first noncontrast-enhanced CT scan served as the baseline with scanning performed from the cranial end of the sternum to the inframammary fold. Subsequently, an enhanced zoomed scan was obtained to visualize the entire breast. A bolus of 100 ml of nonionic contrast material (300 mgI/ml) was injected intravenously at a rate of 3 ml per second via an antecubital vein on the side opposite the affected breast using an automated injector. Image acquisition was started 40 s after the start of the bolus injection. The reconstruction interval was 5 mm.

The tumor shape was classified into two types: localized tumors visualized as single lesions and nonlocalized tumors, including those with surrounding lesions, multiple lesions, or glandular spreading (Fig. 1). CT imaging was used before both NC and surgery. The maximum tumor size measurements and the tumor shape classification were obtained using the CT images and compared with the size measured during the pathological examination.

Results

From May 1998 to July 2006, 403 patients were administered an anthracycline and/or a taxane as NC at the NCCH. Excluding the patients who received trastuzumab, the indication of which was not clear at the time of the study, concomitantly with a taxane, 368 patients who were diagnosed with breast cancer using pretreatment cutting needle biopsies were included in this study. The patient backgrounds are shown in Table 1. Among the patients, 194 (53%) were aged 50 years or younger and 174 (47%) were aged 51 years or older. The clinical stages of the patients at the first visit were IIA, IIB, IIIA, and IIIB for 29%, 31%, 13%, and 20%, respectively. According to the histological examinations of pretreatment cutting needle biopsies, 333 patients (90%) had an IDC, 19%, 36%, and 36% of which were classified as papillotubular type, solid-tubular type and scirrhous type, respectively. Other than IDC, 14 patients (4%) had an invasive lobular carcinoma (ILC) and 7 patients (2%) had a mucinous carcinoma.

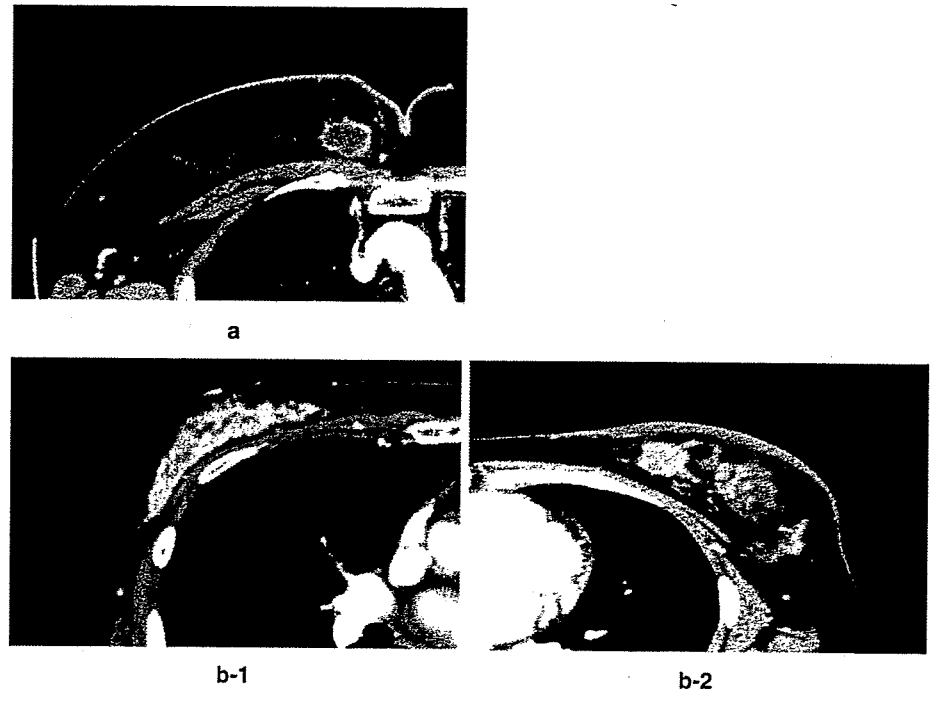

Fig. 1 Classification of tumor by CT imaging. **a** Localized type. **b-1** Nonlocalized type: glandular spreading. **b-2** Nonlocalized type: tumor with surrounding lesions

Table 1 Patient and disease characteristics ($N = 368$)

Parameter	No. of patients	%
Age (years)		
≤50	194	53
≥51	174	47
Clinical stage		
IIA	105	29
IIB	114	31
IIIA	74	13
IIIB	75	20
Pretreatment pathology		
Invasive ductal carcinoma	333	90
Papillotubular type	68	19
Solid-tubular type	131	36
Scirrhous type	134	36
Invasive lobular carcinoma	14	4
Mucinous carcinoma	7	2
Other	14	4
Hormone receptors		
ER positive	150	41
PgR positive	218	59
HER2		
Positive	57	15
Histological grade		
G1	18	5
G2	169	46
G3	181	49
Neoadjuvant chemotherapy		
AC	3	1
ACT	75	20
AT	185	50
FECT	92	25
T	13	4
Surgery		
Partial mastectomy	136	37
Total mastectomy	232	63
Clinical response		
CR	99	27
PR	218	59
NC	46	13
PD	5	1
Pathological response		
pCR	64	17
pINV	304	83
Postoperative pathological tumor size (mm)		
Median	24	
Range	0–130	
No. of pathological LN metastases		
0	164	45
1–3	108	29
4–9	58	16
≥10	38	10

PgR, progesterone receptor; *ER*, estrogen receptor; *CR*, complete response; *PR*, partial response; *NC*, neoadjuvant chemotherapy; *pCR*, pathological complete response; *LN*, lymph node

