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Cancer biomarker HER-2/neu in breast cancer in Indian women

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Rajeev Singhai[1]
Amit V Patil[2]
Vinayak W Patil[1]

[1]Department of Biochemistry, Grant Medical College and Sir J J Group of Hospitals, Mumbai, India; [2]Department of General Surgery, Government Medical College, Miraj, Maharashtra, India

Aim and objectives: In Indian women with breast cancer, the HER-2/neu gene is amplified in 30% of cases. Elevated serum HER-2/neu levels have been shown to be associated with a poor clinical prognosis and decreased survival in early stage breast cancer patients, and testing for this may help to manage the disease. The present study was therefore to estimate serum HER-2/neu levels in breast cancer patients and associate these with other prognostic factors.

Materials and methods: Serum HER-2/neu levels were studied in 207 patients with breast cancer, 15 with benign breast diseases, (BBD) and 175 age-matched healthy controls. Patients' age, menopausal status, node, and estrogen receptor (ER) and progesterone receptor (PgR) status were compared with serum HER-2/neu levels.

Results: Serum HER-2/neu overexpression was associated with age, disease stage and positive nodal status but not with menopausal status. Serum HER-2/neu levels were negatively correlated with hormone receptor positivity.

Conclusion: HER-2/neu serum tests should be done more frequently in Indian women with breast cancer, irrespective of their ER and PgR hormone receptor status. ELISA is a reliable and economical tool to assess the HER-2/neu status in tumors, when breast tissue samples are not available.

Keywords: breast cancer, serum HER-2/neu receptor assay, hormone receptor, ER, PgR

Introduction

Human Epidermal Growth Factor Receptor-2 (HER-2/neu or c-erbB2) gene is a proto-oncogene mapped on chromosome 17q and encodes a transmembrane tyrosine kinase growth factor receptor.[1] HER-2/neu protein, also called p185HER-2/neu, is derived from human epidermal growth factor receptor, as it shows substantial homology with the epidermal growth factor receptor, EGFR.[2,3] HER-2/neu gene amplification, measured using Fluorescent In Situ Hybridization (FISH) has been found to be associated with the development of breast cancer.[2] HER-2/neu protein is a component of a four-member family of closely related growth factor receptors, including EGFR or HER-1 (erb-B1); HER-2/neu (erb-B2); HER-3 (erb-B3) and HER-4 (erb-B4).[4] The full-length glycoprotein (p185) has a molecular mass of 185,000 Da and is composed of an internal tyrosine kinase domain, a short transmembrane portion, and an extracellular domain (ECD) that is similar to the three other members of the HER family.[5] HER-2/neu gene amplification was determined by Southern blotting analysis to independently predict time-to-disease relapse and overall survival in breast cancer patients in a study by Slamon et al.[6] Subsequently, Berger et al[7] reported that HER-2/neu protein overexpression, determined by immunohistochemistry, correlated with lymph node status and breast

Correspondence: Rajeev Singhai
C-505, Beach Classic CHS Ltd, near Gorai Pumping Station; Chikoowadi, Borivali (West); Mumbai-400092, India
Tel +9196999856615
Email dr.rajeevj@gmail.com

cancer tumor grade. However, an immunohistochemical study by van de Vijver et al[8] failed to show a significant association of HER-2/neu protein immunostaining with disease outcome. HER-2/neu gene copy number by Southern blotting analysis correlated with mitotic activity and negative estrogen receptor (ER) and progesterone receptor (PgR) status, but could not link gene expression with disease outcome, according to Heintz et al.[9] HER-2/neu protein overexpression was first reported in in-situ breast cancer by van de Vijver et al.[8] HER-2/neu gene amplification FISH and/or protein overexpression of c-erbB2 may contribute to transformation and tumorigenesis in breast cancer. HER-2/neu has been extensively studied in breast cancer, and approximately 20%–30% of patients have tumors that overexpress this receptor, often as a result of gene amplification.[10] Amplification of HER-2/neu gene is regarded as an established predictive and prognostic cancer biomarker for breast cancer, particularly for the management of advanced breast cancer.[11]

We undertook this study to evaluate the serum HER-2/neu levels in normal healthy individuals, individuals with benign breast disease, and untreated breast cancer patients, and tried to associate these levels with other prognostic factors such as age, menopausal status, stage of disease, node involvement, and levels of hormone receptors ER and PgR.

