Accurate Identification of HER2-Positive Patients Is Essential for Superior Outcomes With Trastuzumab Therapy

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Purpose/Objectives: To review the clinical significance, methods of testing, and outcomes of trastuzumab (Herceptin®) treatment for *HER2* gene amplification and HER2 protein overexpression in breast cancer.

Data Sources: Published articles and abstracts, online resources, a clinical handbook, and product information.

Data Synthesis: *HER2* gene amplification or HER2 protein overexpression can be found in 20%–25% of breast cancers and is important pathogenic and prognostic information. HER2 also predicts patient response to trastuzumab. Patients with HER2-positive metastatic breast cancer benefit from trastuzumab whether selected by immunohistochemistry, which measures the HER2 protein, or fluorescence in situ hybridization (FISH), which measures the *HER2* oncogene. However, patients who are identified accurately as *HER2* gene-amplified by FISH derive the greatest benefit.

Conclusions: Accurate testing is crucial for appropriate identification of patients for trastuzumab therapy. FISH is the most reproducible and accurate method.

Implications for Nursing: Education regarding HER2 testing and trastuzumab helps patients to make informed decisions and facilitates active participation in their care as well as enhances dialogue with physicians.

Key Points . . .

- HER2 testing is recommended for all newly diagnosed patients with breast cancer because *HER2* gene amplification or HER2 protein overexpression correlates with poor clinical outcomes.
- HER2 testing is critical because HER2-positive patients may benefit from trastuzumab therapy, which has been shown to significantly improve response rates, time to disease progression, and overall survival.
- Immunohistochemistry and fluorescence in situ hybridization (FISH) have been approved for the determination of HER2 status; however, FISH has demonstrated superior sensitivity and specificity. Patients with *HER2* gene amplification by FISH have been shown to benefit from trastuzumab therapy.

Breast cancer is the most commonly diagnosed cancer among women and the second leading cause of cancer death (Jemal et al., 2005). The American Cancer Society estimated that more than 211,000 new cases of breast cancer would be diagnosed in the United States in 2005 and more than 40,000 women would die as a result of the disease (Jemal et al.). Breast cancer survival is determined by a variety of prognostic and predictive indicators. Breast cancer's prognostic factors (e.g., tumor size and type, number of positive lymph nodes, nuclear grade, absence or presence of estrogen and/or progesterone receptors) (National Comprehensive Cancer Network [NCCN], 2005; Rosenzweig, Rust, & Hoss, 2000) influence the clinical outcome of the disease regardless of treatment, whereas predictive factors, such as HER2 overexpression or amplification, correlate with prognosis because they are linked to patients' responses to particular therapies.

Several newly recognized prognostic and predictive factors have begun to be used in the management of breast cancer (NCCN, 2005). One factor is the human epidermal growth factor receptor-2, or HER2. Overexpression of HER2 is associated strongly with a poor prognosis in breast cancer, indicating a more aggressive disease and shortened overall survival (Slamon et al., 1987, 1989). The five-year overall survival rate for HER2-positive patients is significantly shorter than for those who are HER2 negative (58% versus 77%, respectively; p = 0.004) (Sjogren, Inganas, Lindgren, Holmberg, & Bergh, 1998). Using multivariate survival analysis, Slamon et al. (2001) found *HER2* gene amplification to be more predictive for clinical outcome than any other prognostic factor, with the exception of the number of positive lymph nodes (Slamon et al., 1987, 1989). NCCN and American Society of Clinical Oncology (ASCO) guidelines recommended HER2 testing for all patients with newly diagnosed breast cancer (Bast et al., 2001; NCCN). HER2 testing is critical because of the demonstrated survival benefit of trastuzumab (Herceptin®, Genentech, Inc., South San Francisco, CA) therapy in combination with chemotherapy for

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Digital Object Identifier: 10.1188/06.ONF.265-272

patients with HER2-positive metastatic breast cancer (Slamon et al., 2001).

Oncology nurses must be knowledgeable regarding all facets of breast cancer prognosis, diagnosis, and treatment. This article reviews the clinical significance of *HER2* gene amplification and HER2 protein overexpression in methods of breast cancer testing. Implications for nursing and recommendations for patient and family education also are discussed.