Immunohistological examinations revealed that 41%, 59%, and 15% of the patients were positive for ER, PgR, and HER-2, respectively. The histological grade was G2 and G3 in 46% and 49% of the patients, respectively, indicating that many patients had relatively high-grade disease. As NC regimens, AC, ACT, AT, FECT, and T were used in 1%, 20%, 50%, 25%, and 4% of the patients, respectively. The clinical response rate to NC was 86% (27% for cCR and 59% for cPR), and 64 patients (17%) achieved a pCR pathological response. The median postoperative pathological tumor size was 24 (range, 0–130) mm. Whereas 45% of the patients were node-negative, 16% of the patients had four or more and approximately 10% of the patients had ten or more metastatic lymph nodes. Among the 368 patients, we further examined 267 patients who underwent CT imaging before treatment (Table 2). Classification of the tumor shape based on CT imaging showed localized tumors in 65 patients (24%). The median maximum tumor size measured using pretreatment CT was 40 (range, 15–120) mm. When we compared pretreatment maximum tumor size and the postoperative pathological tumor size in these patients, the treatment reduced the maximum tumor size by 30% or more in 146 patients (55%).

Table 3 shows the results of univariate analysis performed to evaluate the relationship between the efficacy of

Table 2 Tumor characteristics in CT images ($N = 267$)

Parameter	No. of patients	%
Tumor type		
Localized type	65	24
Nonlocalized type	202	76
Pretreatment tumor size (mm)		
Median	40	
Range	15–120	
Tumor reduction rate[a]		
>30%	146	55
<30%	121	33

[a] x100 (Pretreatment tumor size − pathological tumor size)/pretreatment tumor size); pretreatment tumor sizes were measured in imaging from computed tomography

Table 3 Univariate analysis of predictive markers in pathological response and tumor reduction

Parameter	pCR		Tumor reduction rate >30%	
	n (%)	*p* value	*n* (%)	*p* value
Age (years)				
≥51	42[a] (22)	0.022	61 (52)	N.S.
≤50	22 (13)		85 (56)	
Invasive ductal carcinoma				
Solid-tubular type	35[a] (27)	0.0006	60[a] (67)	0.005
Scirrhous type	12[a] (8)	0.0006	50 (52)	N.S.
Papillotubular type	8 (12)	N.S.	29 (54)	N.S.
ER-negative	53[a] (24)	<0.0001	96 (59)	N.S.
ER-positive	11 (7)		50 (48)	
PgR-negative	50[a] (23)	0.0005	92 (58)	N.S.
PgR-positive	14 (9)		54 (50)	
HER2 3+	19[a] (33)	0.004	24 (55)	N.S.
HER2 2+	6 (11)		27 (66)	
HER2 <1+	39 (15)		95 (52)	
Histological grade G3	45[a] (25)	0.001	89[a] (70)	<0.0001
G2	17 (10)		49 (39)	
G1	2 (11)		7 (58)	
Clinical response				
CR + PR	62[a] (20)	0.0017	138[a] (60)	<0.0001
NC + PD	2 (3)		8 (22)	
CT tumor type				
Localized type	16 (24)	0.063	48[a] (74)	0.0003
Nonlocalized type	29 (14)		98 (49)	

[a] $p < 0.05$

CT, computed tomography; *ER*, estrogen receptor; *PgR*, progesterone receptor; *CR*, complete response; *PR*, partial response; *NC*, neoadjuvant chemotherapy

NC and the clinicopathological examination results. Significantly higher percentages of patients achieved pCR if they were aged 50 years or older, had solid-tubular type disease, were negative for ER or PgR, were positive for HER-2, had histological grade 3 disease, demonstrated positive clinical sensitivity (CR [complete response] + PR [partial response]), or were classified as having localized disease using pretreatment CT imaging. Conversely, significantly lower percentages of patients experienced pCR if their tumors were histologically classified as scirrhous. When the pretreatment maximum tumor size and the postoperative pathological maximum tumor size were compared, the clinicopathological factors that were significantly associated with 30% or more reductions in tumor size were having solid tubular-type disease, testing negative for ER, classification of histological grade 3, positive clinical sensitivity (CR + PR), and classification as localized tumors based on pretreatment CT imaging. Table 4 shows the results of multivariate analysis of these factors. In this analysis, the factor that was significantly associated with reduced rates of pCR was tumors classified as scirrhous. Other factors did not significantly influence the pathological response. Histological grade 3, positive clinical sensitivity (CR + PR), and classification as localized tumors were significantly associated with tumor size reduction.

Discussion

In recent years, NC has been used not only for locally advanced breast cancer but also for relatively early-stage breast cancer. This type of therapy is used to (1) achieve pCR; (2) enable breast conservation by reducing the size of the tumor; and (3) evaluate the sensitivity of the breast cancer to anticancer drugs.

The primary purpose of NC is to achieve pCR, which is based on the understanding that patients who experience pCR after NC have better prognoses relative to other patients [8]. To accomplish this purpose, it is necessary to characterize the cases of breast cancer that are more likely to achieve pCR and to select anticancer drugs that are appropriate for each case. Immunohistological examinations, including analyses of hormone receptors, HER-2 and

Table 4 Multivariate analysis

Parameter	pCR		Tumor reduction rate >30%	
	p value	Odds ratio	*p* value	Odds ratio
Age >51 years	NS		NS	
Solid-tubular type	NS		NS	
Scirrhous type	0.008	0.2 (−1.441 to −0.239)	NS	
ER-negative	NS		NS	
PgR-negative	NS		NS	
HER2 3+	NS		NS	
Histological grade G3	NS		<0.0001	3.76 (0.349–0.989)
CR + PR	NS		0.0003	5.28 (0.405–1.309)
Localized type	NS		0.012	2.42 (0.104–0.796)

CR, complete response; *PR*, partial response; *NS*, not significant

Ki-67, have been reported to relate to the efficacy of PST [9–12]. In our study, we examined the characteristics of breast cancer tumors that made it easier to achieve pCR with NC. In univariate analysis, histological grade 3 and solid-tubular type tumors as well as lack of ER and PgR overexpression and the presence of HER-2 overexpression were shown to be significantly associated with improved treatment efficacy. However, multivariate analysis revealed that cases classified as scirrhous type were significantly less likely to achieve pCR. Interestingly, PST has been reported to be less effective for ILC [13–15]. In this study ILC had few effect of tumor size reduction of NC and there was no pCR case in ILCs (data not shown). However, ILC was rare in Japan formerly and there were few ILC patients in this study. One of the reasons for this low efficacy may be that tumor cells from ILCs are relatively isolated and are distributed among the fibrous stroma, leading to less blood flow to the tumor and less drug accessibility. Scirrhous-type tumors, which were associated with less NC efficacy, are histologically similar to ILCs growing as the stroma grows with relatively isolated tumor cells. Therefore, these histological features may be related to the efficacy of NC for these tumors.

