A$_2$A blockade enhances anti-metastatic immune responses

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The specific targeting of tumor-elicited immunosuppression is a promising strategy for the treatment of cancer. We have recently demonstrated that targeting the immunosuppressive pathway mediated by CD73-derived adenosine through the blockade of A$_{2A}$/A$_{2B}$ adenosine receptors significantly reduced the metastatic potential of CD73$^+$ breast carcinomas and melanomas via both immunological and non-immunological mechanisms.

We chose AT-3 breast carcinoma and B16F10 melanoma cells since they constitute a weakly metastatic and a highly metastatic tumor model, respectively. In both settings, CD73 expression significantly enhanced tumor metastasis. Although the major biological function of CD73 is the generation of adenosine, this ectoenzyme has been attributed with additional roles. Therefore, we investigated whether exogenous adenosine could mimic the pro-metastatic effects of CD73. The pre-treatment of mice with 5’-(N-ethylcarboxamido) adenosine (NECA), a stable analog of adenosine that operates as a pan-agonist for A$_1$, A$_{2A}$, A$_{2B}$, and A$_3$ receptors, significantly enhanced the metastatic potential of B16F10 tumor cells. To investigate which adenosine receptors would be involved in the effects of NECA, we simultaneously treated mice with NECA and selective A$_{2A}$ (SCH58261) or A$_{2B}$ (PSB-1115) antagonists. Both SCH58261 and PSB-1115 partially reversed the pro-metastatic effects of NECA. Accordingly, a selective A$_{2A}$ (CGS21680) or A$_{2B}$ (BAY60–6583) agonist was sufficient to exacerbate tumor metastasis. Although these results indicated that the activation of A$_{2A}$ or A$_{2B}$ receptors could promote the metastatic dissemination of malignant cells, they did not formally demonstrate that this pathway would underpin the increased metastatic potential of CD73$^+$ tumors. Therefore, we investigated the ability of these antagonists to reduce the dissemination of B16F10-CD73$^+$ and 4T1.2 cells, breast carcinoma cells that endogenously express CD73. A$_{2A}$ or A$_{2B}$ blockade significantly reduced the metastatic potential of these cancer cell lines. To confirm that the effects of SCH58261 were mediated by the A$_{2A}$ receptor we investigated the metastatic dissemination of B16F10-CD73$^+$ tumor cells in A$_{2A}^+$-deficient (Adora2a$^{-/-}$) mice. These mice were significantly protected against metastases as compared with their wild-type (WT) counterparts, confirming the pro-metastatic role of host A$_{2A}$ receptors.

To investigate whether the blockade of A$_{2A}$ or A$_{2B}$ receptors would reduce metastasis via an immunological mechanism, we next examined whether A$_{2A}$/A$_{2B}$ targeting was effective in immunocompromised mice lacking natural killer (NK) and T cells. We observed that NECA promotes metastasis in these mice, albeit to a lesser extent than in WT animals. Notably, the blockade of A$_{2A}$ receptors was no longer effective in immunocompromised mice, indicating that A$_{2A}$ stimulation enhances the metastatic dissemination of cancer...
cells as it suppresses host lymphocytes. By contrast, the blockade of A2B maintained its ability to limit metastatic dissemination in the absence of NK and T cells, indicating that A2B stimulation enhances metastasis through a distinct mechanism. Since the metastatic dissemination of B16F10 cells is known to be controlled by NK cells and that the anti-metastatic effects of A2A blockade relied on host lymphocytes, we hypothesized that such anti-metastatic effects might be due to enhanced NK-cell effector functions. Indeed, we observed that the stimulation of A2A receptors suppresses the ability of NK cells to kill B16F10 or 4T1.2 cancer cells in vitro and that the activity of the A2A antagonist SCH58261 is attenuated in perforin-deficient (Prf−/−) mice. Since the phenotype of Prf1−/− mice could potentially be explained by enhanced cytotoxic functions of either NK cells or CD8+ T lymphocytes, we analyzed the phenotype of tumor-infiltrating NK cells in mice treated with A2A or A2B antagonist. Intratumoral NK cells isolated from mice treated with SCH58261, but not PSB-1115, exhibited increased expression levels of granzyme B. Taken together, these results indicate that the blockade of A2A receptors exacerbates the cytotoxic activity of NK cells in vivo.

Although our data show an unequivocal role for A2A-mediated immunosuppression in the pro-metastatic effect of CD73, this is not the only mechanism whereby CD73 stimulates tumor metastasis. Indeed, we found that CD73 expression promotes the metastatic dissemination of tumor cells in immunocompromised mice, indicating that CD73 also exerts tumor-promoting effects via non-immunological mechanisms. Notably, the autoactivation of A2B receptors on neoplastic cells has previously been shown to enhance their invasive potential by stimulating the formation of filopodia.3,9 Intriguingly, it has recently been shown that CD73 can promote the metastatic dissemination of tumor cells in vivo independently of its catalytic activity, indicating that the activation of adenosine receptors may not fully account for the pro-metastatic effects of CD73.10

In summary, our data indicate that CD73 favors tumor metastasis by multiple mechanisms including the generation of adenosine, and activation of A2A receptors of the host (Fig. 1). Our data clearly suggest that the blockade of A2A or A2B represents a potential therapeutic strategy to limit metastasis. As antagonists of these receptors are already under clinical development for other indications and show good safety profiles, the translation of our findings to cancer patients appears feasible.

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Figure 1. The expression of CD73 by malignant cells enhances metastasis through the activation of A2A and A2B adenosine receptors. (A) The expression of CD73 on malignant cells converts AMP into adenosine, which activates A2A receptors on natural killer (NK) cells. This inhibits the cytotoxic functions of NK cells as well as their ability to produce pro-inflammatory cytokines including interferon-γ (IFNγ). (B) The activation of A2A receptors also stimulates metastatic dissemination through an alternative, hitherto unclear, pathway. This may potentially coincide with the activation of A2B receptors on tumor cells. (C) CD73 may also promote metastasis in an adenosine-independent manner. (D) The blockade of A2A or A2B receptors with the A2A antagonist SCH58261 or the A2B antagonist PSB-1115, respectively, significantly reduces the metastatic dissemination of CD73+ tumors.
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Disclosure of Potential Conflicts of Interest
No potential conflicts of interest were disclosed.

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