Neoadjuvant endocrine therapy in primary breast cancer:
Indications and use as a research tool

Yeehong Chia
Washington University School of Medicine in St. Louis
M. J. Ellis
Washington University School of Medicine in St. Louis
Cynthia Ma
Washington University School of Medicine in St. Louis
Neoadjuvant endocrine therapy has been increasingly employed in clinical practice to improve surgical options for postmenopausal women with bulky hormone receptor-positive breast cancer. Recent studies indicate that tumour response in this setting may predict long-term outcome of patients on adjuvant endocrine therapy, which argues for its broader application in treating hormone receptor-positive disease. From the research perspective, neoadjuvant endocrine therapy provides a unique opportunity for studies of endocrine responsiveness and the development of novel therapeutic agents.

Published online 10 August 2010
© 2010 Cancer Research UK

**Keywords:** breast cancer; oestrogen receptor; neoadjuvant endocrine therapy; genomics; relapse risk

For patients with locally advanced breast cancer, neoadjuvant chemotherapy is commonly recommended to improve surgical outcomes. However, for postmenopausal women with oestrogen receptor (ER)-positive disease, endocrine treatment is a logical alternative because of its established efficacy in the adjuvant setting (EBCTCG, 2005) and the increasing recognition that chemotherapy may be less effective in ER+ HER2− disease (Berry et al., 2006; Hayes et al., 2007). Historically, neoadjuvant endocrine therapy was reserved for older and frail patients with ER+ breast cancer. However, recent studies of this treatment modality in younger and healthier postmenopausal women showed that the improved surgical outcomes and response observed with the endocrine approach do not show an interaction with age (Olson et al., 2009), justifying the increased acceptance of neoadjuvant endocrine therapy in younger postmenopausal women with better performance status. For premenopausal women, neoadjuvant endocrine therapy remains investigational.

In this review, we will present results of the major neoadjuvant aromatase inhibitor (AI) trials and discuss recent progress in using neoadjuvant endocrine therapy as a research tool to assess endocrine responsiveness and evaluate novel therapeutic interventions.

**NEOADJUVANT ENDOCRINE THERAPY: THE CLINICAL DATA**

The potential benefit of endocrine therapy in the neoadjuvant setting was initially suggested in earlier studies of tamoxifen, as a primary treatment approach for elderly women with breast cancer who were too frail to undergo other forms of therapy such as surgery (Preece et al., 1982; Horobin et al., 1995; Bergman et al., 1995). The clinical response rate was in the range of 30% and higher, with long-lasting responses observed in some of these patients (Preece et al., 1982; Bergman et al., 1995). Subsequent randomised trials of tamoxifen vs surgery followed by tamoxifen conducted in elderly women with operable breast cancer showed that surgery is essential for optimal local control, but tamoxifen alone achieved a similar overall survival compared with surgery followed by tamoxifen (Willsher et al., 1997; Mustacchi et al., 2003; Hind et al., 2006; Chakrabarti et al., 2010). These investigations laid the foundation for the design of subsequent studies of AIs in younger and healthier postmenopausal women with bulky hormone receptor (HR)-positive disease to achieve better surgery outcome. The letrozole P024 trial (Eiermann et al., 2001), the Immediate Preoperative Anastrozole, Tamoxifen or Combined with Tamoxifen (IMPACT) trial (Smith et al., 2005) and the Preoperative ‘Arimidex’ Compared to Tamoxifen (PROACT) trial (Cataliotti et al., 2006) were three of these studies (Table 1).

In the P024 trial, letrozole treatment was associated with a statistically significant improvement in the rate of breast conservation compared with tamoxifen. The anastrozole-based IMPACT and PROACT trials also showed a trend favouring the AI arm, although the results in comparison with tamoxifen were not statistically significant (Smith et al., 2005; Cataliotti et al., 2006). A meta-analysis of these trials supported the notion that an AI was more effective than tamoxifen for promoting breast conservation (Seo et al., 2009). A promising 76% rate of breast conservation was also observed in a single arm phase II study of neoadjuvant exemestane in postmenopausal patients with HR+ tumours 3 cm or greater after 12 weeks of therapy (Mineritsch et al., 2008). The American College of Surgeons Oncology Group has recently completed accrual to the randomised phase III Z1031 trial to determine whether there are any differences in efficacy between the three approved AIs in this setting (NCT00698971). Preliminary data from this trial indicate that there are no clinically significant differences between these agents as neoadjuvant treatment (Ellis et al., 2010).