It has been reported that NC is useful for breast conservation after a reduction of tumor size [16–18]. In the EORTC10902 study, NC enabled breast conservation in 57 of 246 (23%) patients who were scheduled to undergo total mastectomies [16]. In the present study, we characterized the tumor sizes, which tended to be reduced by NC, using pretreatment CT imaging as well as clinicopathological examinations. Magnetic resonance imaging (MRI) is more widely used to plan adequate surgical treatment for early breast cancer than CT probably because of the risk of radiation exposure. However, CT scan has an important advantage compared with MRI because CT breast images are obtained in the supine position used during surgery, thus providing precise information about the tumor extent; in contrast, in most previous studies of MRI, patients were examined in the prone position to minimize motion of the breast during breathing. There are helical CT scanners in many medium and small Japanese hospitals. Therefore, we can use CT without circumstance. As a result, a significant reduction of tumor size was observed in cases classified as localized tumors, as well as those categorized as histological grade 3 disease and those that achieved CR or PR in terms of clinical efficacy. There are previous reports about NC reducing the sizes of tumors and the safety of breast-conserving therapy, including one from our institution [18–20]. When the tumors show sporadic shrinkage, they need to be resected carefully after NC because the remaining tumor cells can be diffusely distributed. In contrast, when the shrinkage pattern is concentric, NC is thought to be more effective for reducing the tumor size, making breast-conserving therapy safer. Therefore, localized tumors may achieve a favorable degree of reduction because they often shrink in a concentric manner. In evaluation of the tumor reduction rate, we classified the tumor shape, measured the pretreatment tumor size, and compared it with the post-operative pathological tumor size. The classification of tumors into localized or nonlocalized types using CT imaging provides a basis for making this determination. Localized tumors responded well to NC and were reduced into smaller, concentric tumors that could be safely treated by wide excision, giving a negative margin status. However, nonlocalized tumors diminished into a mosaic pattern of residual tumor cells, giving a positive margin status when treated with breast conserving therapy and tumor reduction rate were low. Multivariate analysis demonstrated that classification by CT was a powerful predictor of the tumor reduction rate by NC in this study. To the best of our knowledge, this is the first report to show that the tumor shape is useful as a predictive criterion for the efficacy of NC.

Breast cancer therapy with anticancer drugs is thought to result in equivalent survival rates when performed before or after surgery [8, 16]. Currently, both anthracyclines and taxanes are sufficiently used to increase the percentage of patients achieving pCR; however, there are no definitive criteria that detail the proper indications of various anticancer drugs for different types of tumors. Therefore, unnecessary drugs may be administered to patients in excessive doses. The postoperative adjuvant therapy for primary breast cancer is provided in accordance with the recommendations from the St. Gallen consensus meeting [21]. Although adjuvant chemotherapy is considered to be standard for node-positive patients, many aspects concerning the administration of anticancer drugs to node-negative patients have not been clarified. In particular, whether the anthracyclines and taxanes used for NC are necessary for these node-negative patients is not clear, and thus, these drugs may be used excessively for these patients. We believe that it is critical to predict the efficacy of drugs used for different purposes to determine which drugs and doses should be for each patient. In the NSABPB-27 study, the addition of a taxane to an anthracycline did not result in a significantly improved survival rate, which suggested that more specific criteria are needed to identify the cases in which taxanes produce an additive effect [1]. In recently published studies, the sensitivity of a certain drug was evaluated and then therapy was continued only for patients who experienced efficacy by adding the drug, whereas surgeries were performed for those who did not benefit from the medication. In fact, there are patients who do not benefit from widely used anticancer drugs, including anthracyclines and taxanes [21, 22]. Performing NC aggressively in these patients is disadvantageous. Thus,

it is important to identify tumors resistant to NC before the treatment and to exclude such cases from NC.

We have examined the predictability of NC efficacy, which has no current definitive indication. Regarding the prediction of efficacy to achieve pCR, high degrees of responsiveness is reportedly obtained with the concomitant use of trastuzumab in patients who have HER-2 overexpression [2]. At our institution, trastuzumab has been administered to these patients in recent years, leading to a markedly high pCR rate, which surpassed that achieved using NC with anthracyclines and taxanes. These patients, however, were not included in this study because we only recently started routinely using trastuzumab and many patients who showed HER-2 expression did not receive this agent early in the study. The examination of both pCR and tumor size reduction in the present study identified several factors that are useful to determine the indications of NC. This study indicated that pCR of scirrhous type for NC was difficult and the primary tumor with localized tumor type in CT imaging or histological grade 3 will be fairly reduced by NC. However, these features could not predict the response completely and terminate the NC premature in nonresponders. Additional cases and prospective studies that are focused on particular types of cases are necessary.