Consequences of *HER2* Gene Amplification and HER2 Protein Overexpression in Breast Cancer

The discovery of HER2 and its role in invasive breast cancer was a vital development in understanding the course and treatment of the disease. The *HER2* oncogene, located on chromosome 17, codes for the HER2 protein, which is a receptor located on the cell surface that is involved in regulating growth and development (Coussens et al., 1985). HER2 is a member of the HER family of receptors, which also includes the epidermal growth factor receptors HER1, HER3, and HER4. The receptors share a common general structure consisting of an extracellular binding site, a region that spans the plasma membrane, and an intracellular tyrosine kinase domain (see Figure 1). On activation, HER2 pairs with the other receptors in the HER family, transmitting signals across the cell membrane, through the cytoplasm, and into the nucleus. The signals stimulate the activation of various genes, which can lead to cell division.

HER2 is expressed in normal and cancerous tissues. However, relatively few HER2 molecules can be found on the surface of normal cells, so the growth signals initiated by the receptor are relatively weak. In contrast, HER2 is overexpressed in approximately 20%–25% of breast cancers, resulting in increased signaling, cell proliferation, and malignant growth (Slamon et al., 1987, 1989), which explains the poor prognosis of patients with breast cancer who have HER2 overexpression.

HER2 protein overexpression is caused by amplification of the *HER2* gene. In published studies, 98% of breast cancer biopsy specimens with HER2 protein overexpression also had *HER2* gene amplification and 100% of those with gene amplification had protein overexpression (Kallioniemi et al., 1992; Pauletti, Godolphin, Press, & Slamon, 1996; Slamon et al., 1989). Amplification and overexpression correlate with poor clinical outcomes (Paik et al., 1990; Slamon et al., 1987, 1989; Winstanley et al., 1991). HER2-positive tumors are aggressive, correlate with positive nodal status, and have a high S-phase fraction as well as a high nuclear grade (Gusterson et al., 1992; Paik et al., 1990; Pauletti et al., 2000; Slamon et al., 1987).

HER2 may be a predictive factor for responsiveness to chemotherapy, but the hypothesis remains controversial. HER2-positive patients may derive greater clinical benefit from anthracycline-based therapy and poorer clinical benefit from taxane therapy (without trastuzumab) than HER2-negative patients (Kim, Tanabe, Uchida, Osaki, & Toge, 2002). Studies examining the relationship between HER2 overexpression and response to adjuvant endocrine therapy have reached conflicting conclusions. A number of reports have indicated that HER2-positive patients may not benefit from adjuvant endocrine (usually tamoxifen) therapy (Bianco et al., 2000; Carlomagno et al., 1996; Sjogren et al., 1998; Yamauchi, Stearns, & Hayes, 2001). However, an analysis of a large, cooperative group study found that the disease-free survival risk reduction associated with adjuvant tamoxifen was 44% in HER2-positive patients and only 25% in HER2-negative patients (Berry et al., 2000).

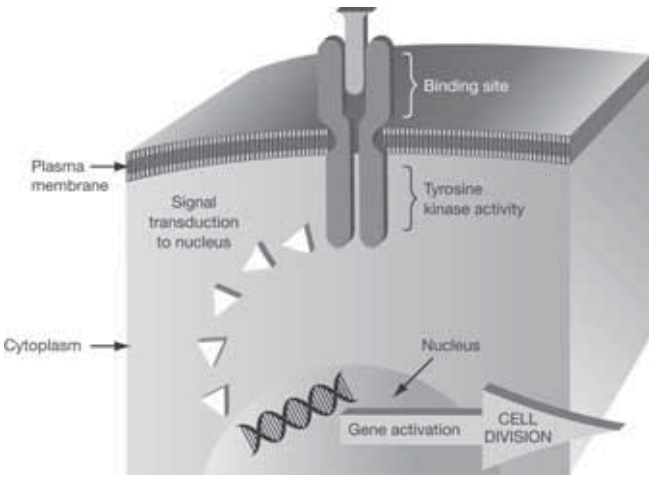

Figure 1. HER2 Transmembrane Signal Transduction Pathway

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Testing for HER2 Status

Positive HER2 status identifies patients who are likely to have aggressive disease and poor prognoses. ASCO and NCCN guidelines recommended HER2 testing for all women with breast cancer (Bast et al., 2001; NCCN, 2005). Treatment with trastuzumab has been shown to improve the disease course and prognosis in patients with metastatic breast cancer (Cobleigh et al., 1999; Fornier, Risio, Van Poznak, & Seidman, 2002; Slamon et al., 2001; Vogel et al., 2002). The safety and efficacy of trastuzumab for early-stage HER2-positive breast cancer is currently under investigation in four large randomized clinical trials: the National Surgical Adjuvant Breast and Bowel Project (No. B-31), North Central Cancer Treatment Group (No. N9831), Breast Cancer International Research Group (BCIRG) (No. 006), and Herceptin Adjuvant, a European trial. Accurately identifying HER2-positive patients as early as possible is essential for providing the opportunity for patients to take part in the adjuvant trastuzumab clinical trials or to benefit from trastuzumab in the metastatic setting. Findings from the first interim analysis of the BCIRG study were presented at the 28th Annual San Antonio Breast Cancer Symposium (Slamon et al., 2005). Between April 2001 and March 2004, 3,222 patients were recruited. At a median follow-up of 23 months, the two Herceptin-containing arms of the trial met the disease-free survival endpoint, confirming a benefit of Herceptin when combined with docetaxel or with docetaxel and carboplatin without an anthracycline (Slamon et al., 2005).

