Plasmacytoid Dendritic Cells Induce CD8+ Regulatory T Cells In Human Ovarian Carcinoma

Shuang Wei, Ilona Kryczek, Linhua Zou, Ben Daniel, Pui Cheng, Peter Mottram, Tyler Curiel, Andrzej Lange, and Weiping Zou

Tulane University Health Science Center, New Orleans, Louisiana and Institute of Immunology and Experimental Therapy, Polish Academy of Sciences, Wroclaw, Poland

Abstract

To directly dissect the role of each immune component in human tumor immunopathogenesis, we have studied the interaction between dendritic cells and T cells in the tumor environment of patients with ovarian carcinoma. We previously reported that functional plasmacytoid dendritic cells, but not functionally mature myeloid dendritic cells, accumulated in tumor microenvironments. We now show that tumor ascites plasmacytoid dendritic cells induce tumor-associated antigen–specific CD8+ T cells with effector functions. Strikingly, tumor ascites plasmacytoid dendritic cells induced interleukin-10+CCR7+CD45RO+CD8+ regulatory T cells. Four characteristics have been identified in tumor plasmacytoid dendritic cell–induced CD8+ regulatory T cells: (a) induction of CD8+ regulatory T cells is independent of CD4+CD25+ T cells; (b) CD8+ regulatory T cells significantly suppress myeloid dendritic cell–mediated tumor–associated antigen–specific T cell effector functions through interleukin-10; (c) repetitive myeloid dendritic cell stimulation can recover CD8+ regulatory T cell–mediated poor T cell proliferation, but not T cell effector function; (d) CD8+ regulatory T cells express functional CCR7, and efficiently migrate with lymphoid homing chemokine MIP-3β. Primary suppressive CCR7+CD45RO+CD8+ T cells are found in the tumor environment of patients with ovarian cancers. Thus, tumor-associated plasmacytoid dendritic cells contribute to the tumor environmental immunosuppressive network. Collectively, tumors manipulate tumor microenvironmental dendritic cell subset distribution and function to subvert tumor immunity. The data are relevant to understanding tumor immunopathology as well as reevaluating tumor immunotherapeutic strategies. (Cancer Res 2005; 65(12): 5020-6)

Introduction

Human cancers are able to prime tumor-specific immunity. There exist tumor-specific T lymphocytes in blood, tumor tissues, and lymph nodes in cancer patients. Isolated tumor–associated antigen–specific T cells can kill autologous tumor cells. Functional tumor–associated antigen–specific T cell lines can be established from tumor T cells (1–5). Furthermore, studies have shown increases in tumor–associated antigen–specific cytotoxic CD8+ T cells without evidence of clinical regression in some patients (2, 6, 7). This suggests that tumor–associated antigen–specific T cells might be functionally inhibited in vivo. The underlying mechanisms were extensively reviewed (8).

Dendritic cells play a critical role in establishing tumor immunity. However, because of the rarity of dendritic cells in vivo, primary dendritic cell studies are confined to in vitro differentiated myeloid dendritic cells. Published, detailed studies of functional human dendritic cells in tumor environment are rare (9). Furthermore, another dendritic cell subset, plasmacytoid dendritic cells are technically more difficult to study. T cell activation pattern induced by plasmacytoid dendritic cells are largely determined in the allogeneic system. Little is known of the role of tumor environmental plasmacytoid dendritic cells in tumor immunity (9, 10). These limitations may significantly underestimate the impact of the dendritic cell system in tumor pathology. We have studied malignant ascites of patients with ovarian carcinoma. Malignant ascites contains viable tumor and immune cells, and serves as a model for the tumor microenvironment (9–13). We identified a significant population of plasmacytoid dendritic cells in malignant ascites. In an allogeneic system, normal blood plasmacytoid dendritic cells (14, 15) and tumor plasmacytoid dendritic cells (9) induce interleukin (IL)-10 expressing suppressive T cells. In this report, we further studied the pathologic interaction between tumor ascites T cells and tumor ascites plasmacytoid dendritic cells, and its impact on tumor–associated antigen–specific T cell immunity.

Materials and Methods

Human subjects. We studied previously untreated patients with epithelial ovarian carcinomas, International Federation of Gynecology and Obstetrics stages I, II, III, and IV. Patients gave written, informed consent. Clinical specimens were collected at the Tulane University, New Orleans. The study was approved by local Institutional Review Boards.