Materials and methods

Breast cancer patients' samples and data were collected from the Department of Biochemistry and Histopathology, Grant Medical College and Sir J J Group of Hospitals, Mumbai, India. Of 256 selected patients, 207 female patients had histopathologically confirmed breast cancer, and 15 patients had benign breast disease (BBD). The remaining 34 patients were excluded from the study, as they were treated cases. Histopathologic examination confirmed invasive breast cancer in different stages of disease in 207 patients, aged 25 to 75 years. A group of 175 age matched (±2 years) healthy female controls were arbitrarily selected from patients' relatives. Information on patients' age, menopausal status, disease stage, ER and PgR status, and clinical nodes was noted from case files.

Blood samples were collected in plain tubes, and centrifuged to separate the serum. Serum samples of 0.3 mL were stored at −70°C until analysis within 1 month. Levels of serum HER-2/neu were measured by modified sandwich enzyme immunoassay.[12] Anti-sp185-HER-2/neu human monoclonal coating antibody (Bender MedSystems GmbH, Vienna, Austria) was adsorbed on to micro wells. Sp185-HER-2/neu (ELISA Kit, Bender MedSystems GmbH) present in sample or standards bound to antibodies adsorbed to micro wells, and horse radish peroxidase (HRP)-conjugated monoclonal anti-sp185-HER-2/neu antibodies (Bender MedSystems GmbH) were then added to the wells. Following incubation, unbound enzyme conjugated anti-sp185-HER-2/neu was removed by washing and tetra-methyl benzidine (TMB)(Sigma Aldrich, Mumbai, India) solution reactive with HRP was added to the wells.

Colored product was formed in proportion to the amount of soluble p185-HER-2/neu present in the sample. Reaction was terminated by addition of sulphuric acid (Sigma Aldrich) and absorbance was measured at 450 nm. A standard curve was prepared from 10 ng/mL stock standard sp185-HER-2/neu by diluting at 5, 2.5, 1.25, 0.625, 0.312 and 0.156 ng/mL respectively, at a 1:100 dilution, with assay buffer and sample concentration. Estimates of precision for the analysis systems (Bender MedSystems GmbH) are shown in Table 1. The cut-off value used in this study was 15 ng/mL as per kit recommendation. The observed range in control individuals for HER-2/neu was 3.5–13.5 ng/mL which was found to match the cut-off range in accordance with the kit recommendation.

Statistical analysis

Results were evaluated statistically using ANOVA. Data were transformed to a natural logarithmic scale. Analyses of variance using the post hoc Tukey test were performed to compare serum HER-2/neu levels, menopausal status and stage of disease. Student's *t*-test was used to compare serum HER-2/neu levels between patients with different age groups, node status and hormone receptor (ER, PgR) status. Multivariate logistic regression was used to find association of risk factors with the elevated serum HER-2/neu levels. Result estimation was performed using SPSS (v 16.0; SPSS Inc, Chicago, IL).

Results

In our study of 207 histopathologically confirmed breast cancer patients, 53 were HER-2/neu positive (25.6%) compared with the cut-off value of <15 ng/mL for normal levels. Serum HER-2/neu levels increased progressively with stage of disease (Table 2). Levels were not elevated in 15 cases of benign breast disease. Our study showed that increased serum

Table 1 Precision check for serum HER-2/neu (ng/mL) assay by Bender Med System analysis

Within run (intra batch)			Between run (inter-batch)		
Mean	**SD**	**CV%**	**Mean**	**SD**	**CV%**
12.2	0.26	2.1	12.9	0.33	2.6

Abbreviations: CV, coefficients of variation; SD, standard deviation.

Table 2 Levels of serum HER-2/neu in Indian breast cancer patients

Parameters	Number of cases	HER-2/neu levels
Age in years	<40 n = 52	16.850 ± 1.820
	>40 n = 155	21.32 ± 3.251*
Lymph node status	Negative n = 105	13.32 ± 0.910
	Positive n = 102	21.76 ± 2.360**
Menopausal	Pre. n = 84	16.17 ± 1.770
	Post. n = 116	15.34 ± 1.161
	Peri. n = 7	24.96 ± 13.920
Stages[a]	Control n = 175	8.070 ± 1.221
	BBD n = 15	8.25 ± 0.520
	I n = 14	9.40 ± 0.630
	II n = 64[b]	14.05 ± 1.090
	III n = 105[c]	18.43 ± 1.791
	IV n = 24[c]	22.941 ± 5.642
Histopathologic grades (Grade 1–3)[d]		9.60 ± 8.550
	G1 6 (5.6)	
	G2 42 (38.9)	
	G3 46 (42.6)	
ER	Positive n = 117	12.04 ± 0.800**
	Negative n = 90	23.42 ± 2.341
PgR	Positive n = 114	12.02 ± 0.840**
	Negative n = 93	23.19 ± 2.290

