The prostaglandin E receptor 4 is differentially expressed in metastatic breast cancer, both in metastases to the brain and to the lymph nodes.

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Metastasis to the brain is a clinical problem in patients with breast cancer¹⁻³. We mined published microarray data^{4,5} to compare primary and metastatic tumor transcriptomes to discover genes associated with brain metastasis in patients with metastatic breast cancer. We found that the prostaglandin E receptor 4, encoded by PTGER4, was among the genes whose expression was most different in the metastatic tumor tissues of patients with metastatic breast cancer, both in metastases to brain and to the lymph nodes when compared to primary tumors of the breast or normal breast tissue, respectively. We observed significant down-regulation of PTGER4 in metastasis to the brain. Molecular functions and down-regulation of PTGER4, described as a tumor suppressor in B-cells⁶, may be important for metastasis of primary tumor-derived cancer cells to the lymph nodes and to the brain in humans with metastatic breast cancer, and suggests some level of common origin for metastases that reside in the lymph nodes and colonize the brain.

Keywords: breast cancer, metastasis, brain metastasis, central nervous system metastasis, lymph node metastasis, PTGER4, prostaglandin E receptor 4, systems biology of breast cancer, targeted therapeutics in breast cancer.

One report described a 34% incidence of central nervous system metastases in trastuzumab-treated patients with breast cancer². This alarmingly high frequency of CNS metastasis events demands an enhanced understanding of the transcriptional makeup of brain metastatic tissues to support identification of therapeutic targets, whether they are treatment related or not. We performed a global comparative analysis of primary and metastatic tumors in patients with metastatic breast cancer^{4,5}. We discovered transcriptome-wide differential expression of PTGER4 in brain and lymph node metastases of patients with metastatic breast cancer.

Methods

We used datasets GSE125989⁴ and GSE124648⁵ for this global differential gene expression analysis of brain metastatic breast cancer in conjunction with GEO2R. GSE125989 was generated using Affymetrix Human Genome U133A 2.0 Array technology with $n=16$ primary tumors from patients with breast cancer and $n=16$ brain metastases from patients with brain metastatic breast cancer. GSE124648, a microarray dataset, was generated using Affymetrix Human Genome U133A Array technology with $n=10$ normal breast tissues and $n=44$ lymph node metastases from patients with breast cancer; platform GPL96 was used for this analysis. 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 PTGER4 gene expression was significantly between primary breast tumors and brain metastases in humans with breast cancer using a two-tailed, unpaired t-test with Welch's correction. We used PRISM for all statistical analyses of differential gene expression in human breast cancer (Version 8.4.0)(455).

Results

We performed global comparative transcriptome analysis of the primary and metastatic tumor tissues of patients with brain and lymph node metastatic breast cancer using published microarray data^{4,5} to describe the transcriptional landscape of metastasis in human breast cancer in an unbiased fashion and for the discovery of novel therapeutic targets.

PTGER4 is differentially expressed in the brain metastases of patients with brain metastatic breast cancer.

We identified prostaglandin E receptor 4, encoded by PTGER4, as among the genes whose expression was most significantly different in the brain metastases of patients with brain metastatic breast cancer⁴ (Table 1). When sorting each of the genes expressed in brain metastases based on significance of difference as compared to the primary tumors of patients with brain metastatic breast cancer, PTGER4 ranked 199 out of 22277 total transcripts (Table 1), equating to 99.1% differential expression. Differential expression of PTGER4 in the brain metastases of patients with brain metastatic breast cancer was statistically significant (Table 1; $p=1.45E-03$).

We asked whether we could validate differential expression of PTGER4 was specific to brain metastasis or if we could observe differential expression of PTGER4 in lymph node metastasis. Comparison of global gene expression profiles of 10 normal breast tissues to 44 lymph node metastases⁵ revealed that PTGER4 was among the genes whose expression was most significantly

different transcriptome-wide between the breast and lymph node metastases in patients with metastatic breast cancer (Table 2). When sorting each of the genes expressed in lymph node metastases based on significance of difference in expression as compared to normal breast tissues, PTGER4 ranked 2750 out of 22283 total transcripts (Table 2), equating to 87.7% differential expression. Differential expression of PTGER4 in lymph node metastases from patients with metastatic breast cancer was statistically significant (Table 2; $p=3.77E-04$).

PTGER4 is expressed at significantly lower levels in the brain metastases of patients with brain metastatic breast cancer.

We obtained exact mRNA expression levels for PTGER4, in primary tumors of the breast and in brain metastasis of patients with brain metastatic breast cancer to determine magnitude and direction of change in PTGER4 expression in brain metastatic tissues. PTGER4 was expressed at lower levels in the brain metastases of patients with breast cancer as compared to primary tumors of the breast, and this difference was statistically significant (Figure 1; $p=0.0024$). We calculated a mean fold change of 0.72 ± 0.24 in PTGER4 expression when comparing primary tumors of the breast to brain metastatic tissues in patients with breast cancer (Table 1).

Thus, by mining published microarray data^{4,5} in an unbiased and systematic fashion, we identified PTGER4 as a differentially expressed gene in metastatic breast cancer, both in brain metastases and in lymph node metastases when compared to tissues of the breast, transformed and benign; PTGER4 was expressed at significantly lower levels in brain metastases as compared to primary tumors of the breast.

Discussion

We provided evidence here that the prostaglandin E receptor 4, encoded by PTGER4 is among the genes whose expression is most different in the brain and lymph node metastases of patients with metastatic breast cancer. PTGER4 has been described as a tumor suppressor in the B-cell⁶. PTGER4 may be of relevance to any number of steps required for metastasis to the lymph nodes and to the brain, and suggests some level of common origin for metastases that reside in the lymph nodes and colonize the brain.

References

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Rank	ID	p-value	t	B	FC	Gene	Gene name
199	204896_s_at	1.45E-03	-3.4611119	-1.0617	0.72 ± 0.24	PTGER4	prostaglandin E receptor 4

Table 1: PTGER4 is differentially expressed in brain metastases in metastatic breast cancer when compared to primary tumors of the breast.

Rank of differential expression, probe ID, *p*-value with respect to differential expression, *t*, a moderated *t*-statistic, *B*, the log-odds of differential expression between the two groups compared, fold change (FC) of PTGER4 expression between the brain metastases of patients with breast cancer and primary tumors of the breast, gene and gene name are listed in this chart.

Rank	ID	p-value	t	B	Gene	Gene name
2750	204897_at	3.77E-04	3.786725	-0.539824	PTGER4	prostaglandin E receptor 4

Table 2: PTGER4 is differentially expressed in lymph node metastases in metastatic breast cancer when compared to normal breast tissues.

Rank of differential expression, probe ID, *p*-value with respect to differential expression, *t*, a moderated *t*-statistic, *B*, the log-odds of differential expression between the two groups compared, gene and gene name are listed in this chart.

Figure 1: PTGER4 is expressed at significantly lower levels in the brain metastases of patients with brain metastatic breast cancer.

The mRNA expression level of PTGER4 in primary tumors of the breast (left) and in the brain metastases of brain metastatic breast cancer patients (right) is graphically represented here with mean PTGER4 levels marked and the result of a statistical test evaluating difference in mRNA expression level between brain metastases and primary tumors of the breast, a *p*-value, listed above.