Cross Stratification and Differential Risk by Breast Cancer Index and Recurrence Score in women with hormone receptor positive lymph-node negative early stage breast cancer

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Running title: Differential Risk for distant recurrence by Breast Cancer Index and Recurrence Score

Key words: breast cancer index, oncotype recurrence score, cross-stratification, distant recurrence risk

Funding
This work was supported by Cancer Research UK, AstraZeneca, and the National Institute for Health Research Biomedical Research at the Royal Marsden (London, UK).

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Disclosures
IS has nothing to declare. YZ, BS, and CAS are employees of bioTheranostics. MD received commercial support from AstraZeneca, speaker's bureau honoraria from Ventana, and is consultant for Genoptix. JC received research grants from AstraZeneca. YZ, CAS, and DS are named inventor on a patent to use the breast cancer index, *HOXB13/IL17BR*, and molecular grade index assays to predict breast cancer outcome.

Word count: 21852164
Number of tables/figures: 54

Translational Relevance

This is the first study to examine the ability of the Breast Cancer Index to re-stratify discrepant risk groups for distant recurrence by the Oncotype Recurrence Score. The study was conducted in a set of 665 postmenopausal women with lymph node negative, hormone receptor positive breast cancer treated with either tamoxifen or anastrozole alone. Our results show that the Breast Cancer Index re-stratifies women with low or intermediate risk for distant recurrence by the Recurrence Score into clinically relevant different risk groups with significantly different risk of distant recurrence at 10 years of follow-up. In contrast, the Recurrence Score did not significantly re-stratify any patients into different risk categories. Our results showed that the prognostic value of BCI may have potential clinical impact in terms of improving individualized risk stratification for patients with lymph-node negative early stage breast cancer.

Abstract

Background: Previous results from the TransATAC study demonstrated that both the Breast Cancer Index (BCI) and the Onco*type*DX Recurrence Score (RS) added significant prognostic information to clinicopathologic factors over a 10-year period. Here, we examined cross-stratification between BCI and RS to directly compare their prognostic accuracy at the individual patient level.

Patients and methods: 665 patients with hormone receptor positive (HR+) and lymph-node negative disease were included in this retrospective analysis. BCI and RS risk groups were determined using pre-defined clinical cut-points. Kaplan-Meier estimates of 10-year risk of distant recurrence (DR) and log-rank tests were used to examine cross-stratification between BCI and RS.

Results: As previously reported, both RS and BCI were significantly prognostic in years 0 to 10. BCI provided significant additional prognostic information to the Clinical Treatment Score (CTS)CTS plus RS (ΔLR-χ^2=11.09; P<0.001) whereas no additional prognostic information was provided by RS to CTS plus BCI (ΔLR-χ^2=2.22; P=0.1). Re-stratification by BCI of the low and intermediate RS risk groups led to subgroups with significantly different DR rates (*P*<0.001 and *P*=0.003, respectively). In contrast, re-stratified subgroups created by re-stratification by RS of BCI risk groups did not differ significantly.

Conclusions: In this retrospective analysis, BCI demonstrated increased prognostic accuracy versus RS. Notably, BCI identified subsets of RS low and RS intermediate risk patients with significant and clinically relevant rates of DR. These results indicate that additional subsets of women with HR+, lymph-node negative breast cancer identified by BCI may be suitable candidates for adjuvant chemotherapy or extended endocrine therapy.

Introduction

Breast cancer is the most common cancer and the second leading cause of cancer-related death in women worldwide [1]. As a result of significant advancements in the molecular characterization of breast cancer etiology, clinical management has evolved to include a comprehensive assessment of the underlying biology of the patient's tumor alongside the clinicopathological paradigm to determine treatment strategies [2, 3]. The ongoing challenge in breast cancer is the effective treatment of a heterogeneous disease associated with a wide spectrum of morphologic and molecular subtypes with variable outcomes [3].