The U.S. Food and Drug Administration (FDA) approved two methods for determining HER2 status for the selection of patients for trastuzumab therapy: immunohistochemistry (IHC) and fluorescence in situ hybridization (FISH). IHC measures the expression of the HER2 protein, and FISH directly measures the number of copies of the *HER2* oncogene. Both require tumor tissue. Despite agreement on the need for testing, considerable controversy exists regarding the optimal HER2 testing

algorithm. Tumor samples initially tested by FISH generally do not require further analysis, whereas samples initially tested by IHC may require further verification by FISH. Both approaches are currently in general use.

Immunohistochemistry

IHC is the most frequently used method for assessing HER2 protein overexpression (Horton, 2001; Schaller, Evers, Papadopoulos, Ebert, & Buhler, 2001). IHC also is used routinely for surgical pathology assessments such as examination of estrogen or progesterone receptor status.

Two FDA-approved IHC kits for HER2 exist: HercepTest® (DakoCytomation, Carpinteria, CA) and Pathway® (Ventana Medical Systems, Inc., Tucson, AZ). HercepTest scores HER2 expression in tumor samples on a four-point scale (i.e., 0, 1+, 2+, 3+) based on the percentage of tumor cells that are positive for HER2 and the intensity of staining. Samples scored as 0 or 1+ are defined as negative for HER2 overexpression (see Figure 2). Samples scored as 2+ or 3+ are defined as HER2 positive, and patients with metastatic breast cancer tumors scoring 2+ or 3+ are eligible for treatment with trastuzumab (Genentech, Inc., 2000). Although a good correlation exists between IHC scores of 3+ and FISH results, several studies have shown poor correlation between IHC 2+ scores and FISH results (Dybdal et al., 2005; Fornier et al., 2002; Mass et al., 2005; Paik et al., 2002; Roche et al., 2002).

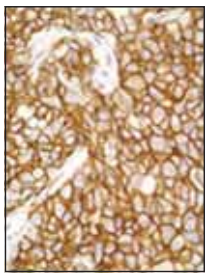
Despite its widespread use, IHC has several major shortcomings. The successful and accurate determination of HER2 status by IHC in routine clinical specimens can be compromised by several factors, including the method of tissue preservation (i.e., frozen versus formalin-fixation and paraffin-embedding), reagents (i.e., chemicals and tools used to perform the assay), the age of the tissue sample, the method of antigen retrieval (e.g., heating or microwaving samples so the antibody will recognize the protein), and the specificity and sensitivity of the antibody used for the assay (Fornier et al., 2002; Pauletti et al., 2000; Press, Hung, Godolphin, & Slamon, 1994; Schaller et al., 2001). For example, IHC is not as effective in formalin-fixed tissue as in frozen specimens (Press et al., 2002), and the ability to detect HER2 in samples embedded in fixed paraffin wax may decrease over time, so IHC should be performed on tissue that has been stored for no more than a few months. In addition, prolonged antigen retrieval can artificially increase antibody reactivity and lead to false-positive results. Another major shortcoming of IHC is the lack of consistent interpretation of results (Allred, Harvey, Berardo, & Clark, 1998). Because IHC scores are determined by subjective interpretation of staining, significant variability can occur among individuals (lack of reproducibility) and laboratories (lack of concordance) ("Clinical Laboratory Assays," 2002; Schaller et al.), especially for samples scored as 1+ (negative) or 2+ (positive) ("Clinical Laboratory Assays"; NCCN, 2005; Perez et al., 2002; Tubbs et al., 2001). In other words, samples scored as 1+ or 2+ by one laboratory often are classified differently by another. In contrast, concordance in samples scored as 0 (negative) or 3+ (positive) is strong among different laboratories. Increased patient survival was shown only in the highest (i.e., score of 3+) immunostaining group (Pauletti et al., 2000).

