Over-expression of ribonucleotide reductase regulatory subunit M2 in human endometrial cancer.

Shahan Mamoor, MS¹
¹shahanmamoor@gmail.com
East Islip, NY USA

Gynecologic cancers including cancers of the endometrium are a clinical problem¹⁻⁴. We mined published microarray data^{5,6} to discover genes associated with endometrial cancers by comparing transcriptomes of the normal endometrium and endometrial tumors from humans. We identified ribonucleotide reductase regulatory subunit M2, encoded by RRM2, as among the most differentially expressed genes, transcriptome-wide, in cancers of the endometrium. RRM2 was expressed at significantly higher levels in endometrial tumor tissues as compared to the endometrium. Importantly, in human endometrial cancer, primary tumor expression of RRM2 was correlated with overall survival in white patients with low mutational burden. RRM2 may be a molecule of interest in understanding the etiology or progression of human endometrial cancer.

Keywords: endometrial cancer, gynecologic cancers, endometrium, RRM2, ribonucleotide reductase regulatory subunit M2, systems biology of endometrial cancer, targeted therapeutics in endometrial cancer.

Endometrial cancer is the most common gynecologic cancer in the developed world¹. Over the last three decades, the incidence of endometrial cancer has increased 21%⁴ and the death rate has increased 100%³. We harnessed the power of independently published microarray datasets^{5,6} to determine in an unbiased fashion and at the systems-level genes most differentially expressed in endometrial tumors. We report here the differential and increased expression of the ribonucleotide reductase regulatory subunit M2 (RRM2) in human endometrial cancer.

Methods

We utilized datasets GSE63678⁵ and GSE17025⁶ for this global differential gene expression analysis of human endometrial cancer in conjunction with GEO2R. GSE63678 was generated using Affymetrix Human Genome U133A 2.0 Array technology with $n=5$ control endometrial tissues (including $n=4$ uterine myomas and $n=1$ benign cyst) and $n=7$ endometrial cancers (including $n=2$ endometrial adenocarcinomas, $n=3$ mixed endometrioid adenocarcinomas, and $n=2$ adenocarcinomas with squamous differentiation); analysis was performed using platform GPL571. GSE17025 was generated using Affymetrix Human Genome U133 Plus 2.0 Array technology with $n=5$ normal endometrial tissues (inactive endometrium) and $n=91$ endometrial cancers; analysis was performed using platform GPL570. 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 RRM2 gene expression was significantly different between control endometrial tissue and endometrial tumor tissue in humans using a two-tailed t-test. For Kaplan-Meier survival analysis, we used the Kaplan-Meier plotter tool⁷ for correlation of RRM2 mRNA expression levels with overall survival in $n=543$ endometrial cancer patients.

Results

We harnessed the power of blind comparative transcriptome analysis using published microarray data^{5,6} to discover in an unbiased fashion genes associated with endometrial cancer in humans.

RRM2 is differentially expressed in endometrial cancer.

We identified ribonucleotide reductase regulatory subunit M2, encoded by RRM2, as among the genes most differentially expressed in cancers of the endometrium when compared to benign endometrial tissues (Chart 1). When sorting each of the genes expressed in endometrial tumor tissue based on significance of change in expression as compared to benign endometrial tissue, RRM2 ranked 64 out of 22273 transcripts, equating to 99.7% differential expression (Chart 1). Differential expression of RRM2 in human endometrial cancers was statistically significant (Chart 1; $p=5.56E-05$).

We queried a second microarray data to validate differential expression of RRM2 in endometrial cancer. Again, we observed differential expression of RRM2 when comparing endometrial tumor tissue to benign endometrial tissue (Chart 2). When sorting each of the genes expressed in endometrial tumor tissue based on significance of change in expression as compared to benign endometrial tissue, RRM2 ranked 65 out of 54675 transcripts, equating to 99.9% differential expression (Chart 2). Differential expression of RRM2 in human endometrial cancers was statistically significant (Chart 2; $p=2.65E-08$).

RRM2 is expressed at significantly higher levels in endometrial cancers as compared to benign endometrial tissue.

We obtained exact mRNA expression levels for RRM2 in endometrial tumor tissues and from benign endometrial tissue to evaluate direction and statistical significance of change in expression of RRM2 in human endometrial cancer. RRM2 was expressed at higher levels in endometrial tissue as compared to normal endometrial tissue, and this difference was statistically significant (Figure 1; $p=0.0002$). We calculated a mean fold change of 1.51 in RRM2 mRNA levels in human endometrial cancer, as RRM2 was expressed at 6.38 ± 0.87 arbitrary units (A.U.) in control endometrial tissue but at 9.63 ± 1.08 A.U. in endometrial tumor tissue.

RRM2 expression is correlated with patient survival outcomes in endometrial cancer.

We performed Kaplan-Meier survival analysis to evaluate correlation between RRM2 primary tumor expression and survival outcomes in 543 patients with endometrial cancer. We observed a correlation between primary tumor expression of RRM2 and overall survival in patients with endometrial cancer, in white patients with low mutational burden (Figure 2). RRM2 primary tumor mRNA levels were a negative prognostic indicator in white endometrial cancer patients with low mutational burden. White patients with low mutational burden whose primary tumors expressed low levels of RRM2 possessed median OS of 78.4 months, while white patients with low mutational burden whose tumors expressed high levels of RRM2 possessed median OS of 31.53 months. This difference in OS based on RRM2 tumor expression in white patients with endometrial cancer with low mutational burden was statistically significant (Figure 2, Chart 3; logrank p -value: 0.00034; hazard ratio: 3.57 (1.7-7.47)). RRM2 primary endometrial tumor expression was not correlated with overall survival in white patients with high mutational burden (Figure 2, Chart 3; logrank p -value: 0.24; hazard ratio: 1.62 (0.72-3.68)), nor in black patients with high (Figure 2, Chart 3; logrank p -value: 0.55; hazard ratio: 1.67 (0.3-9.26)) or low mutational burden (Figure 2, Chart 3; logrank p -value: 0.99; hazard ratio: 0.99 (0.33-2.96)).