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ORIGINAL PAPER

Immunohistochemical expression of PTEN and phosphorylated Akt are not correlated with clinical outcome in breast cancer patients treated with trastuzumab-containing neo-adjuvant chemotherapy

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Abstract The loss of PTEN and phosphorylated Akt (pAkt) expression is thought to be involved in the mechanism leading to trastuzumab resistance in patients with HER2-positive breast cancer. We retrospectively performed immunohistochemical analyses for estrogen receptor, progesterone receptor, HER2/neu, PTEN, pAkt, and p53 expression in tumor specimens obtained before and after trastuzumab-containing neo-adjuvant chemotherapy. The intensity of staining was evaluated for each biomarker, and the correlations between the immunohistochemical profiles and the clinical outcome were analyzed. The changes in the immunohistochemical profiles between specimens obtained before and after trastuzumab-containing neo-adjuvant chemotherapy were evaluated for patients with residual tumors. The present study included 44 patients with breast cancer who received trastuzumab-containing neo-adjuvant chemotherapy. Seventeen patients achieved a pathological complete response. The patients were positive for PTEN and pAkt (PTEN = 14%, $N = 6/44$; pAkt, 80%, $N = 35/44$). The expression of both PTEN and pAkt were not correlated with pathological complete response. Persistent HER2/neu over-expression after neo-adjuvant chemotherapy was significantly associated with recurrence. Among 27 patients with residual cancer, the percentages of patients with HER2/neu-positive or pAkt-positive tumors were low, but PTEN expression was elevated. The present study suggested that neither the immunohistochemical expression of PTEN nor the expression of pAkt was associated with the clinical outcome of trastuzumab-containing neo-adjuvant chemotherapy. Except among patients with pathological complete remission, the persistent over-expression of HER2/neu may be a poor prognostic factor.

Keywords Breast cancer · Neoadjuvant chemotherapy · pAkt · PTEN · Trastuzumab

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Introduction

Breast cancer remains the major cause of death from cancer among woman throughout the world. Most breast cancers are thought to be systemic diseases at the time of diagnosis, and recurrence as a result of sub-clinical micro-metastasis is common. Recent advances in multidisciplinary approaches for treating breast cancer, including both neo-adjuvant chemotherapy and adjuvant chemotherapy, have played important roles in improving the survival rate [1]. A previous study revealed that patients who achieved a pathological complete response (pCR) had longer relapse-free survival periods than patients without pCR after neo-adjuvant

chemotherapy [2]. This study suggested that the chem otherapeutic response at the primary lesion may be correlated with the chemotherapeutic response of micrometastases; therefore, the selection of a chemotherapeutic regimen that best enables pCR may improve both the relapse-free and overall survival rates.

The epidermal growth factor receptor/HER family is involved in cell proliferation, differentiation, and survival. HER2/neu over-expression and *HER2/neu* amplification are widely known markers of aggressive tumor behavior, and a poor clinical outcome in breast cancer patients are observed in approximately 20–30% of breast cancer patients [3]. Trastuzumab, a monoclonal antibody against HER2/neu, has been shown to have a significant efficacy in both adjuvant and metastatic settings [4, 5]. Recently, a randomized phase II trial revealed that trastuzumab-containing neo-adjuvant chemotherapy significantly improved the pCR rate, compared with neo-adjuvant chemotherapy alone, in patients with HER2/neu-positive breast cancer [6].

Immunohistochemistry and fluorescence in situ hybridization (FISH) are currently available methods for identifying patients who are likely to benefit from trastuzumab; however, trastuzumab is ineffective in some patients and progression may still occur. Currently, the possible mechanisms of trastuzumab-resistance include the down-regulation of p27; the activation of insulin-like growth factor receptor (IGF-1R); the loss of expression of PTEN, pAkt, or the interaction HER receptor family; the masking of HER2/neu by membrane-associated glycoprotein mucin-4; angiogenesis; or antibody-dependent cellular toxicity [7]. These hypotheses remain controversial, and some studies that have assessed IGF-1R and p53 levels in clinical samples have reported negative results [8, 9].

PTEN is a dual phosphatase that mainly dephosphorylates position D3 of membrane phosphatidylinositol-3, 4, 5 triphosphate (PI3, 4, 5P3) and is a negative regulator of pAkt. Recently, Nagata et al. suggested that PTEN activation contributes to trastuzumab-induced tumor inhibition and that the loss of PTEN predicts trastuzumab resistance in patients with breast cancer [10]. The authors also validated their hypothesis in 47 metastatic breast cancer patients treated with a taxane-plus-trastuzumab therapy, revealing a statistically significant difference in the clinical response [10]. To test this hypothesis in patients with HER2-positive primary breast cancer, we compared the relationship between clinical outcome and the expression of immunohistochemical profiles, including those of p53, hormone receptors, PTEN, and pAkt, in patients receiving trastuzumab-containing neo-adjuvant chemotherapy. In addition, we investigated the changes in these profiles using specimens obtained before and after trastuzumab-containing neo-adjuvant chemotherapy.

Patients and methods

Patients

A total of 229 patients with breast cancer were treated with neo-adjuvant chemotherapy between January 1999 and January 2006 at the National Cancer Center Hospital. There were 49 patients who were classified as having HER2/neu-positive breast cancer (HER2/neu 3+ or HER2/neu 2+ and FISH-positive) and who received trastuzumab-containing neo-adjuvant chemotherapy. Of these, we identified 44 patients with adequate tumor tissue samples available for retrospective research. Trastuzumab was administered initially using an intravenous loading dose of 4 mg/kg, followed by weekly infusions of trastuzumab (2 mg/kg) in combination with weekly paclitaxel therapy. The dosages of the neo-adjuvant chemotherapy regimens were followed as: CEF therapy (cyclophosfamide, 500 mg/m^2, i.v. on day 1; epirubicin, 100 mg/m^2, i.v. on day 1; 5FU, 500 mg/m^2, i.v. on day 1; 21-day cycles), AC therapy (doxorubicin, 60 mg/m^2, i.v. on day 1; cyclophosphamide, 600 mg/m^2, i.v. on day 1; 21-day cycles), AT therapy (doxorubicin, 50 mg/m^2, i.v. on day 1; docetaxel, 60 mg/m^2, i.v. on day 1; 21-day cycles), and weekly paclitaxel therapy (80 mg/m^2, i.v. on day 1; 7-day cycles).