Genomic tools and expression-based multi-gene signatures have increased prognostic information for early stage breast cancer patients beyond traditional clinicopathological factors [4-6]. The 21-gene based Recurrence Score (Onco*type*DX; RS) is a well-established multi-gene assay, which was developed to assess the risk of distant recurrence in women with hormone receptor positive, node-negative breast cancer treated with tamoxifen [7]. The RS classifies women into low (RS<18), intermediate (RS: 18-30), and high (RS>30) risk groups for distant recurrence (DR). The RS has been validated and evaluated in a number of clinical trials, and results confirm the prognostic value of RS beyond that of clinical parameters for DR in the first five years after diagnosis [7-9]. The Breast Cancer Index (BCI) is a second generation gene expression signature developed from the combination of two biomarkers: the HOXB13:IL17BR expression ratio (H/I) and the Molecular Grade Index (MGI) [10]. H/I is a biomarker that is associated with tumor responsiveness to endocrine therapy in breast cancer [10, 11]. MGI consists of the average expression of five cell cycle-associated genes and provides quantitative and

objective molecular assessment of tumor grade and proliferative status [10, 12]. The linear, but not cubic, BCI score provides an estimate for a patient's risk for DR and stratifies patients into different risk groups in the early (year 0-5), late (year 5-10) and overall (year 0-10) time periods [10, 13].

In a previous study, the linear BCI score was shown to provide more prognostic information for distant recurrence than RS [13]. However, in women with discrepant scores their values have not been evaluated to date. Here, we investigate the comparative prognostic strength, agreement and clinical significance of cross stratification by the RS and BCI.

Methods

Study population

The translational Arimidex, Tamoxifen Alone or Combination (TransATAC) study collected formalin-fixed paraffin embedded (FFPE) blocks from women with hormone receptor positive breast cancer who did not receive chemotherapy as part of their initial treatment, and who were randomised to either anastrozole or tamoxifen [14]. For this analysis, only women with lymph node-negative disease and data on both molecular scores have been included (N=665).

Analytical methods

Analytical methods for RS and BCI (linear model) have been described in detail previously [5, 6, 14]. In brief, RNA was extracted by Genomic Health and gene expression analysis for both scores was done by real time RT-PCR. Risk stratification with RS and BCI was based on pre-specified cut-off points for 10-year risk of DR: RS <18: low risk, 18-31: intermediate risk, >31: high risk, and BCI <5.0825: low risk, 5.0825-6.5025: intermediate risk, >6.5025: high risk.

Statistical analyses

The primary objective of this analysis was to determine the differential risk of DR for women with discrepant RS and BCI scores. The primary endpoint for the comparison was time to DR with death before DR being treated as a censoring event. The association between the risk score/categories and distant recurrence was assessed using hazard ratios (HR) derived from Cox proportional hazard models with associated 95% Confidence Intervals (CI). HR for the continuous risk scores were

computed for a difference between the 25th and 75th percentile of the continuous scores (interquartile HR).

For multivariate analyses, each score was combined with the Clinical Treatment Score (CTS, an algorithm combining nodal status, tumor size, grade, age and treatment) to determine the added prognostic information in that score. Changes in likelihood ratio values (ΔLR-χ^2) were used to measure and compare the relative amount of information of one score compared to the other. The Net Reclassification Index (NRI) was used to determine the net improvement in prognostic prediction by BCI compared to the RS for patients with and without DR. *P*-values were two-sided, based on normal approximation and all confidence intervals (CI) were at the 95% level. Analyses were performed using STATA version 13.1 (College Station, Texas USA).

Results

665 postmenopausal women with HR+, lymph-node negative disease have been included in this retrospective analysis. Of these, 72 (10.8%) had a DR before 10 years of follow-up. Detailed baseline characteristics for this study group have been published previously [13]. In brief, median age was 62.4 years (IQR 46.7 to 88.4), most women had moderately differentiated tumors (51.7%), and tumor size of less or equal to 2cm (73.1%).

Table 1 shows Hazard Ratios and prognostic information provided (LR-χ^2) by each score and in addition to the CTS and the other score (ΔLR-χ^2). There was a significant effect of adding BCI to CTS plus RS (ΔLR-χ^2=11.09, *P*=0.0009) whereas no additional prognostic information to the CTS plus BCI was added by the RS (ΔLR-χ^2=2.22, *P*=0.1). Table 2 shows the cross-stratification by RS and BCI into the respective risk groups. Overall, BCI classified fewer women into intermediate risk (25.0% vs. 26.8%) but more patients into high risk than RS (16.4% vs. 14.9%). In total, 283 (42.6%) women were classified into the low, 49 (7.4%) into the intermediate, and 55 (8.3%) into high risk groups by both BCI and RS, leading to a concordance of 58.2% between RS and BCI risk categories (Table 2). Among the 278 (41.8%) discordant cases, 24.414.3% of BCI low risk patients were re-stratified into RS-intermediate and 3.11.8% into RS-high risk groups (Table 2). In contrast, BCI re-classified 21.912.8% and 5.23.0% of RS-low risk patients as BCI-intermediate and BCI-high risk, respectively (Table 2).