Ascites, ascites cells, and tumor-draining lymph nodes. We collected and prepared single cells from ascites, blood, and lymph nodes as previously described (9, 16). CD3, CD14, CD16, CD19, and CD56-expressing cells were depleted using paramagnetic beads (Miltenyi, Auburn, CA), and plasmacytoid dendritic cells were sorted with FACS Aria gating on CD4+CD123+HLA-DRhighCD11c–. Cell populations were ≥99% pure by flow cytometry analysis (fluorescence-activated cell sorting, FACS). Tumor ascites T cells were obtained by depletion. CD14, CD16, CD19, and CD56 negative cells were sorted using microbeads (Miltenyi), and sorting CD45+ cells by flow cytometry. Cellular purity was ≥98% as determined by FACS staining with anti-human CD3 antibody. Antibodies for flow cytometry and depletion were purchased from BD Pharmingen, San Jose, CA. Autologous ascites cells were used throughout this study.

Peripheral blood cells. Peripheral blood was collected aseptically from normal volunteers or patients by venipuncture or by cytophoresis, and mononuclear cells were then obtained by ficoll-hypaque density centrifugation. Blood plasmacytoid dendritic cells were obtained as described for tumor ascites plasmacytoid dendritic cells. Cells were ≥98% pure as determined by FACS.
In vitro tumor-associated antigen–specific T cell stimulation. Tumor myeloid dendritic cells were differentiated from tumor macrophages as previously described (17). Tumor plasmacytoid dendritic cells were sorted from ascites as we previously described (9). Dendritic cells were actived with CD40L (200 ng/mL) for 24 hours (17), and loaded with three distinct HLA-A2-binding Her-2/neu peptides (13, 18) at 5 μg/mL each: p369-384 (KIGFSLAFIPESDGVGPA), p688-703 (RRLQETELYEPLTPS), and p971-984 (ELSYFESMRDPO). Peptide-loaded myeloid dendritic cells (tumor-associated antigen–myeloid dendritic cell) or peptide-loaded plasmacytoid dendritic cells (tumor-associated antigen–plasmacytoid dendritic cells; refs. 13, 18) at 10^5/mL in the presence of IL-2 (50 units/mL; R & D Systems, Minneapolis, MN) for 6 days (one round of stimulation). In some experiments, CD25+ or CCR7+ ascites T cells were initially depleted with magnetic beads, and CD25+ T cells or CCR7+ T cells were then stimulated with tumor-associated antigen–plasmacytoid dendritic cells. T cells might receive several rounds of the identical stimulation as noted. T cell phenotypes, tumor-associated antigen–specific T cell proliferation, cytokines and cytotoxic activity were detected as we described (9, 16). In some cases, T cells were stained with mouse anti-human CCR7-PE (clone 150503, mouse IgG2, R & D) and mouse anti-human CD8-APC (289-13804, IgG 2a, PharMingen) for 2 hours, and then subjected to in vitro migration assay as we have previously described (13).

Migration assay. After two rounds of stimulation with tumor-associated antigen–plasmacytoid dendritic cells, ascites T cells (0.5-2×10^5/mL; on day 13) were divided into tumor-associated antigen–myeloid dendritic cells (10^5/mL) and primary ascites T cell (5×10^5/mL) coculture for 6 days. Tumor-associated antigen–specific T cell proliferation and cytokines were detected as we described (9, 13, 16). In some cases, anti-human IL-10 receptor (250 ng/mL; 3F8, rat anti-human IgG2a, PharMingen) and anti-human IgG (250 ng/mL; R35-95, rat anti-human IgG2a, PharMingen) were added into the coculture. Migration assay. After two rounds of stimulation with tumor-associated antigen–plasmacytoid dendritic cells, autologous CD40L-activated tumor-associated antigen–myeloid dendritic cells, day 13 T cells (2×10^6) were initially incubated with 500 ng/mL mouse anti-human CCR7 monoclonal antibody (clone 150503, mouse IgG2, R & D) or control monoclonal antibody (clone G155-178, mouse IgG2a, BD PharMingen) for 2 hours, and then subjected to in vitro migration assay as we have previously described (9). Recombinant, human chemokines (MIP-3α and MIP-3β), 100 ng/mL each; R & D) were added to the lower chamber. The identity of migrating cells was confirmed by FACS for CD8 and CCR7.