Another shortcoming of IHC is that false-positive and false-negative results can occur; therefore, some people who would benefit from trastuzumab therapy do not receive it and others who may not benefit receive the drug unnecessarily (Pauletti et al., 2000; Press et al., 2005; Ridolfi, Jamehdor, & Arber, 2000; Tubbs et al., 2001). Recent studies have found that large-volume central testing laboratories are likely to produce more accurate IHC results than community-based facilities; a high percentage of results from community-based laboratories cannot be confirmed at central facilities (Paik et al., 2002; Roche et al., 2002). Consequently, the pathology community has recognized the need for the standardization of IHC assays at central reference laboratories that demonstrate proficiency and good quality assurance.

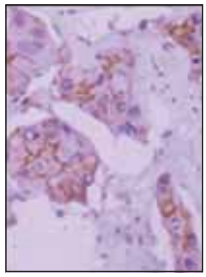
Fluorescence in Situ Hybridization

In contrast to IHC, FISH provides an objective rather than subjective assessment of HER2 status. FISH directly measures the level of *HER2* gene amplification by quantitating *HER2* gene copy numbers. The only FDA-approved FISH test kit is PathVysion® (Vysis Inc., Downers Grove, IL).

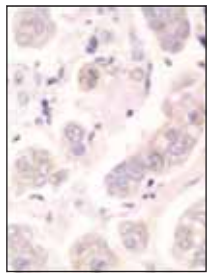
The PathVysion kit uses two segments of DNA, called probes, to examine two different genetic loci (Vysis Inc., 2000). The probe for the *HER2* gene is labeled with a red fluorescent



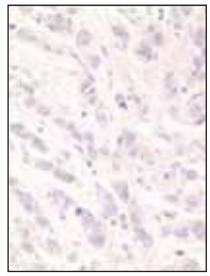
Immunohistochemistry (IHC) score of 3+: complete membrane staining observed in > 10% of tumor cells



IHC score of 2+: weak-to-moderate complete staining in > 10% of tumor cells



IHC score of 1+: faint or barely perceptible membrane staining in > 10% of tumor cells; cells are stained in only part of the membrane.



IHC score of 0: no staining observed or membrane staining in < 10% of tumor cells

Figure 2. Examples of HER2 Staining by Immunohistochemistry

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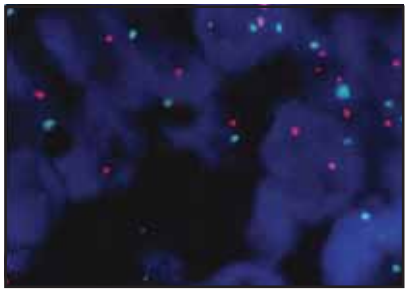
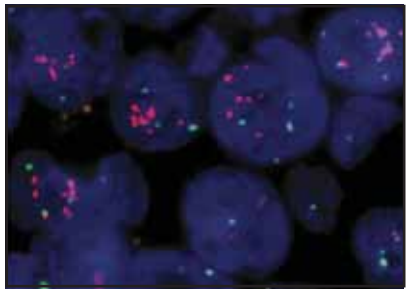
tag. The other probe, labeled with a green fluorescent tag, is for chromosome 17. The *HER2* gene resides on chromosome 17; therefore, the number of copies of chromosome 17 in individual cells is determined as an internal control to ensure that any apparent amplification of the *HER2* gene is not merely an artifact resulting from the presence of multiple copies of chromosome 17. By determining the ratio of the *HER2* fluorescence signal to the chromosome 17 fluorescence signal, *HER2* gene amplification can be recognized. Cells without *HER2* gene amplification have approximately the same number of copies of the *HER2* gene as chromosome 17, so the signal ratio is close to 1 (see Figure 3). In cells with *HER2* gene amplification (i.e., FISH positive), the signal ratio of *HER2* to chromosome 17 is 2 or higher. FISH-positive patients are eligible for treatment with trastuzumab. Patients with a signal ratio less than 2 are designated FISH negative and typically are not candidates for trastuzumab therapy.

The advantages of FISH include stability of the target (DNA), the ability to assess *HER2* gene amplification in individual tumor cells, and high reliability (Schaller et al., 2001). Two factors that can contribute to inaccuracy in testing results with FISH include potential interference of some fixatives with the assay (Bartlett et al., 2001) and failure to include appropriate controls for assay validation (Roche et al., 2002). FISH is technically demanding and requires a specialized fluorescence microscope; however, the test is a proven, effective technique in cytogenetics laboratories, where it has important applications in clinical hematology and prenatal chromosomal analysis (Gray & Pinkel, 1992).