Notes: Values are mean ± SE.ER, PgR: *$P < 0.01$, **$P < 0.001$, when compared with age <40 years. In terms of age Student's *t*-test was used: [a]$P < 0.001$ (ANOVA), [b]$P < 0.05$, [c]$P < 0.001$, [d]$P = 0.011$ compared with BBD, post hoc Tukey test.
Abbreviation: BBD, benign breast disease.

HER-2/neu levels were significantly related to age, clinical stage of disease, nodes, and hormone receptors including ER and PgR, but not to menopausal status (Table 2).

Multivariate logistic regression analysis showed an inverse risk relationship between serum HER-2/neu levels and ER and PgR status (Table 3).

By the adjusted odds ratio (OR), it was observed that for age >40 years, node positivity stage 2 and 3 were positively related to elevated HER-2/neu levels and ER, while PgR was negatively related to the elevated serum HER-2/neu levels (Table 3). HER-2/neu was not reported to be elevated in benign breast tissue,[13] whereas the level of HER-2/neu oncoprotein elevation in malignant specimens was apparent at all stages, from intraductal to invasive phases of primary breast cancer and to subsequent metastases.[14]

Associations between tissue anti-HER-2/neu as determined by DakoHerceptest primary antibody (DakoCytomation, Copenhagen, Denmark) and CB11 (Vision Biosystems, Norwell, MA) primary antibody, and serum HER-2/neu extracellular domain (ECD) pretreatment levels were explored. The HER-2/neu receptor on breast cancer tissues was tested in 55 patients (20 cases positive and 35 cases negative; $P = 0.002$; Correlation 63.6%; 95% CI: 56.4–67.2%).

The Fisher's exact test indicates an association between elevated serum HER-2/neu levels and each immunohistochemistry (IHC) test. Correlation was estimated for each IHC test. ECD levels were correlated with tissue HER-2/neu overexpression by Dako Hercep Test: 85% of patients whose disease showed 2/3+ overexpression by Dako also had elevated ECD levels in the serum prior to start of therapy ($P = 0.022$). However, among patients whose disease tested 0/1+ by Dako Hercep Test, 55% had elevated ECD levels.

A similar association was observed with the monoclonal antibody CB11. Ninety-five percent of patients with CB11 staining intensity of 2/3+ had elevated levels of ECD at baseline ($P = 0.002$).

All histopathologic grades (mean 9.60 ± 8.550, $P = 0.011$) were compared in terms of age using Student's *t*-test. Six patients were in Grade 1 (5.6%), 42 patients were in Grade 2 (38.9%), and 46 patients were in Grade 3 (42.6%).

Discussion

Elevated HER-2/neu ECD concentration was related to histopathologic tumor size, grade, presence of comedo-type cancer and tissue HER-2/neu expression.[15] Interestingly, elevated serum HER-2/neu levels have been shown to be correlated with decreased survival and absence of clinical response to hormonal therapy, even when ER assays are

Table 3 Multivariate logistic regression analysis for predicting HER-2/neu levels

Parameters	Coefficient	SE	Wald statistic	*P*-value	Adjusted OR
Age > 40 years	0.845	0.50	2.856	0.091	2.320
Lymph node+	1.890	0.505	14.15	<0.001	6.671
Stage 1	–5.941	14.94	0.158	0.691	0.003
Stage 2	1.030	0.740	1.940	0.163	2.81
Stage 3	0.321	0.611	0.270	0.579	1.38
Stage 4	0.42	0.601	0.505	0.477	0.65
ER +ve	–1.15	0.960	1.437	0.231	0.31
PgR +ve	–1.25	0.969	1.685	0.194	0.28

Abbreviations: SE, standard error of mean; OR, odds ratio.

positive.[16] HER-2/neu, a 185-kDa transmembrane receptor is an attractive target for cancer therapeutics. Trastuzumab (Herceptin), a HER-2/neu directed monoclonal antibody, has demonstrated clinical benefit both as a single agent[17] and in combination with chemotherapy.[18]