Net Reclassification Index (NRI) was used to evaluate the incremental risk prediction improvement achieved by BCI as compared to RS for DR and non-events groups, separately (Table 3). For those with DR, the BCI classified 21 women into higher and 14 into lower risk categories compared to the RS (Table 3). This translates into a net reclassification of 9.7% by BCI for women with a DR. For non-events, BCI re-classified 125 women into lower and 118 into higher risk categories than RS, resulting in a net reclassification of only 1.2% by BCI. The overall NRI for BCI vs. RS was 10.9%, which was statistically significant (*P*=0.001) (Table 3).

The comparison of prognostic accuracy of RS and BCI was further assessed by Kaplan-Meier analysis. Figures 1 and 2 show cumulative Kaplan-Meier curves for 10-year DR rates for the cross-classification between RS and BCI risk groups. BCI re-stratified both RS-low and RS-intermediate patients further into risk subsets with significantly differential risk of DR (LR-χ^2=14.64, *P*<0.001 and LR-χ^2=11.75, *P*=0.003, respectively; Figure 1A and 1B). Among the 388 women categorized by RS as low risk, 20 women were reclassified as being high risk by BCI and had a DR risk of 23.3% by 10 years, which incurs a 7 times higher risk of distant recurrence compared with those reclassified as the BCI-low risk group (HR=6.77 (2.12-21.58); Figure 1A). Those reclassified into the intermediate risk group by BCI had a three times higher risk of DR than those in the low RS risk group (HR=2.94 (1.16-7.46)) with a 10-year risk of DR of 12.2% (Figure 1A). Similarly, among the 178 women classified by RS as intermediate risk, 95 women were downgraded to low risk by BCI with a 10-year DR risk of 7.1% in contrast to 34 women who were upgraded to high risk by BCI with a 10-year DR risk of 27.8% (Figure 1B). Among women classified by RS as intermediate risk, those classified by BCI as intermediate or high risk group

had a 4 to 5 times actual higher risk of distant recurrence by 10 years than those classified by BCI as low risk (HR=3.80 (1.40-10.27) and HR=4.83 (1.72-13.59), respectively) (Figure 1B). Among the 99 women categorized by RS as high risk, 12 were reclassified by BCI as low risk with a non-significantly lower risk of DR than those in the intermediate and higher risk groups, (Figure 1C). However, no significant reclassification of any of the BCI risk groups by the RS was observed in terms of 10-year DR risk (Figure 2).

Discussion

As Wwe have previously shown reported [13], that the linear BCI added significant prognostic information for distant recurrence beyond that of clinical parameters and the Oncotype Dx RS for overall cumulative risk of 10 year DR in HR+, lymph-node negative breast cancer [13] in the TransATAC population. Further analysisOur results showed that BCI re-categorized patients within low and intermediate RS risk groups in a statistically significant manner. In contrast, RS did not significantly re-classify any of the risk groups identified by BCI. This was also reflected in the significant net reclassification index of 10.9% for BCI vs. RS.

BCI is a gene expression–based signature that algorithmically integrates the differential expression of 5 cell cycle related genes (MGI), and the expression ratio of HOXB13/IL17BR (H/I) [10]. BCI has been shown to be a significant prognostic factor in women with hormonal receptor-positive, lymph-node negative disease for both early (0-5 years) and late (5-10 years) follow-up periods[10, 13]. RS is based on a 21-gene signature that was developed in a tamoxifen-treated, lymph node negative population, and is in part driven by proliferation genes [7, 15]. The RS has shown to be a strong prognostic marker particularly in the early follow-up period (0-5 years) [16]. Although functionally similar in the ability of the two scores to profile mitogenic activity, there is no overlap in the gene characteristics between RS and BCI. The correlation between BCI and RS or CTS was weak (rho=0.49, rho=0.45, respectively) and therefore the significant additional prognostic information shown in our analysis by BCI is not accounted for by either clinical parameters or RS. Some comparative studies have shown that multi-gene signatures provide comparable prognostic performance despite modest overlap [17, 18]. However, these studies

utilized public microarray datasets derived from tumor bank specimens, which may present selection bias with respect to the intended patient population. Here, we assessed the genomic signatures at the individual patient level data with clinical outcome from the TransATAC study.