A. Cells without *HER2* gene amplification: The ratio of *HER2* to chromosome 17 equals 1 (i.e., two copies of *HER2* to two copies of chromosome 17).



B. Cells with *HER2* gene amplification: The ratio of *HER2* to chromosome 17 is ≥ 2 (i.e., 15 copies of *HER2* to three copies of chromosome 17).

Figure 3. Representative Fluorescence in Situ Hybridization Results

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The results of FISH analysis are affected less by the method of fixation than the results of IHC. In comparison with IHC performed on frozen material, FISH has superior sensitivity (98%) and specificity (100%) (Pauletti et al., 1996; Press et al., 1997). Therefore, FISH would be expected to correctly identify virtually all candidates for trastuzumab therapy. Furthermore, the results of FISH are highly reproducible among observers and laboratories ("Clinical Laboratory Assays," 2002; Persons, Borelli, & Hsu, 1997; Press et al., 2005), and FISH is generally accepted to be more reproducible than IHC for the determination of HER2 status (Paik et al., 2002). A recent proficiency survey highlighted this consistency, showing remarkable concordance among laboratories for FISH results in contrast to substantial variability among laboratories for IHC results ("Clinical Laboratory Assays"). In addition, a recent report from the BCIRG found poor agreement (79%) between IHC results from outside laboratories and FISH performed at central laboratories, whereas agreement between outside and central laboratories regarding FISH results was substantially higher (92%) (Press et al., 2005). The BCIRG also found that FISH has a relatively low rate of false-positive and false-negative results compared with IHC (Press et al., 2005). *HER2* gene amplification by FISH also may be a better predictor than IHC of patient response to trastuzumab (Mass et al., 2005).

The recommendation has been made to verify equivocal IHC results (i.e., scores of 1+ or 2+) with FISH to ensure the appropriate selection of patients for trastuzumab ("Clinical Laboratory Assays," 2002; NCCN, 2005; Perez et al., 2002; Tubbs et al., 2001) and that when discordance arises between FISH and IHC results, FISH results should be used (Fornier et al., 2002). However, verifying IHC results may prolong the length of time before treatment is received. Therefore, an accurate determination of HER2 status must be made at the time of initial diagnosis to give patients the best opportunity to receive treatments that may effectively extend survival.

HER2 Status Predicts Benefit From Therapy With Trastuzumab

The ability of trastuzumab to inhibit growth is hypothesized to involve cytotoxic and cytostatic processes. These include inhibition of abnormal growth signals by downregulating HER2 expression (Sliwkowski et al., 1999), activation of the immune system to attack the tumor (i.e., antibody-dependent cellular cytotoxicity) (Sliwkowski et al.), augmentation of chemotherapy-induced cytotoxicity (Pegram & Slamon, 1999), and inhibition of angiogenesis (Izumi, Xu, di Tomaso, Fukumura, & Jain, 2002). Trastuzumab is approved by the FDA for the treatment of patients with metastatic breast cancer whose tumors overexpress HER2. The drug is approved for administration in combination with paclitaxel in women who have not received chemotherapy previously for advanced disease and as monotherapy in women who have received chemotherapy previously for metastatic disease (Rieger, 1999). The clinical benefit of trastuzumab in combination (with anthracycline, cyclophosphamide, or paclitaxel) or alone in women with HER2-positive metastatic breast cancer was demonstrated in three pivotal clinical trials. Trastuzumab also has been shown to be effective in combination with other chemotherapeutic agents, such as cisplatin (Pegram et al., 1998), docetaxel (Esteva et

al., 2002), vinorelbine (Burstein et al., 2001), and taxane and platinum combination therapy (Robert et al., 2002).