Tissue samples and microscopic and immunohistochemical analysis

Tissue samples were obtained from core-needle biopsy specimens before neo-adjuvant chemotherapy and from surgical specimens (mastectomy or lumpectomy) after neo-adjuvant chemotherapy. All hematoxylin-eosin stained core-needle biopsy specimens were reviewed by a pathologist (K. T.), and tissue sample were confirmed to contain adequate amounts of cancer tissue for use in the present study.

After surgical treatment, the pathologist evaluated the pathological responses of all the specimens using hematoxylin-eosin staining slides. pCR was defined as the complete disappearance of invasive cancer cells in the primary tumor and the axilla. We also evaluated the immunohistochemical changes in biomarker expression in the 27 patients who did not achieve pCR.

The pathological and immunohistochemical examinations were conducted by the same pathologists (K. T. and K. S.), who were blinded to the clinical statuses of the patients. Formalin-fixed, paraffin-embedded tissue samples were sectioned 4-μm thick and mounted on charged slides. Immunochistochemical staining of p53 (clone DO7; Dako, Glostrup, Denmark), ER (clone 1D5; Dako), and PgR (clone PgR636; Dako), were performed using the streptoavidin–biotin method, and were considered to be positive if

10% or more of the nuclei in the invasive component of the tumor was stained [8, 11]. The HER2/neu status, as assessed using Herceptest (Dako), was scored on a scale of 0–3+, according to the Dako scoring system. Clone 6H2.1 (Dako) and clone 14-5 (Dako) were used for immunohistochemical staining of PTEN and pAkt, respectively. For PTEN and pAkt, the slides were pretreated using heat-induced epitope retrieval and target retrieval solution, pH 9.0 (S2368; Dako), at 95–99°C for 40 min and then cooled for 20 min at room temperature. Immunohistochemistry was performed using the specified detection systems (ChemMate; Dako). Finally, the slides were incubated in DAB + substrate/chromogen solution (K3468; Dako) for 10 min, rinsed in diluted water, counterstained with hematoxylin, and mounted. Negative controls, in which the primary antibody was omitted, were also included in each run. Primary lung cancers and the stroma of endometria with a strong staining pattern (3+) were used as positive controls for PTEN, while primary lung cancer with a strong staining pattern (3+) was used as a positive control for pAkt in each run. The positive staining for PTEN was defined as cytoplasmic staining, which was same as internal control such as peripheral nerve. Positive staining for pAkt was defined as distinct cytoplasmic staining, which was recognized by low power fields. We defined cases with a score of 0 as being negative for PTEN and pAKT in the statistical analysis.

Statistical analysis

The Kaplan–Meier method was used to estimate the recurrence-free survival and the overall survival. Recurrence-free survival was measured from the first day of treatment until recurrence or the final day of the follow-up period without recurrence; Overall survival was measured from the first day of treatment until death or the final day of the follow-up period. The relationships between the expression of the biomarkers (p53, estrogen receptor, progesterone receptor, HER2/neu, PTEN, and pAkt), and the clinical outcomes of the patients were compared using the Chi-square test, the Fisher-exact test, and the log-rank test. All the statistical analyses were performed using SPSS 12.0J (SPSS Inc., Chicago, IL, USA), and the significance level for the results was set at 0.05 (two-sided).

Results

The present study included 44 patients. The patient's clinical characteristics are summarized in Table 1. Eighteen patients received CEF therapy followed by weekly paclitaxel/trastuzumab therapy, 11 patients received AC therapy followed by weekly paclitaxel/trastuzumab therapy, 8 patients received AT therapy followed by weekly paclitaxel/trastuzuab therapy, and 7 patients received weekly paclitaxel/trastuzumab therapy. None of the patients had progressive disease during neo-adjuvant chemotherapy. The median time between the last administration of neo-adjuvant chemotherapy until surgery was 5 weeks. Among 28 patients who had undergone a mastectomy, 9 patients received adjuvant radiotherapy. Sixteen patients received breast-conserving surgery followed by adjuvant radiotherapy. Nine patients received adjuvant hormone therapy.

Table 1 Patient characteristics

Characteristics	Value
Median age (range)	57 (33–78)
Side (right/left)	21/23
Median ECOG performance status	0
Menopausal status	
Pre-menopause	15 (34%)
Post-menopause	29 (66%)
Median clinical tumor size (range)	50 mm (20–120)
Number of patients with clinical lymph node swelling	23 (52%)
UICC-TNM staging	
IIA	15 (34%)
IIB	13 (30%)
IIIA	10 (23%)
IIIB	6 (13%)

After primary treatment, 12 patients developed recurrent disease: 3 loco-regional recurrences and 9 systemic recurrences. The sites of first relapse included six lung metastases, five liver metastases, three brain metastases, three loco-regional metastases, one bone metastasis, and one lymph node metastasis. Five patients died as a result of disease progression. The 5-year survival rate was 84%, and the 5-year recurrence-free survival rate was 65%.

Of the 44 patients, 17 patients achieved pCR. The median pathological tumor size of the patients with non-pCR was 15 mm (range, 0–100 mm). Significant differences in recurrence-free survival but overall survival were seen between patients with or without pCR (log-rank test, $P = 0.016$, 5-year recurrence-free survival rate; 86% vs. 52%, $p = 0.086$, 5-year survival rate; 100% vs. 77%, respectively). The relationship between pCR and the results of immunohistochemical staining of the biomarkers before neo-adjuvant chemotherapy are summarized in Table 2. None of the biomarkers examined in the specimens obtained at the time of diagnosis were significantly associated with either pCR or recurrence (Chi-square test, Fisher-exact test, $P > 0.1$).