T cell repetitive stimulation with tumor plasmacytoid dendritic cells and myeloid dendritic cells. Autologous tumor T cells were labeled with 10 μM 5,6-carboxyfluorescein diacetate succinimidyl ester (Molecular Probes, Eugene, OR) for 10 minutes in the dark at 37°C. 5,6-Carboxyfluorescein diacetate succinimidyl ester–labeled tumor T cells (5×10^6/mL) were divided into three groups. Group 1 received three rounds of identical stimulation with tumor-associated antigen–plasmacytoid dendritic cells. Group 2 received three rounds of identical stimulation with tumor-associated antigen–myeloid dendritic cells. Group 3 initially received one round of stimulation with tumor-associated antigen–plasmacytoid dendritic cells and followed two rounds of stimulation with tumor-associated antigen–myeloid dendritic cells. Tumor-associated antigen–specific T cell proliferation and cytokines were detected as we previously described (9, 13, 16). Autologous tumor-associated antigen–dendritic cell (10^5-10^6/mL) were used.

Real-time reverse transcriptase PCR. CCR7+CD45RO+CD8+ T cells were then stimulated with tumor-associated antigen–plasmacytoid dendritic cells (tumor-associated antigen–plasmacytoid dendritic cell). Autologous CD40L-activated tumor-associated antigen–myeloid dendritic cells induced specific T cell activation as expected (Fig. 1).

To study the function of tumor plasmacytoid dendritic cells in the context of tumor-associated antigen–specific T cell immunity, we sorted tumor plasmacytoid dendritic cells from ascites (9, 20). The functional identity of plasmacytoid dendritic cells were confirmed by their capacity to produce copious amounts of type I IFN after adenosvir virus activation (9). Tumor plasmacytoid dendritic cells were loaded with HLA-A2-specific Her-2/neu peptides (tumor-associated antigen–myeloid dendritic cells; refs. 13, 18). Autologous CD40L-activated tumor-associated antigen–myeloid dendritic cells induced specific T cell activation as expected (Fig. 1). To determine whether tumor plasmacytoid dendritic cells in the context of tumor-associated antigen–specific T cell immunity, we sorted tumor plasmacytoid dendritic cells from ascites (9, 20). The functional identity of plasmacytoid dendritic cells were confirmed by their capacity to produce copious amounts of type I IFN after adenosvir virus activation (9). Tumor plasmacytoid dendritic cells were loaded with HLA-A2-specific Her-2/neu peptides (tumor-associated antigen–myeloid dendritic cell). Autologous CD40L-activated tumor-associated antigen–plasmacytoid dendritic cells induced a modest T cell proliferation. Tumor plasmacytoid dendritic cells were significantly less efficient in inducing T cell proliferation than myeloid dendritic cells (n = 4; *, P < 0.001 for all; Fig. 1A). Strikingly, tumor plasmacytoid dendritic cells induced strong T cell IL-10 (221 ± 53 pg/mL; Fig. 1B), little T cell IFN-γ (Fig. 1C), and poor cytotoxic activity (Fig. 1D; n = 4; *, P < 0.001 for all, compared with myeloid dendritic cell). No significant T cell IL-4, IL-5, IL-13 and transforming growth factor-β (TGF-β) were detected in the culture. Primary tumor ascites tumor-associated antigen–plasmacytoid dendritic cells (without CD40L activation) did not induce important T cell proliferation (<1,000 c.p.m.) and cytokine production (IL-10, <30 pg/mL; IFN-γ, <0.1 ng/mL). The results indicate that tumor plasmacytoid and myeloid dendritic cells induced distinct T cell responses.