**YH Chia1, MJ Ellis1,2 and CX Ma*1,2**

1Department of Medicine, Division of Oncology, Washington University, 660 South Euclid Avenue, St Louis, MO 63110, USA; 2Siteman Cancer Center, Washington University, 660 South Euclid Avenue, St Louis, MO 63110, USA

*Correspondence: Dr CX Ma; E-mail: cma@dom.wustl.edu
Received 18 March 2010; revised 24 June 2010; accepted 19 July 2010; published online 10 August 2010
PREOPERATIVE ENDOCRINE THERAPY IN PREMENOPAUSAL WOMEN

In an early study by Gazet et al (2001), 13 premenopausal women with ER+ breast cancer received neoadjuvant goserelin, a gonadotropin-releasing hormone (GnRH) analogue. At 3 months, seven of the 13 women had an overall response by clinical assessment, suggesting that premenopausal women may also benefit from neoadjuvant endocrine manipulation (Gazet et al, 2001). Torrisi et al (2007) investigated the use of letrozole and a GnRH analogue as primary therapy in premenopausal women with ER+ breast cancer. These patients received a GnRH analogue for a median of 5.2 months and letrozole for a median of 4 months. In the 32 evaluable patients, one achieved a pathological complete response (pCR) and 15 obtained a clinical and imaging partial response (Torrisi et al, 2007). These studies suggest that neoadjuvant endocrine therapy is effective in selected premenopausal women with ER+ breast cancer and further study in this patient population is needed.

COMPARISON WITH PREOPERATIVE CHEMOTHERAPY

A direct comparison between neoadjuvant chemotherapy and endocrine therapy was reported by Semiglazov et al (2007), in which 239 postmenopausal women with untreated invasive breast cancers that were ER+ breast cancer received letrozole or paclitaxel every 3 weeks for four cycles (n = 118) or AI treatment with either anastrozole (n = 60) or exemestane (n = 61) for 3 months (Semiglazov et al, 2007). The clinical overall response rates of pCR and disease progression did not differ significantly among the groups. The breast conservation rate was slightly higher in the AI groups at 33% compared with 24% in the chemotherapy arm. These findings support the hypothesis that AI therapy is an appropriate low toxicity neoadjuvant approach, but a definitive randomised study that compares neoadjuvant endocrine therapy to chemotherapy has yet to be reported. Ideally, a trial that compares the two approaches would take a predictive model forward into the clinical trial design, as subpopulations of breast cancer may benefit more from chemotherapy, while others from endocrine manipulation (van de Vijver et al, 2002; Paik et al, 2004; Parker et al, 2009).

More recently, the GEICAM cooperative group reported a randomised phase II trial of chemotherapy vs exemestane in pre- and postmenopausal women (Alba et al, 2010). Ninety-five patients with localised ER+, PgR+, HER2− and CK8/18+ (immunohistochemistry marker for luminal subtype) breast cancer were randomly assigned to chemotherapy (epirubicin plus cyclophosphamide every 3 weeks for four cycles followed by docetaxel every 3 weeks for four cycles) (n = 47) or exemestane (with goserelin if premenopausal) (n = 48). Tumour response was measured by magnetic resonance imaging. More than 50% of the participants were premenopausal women (n = 24 in the chemotherapy arm and n = 27 in the hormonal therapy arm). The response rate was higher for chemotherapy in the premenopausal patients (18 of the 24 in the chemotherapy arm vs 12 of the 27 in the hormonal therapy arm, P = 0.027), but in postmenopausal women and those with a low baseline Ki67, responses were comparable. The underperformance of exemestane and goserelin in premenopausal women may reflect the fact that this can be inadequate for endocrine therapy in some patients, with a failure to suppress ovarian function. Alternatively, primary endocrine therapy resistance is likely to be higher in a premenopausal population and a more accurate predictive model for endocrine therapy efficacy is needed.