Table 2 Relationship between pCR and immunohistochemical profiles in specimens at the time of diagnosis (Chi-square test and Fisher-exact test)

Variables	Total (%) $n = 44$	pCR		*P*-value
		pCR ($n = 17$)	Non-pCR ($n = 27$)	
Grade[a]				0.99
1	4 (9)	1	3	
2–3	40 (91)	16	24	
p53				0.680
Negative	25 (57)	9	16	
Positive	19 (43)	8	11	
ER				0.065
Negative	39 (89)	13	26	
Positive	5 (11)	4	1	
PgR				0.273
Negative	41 (93)	17	24	
Positive	3 (7)	0	3	
ER and/or PgR				0.402
Negative	37 (85)	13	24	
Positive	7 (15)	4	3	
PTEN				0.186
Negative	38 (86)	13	25	
Positive	6 (14)	4	2	
pAkt				0.275
Negative	9 (20)	5	4	
Positive	35 (80)	12	23	

Abbreviations: *pCR* pathological complete response

[a] Grade was defined using hematoxylin-eosin staining

Table 3 Relationship between recurrence and immunohistochemical profiles in residual tumor specimens obtained after neoadjuvant chemotherapy (Chi-square test and Fisher exact test)

Variables	Recurrence		*P*-value
	Rec[b] ($n = 11$)	Non-rec ($n = 16$)	
Grade[a]			0.618
1	1	4	
2–3	10	12	
p53			0.411
Negative	6	12	
Positive	5	4	
ER			0.99
Negative	10	14	
Positive	1	2	
PgR			0.99
Negative	11	15	
Positive	0	1	
ER and/or PgR			0.624
Negative	10	13	
Positive	1	3	
HER2/neu			0.008
Negative	0	8	
Positive	11	8	
PTEN			0.391
Negative	7	13	
Positive	4	3	
pAkt			0.453
Negative	5	5	
Positive	6	11	

Abbreviations: *Rec* recurrence

[a] Grade was defined using hematoxylin-eosin staining

[b] Twelve patients had recurrences in the present study. One patient with pCR was excluded in this statistical analysis

The relationship between recurrence and the results of immunohistochemical staining in the surgical specimens obtained after neo-adjuvant chemotherapy are summarized in Table 3. Only a persistent HER2/neu-positive status in the surgical specimens obtained after neo-adjuvant chemotherapy was significantly associated with recurrence (Fisher-exact test, $P = 0.008$), and the expressions of the other biomarkers were not associated with recurrence.

The proportions of changes in the immunohistochemical profiles before and after neo-adjuvant chemotherapy are summarized in Fig. 1. The changes in the immunohistochemical profiles were not correlated with clinical outcome (data not shown).

Discussion

This study demonstrated that clinical outcome, including pCR, recurrence, was not correlated with the immunohistochemical profiles of p53, estrogen receptor, progesterone receptor, PTEN, or pAkt in specimens obtained before trastuzumab-containing neo-adjuvant chemotherapy.

Interestingly, there were 38 patients with negative PTEN expression and 13 patients who achieved a pCR in the present study. Although we had hypothesized that the loss of PTEN and pAkt expression would influence the clinical outcome of trastuzumab-containing therapy, such as the rate of pCR, the results of the present study did not support our hypothesis, which had been based on the results of Nagata et al's study [10]. One explanation for this contradiction is that the neo-adjuvant chemotherapy used in the present study contained cytotoxic agents plus trastuzumab. HER2/neu over-expression is reportedly associated with sensitivity to anthracycline-containing chemotherapy [12]. Therefore, cytotoxic neo-adjuvant chemotherapy including anthracycline may be a confounding factor in evaluations of the impact of the loss of PTEN. There are also multiple

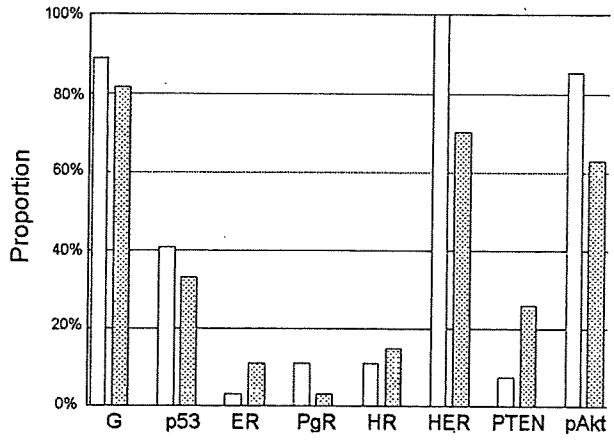

Fig. 1 Proportions of changes in the immunohistochemical profiles of specimens obtained before and after neo-adjuvant chemotherapy in patients with non-pCR ($n = 27$). Abbreviations: G, grade; HR, hormone receptor positive for ER and/or PgR; HER, HER2/neu

hypotheses regarding the mechanism(s) of primary or acquired resistance to trastuzumab [13]. Thus, the mechanism of trastuzumab-resistance may be difficult to explain using only one hypothesis.

The limitations of this study included the small sample size and the considerable heterogeneity in the chemotherapy treatment regimens. However, the majority of the patients had received chemotherapy that had included both an anthracycline and a taxane, and the treatment outcome among the patients was considered representative.

More essentially, the negative results might be attributable to the antibodies used for PTEN and pAkt detection or to a technical problem related to the immunohistochemistry studies. The loss of PTEN and pAkt expression has been reported to occur at various frequencies, [14–16] and the high frequency of the loss of PTEN and pAkt expression observed in the present study was the same as that in previous studies [14, 16]. The monoclonal antibody used in this study, 6H2.1, has been reported to be the only antibody correlated with the presence of molecular alterations in PTEN and to be associated significantly with immunostaining for pAkt; thus, we considered 6H2.1 to be the most suitable antibody for detecting the inactivation of PTEN, compared with the three other known antibodies [17]. In addition, 6H2.1 has been shown to have the same reactivity as the antibody that was used to analyze the loss of PTEN expression in a previous study by Nagata et al [10]. The immunohistochemical staining experiments in the present study were prudentially performed using both positive and negative controls, according to the methods described in a previous study [18], and we believe that any technical problems that may have occurred were of a limited nature.