Tumor ascites contain CD4+CD25+FOXP3+ T cells (CD4+ regulatory T cells; ref. 13). To determine whether CD4+ regulatory T cells affected IL-10 production induced by tumor plasmacytoid dendritic cells, we did similar experiments by initially deleting CD25+ ascites T cells with magnetic beads, and stimulated CD25+ ascites T cells with tumor-associated antigen–plasmacytoid dendritic cells. We detected similar level of IL-10 (195 ± 73 pg/mL versus 221 ± 53 pg/mL; n = 4) in the supernatant from CD25+ ascites T cell and tumor-associated antigen–plasmacytoid dendritic cell coculture (P = 0.078, compared with no CD25 depletion). The data suggest that CD4+ regulatory T cells are not essential for tumor plasmacytoid dendritic cells to induce IL-10-expressing T cells. To determine whether CD4+ regulatory T cells affected IL-10 production induced by tumor plasmacytoid dendritic cells, we did similar experiments by initially deleting CD25+ ascites T cells with magnetic beads, and stimulated CD25+ ascites T cells with tumor-associated antigen–plasmacytoid dendritic cells. We detected similar level of IL-10 (195 ± 73 pg/mL versus 221 ± 53 pg/mL; n = 4) in the supernatant from CD25+ ascites T cell and tumor-associated antigen–plasmacytoid dendritic cell coculture (P = 0.078, compared with no CD25 depletion). The data suggest that CD4+ regulatory T cells are not essential for tumor plasmacytoid dendritic cells to induce IL-10-expressing T cells.
Tumor plasmacytoid dendritic cell–induced IL-10+CCR7+CD8+ T cells are suppressive. We next studied whether tumor plasmacytoid dendritic cell–induced IL-10+CCR7+CD8+ T cells are suppressive. To this end, autologous tumor ascites T cells were initially activated with tumor-associated antigen–plasmacytoid dendritic cells as described (Fig. 1A). Then, different concentrations of tumor plasmacytoid dendritic cell–activated T cells were added into autologous tumor-associated antigen–myeloid dendritic cell and T cell coculture system. As expected, myeloid dendritic cells induced strong tumor-associated antigen–specific T cell proliferation in the absence of plasmacytoid dendritic cell–activated T cells (Fig. 3A and B). Interestingly, tumor plasmacytoid dendritic cell–activated T cells significantly inhibited myeloid dendritic cell–mediated, Her2/neu-specific T cell proliferation in a dose-dependent manner (n = 4; *P < 0.05, **P < 0.01, compared with controls; Fig. 3A). Tumor-associated antigen–specific T cell IFN-γ production was also suppressed (n = 4; *P < 0.01; Fig. 3C). Interestingly, mouse neutralizing anti-human IL-10 receptor antibody significantly recovered T cell functions (Fig. 3B and C). The data indicate that tumor plasmacytoid dendritic cell–induced CD8+ T cells are suppressive and that IL-10 is critical for this suppression.

Myeloid dendritic cell stimulation fails to recover tumor plasmacytoid dendritic cell–elicited poor T cell function. Myeloid dendritic cells have been used as immune-boosting vaccines to treat patients with cancers. It is unknown whether repetitive myeloid dendritic cell vaccination could override the T cell immunosuppressive function induced by tumor plasmacytoid dendritic cells. To test this possibility, autologous tumor ascites T cells were initially stimulated with tumor plasmacytoid dendritic cells followed by repetitive myeloid dendritic cell stimulation. As expected, repetitive myeloid dendritic cell stimulation (without plasmacytoid dendritic cells) induced strong tumor-associated antigen–specific T cell proliferation (n = 4; Fig. 3D). Repetitive plasmacytoid dendritic cell stimulation (without myeloid dendritic cells) induced a modest tumor-associated antigen–specific T cell proliferation (n = 4; Fig. 3D). Interestingly, after two rounds of myeloid dendritic cell stimulation, T cells prestimulated with tumor plasmacytoid dendritic cells exhibited strong T cell proliferation and cellular divisions, comparable to T cells that received three rounds of myeloid dendritic cell stimulation (Fig. 3D and E). However, after myeloid dendritic cell stimulation, the T cells previously stimulated with tumor plasmacytoid dendritic cells produced IL-10 (170 ± 68 pg/mL) and expressed little IFN-γ (0.12 ± 0.05 ng/mL), which was largely observed in the first two cell divisions (5 ± 2% IFN-γ+ T cells; Fig. 3E). The IL-10-expressing cells were CD8+ T cells, similar to tumor plasmacytoid dendritic cell stimulation alone.
lymph nodes in the same individual patients \((n = 8)\) and from peripheral blood in normal donors \((n = 5)\). Direct intracellular staining revealed a negligible level of IL-10 protein in the sorted T cells. However, real-time reverse transcriptase-PCR showed high levels of IL-10 mRNA in CCR7\(^+\)CD45RO\(^+\)CD8\(^+\) T cells from peripheral blood, primary tumor ascites, and primary tumor-draining lymph node in patients with ovarian cancer, whereas normal blood CCR7\(^+\)CD45RO\(^+\)CD8\(^+\) T cells expressed a negligible level of IL-10 mRNA \((*, P < 0.001, \text{compared with normal blood;} \ Fig. 4A)\). Furthermore, the level of IL-10 mRNA was at least 2-fold higher in CCR7\(^+\)CD45RO\(^+\)CD8\(^+\) T cells from tumor ascites than that from blood and lymph nodes \((Fig. 4A)\). All the CCR7\(^+\)CD45RO\(^+\)CD8\(^+\) T cells expressed comparable, but low levels of IFN-\(\gamma\), whereas activated normal T cells expressed high IFN-\(\gamma\) \((Fig. 4B)\). Altogether, IL-10 is highly expressed in primary CCR7\(^+\)CD45RO\(^+\)CD8\(^+\) T cells in vivo in patients with ovarian carcinoma.