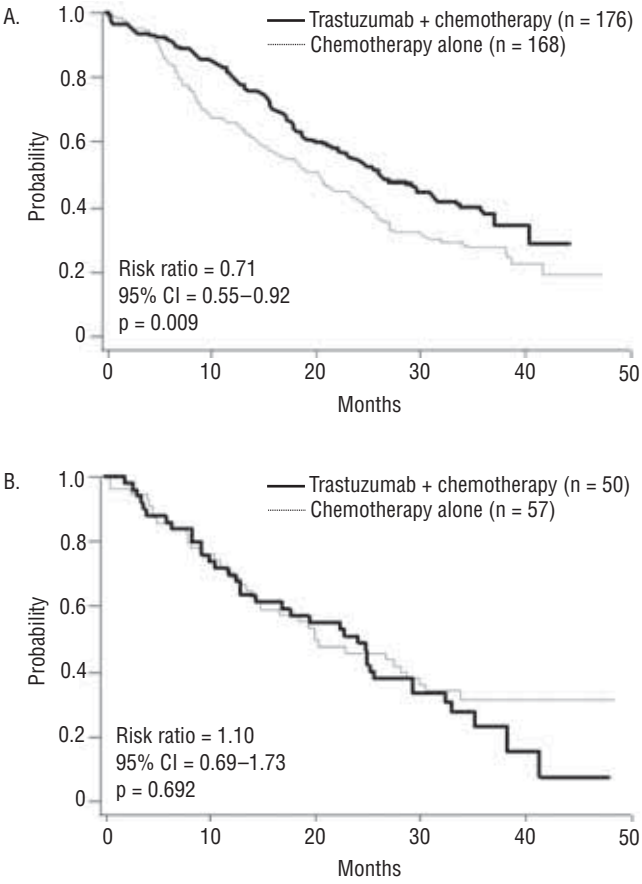
The efficacy of trastuzumab in combination with chemotherapy (anthracycline, cyclophosphamide, or paclitaxel) versus chemotherapy alone as first-line treatment for women with HER2-overexpressing metastatic breast cancer was demonstrated in a randomized phase III trial (Slamon et al., 2001). Four hundred and sixty-nine women who had not received chemotherapy previously for metastatic disease were enrolled. The addition of trastuzumab to chemotherapy produced statistically significant improvements, compared with chemotherapy alone, in overall response rate (50% versus 32%; $p < 0.001$), time to disease progression (7.4 versus 4.6 months; $p < 0.001$), and median overall survival (25.1 versus 20.3 months; $p = 0.046$).

Trastuzumab also produced durable, objective responses when administered as a single agent for first-, second-, or third-line therapy in women with HER2-overexpressing metastatic breast cancer (Cobleigh et al., 1999; Vogel et al., 2002). Among 222 women receiving trastuzumab as second- or third-line therapy, 15% had an objective tumor response, with 8 complete and 26 partial responses. The median response duration was 9.1 months (range = 1.6–26+ months), and the median time to disease progression was 3.1 months (range = 0–28+ months) (Cobleigh et al.). In Vogel et al.'s study, 114 women were randomized to receive either standard-dose trastuzumab (4 mg/kg loading dose followed by 2 mg/kg weekly) or a higher dose (8 mg/kg followed by 4 mg/kg weekly) as first-line therapy. Response rates were similar regardless of the trastuzumab dose. Objective responses were observed in 26% of patients, including 7 complete and 23 partial responses. However, 13 other patients had minor responses or stable disease for longer than six months. Thus, the overall clinical benefit rate (i.e., complete response, partial response, minor response, stable disease longer than six months) was 38% (95% confidence interval [CI] = 28.8%–46.9%). The median duration of survival for all patients was 24.2 months (95% CI = 16.9–31.7 months).

Fluorescence in Situ Hybridization Clinical Outcomes Analysis

Many HER2-positive patients derive clinical benefit from trastuzumab therapy. However, in three pivotal trastuzumab clinical trials, patients whose tumors were positive for HER2 expression based on IHC scores of 3+ had higher response rates than those whose scores were 2+ (Cobleigh et al., 1999; Slamon et al., 2001; Vogel et al., 2002). Given the poor reproducibility and concordance for tumor samples scored 2+, the observation of poorer response rates for patients with such tumors suggests that some were assigned HER2 positivity incorrectly. The theory was tested in a retrospective analysis of breast cancer histology specimens from the three trials. Samples originally scored as 2+ or 3+ by IHC were retested for *HER2* gene amplification by FISH, and the relationship between *HER2* gene amplification status and clinical outcome in patients treated with trastuzumab was evaluated (Mass et al., 2005). The retrospective subgroup analysis confirmed the theory by showing that, in patients who were IHC positive, the objective response rate and overall survival associated with trastuzumab therapy were higher in those who were also FISH positive, compared with those who were FISH negative (Mass et al.).