Another recent study has described a patient cohort that received single-agent trastuzumab in a neo-adjuvant setting; in this previous study, no relationship between tumor response and pAkt expression was reported [19]. Although the different definition of response among patients with operable breast cancer and those with metastatic disease, that is clinical tumor regression and pathological eradication of the tumor, may be one possible explanation for the conflicting results among the studies. At any rate, it is difficult to make any conclusions regarding the role of the loss of PTEN and pAkt expression based on these limited data sets [14, 19], and the exploration of the PI3 K signaling pathway may not lead to a simple breakthrough in our understanding of trastuzumab resistance.

Although changes in the immunohistochemical profiles were frequently observed, such changes may not be useful for predicting clinical outcome. A previous study reported that neo-adjuvant chemotherapy had a minor, but significant (8%), effect on hormone status [20]. However, the HER2/neu status reportedly remained unchanged after neo-adjuvant chemotherapy; thus, HER2/neu expression was regarded as a stable phenotype [20, 21]. Conversely, other studies have reported that the HER2/neu status changed in 15–25% of patients, and the hormone receptor status changed in 26–42% of patients, after neo-adjuvant chemotherapy [22, 23]. Most HER2/neu status changes tend to represent down-regulation [23]. The frequency of changes in immunohistochemical profiles and their influences on clinical outcome are still controversial in neo-adjuvant chemotherapy settings. In addition, these studies included only patients treated without trastuzumab, so the influence of trastuzumab on HER2/neu expression is uncertain. The results of the present study suggest that the HER2/neu status may be altered and down-regulated by the addition of trastuzumab therapy to neo-adjuvant chemotherapy. Further studies on the effects of treatment on immunohistochemical profile changes, tumor cell biology, and/or trastuzumab resistance are needed.

In present study, persistent HER2/neu over-expression in the surgical specimen after trastuzumab-containing neo-adjuvant chemotherapy was associated with recurrence in patients without pCR; this observation may hold a clue to solving the mechanism of resistance to trastuzumab therapy. Previous studies have demonstrated that the down-regulation of target molecules, as shown by immunohistochemical staining in specimens obtained before and after neo-adjuvant chemotherapy, was significantly associated with both the tumor response and RFS, while persistent expression was associated with relapse [24, 25]. In addition, a recent study revealed that a short period of administration, such as 3 weeks of trastuzumab therapy, did not lead to the down-regulation of HER2/neu and did not result in any changes in expression level [19]. Concerning these results, the cancer cells with persistent HER2/neu over-expression after 3 months of trastuzumab treatment may be truly resistant to trastuzumab.

In the coming era of molecular-targeted drugs, multiple options of targeted therapy is becoming an increasingly important problem [7, 13]. However, the selection of appropriate candidates for trastuzumab therapy, which has now become a "classic" targeted therapy, still requires more investigation.

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Original article

21-Gene expression profile assay on core needle biopsies predicts responses to neoadjuvant endocrine therapy in breast cancer patients

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ABSTRACT

This study examined postmenopausal estrogen receptor-positive breast cancer patients who received prospective neoadjuvant endocrine therapy (NAET) with tamoxifen or anastrozole to determine if the 21-gene recurrence score (RS) predicts NAET responses. RS scores were determined from pretreatment core biopsy specimens. Although half of the specimens yielded insufficient RNA, the remaining samples were highly representative. Patients with a low RS tended to respond better than those with an intermediate or high RS ($n = 43$). Response rates by RS were similar between the tamoxifen and anastrozole groups. Patients with a low RS tended to have better relapse-free survival (RFS) than those with an intermediate or high RS (5y-RFS; 100% vs. 84% and 73%, respectively). These results suggest that RS predicts responses to NAET with tamoxifen or anastrozole. Because this pilot study examined a small sample size, these results should be validated in larger studies.

Introduction

Compared to postoperative chemotherapy, preoperative systemic therapy in women with early breast cancer is a standard treatment that allows more breast-conserving surgery without negatively affecting patient survival. Several studies have shown that administering chemotherapy before definitive local surgery can result in overall tumor response rates over 70% with complete clinical response rates over 10%.[1–3] Perhaps less appreciated is the potential role for preoperative endocrine therapy in women with locally advanced estrogen receptor-positive breast cancer. For these patients, multiple studies have shown overall response rates to hormone manipulation over 50% in a neoadjuvant setting, while the rate of complete clinical responses is less.[4–7]

The 21-gene expression profile assay is a genomic classifier validated for women with lymph node-negative, estrogen receptor-positive breast cancer.8. The assay is based on RT-PCR analysis of the expression of 21 genes and yields a "Recurrence Score (RS)" that is reported as a value from 0 to 100. This value corresponds to the risk of recurrence at 10 years for node-negative, estrogen receptor (ER)-positive breast cancer and the benefit of adjuvant tamoxifen treatment. The 21-gene expression profile assay has been validated in several data sets[9] and is the current genomic risk classifier used in the large TAILORx trial sponsored by the Breast Intergroup.

Recently published data have shown that RS correlates with chemotherapy responses in the adjuvant situation.[10] The NSABP B-20 study showed that the addition of CMF or MF chemotherapy resulted in a modest 4.4% benefit for the 10-year distant recurrence risk in estrogen receptor-positive, lymph node-negative patients. However, a recent analysis showed that most of this benefit was restricted to patients with a high RS who collectively had a 28% absolute and 74% relative risk reduction from chemotherapy. Similarly, two studies in patients treated with neoadjuvant chemotherapy showed that a higher RS predicted clinical responses to chemotherapy with either a taxane- or anthracycline-based regimen.[11,12]

Conversely, data from the NSABP B-14 study population have shown that the benefit of tamoxifen in the adjuvant population was related to a lower RS.[13] The purpose of this pilot study is to explore if the clinical response rate to neoadjuvant endocrine therapy is likewise associated with a lower RS.