Results of this study may have implications for clinical decision making related to early stage breast cancer and potential disease management. For example, patients in the RS low risk group are generally considered to have a favorable prognosis with 5 years of endocrine therapy alone and are unlikely to benefit from adjuvant chemotherapy [7, 8]. Recent data from the TAILORx trial has confirmed the excellent prognosis for patients with the lowest RS scores (0-10) over the first 5 years post-diagnosis [19]. However, in the present study, BCI identified approximately 22% of RS low risk patients as intermediate risk and 5% as high risk. These findings suggest that a significant proportion of RS low risk patients are at an elevated risk of late recurrence, and may benefit from extended endocrine therapy. Notably, the H/I component of the BCI test has been shown to be predictive of benefit from extended endocrine therapy in the MA.17 trial [11]. BCI also re-categorized women who were classified by RS into the high risk into a low risk group. Although some of these women had large and poorly differentiated tumors, the low risk of DR overall is an indication that the benefit of additional endocrine or adjuvant chemotherapy is uncertain is this group. We have previously published data on cross-classification by the CTS and PAM50 ROR in the TransATAC study [20] where the ROR categorised more women into the high risk group than the CTS alone. Both of these findings suggest the importance of non-clinical tumor characteristics, such as biology of these tumors, that need to be taken into account when assessing DR risk, specifically after

5 years of endocrine treatment [16]. Finally, BCI significantly re-stratified the RS intermediate risk group, a categorization that presents challenges for clinical decision-making, identifying approximately half of these patients as having a low risk of recurrence and half with an elevated risk of recurrence. Of note, the subset of patients re-stratified by BCI as intermediate or high risk appeared to have an elevated risk for both early and late recurrences; in contrast to those categorised to low risk groups by BCI or RS. While not evaluated in this study, these results suggest a potential role for both adjuvant chemotherapy and extended endocrine therapy that should be evaluated in future studies. RS cross stratification of the BCI intermediate risk group resulted in a trend towards statistical significance, with approximately half of patients downgraded to RS low risk.

Strengths of this analysis are the large sample size of women with lymph-node negative disease, with a median follow-up of 10 years. Furthermore, this patient population comes from a well described clinical trial using both tamoxifen and anastrozole. Limitations of this studyOur study has limitations. are thatinclude that oOnly a subset of the patients (n=665) from the main ATAC trial were included in this analysis (N=665) of whom 10.8% had a distant recurrence. Secondly, none of these women have received chemotherapy and therefore our results may not apply to chemotherapy-treated women. Of note, patients with a high RS would receive adjuvant chemotherapy and therefore have a lower risk of distant recurrence. FurthermoreFinally, this analysis focused on women with lymph-node negative disease and therefore our results are not applicable to women with lymph-node positive disease.

In summary, this study confirmed that linear BCI provided statistically significant prognostic information in addition to traditional clinical factors and RS in women with HR+, lymph-node negative disease treated with adjuvant endocrine therapy. New findings from this analyses are that the BCI re-classifies quite a few women into different risk categories than RS, and that these reclassifications were associated with substantial differences in patient outcomes. Therefore, our findings on the prognostic value of BCI may have potential clinical impact with respect to improving individualized risk stratification for patients with lymph-node negative early stage breast cancer.

Acknowledgements

We thank the ATAC trialists and pathologist and are indebted to the women who participated in the ATAC trial.

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Figure legends

Figure 1: Kaplan-Meier analysis for 10-year distant recurrence rates in BCI risk groups within RS-Low (N=388, Figure 1A), RS-Intermediate (N=178, Figure 1B), and RS-High (N=99, Figure 1C) risk groups. Distant recurrence differences were evaluated by log-rank test.