Thus, by mining published microarray data^{5,6} in an unbiased and systematic fashion, we identified ribonucleotide reductase regulatory subunit M2, encoded by RRM2, as among the genes whose expression was most different, transcriptome-wide, in the endometrial tumor tissue of patients with endometrial cancer when compared to benign endometrial tissue; we observed

significantly increased expression of RRM2 in endometrial tumor tissue as compared to benign endometrial tissue. Further, we found a correlation between RRM2 expression and patient survival outcomes in human endometrial cancer, as overall survival was inferior in patients whose tumors expressed higher levels of RRM2 as compared to patients whose tumors expressed lower levels of RRM2, in white patients with low mutational burden, but not in white patients with high mutational burden, nor in black patients with high or low mutational burden.

Discussion

We provided evidence here that ribonucleotide reductase regulatory subunit M2 is among the genes most differentially expressed in human endometrial cancer, that mRNA for RRM2 is present at significantly increased quantity in endometrial tumor tissue as compared to benign endometrium, and that RRM2 primary tumor expression is correlated with overall survival in white endometrial cancer patients with low mutational burden. These data suggest RRM2 may be of importance to fundamental biological processes that underlie the initiation, progression or maintenance of human endometrial cancer.

References

1. Amant, F., Moerman, P., Neven, P., Timmerman, D., Van Limbergen, E. and Vergote, I., 2005. Endometrial cancer. *The Lancet*, 366(9484), pp.491-505.
2. Sorosky, J.I., 2008. Endometrial cancer. *Obstetrics & Gynecology*, 111(2), pp.436-447.
3. Morice, P., Leary, A., Creutzberg, C., Abu-Rustum, N. and Darai, E., 2016. Endometrial cancer. *The Lancet*, 387(10023), pp.1094-1108.
4. Sorosky, J.I., 2012. Endometrial cancer. *Obstetrics & Gynecology*, 120(2 Part 1), pp.383-397.
5. Pappa, K.I., Polyzos, A., Jacob-Hirsch, J., Amariglio, N., Vlachos, G.D., Loutradis, D. and Anagnou, N.P., 2015. Profiling of discrete gynecological cancers reveals novel transcriptional modules and common features shared by other cancer types and embryonic stem cells. *PLoS One*, 10(11), p.e0142229.
6. Day, R.S., McDade, K.K., Chandran, U.R., Lisovich, A., Conrads, T.P., Hood, B.L., Kolli, V.K., Kirchner, D., Litzi, T. and Maxwell, G.L., 2011. Identifier mapping performance for integrating transcriptomics and proteomics experimental results. *BMC bioinformatics*, 12(1), p.213.
7. Nagy, A., Munkacsy, G. and Gyorffy, B., 2020. Pancancer survival analysis of cancer hallmark genes. *bioRxiv*.

Rank: 64
Probe ID: 209773_s_at
p-value: 5.56E-05
t: -6.03564
B: 2.18856
Gene: RRM2
Gene name: ribonucleotide reductase regulatory subunit M2

Chart 1: RRM2 is differentially expressed in endometrial cancer when comparing primary endometrial tumors to benign endometrial tissue.

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.

Rank: 65
probe ID: 209773_s_at
p-value: 2.65E-08
t: -6.0478458
B: 8.77901
Gene: RRM2
Gene name: ribonucleotide reductase regulatory subunit M2

Chart 2: RRM2 is differentially expressed in endometrial cancer when comparing primary endometrial tumors to benign endometrial tissue.

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 1: RRM2 is expressed at significantly higher levels in the endometrial tumors of patients with endometrial cancer when compared to benign endometrium.

The mRNA expression level of RRM2 in benign endometrial tissue (left) and in primary tumors of the endometrium (right) is graphically depicted; the result of a statistical test evaluating significance of difference in RRM2 expression between benign endometrial tissue and primary tumors of the endometrial tissue is $p=0.0002$.

Figure 2: Correlation between RRM2 primary tumor expression and overall survival in endometrial cancer, in white patients with low mutational burden.

Depicted in this Kaplan-Meier plot is the probability of overall survival for $n=543$ total endometrial cancer patients stratified into two groups, based on low or high expression of RRM2 in patient primary tumors, in black patients with high mutational burden (top left), black patients with low mutational burden (top right), white patients with high mutational burden (bottom left), and white patients with low mutational burden (bottom right). The log rank p -value denoting statistical significance of difference in overall 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 RRM2 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.

Low RRM2 expression: 78.4 months
High RRM2 expression: 31.53 months

Chart 3: Median overall survival is superior in endometrial cancer patients with low primary tumor expression of RRM2, in white patients with low mutational burden.

The median OS (overall survival) of white endometrial cancer patients with low mutational burden, with low primary tumor expression of RRM2 and high primary tumor expression of RRM2 is listed in this chart.