RECEPTOR STATUS AS SELECTION CRITERIA FOR NEOADJUVANT ENDOCRINE THERAPY

Oestrogen receptor positivity remains the single most important criterion for eligibility for neoadjuvant endocrine therapy. Patients with an ER Allred score of 6 and above are the most likely to respond (Ellis et al, 2001). The data on PgR status does not support its use as a selection criterion in the context of ER positivity, and PgR+ ER− tumours are too uncommon to make a definitive statement with regard to their management (Ellis et al, 2001). HER2 status has been investigated in both the IMPACT and the PO24 studies. Although the presence of HER2 amplification does not preclude a meaningful response to an AI in the neoadjuvant setting (Ellis et al, 2001; Smith et al, 2005), HER2 positivity is associated with a lower suppression of Ki67, a marker of cell proliferation, in response to either tamoxifen or letrozole (Ellis et al, 2006),
suggesting treatment resistance to endocrine therapy alone. In practice, most patients with HER2+ tumours receive trastuzumab in combination with a chemotherapy regimen because of the high pCR rate. Although the combination of trastuzumab and an AI has shown promising results in patients with metastatic disease (Marcom et al., 2007; Kaufman et al., 2009), it has not been adequately tested in the neoadjuvant setting.

PREDICTING LONG-TERM OUTCOMES AFTER NEOADJUVANT THERAPY

Neoadjuvant chemotherapy studies have firmly established that response, and particularly pCR, is a strong predictor of survival in breast cancer patients. However, in the subset of patients with ER+ HER2− disease treated with chemotherapy, pCR has limited value, as these patients often do well despite the absence of pCR because of effective adjuvant endocrine therapy (Buchholz et al., 2001). Pathological CR is very uncommon in response to neoadjuvant endocrine therapy. In three relatively large studies with letrozole, the pCR rate was no more than 1% (Eiermann et al., 2001; Baselga et al., 2009; Olson et al., 2009). Although residual cancer burden after neoadjuvant chemotherapy has been shown to predict distant relapse-free survival (Symmans et al., 2007), the application of this measure to patients who underwent neoadjuvant endocrine therapy remains to be evaluated. To identify alternative post-treatment factors that predict breast cancer survival after neoadjuvant endocrine therapy, Dowsett et al. (2007) examined Ki67 expression before and after 2 weeks of endocrine therapy. Patients with higher Ki67 expression after 2 weeks of endocrine therapy had a significantly lower recurrence-free survival (Dowsett et al., 2007). In a multivariable analysis conducted on the P024 trial (Ellis et al., 2008a), four factors were determined to have independent prognostic value for relapse and death after relapse. These included pathological tumour size (T1/2 vs T3/4), pathological node status (positive or negative) and two biomarkers in the surgical resection specimen, the natural logarithm of the Ki67 value and the ER status of the tumour. A prognostic score, the preoperative endocrine prognostic index (PEPI), was developed, which weighs each of these factors according to their associated hazard ratios (Table 2). The total PEPI score assigned to each patient is the sum of the risk points derived from the pT stage, pN stage, Ki67 level and ER status of the surgical specimen. An HR in the range of 1–2 receives one risk point; an HR in the 2–2.5 range, two risk points; an HR greater than 2.5, three risk points. The total risk point score for each patient is the sum of all the risk points accumulated from the four factors in the model. For example, a patient with a T1 N0 tumour, a Ki67 staining percentage of 3% and an ER status of 2 will have a total relapse score of 7 (9/3 + 4/3 + 2/3 + 3/3 + 1/3). The natural logarithmic interval corresponding to the per cent Ki67 values on the original percentage scale.

## Table 2 The PEPI

<table>
<thead>
<tr>
<th>Pathology, biomarker status</th>
<th>RFS</th>
<th>BCSS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HR</td>
<td>Points</td>
</tr>
<tr>
<td>Tumour size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1/2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>T3/4</td>
<td>2.8</td>
<td>3</td>
</tr>
<tr>
<td>Node status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative</td>
<td>3.2</td>
<td>3</td>
</tr>
<tr>
<td>Positive</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Ki67 level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0−2.7% (0–1b)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>&gt;2.7−7.3% (1–2b)</td>
<td>1.3</td>
<td>1</td>
</tr>
<tr>
<td>&gt;7.3−19.7% (2–3b)</td>
<td>1.7</td>
<td>1</td>
</tr>
<tr>
<td>&gt;19.7–53.1% (3–4b)</td>
<td>2.2</td>
<td>2</td>
</tr>
<tr>
<td>&gt;53.1% (&gt;4b)</td>
<td>2.9</td>
<td>3</td>
</tr>
<tr>
<td>ER status, Allred score</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–2</td>
<td>2.8</td>
<td>3</td>
</tr>
<tr>
<td>3–8</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Abbreviations: PEPI = preoperative endocrine prognostic index; RFS = relapse-free survival; BCSS = breast cancer-specific survival; HR = hazard ratio; ER = estrogen receptor. *To obtain the PEPI score, risk points for RFS and BCSS were assigned depending on the HR defined in the P024 analysis (Ellis et al., 2008a). The total PEPI score assigned to each patient is the sum of the risk points derived from the pT stage, pN stage, Ki67 level and ER status of the surgical specimen. An HR in the range of 1–2 receives one risk point; an HR in the 2–2.5 range, two risk points; an HR greater than 2.5, three risk points. The total risk point score for each patient is the sum of all the risk points accumulated from the four factors in the model. For example, a patient with a T1 N0 tumour, a Ki67 staining percentage of 1% and an ER Allred score of 2 will have a total relapse score of 3+3+2+3 = 11. The natural logarithmic interval corresponding to the per cent Ki67 values on the original percentage scale.