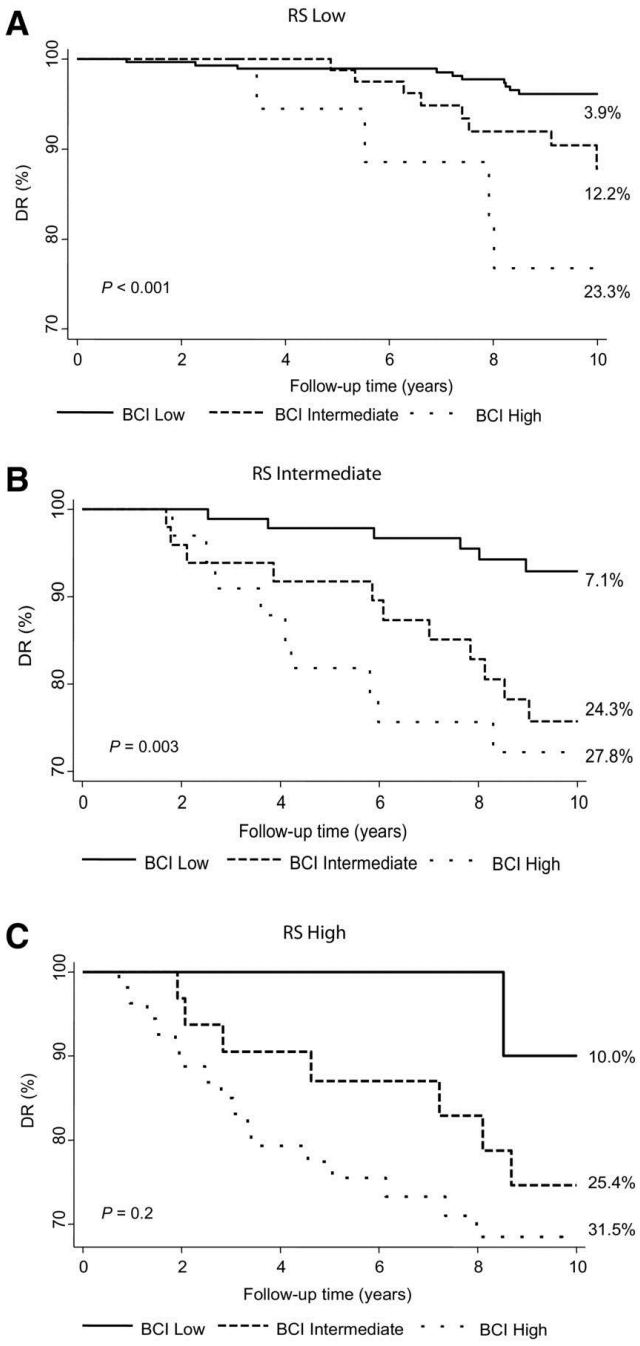

Figure 2: Kaplan-Meier analysis for 10-year distant recurrence rates in RS Risk Groups within BCI-Low (N=390, Figure 2A), BCI-Intermediate (N=166, Figure 2B), and BCI-High (N=109, Figure 2C) risk groups. Distant recurrence differences were evaluated by log-rank test.