The relationship between FISH positivity and clinical outcome is illustrated by the retrospective analysis of the data from the trial of trastuzumab in combination with chemotherapy (Slamon et al., 2001). In women who were FISH positive, the addition of trastuzumab provided significant clinical benefit. The objective response rate was 54% in those treated with trastuzumab plus chemotherapy versus 30% in those treated with chemotherapy alone ($p < 0.0001$), and the objective response rate in FISH-positive patients treated with trastuzumab plus chemotherapy was 16% higher than in FISH-negative patients (54% versus 38%, respectively) (Mass et al., 2005). FISH-positive women treated with trastuzumab plus chemotherapy also survived longer (median = 26.2 months) than those treated with chemotherapy alone (median = 20.3 months; risk ratio = 0.71; 95% CI = 0.55–0.92; $p = 0.0009$). In contrast, the addition of trastuzumab provided no apparent clinical benefit compared with chemotherapy alone in women who were FISH negative. No significant differences in objective response rates or overall survival were noted between those who received trastuzumab



Overall survival time by HER2 amplification status for patients receiving chemotherapy with trastuzumab versus chemotherapy alone (study H0648g): (A) patients with FISH-positive tumors, (B) patients with FISH-negative tumors

CI—confidence interval; FISH—fluorescence in situ hybridization

Figure 4. Overall Survival Time for Patients

Note. From "Evaluation of Clinical Outcomes According to HER2 Detection by Fluorescence in Situ Hybridization in Women With Metastatic Breast Cancer Treated With Trastuzumab," by R.D. Mass, M.F. Press, S. Anderson, M.A. Cobleigh, C.L. Vogel, N. Dybdal, et al., 2005, *Clinical Breast Cancer, 6,* p. 243. Copyright 2005 by the Cancer Information Group. Reprinted with permission.

Table 1. Objective Response Rates by *HER2* Amplification Status for Patients Treated With Trastuzumab and Chemotherapy Versus Chemotherapy Alone

	Trastuzumab and Chemotherapy		Chemotherapy Alone		
Study	**Evaluable Patients**	**Objective Responses (%)**	**Evaluable Patients**	**Objective Responses (%)**	**p Value**
HER2 Amplification					
FISH Positive	176	95 (54)	168	51 (30)	< 0.0001
FISH Negative	50	19 (38)	57	22 (39)	NS

FISH—fluorescence in situ hybridization; NS—not significant

Note. From "Evaluation of Clinical Outcomes According to HER2 Detection by Fluorescence in Situ Hybridization in Women With Metastatic Breast Cancer Treated With Trastuzumab," by R.D. Mass, M.F. Press, S. Anderson, M.A. Cobleigh, C.L. Vogel, N. Dybdal, et al., 2005, *Clinical Breast Cancer, 6,* p. 242. Copyright 2005 by the Cancer Information Group. Reprinted with permission.

plus chemotherapy and those who received chemotherapy alone (see Figure 4 and Table 1).

The same trends were observed in women with metastatic breast cancer who were treated with single-agent trastuzumab. In a study of single-agent trastuzumab as first-line therapy (Vogel et al., 2002), the overall response rate (i.e., complete response plus partial response) was 27% higher in FISH-positive patients compared with FISH-negative ones (34% versus 7%, respectively) (Mass et al., 2005). In a study of single-agent trastuzumab as second- or third-line therapy following relapse (Cobleigh et al., 1999), objective responses occurred in 19% and 0% of FISH-positive and FISH-negative patients, respectively. Time to disease progression and median overall survival also were longer in FISH-positive patients compared with FISH-negative patients (Mass et al.) (see Table 2). Therefore, the data suggest that clinical benefit from trastuzumab is linked directly to FISH-positive patients.

Nursing Implications

Patients with breast cancer have the right to access information, participate in decisions, and have full informed consent but may need help interpreting their pathology reports and making informed decisions (Rosenzweig et al., 2000). Oncology nurses play an integral part in patient assessment and education and have a key role in developing patient care plans. After physicians provide diagnoses, nurses often are the first individuals to review with patients pathology reports and tumor factors used for making treatment decisions. Therefore, oncology nurses must be knowledgeable regarding diagnostic factors for breast carcinoma and their roles in the treatment decision-making process.

Understanding the issues involved in HER2 testing and the basic principles underlying the use of trastuzumab is central for assisting patients with interpreting HER2 test results and understanding the implications for cancer treatment. Family members also must be informed and educated. Strategies for patient and family education include using diagrams and cartoons to depict key concepts as well as printed materials with definitions of key terms and explanations of concepts for patients to take home and refer to at a later time. Nurses also can provide information on other resources, such as the American Cancer Society, the Internet (Web sites such as www.breastcancer.org and www.cancer.org), and patient support groups.

Physicians may inform patients that they are HER2 positive or negative without giving further explanation. Patients need to know that asking questions to ensure that they have been identified accurately as HER2 positive or negative is appropriate. More importantly, patients need to know which questions to ask (see Figure 5). Patients and family members must understand HER2 testing methods as well as the results of testing, what results mean, and how they are used. Educating patients regarding these concepts will facilitate active participation in their care and enhance dialogue with physicians, resulting in a more informed, collaborative decision-making process.