genetic studies and access to sophisticated analysis techniques. To date, the number of publications on genomic profiling in the context of neoadjuvant endocrine therapy remains few and the sample sizes are small. For example, Miller et al. (2009) reported on a series of 52 patients, 37% were considered letrozole sensitive and 15% resistant. A predictive model was developed that used all three types of gene expression variable: baseline, on-treatment and change in treatment, to differentiate between the two groups. This paper illustrates the variety of bioinformatics approaches that can be taken when before and on-treatment paired samples are available for analysis (Miller et al., 2009). Other investigations are ongoing to assess the predictive value of established molecular signatures, such as the Netherlands Cancer Institute NKI 70 gene (van de Vijver et al., 2002), 21 gene recurrence score (Paik et al., 2004) or the PAM50 (Parker et al., 2009), performed on tumour samples taken after the initiation of endocrine therapy (Ellis et al., 2008b). The Z1031 trial has recently completed accrual of 375 patients, despite mandatory fresh tumour tissue acquisition, through the provision of tissue acquisition kits and the active collaboration of surgical investigators. Z1031 patients are also consented for massive parallel DNA sequencing to define complete cancer genomes (Ding et al., 2010). Very detailed information on the molecular characteristics of endocrine therapy-resistant and -sensitive tumours is therefore a near-term prospect.

GENOMICS TO DETERMINE THE MOLECULAR BASIS FOR THE VARIABLE RESPONSE TO ENDOCRINE THERAPY

Discovery genomics is a complex process that often requires fresh-frozen material, an adequate sample size, patient consent to

NEOADJUVANT TRIALS TO GENERATE PROOF-OF-PRINCIPLE DATA FOR NOVEL ENDOCRINE THERAPY COMBINATIONS

The superior efficacy of adjuvant aromatase inhibition vs tamoxifen in reducing the risk of recurrence was mirrored by
CONCLUSIONS
Neoadjuvant AI therapy is a clinically valuable, logical and increasingly accepted approach to neoadjuvant systemic therapy for postmenopausal women with ER+ HER2– breast cancer. With an array of new agents and predictive biomarkers to investigate, the time for further randomised trials to compare neoadjuvant endocrine treatment with conventional chemotherapy in a broad spectrum of patients with ER+ breast cancer has probably passed – particularly if the trial under consideration is not prospectively testing a predictive biomarker for endocrine responsiveness. For future investigations, we should also focus on the fact that for ER+ endocrine therapy-resistant disease, conventional chemotherapy may not be adequate treatment. We should therefore use the neoadjuvant setting to address two key issues: the development of more effective mechanism-based treatments for endocrine therapy-resistant disease; and the identification of ER+ breast cancers that can be managed without chemotherapy.

ACKNOWLEDGEMENTS
Dr Ellis is supported in this work by Grants R01 CA095614, U01 CA114722 and P30 CA91842. We thank Susan G Komen for the Cure St Louis CRAFT grant and the Breast Cancer Research Foundation grant to the American College of Surgeons Oncology Group (U10CA076001). Dr Ellis reports the following conflict of interests: patents and licensing, Bioclassifier LLC; research grants, Novartis and AstraZenica; and consulting fees and speaking honoraria, Novartis, AstraZenica and Pfizer. Drs Chia and Ma report no conflict of interest.

REFERENCES
Neoadjuvant endocrine in primary breast cancer

YH Chia et al

© 2010 Cancer Research UK

British Journal of Cancer (2010) 103(6), 759–764
postmenopausal breast cancer with anastrozole, tamoxifen, or both in combination: the Immediate Preoperative Anastrozole, Tamoxifen, or Combined with Tamoxifen (IMPACT) multicenter double-blind randomized trial. *J Clin Oncol* 23: 5108– 5116