Clinical trials have demonstrated that overexpression of HER-2/neu in metastatic breast cancer predicts response to trastuzumab.[19] Lipton et al[20] demonstrated that patients with increased pretreatment circulating HER-2/neu concentrations were relatively resistant to both first- and second-line hormonal therapy. There is a significant association between circulating HER-2/neu ECD levels in the serum with the expression of HER-2/neu in primary tumors, with concordance indices for HER-2/neu of 80%.[21]

Circulating HER-2/neu ECD levels may be a better indicator of resistance to chemotherapy than the expression of HER-2/neu in the primary tumor.[22] In contrast to tissue testing, which is a one-time event, monitoring the circulating levels of HER-2/neu ECD in patients with breast cancer provides a real time assessment of HER-2/neu status and provides important information for management of this disease.[22]

Another advantage of using serum samples is that they may be obtained more easily after relapse. Conversion to positive serum HER-2/neu status occurred in approximately 25%–30% of patients who received first-line hormone therapy. Conversion to serum HER-2/neu positive status occurred with equal frequency in anti-ER and aromatase-inhibitor therapy.[23] Tumors negative for ER and PgR were found to be associated with HER-2/neu positivity. Trastuzumab is a promising but very expensive antibody and patients need to be monitored carefully during treatment.

Determination of the HER-2/neu status at primary diagnosis was not a standard procedure until the 1990s, with the introduction of trastuzumab into routine clinical management of breast cancer patients in many centers, or even until data indicating an effect of adjuvant trastuzumab treatment emerged in 2005. Therefore, there remains a significant group of newly diagnosed metastatic patients with unknown HER-2/neu status.

HER-2/neu proto-oncogene is amplified or overexpressed in approximately 20%–25% of invasive primary breast cancers. Positive HER-2/neu status has been linked with aggressive tumor behavior and resistance to cytotoxic and endocrine therapies. Patients with HER-2/neu amplification or overexpression are eligible for treatment with trastuzumab, a monoclonal antibody directed against HER-2/neu. Trastuzumab inhibits neoplastic cell proliferation in vivo, in vitro and enhances chemo-sensitivity, and has been approved for clinical use in metastatic breast cancer. Based on recently reported results from four large trastuzumab trials (Herceptin Adjuvant trial, the North Central Cancer Treatment Group trial N9831, National Surgical Adjuvant Project-31, and Breast Cancer International Research Group 006), trastuzumab is also indicated in adjuvant therapy in HER-2/neu-positive primary breast cancer.[25] In addition to trastuzumab, other therapeutic strategies have recently been developed to target the HER-2/neu protein, such as the tyrosine kinase inhibitor lapatinib, which appears to have clinical activity after failure of trastuzumab therapy.[24]

Tumors, including metastatic lesions, shed large numbers of tumor cells into the blood circulation, and the presence of circulating tumor cells is of biologic relevance in the metastatic setting. Based on the hypothesis that the phenotype of circulating tumor cells may reflect the phenotype of metastatic disease, characterization of circulating tumor cells may be useful for reassessment of HER-2/neu status and additional therapeutic cancer biomarkers. However, this option is limited to those patients with detectable circulating tumor cells. Reported positivity rates for circulating tumor cells in metastatic breast cancer patients range from 20% to 60%.

In one prospective study, in which 67 patients were included, 21 patients had detectable circulating tumor cells (31%). HER-2/neu was overexpressed in eight of these 21 patients (38%). Meng et al[26] reassessed the HER-2/neu status in 31 metastatic patients with circulating tumor cells. Nine out of 24 patients with initially HER2-negative tumors had HER2-positive cells; this rate (38%) is lower than our observed positivity rate. Four of these nine patients were treated with a Herceptin-containing chemotherapy regimen. Two of these patients exhibited partial or complete remission.[26]

Hayes et al[28] evaluated the number of HER-2/neu positive circulating tumor cells during the course of treatment by flow cytometry in 19 metastatic breast cancer patients. During disease progression, the HER-2/neu status of circulating tumor cells changed from negative to positive in all cases (n = 3). In contrast, patients responding to trastuzumab treatment lost their HER-2/neu positive cell fraction. Meng et al[26] analyzed the urokinase-type plasminogen activator receptor and HER-2/neu gene status in individual breast cancer cells from metastatic breast cancer patients. Five out of 52 formerly HER-2/neu negative cases acquired HER-2/neu positivity. Interestingly, in two initially

HER-2/neu positive patients with disease progression, circulating tumor cells were negative for HER-2/neu after treatment with trastuzumab.

