A single nucleotide variant on chromosome 10 residing within nebulin (C10orf113) distinguishes patients with basal-like human breast cancer.

Shahan Mamoor, MS
shahanmamoor@gmail.com
East Islip, NY 11730

Patients diagnosed with basal-like breast cancer face a more aggressive disease course and more dismal prognosis than patients diagnosed with luminal A and luminal B breast cancer molecular subtypes (1-4). We mined published microarray data (5, 6) to understand in an unbiased fashion the most distinguishing genetic and transcriptional features of tumors from patients with basal or basal-like subtype breast cancer. We identified a single nucleotide polymorphism (rs625223) residing within *NEBL* (C10orf113) as among the most significant genetic differences in the tumors of patients with basal-like breast cancer. In a separate cohort of patients with basal subtype breast cancer, we observed transcriptome-wide differential tumor expression of a C10orf113 transcript. Analysis of patient survival data revealed that C10orf113 primary tumor expression was correlated with recurrence-free survival and distant metastasis-free survival in patients with basal-like breast cancer, but in a contrary manner. Thus, single nucleotide variants on both chromosome 5 (7) and chromosome 10 are fundamental differences that define the genetic composition of basal-like breast cancer in humans.

Keywords: basal subtype, basal-like breast cancer, BLBC, NEBL, systems biology of breast cancer, targeted therapeutics in breast cancer, breast cancer, triple negative breast cancer.

Classification of disease types and disease subtypes enables development of enhanced diagnostic capabilities, prognostic information, as well as a nuanced understanding of human disease that can support superior medical, surgical and radiological treatment of complex diseases such as cancer. Molecular subtypes in human breast cancer include luminal A, luminal B, basal or basal-like, and HER2+. Systems-level analyses, such as comparative tumor transcriptome analyses, can inform such approaches. Importantly, differences in genetic background that can influence disease frequency or progression in basal subtype (1, 2) or triple negative breast cancer (which shares significant overlap with basal subtype breast cancer (3, 4)) are difficult to discern without whole-genome sequencing data. However, in the case of whole genome sequencing, data indicating that changes at the level of the genome at single nucleotide resolution are accompanied by differences in gene expression, between molecular subtypes and at the level of the transcriptome, are still lacking, but could be ascertained based on combined analysis of microarray data that encompasses both transcript and SNP-level data. We mined published microarray data (5, 6) to identify the most significant genetic and transcriptional differences when comparing human breast cancer molecular subtypes. Integrative microarray dataset analysis has provided data illuminating genes whose sequence and expression defines basal-like subtype breast cancers, and we present evidence here.

Methods

We utilized datasets GSE10893 (5) and GSE87049 (6) for this global differential gene expression analysis of basal subtype human breast cancer in conjunction with GEO2R. GSE10893 was generated using Agilent-011521 Human 1A Microarray G4110A technology with $n=37$ basal-like breast tumors and $n=132$ primary tumors of the breast from patients diagnosed with breast cancer of different, non-basal molecular subtypes (luminal A, luminal B, HER2+, claudin, claudin-low, normal-like); analysis was performed using platform GPL8864. GSE87049 was generated using Affymetrix Human Gene 1.0 ST Array [transcript (gene) version] technology with $n=14$ basal-like breast tumors and $n=109$ breast tumors of other molecular subtypes (luminal A, luminal B, HER2-enriched, and normal-like); analysis was performed using platform GPL6244. The Benjamini and Hochberg method of p -value adjustment was used for ranking of differential expression but raw p -values were used to assess statistical significance of global differential expression. Log-transformation of data was auto-detected, and the NCBI generated category of platform annotation was used. A statistical test was performed to evaluate whether C10orf113 gene expression was significantly different between the tumors of patients with basal and non-basal molecular subtype breast cancer using a two-tailed t-test with Welch's correction. For Kaplan-Meier survival analysis, we used the Kaplan-Meier plotter tool (8) for correlation of C10orf113 mRNA expression levels with recurrence-free survival in $n=953$ basal subtype breast cancer patients and with distant metastasis-free survival in $n=630$ basal subtype breast cancer patients.