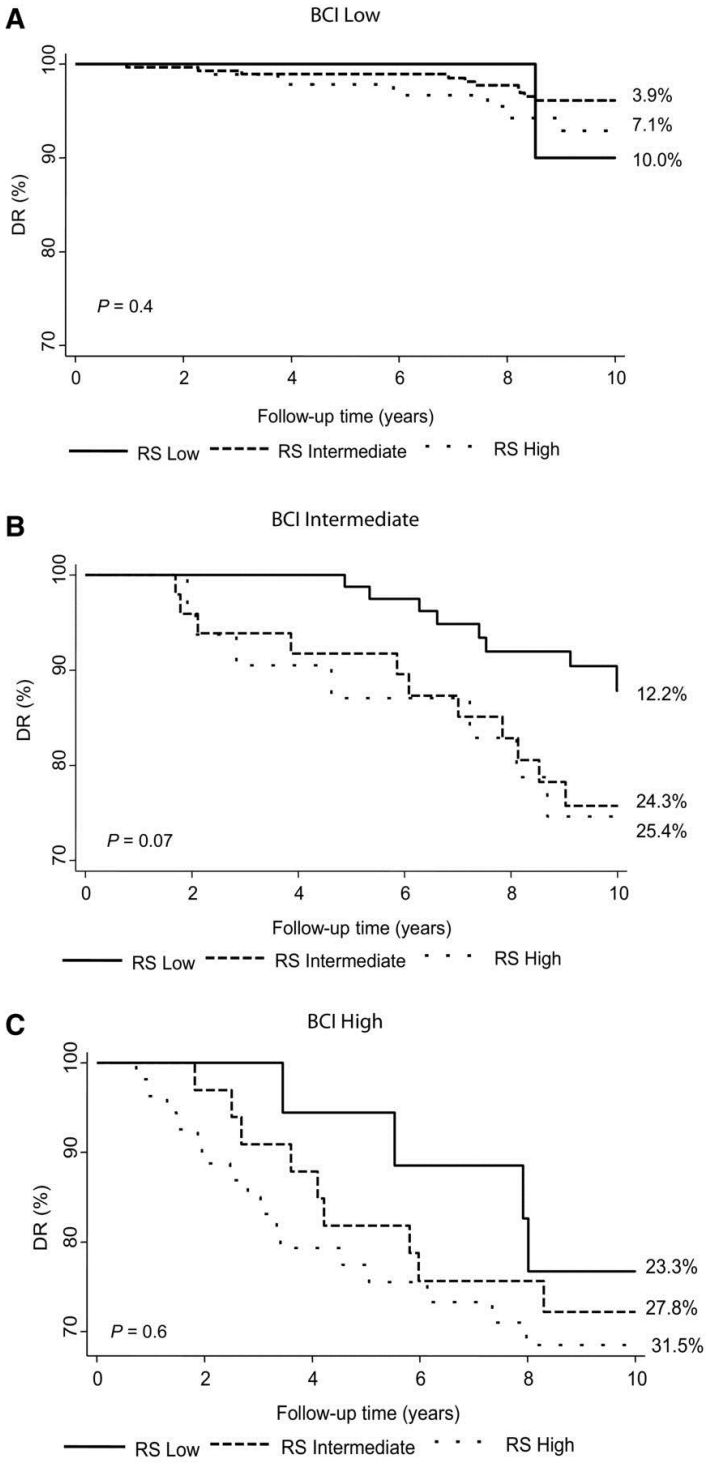

Table 1: Hazard ratio and likelihood ratio tests for BCI and RS (LR-χ^2) in the unvariate analysis and for both scores when added to the CTS and other score (ΔLR-χ^2) in the multivariableriate analysis.

	HR (95% CI)	**LR-χ^2 (*P*-value)**
RS	1.64 (1.39-1.94)	25.16 (<0.0001)
BCI	3.24 (2.31-4.54)	48.96 (<0.0001)
		ΔLR-χ^2 (*P*-value)
CTS+RS+BCI	2.00 (1.32-3.05)	11.09 (0.0009)
CTS+BCI+RS	1.20 (0.95-1.50)	2.22 (0.1)

RS=Onco*type* DX Recurrence Score; BCI=Breast Cancer Index, CTS=Clinical Treatment Score; HR=Hazard Ratio; LR=Likelihood Ratio

Table 2: Cross-stratification of women into respective risk groups by RS and BCI. (Grey shaded area=reclassified into higher risk groups by BCI, blue shaded areas=reclassified into lower risk groups by BCI)

	RS			
BCI	Low	Intermediate	High	**Total**
Low	283	95	12	**390**
Intermediate	85	49	32	**166**
High	20	34	55	**109**
Total	**388**	**178**	**99**	**665**

RS=Onco*type* DX Recurrence Score; BCI=Breast Cancer Index

Table 3: Cross-stratification and Net Reclassification Index (NRI) of distant recurrence and non-events by BCI and RS. (Grey shaded area=reclassified into high risk groups by BCI, blue shaded areas=reclassified into lower risk groups by BCI)

Distant recurrence (N=72)

	RS		
BCI	Low	Intermediate	High
Low	10	6	1
Intermediate	8	11	7
High	4	9	16

Non-events (N=593)

	RS		
BCI	Low	Intermediate	High
Low	273	89	11
Intermediate	77	38	25
High	16	25	39

RS=Onco*type* DX Recurrence Score; BCI=Breast Cancer Index

reclassified into higher risk group by BCI
reclassified into lower risk group by BCI

NRI=[distant recurrence (% upward - % downward)]–[non-events (% upward- % downward)]

NRI for (BCI/RS)=[(21/72)-(14/72)]–[(118/593)-(125/593)]**=10.9%**