The major caveat in all of these observational studies, including the present study, is the low number of patients included. Therefore, large clinical trials must be initiated to evaluate further whether acquisition of HER-2/neu positive circulating tumor cells is predictive of clinical response to HER-2/neu targeted therapy in a subgroup of patients with metastatic breast cancer.

A correlation between serum HER-2/neu levels and tissue HER-2/neu status in metastatic breast cancer has been examined. A serum ECD concentration of 16 µg/L showed a sensitivity and specificity of approximately 90% and 80%, respectively, when IHC and FISH were the reference standards. In contrast, another study determined a cut-off of 37 µg/L with 62% sensitivity and 95% specificity for prediction of the tissue HER-2/neu status. The researchers attributed this discrepancy to a difference in assays and proposed using a higher cut-off value for metastatic breast cancer than for diagnosis of primary breast cancer. A very high serum ECD concentration with negative tissue HER-2/neu could be due to disease recurrence.[27] Trastuzumab is a monoclonal antibody that targets the HER-2/neu receptor and binds to its ECD. Although the exact mechanism of action of trastuzumabis not known, the antibody seems to cause internalization and degradation of the ECD, inhibiting the signal transduction pathway. It also likely triggers cytotoxicity by inducing activity of lymphocytes. Early reports indicate that the combination of trastuzumab and fulvestrant has more profound antitumor activity than either agent alone. This new two-agent strategy is likely to overcome anti-estrogen resistance in breast cancer through dual inhibition of estrogen and HER-2/neu receptors.

In a study where the patient was treated with both trastuzumab and fulvestrant, the clinical benefit could have resulted from either of the drugs or the combination.[19] However, since the patient experienced disease progression on prior endocrine therapy and has had a stable response for more than 2 years, we do not think the response has been solely due to endocrine treatment. This inability to definitively determine which agent led to remission can be considered a limitation of this observation.

ER and PgR were measured by immunohistochemistry on tissue sections. Scores >3 are judged as the cut-off level (Table 4). ER and PgR positivity are denoted by brown nuclear staining of both the invasive and in situ components of breast cancer cells. Positive ER and PgR results were further qualified using a rapid semi-quantitative H score ranging from 0–8 that takes into account both the intensity of staining and proportion of tumor cells staining positive for ER and PgR receptors with appropriate cut-off values for the treatment of advanced disease.

Table 4 Proportion staining, staining intensity and final scores for breast cancer patients with regard to ER and PgR receptors

Score type	Score	Implication of scores
Proportion staining	0	No nuclear staining
	1	<1% nuclear staining
	2	1%–10% nuclear staining
	3	11%–33% nuclear staining
	4	34%–66% nuclear staining
	5	67%–100% nuclear staining
Staining intensity	0	No nuclear staining
	1	Weak staining
	2	Moderate staining
	3	Strong staining
Final	0	Endocrine treatments or tamoxifen will definitely not work and such patients should receive an alternative first-line treatment
	2–3	20% chance of response to endocrine treatment
	4–6	50% chance of response to endocrine treatment
	7–8	75% chance of response to endocrine treatment

Notes: The score for proportion staining was then multiplied by the score for staining intensity to achieve the final score, which is then used to judge the patient's change of response to endocrine treatment. ER and PgR cut-off values >10 femtomoles/ng (fmol/ng); borderline = 5–9 fmol/ng; negative = 3–4 fmol/ng.

Conclusion

HER-2/neu serum tests should be done more frequently in Indian women with breast cancer, irrespective of their ER and PgR status. ELISA is a reliable and economical tool to assess the HER-2/neu status in tumors, when a breast tissue sample is not available. Statistical analysis of the HER-2/neu levels in patient serum samples found that serum HER-2/neu overexpression was associated with age, disease stage and positive nodal status but not with menopausal status. The serum HER-2/neu levels were inversely related to hormone receptor status.

Conversion to positive serum HER-2/neu status occurred in approximately 25%–30% of patients who received first-line hormone therapy. Conversion to serum HER-2/neu positive status occurred with equal frequency in anti-ER and aromatase-inhibitor therapy. Tumors negative for ER and PgR were found to be associated with HER-2/neu positivity. Herceptin is a promising antibody and patients need to be monitored carefully during treatment.

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Disclosure

The authors report no conflicts of interest in this work.

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