Results

SNP array genotyping identifies rs625223 as a defining sequence variation in human basal breast cancer.

We used published microarray data (5) to compare the whole tumor genomes of 37 patients with basal or basal-like subtype breast cancer, with that of 132 patients with disease of other molecular subtype, including luminal A, luminal B, HER2+, claudin, claudin-low and normal-like, to identify single nucleotide polymorphisms that describe the most significant variations in the tumor genomes of patients with basal-like subtype breast cancer (BLBC).

SNP genotyping arrays utilize large differences in signal, after probe hybridization to DNA rather than RNA, to identify polymorphic sites in the genome at single nucleotide resolution. We identified a single nucleotide polymorphism (rs625223) residing within the C10orf113 gene on chromosome 10 as among the most significant genetic differences in the tumors of patients with basal subtype breast cancer

as compared to that of other molecular subtypes. Polymorphism at rs625223 was the sixth most significant difference, genome-wide, when comparing the tumor genomes of basal subtype patients with that of tumors from patients with other molecular subtypes (Rank: 6 out of 108250 total SNPs, equating to 99.99% (p -value: $5.06\text{E-}09$)).

C10orf113 is differentially expressed in basal-like subtype human breast cancer.

Analysis of a second published microarray dataset, comparing tumor transcriptome data from a separate cohort of Mexican patients with basal subtype breast cancer (14 tumors from patients with basal-like breast cancer and 109 tumors from patients with breast cancer of other molecular subtype [luminal A, luminal B, HER2-enriched, and normal-like]) (6) revealed transcriptome-wide differential expression of a C10orf113 transcript in patients with basal subtype human breast cancer (Table 2). When sorting each of the transcripts whose expression was measured globally, C10orf113 expression ranked 5027 out of 33297 total transcripts, equating to 84.9% differential expression; this was statistically significant (p -value: $2.91\text{E-}03$).

C10orf113 expression correlates with recurrence-free survival in basal subtype breast cancer patients.

We asked whether primary tumor expression of C10orf113 was correlated with recurrence-free survival outcomes in patients with basal subtype of human breast cancer. We observed a statistically significant correlation between primary tumor expression of C10orf113 and recurrence-free survival (RFS) in patients with basal subtype human breast cancer (Figure 2; p -value: 0.0068; hazard ratio: 0.74 (0.6-0.92)). C10orf113 primary tumor expression was a positive prognostic indicator with respect to recurrence-free survival in patients with basal subtype cancer. Patients with low tumor expression of C10orf113 possessed median RFS of 20.44 months, while patients with high tumor expression of C10orf113 possessed median RFS of 30.4 months.

C10orf113 expression correlates with distant metastasis-free survival in basal subtype breast cancer patients.

We also asked whether primary tumor expression of C10orf113 was correlated with distant metastasis-free survival in patients with basal-like breast cancer. We observed a correlation between primary tumor expression of C10orf113 and distant metastasis-free survival (DMFS) in patients with basal-like breast cancer which approached statistical significance (Figure 2; p -value: 0.064; hazard ratio: 1.32 (0.98-1.77)). C10orf113 primary tumor expression was a negative prognostic indicator with respect to distant metastasis-free survival in patients with basal subtype cancer. Patients with low tumor expression of C10orf113 possessed median DMFS of 51.96 months, while patients with high tumor expression of C10orf113 possessed median DMFS of 25.2 months.

Discussion

We found through analysis of published microarray datasets (5, 6) that a genomic position marked by SNP rs625223 was among the most significant sequence variations in the tumor genomes of patients with basal subtype human breast cancer when compared with that of patients with breast cancer of other molecular subtypes. rs625223 resides within the C10orf113 gene. Similar comparative tumor transcriptome study based on molecular subtype in a separate patient dataset revealed differential expression of a C10orf113 transcript when comparing tumors of other molecular subtypes against that of tumors from patients of the basal subtype. Kaplan-Meier analysis of patient survival data revealed that C10orf113 expression was positively correlated with recurrence-free survival but negatively correlated