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Patients and methods

This study examined tumors from 87 postmenopausal women who had operable estrogen and progesterone receptor (ER and PgR)-positive breast tumors larger than 3 cm and had received neoadjuvant endocrine therapy (NAET) at the National Cancer Center Hospital, Tokyo. Between February 1999 and July 2002, 37 patients were enrolled in a neoadjuvant tamoxifen study (neo TAM), in which they received tamoxifen for four months preoperatively. Between November 2002 and 2007, 50 patients were enrolled in a neoadjuvant anastrozole study (neo ANZ), in which they received anastrozole for four months preoperatively. Patients who responded to NAET continued the same endocrine therapy postoperatively for five years. When tolerable, patients who showed clinically progressive disease, stable disease, or pathological lymph node involvement after NAET received adjuvant chemotherapy with a regimen containing anthracycline or classical CMF following surgery. All patients provided written informed consent for their core needle biopsy specimens to be examined in this study. The study protocol was approved by the institutional review board of the National Cancer Center Hospital, Tokyo.

Sample preparation for RT-PCR

Ten 3-μm unstained sections and two hematoxylin and eosin sections from each core needle biopsy (CNB) paraffin block were shipped to Genomic Health Inc. (Redwood City, CA) anonymously. Quantitative gene expression was determined by a multianalyte TaqMan RT-PCR assay with standardized operating procedure as reported previously.[8] The RS was calculated on a scale from 0 to 100. Cutoff values were predefined in order to classify patients into the following categories: low-risk (RS less than 18), intermediate-risk (RS higher than 18 but less than 31), and high-risk (RS higher than 31).

Tumor response

Primary tumors were clinically assessed by measuring their size in two dimensions with calipers. A clinical complete response (cCR) was defined according to WHO criteria as the clinical disappearance of the tumor at the end of NAET, and a clinical partial response (cPR) was defined as a ≥50% decrease in tumor area from baseline. Clinical stable disease (cSD) was defined as a decrease of less than 50% in tumor area from baseline or an increase of less than 25% in tumor area from the most reduced size. Clinical progressive disease (cPD) was defined as a ≥25% increase in tumor area from the most reduced size.

Outcome measures

Relapse-free survival (RFS) was defined as the time from the initiation of treatment to local, regional, or distant treatment failure.

Statistical analysis

The chi-squared test was used to compare tumor characteristics among groups. The Kaplan–Meier method was used to estimate RFS curves. An order-restricted version of the log-rank test (a log-rank trend test) was used to test ordered differences between the estimated RFS curves. All p-values were two-sided. Differences with $p < 0.05$ were considered significant.

Results

Of the 87 patients who received neoadjuvant endocrine therapy, we could not obtain informed consent for nine patients because of lost follow up[6] or patients refused to include their specimens.[3] Five tumors were inadequate for this analysis because they contained insufficient invasive cancers (mostly intraductal cancers) in the CNB. For three patients, the remaining specimen was insufficient to generate unstained slides. The total RNA yields were insufficient to assay (<500 ng) in 29 patients. Therefore, a RS was determined in the remaining 43 patients.

The patient characteristics at the time of diagnosis for the 43 assessable patients and all 87 patients who were treated by NAET are summarized in Table 1. One patient in the assessable 21-gene expression profile group did not undergo surgery because of progressive disease during NAET. Fourteen patients received neoadjuvant tamoxifen and 29 received neoadjuvant anastrozole.

The relationship between the RS and the clinical response is shown in Fig. 1. All four tumors with progressive disease had a high-risk RS. On the contrary, one tumor with a complete response had a low-risk RS.

Response rates (cCR + cPR) to NAET for low-risk (<18), intermediate-risk, and high-risk RS were 64%, 31%, and 31%, respectively ($p = 0.11$, by trend test) as shown in Table 2. When divided into the neo Tam and neo ANZ groups, the clinical response rates for the low-risk RS group were about two-thirds in both treatment groups, whereas those in the intermediate- and high-risk RS were approximately one-third. The association between response rates and RS risk categories does not appear to differ between the

Table 1
Characteristics of patients and tumors with an assessable 21-gene expression profile and non-analyzed patients.

	21-Gene expression profile assessable patients ($n = 43$)	Non-analyzed patients ($n = 44$)	
Mean age (range)	61 (48–79)	62.5 (51–87)	
Tumor before NAET			
T2	27 (52%)	25 (48%)	$p = 0.35$
T3	14 (52%)	13 (48%)	
T4	2 (25%)	6 (75%)	
NAET			
Tamoxifen	13 (33%)	26 (67%)	$p = 0.01$
Anastrozole	30 (63%)	18 (37%)	
Clinical response			
CR	1 (17%)	5 (83%)	$p = 0.34$
PR	16 (52%)	15 (48%)	
SD	22 (50%)	22 (50%)	
PD	4 (67%)	2 (33%)	
Axillary nodal status			
Negative	12 (40%)	18 (60%)	$p = 0.03$
1–3	14 (47%)	16 (53%)	
4–9	15 (75%)	5 (25%)	
>10	1 (17%)	5 (83%)	
NA	1		
Adjuvant therapy			
Endocrine only	25 (50%)	25 (50%)	$p = 0.90$
Chemotherapy added	18 (49%)	19 (51%)	
21-gene RS			
Low-risk	11		
Intermediate-risk	16		
High-risk	16		

NAET, neoadjuvant endocrine treatment; NA, not applicable because one patient did not undergo surgery.