Conclusion

Approximately 20%–25% of breast cancers have *HER2* gene amplification or HER2 protein overexpression, which are strong negative prognostic indicators (Pauletti et al., 1996; Slamon et al., 1987, 1989). *HER2* gene amplification and HER2 protein overexpression also predict response to chemotherapy (Kim et

Table 2. Clinical Outcomes by *HER2* Amplification Status in Patients Treated With Trastuzumab Alone

Study	HER2 Amplification	Evaluable Patients	Objective Response (CR plus PR)	Median Time to Progression, Months (Range)	Median Survival Time, Months (Range)
H0649g	FISH positive	173	33 (19%)	3.2 (2.6–3.5)	14.2 (12.4–18.1)
	FISH negative	36	0	1.9 (1.5–2.8)	8.8 (5.8–15.6)
H0650g	FISH positive	82	28 (34%)	4.9 (3.5–6.3)	24.5 (17.4–36.1)
	FISH negative	29	2 (7%)	1.7 (1.5–3.3)	24.4 (10.8–34.7)

CR—complete response; FISH—fluorescence in situ hybridization; PR—partial response

Note. From "Evaluation of Clinical Outcomes According to HER2 Detection by Fluorescence in Situ Hybridization in Women With Metastatic Breast Cancer Treated With Trastuzumab," by R.D. Mass, M.F. Press, S. Anderson, M.A. Cobleigh, C.L. Vogel, N. Dybdal, et al., 2005, *Clinical Breast Cancer, 6,* p. 244. Copyright 2005 by the Cancer Information Group. Reprinted with permission.

Questions About HER2 Testing

- What is HER2?
- How do I know if my breast cancer has too many HER2 receptors?
- What tests do I need to find out if my breast cancer is HER2 positive? Which test is the most accurate? Will my insurance cover the costs for testing?
- Can HER2 testing be done on a tumor that was already biopsied?
- Is HER2 overexpression inherited?
- How does being HER2 positive affect my breast cancer prognosis?

Questions About Treatment

- What are the treatment options for HER2-positive breast cancer?
- What is trastuzumab? How does it work?
- Can I receive trastuzumab alone, or do I need to have chemotherapy along with it (and, if so, why)?
- Will trastuzumab make me feel sick or make me lose my hair?
- What are the side effects of trastuzumab? Will it increase chemotherapy toxicities?
- How frequently does trastuzumab affect heart function? Are there any symptoms I should watch for? If I have heart symptoms, do I need to stop taking trastuzumab? If there are symptoms, are they permanent? What is the worst-case scenario?
- Will my insurance cover the costs? What if my insurance refuses to pay?
- Where can I find more information about trastuzumab?

Figure 5. Key Questions Patients Should Ask When Receiving HER2 Testing Results

Note. Based on information from Mass et al., 2005.

al., 2002) and trastuzumab (Cobleigh et al., 1999; Slamon et al., 2001; Vogel et al., 2002). Because HER2 overexpression is associated with more aggressive cancer and worse prognosis, testing for HER2 status is crucial for the selection of the most appropriate and beneficial treatment.

HER2-positive patients with metastatic breast cancer benefit from trastuzumab therapy whether tested by IHC or FISH. However, retrospective analysis of three clinical trials indicated that clinical benefit among IHC-positive patients is greatest in patients who are IHC 3+ and FISH positive, suggesting that patients considered for trastuzumab therapy with IHC scores less than 3+ should have their scores confirmed by FISH (Mass et al., 2005).

In general, FISH is believed to be more reproducible than IHC for the determination of HER2 status, and recent data suggest the need to improve quality-control measures for IHC (Paik et al., 2002; Press et al., 2005). Further support for the reliability of FISH arose from a retrospective comparison of IHC and FISH results for specimens from three pivotal trials (Dybdal et al., 2005). Seventy-six percent of specimens with 2+ IHC scores were found to be HER2 negative by FISH, suggesting that a majority of patients scored as 2+ by IHC are false positives who may not benefit from trastuzumab therapy. In addition, patients scored as 0 or 1+ would account for approximately 12% of all FISH-positive patients, suggesting that some patients scored as HER2 negative by IHC may be candidates for trastuzumab therapy.

Oncology nurses must understand the issues involved in HER2 testing and the basic principles underlying the use of trastuzumab to assist patients with making informed decisions regarding HER2 testing and treatment options.

The author gratefully acknowledges Dennis J. Slamon, MD, PhD.

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