1 with distant metastasis-free survival in patients with basal or basal-like breast cancer. Changes in
2 C10orf113 expression may be important events to understand as part of the myriad processes that likely
3 govern transformation and tumor maintenance in basal or basal-like human breast cancer. We will
4 continue to dissect, at the single nucleotide level, sequence variation in the human population that favor
5 development and likely define the genetic composition of basal-like breast cancer, variants which in large
6 part appear to be localized to chromosomes 5 and 10 (7).
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Rank: 6
SNP: rs625223
 p -value: 5.06E-09
t: 6.15117684
B: 10.109944
Chromosome: 10

Table 1: A genomic position marked by rs625223 (residing within the C10orf113 gene) on Chromosome 10 is among the most significant genetic differences in the tumor genomes of humans with basal-like breast cancer.

The rank of global differential expression, SNP ID, the p -value with respect to differential expression transcriptome-wide, t, a moderated t-statistic, and B, the log-odds of differential expression between the groups compared are listed in this chart.

Figure 1: rs625223 is significantly enriched in the primary tumors of patients with basal subtype human breast cancer.

A quantitative measure of C10orf113 polymorphism at rs625223 in the tumors of patients with basal subtype breast cancer (left) and in the tumors of patients with breast cancer of non-basal molecular subtype (right) is graphically depicted; the result of a statistical test evaluating significance of difference in this signal between the tumors of basal subtype patients and the tumors of patients with cancer of other molecular subtype is $p<0.0001$.

Rank: 5027
probe: 7932492
p-value: 2.91E-03
t: -3.0377102
B: -2.29899
Gene: C10orf113
Gene name: chromosome 10 open reading frame 113

Table 2: C10orf113 is among the genes most differentially expressed, transcriptome-wide, in a separate cohort of patients with basal subtype breast cancer.

The rank of global differential expression, probe/transcript ID, the *p*-value with respect to differential expression transcriptome-wide, *t*, a moderated *t*-statistic, *B*, the log-odds of differential expression between the groups compared, the gene and gene name are listed in this chart.

Figure 2: C10orf113 primary tumor expression correlates with recurrence-free survival in basal subtype breast cancer patients.

Depicted in this Kaplan-Meier plot is the probability of recurrence-free survival for $n=953$ basal subtype patients stratified into two groups, based on low or high expression of C10orf113 in patient primary tumors. The log rank p -value denoting statistical significance of difference in recurrence-free survival when comparing the two groups, as well as hazard ratio for this comparison is listed above. Listed below is the number of patients at risk (number of patients alive) per interval, after stratification based on C10orf113 expression; in the first interval, number at risk is number of patients alive; in each subsequent interval, number at risk is the number at risk less those who have expired or are censored.

1 Low C10orf113 expression: 20.44 months

2 High C10orf113 expression: 30.4 months

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4 Median RFS is superior in basal subtype breast cancer patients with high primary tumor expression of C10orf113.

5 The median RFS (recurrence-free survival) of basal subtype breast cancer patients, with low primary
6 tumor expression of C10orf113 and high primary tumor expression of C10orf113 is listed in this chart.

Figure 2: C10orf113 primary tumor expression correlates with distant metastasis-free survival in basal subtype breast cancer patients.

Depicted in this Kaplan-Meier plot is the probability of distant metastasis-free survival for $n=630$ basal subtype patients stratified into two groups, based on low or high expression of C10orf113 in patient primary tumors. The log rank p -value denoting statistical significance of difference in distant metastasis-free survival when comparing the two groups, as well as hazard ratio for this comparison is listed above. Listed below is the number of patients at risk (number of patients alive) per interval, after stratification based on C10orf113 expression; in the first interval, number at risk is number of patients alive; in each subsequent interval, number at risk is the number at risk less those who have expired or are censored.

1 Low C10orf113 expression: 51.96 months

2 High C10orf113 expression: 25.2 months

3
4 Median DMFS is superior in basal subtype breast cancer patients with low primary tumor expression of C10orf113.

5 The median DMFS (distant metastasis-free survival) of basal subtype breast cancer patients, with low
6 primary tumor expression of C10orf113 and high primary tumor expression of C10orf113 is listed in this
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