We further tested whether tumor primary CCR7\(^+\)CD45RO\(^+\)CD8\(^+\) T cells were functionally distinct from normal blood CCR7\(^+\)CD45RO\(^+\)CD8\(^+\) T cells. To this end, CCR7\(^+\)CD45RO\(^+\)CD8\(^+\) T cells were sorted from normal blood and ovarian tumor ascites, and cultured with normal allogeneic blood T cells in the presence of anti-CD3 stimulation. Strikingly, CCR7\(^+\)CD45RO\(^+\)CD8\(^+\) T cells from tumor ascites, but not from normal blood, suppressed T cell proliferation in a dose-dependent manner \((P < 0.01 \text{ for all;} \ Fig. 4C)\). Thus, tumor environmental CCR7\(^+\)CD45RO\(^+\)CD8\(^+\) T cells are functionally suppressive T cells \((CD8\(^+\) regulatory T cells)\). These CD8\(^+\) regulatory T cells might be induced by tumor environmental plasmacytoid dendritic cells \((Fig. 2)\).

**Discussion**

Published, detailed functional studies of dendritic cells and T cells in human tumor environment are scarce. Here, we studied the interaction between plasmacytoid dendritic cells and T cells in the tumor microenvironment in ovarian carcinomas. We show that tumor plasmacytoid dendritic cells induce regulatory CD8\(^+\) T cells.

There are several proposals to explain why the immune system fails to control tumor progression, including deletions or mutations

| Table 1. CD45RO\(^+\)CCR7\(^+\)CD8\(^+\) T cells in ovarian cancer patients |
|-----------------------------|------------------|------------------|---------|
| Tumor ascites \((n = 33)\) | Tumor blood \((n = 15)\) | Tumor lymph node \((n = 8)\) | Normal blood \((n = 8)\) |
| CD45RO\(^+\) | 59 \(\pm\) 11 \(\pm\) | 38 \(\pm\) 16 \(\pm\) | 45 \(\pm\) 7 \(\pm\) | 19 \(\pm\) 6 \(\pm\) |
| CCR7\(^+\) | 41 \(\pm\) 15 \(\pm\) | 48 \(\pm\) 6 \(\pm\) | 92 \(\pm\) 6 \(\pm\) | 62 \(\pm\) 12 \(\pm\) |
| CD45RO\(^+\)CCR7\(^+\) | 22 \(\pm\) 8 \(\pm\) | 12 \(\pm\) 5 \(\pm\) | 20 \(\pm\) 5 \(\pm\) | 5 \(\pm\) 3 \(\pm\) |

*Note: Fresh T cells were isolated from normal blood, or from ascites, blood, and draining lymph nodes in patients with ovarian cancer, and stained with mouse anti-human CD45RO, CCR7, CD3, and CD8, and then analyzed by flow cytometry analysis. Results were expressed as the percentage of marked cells in CD8\(^+\)CD3\(^+\) population \((\text{mean} \pm \text{SE})\). \(*P < 0.01, \text{as compared with normal blood.}\)
endothelial growth factor inhibit dendritic cell–differentiation, derived cytokines, such as IL-6, IL-10, M-CSF, and vascular endothelial growth factor inhibit dendritic cell–differentiation.

Apart from these possibilities, the dendritic cell system is thought to contribute to tumor immunopathogenesis. Tumor-associated antigen–specific immunosuppression (13). Tumor environmental CD4+CD25+FOXP3+ T cells contribute to inhibitory cytokines such as TGF-β and IL-10. We recently showed that tumor environmental CD4+CD25+FOXP3+ T cells contribute to tumor-associated antigen–specific immunosuppression (13). Apart from these possibilities, the dendritic cell system is thought to contribute to tumor immunopathogenesis.

Tumor plasmacytoid dendritic cells induce CD8 regulatory T cells (5, 6). We recently showed that tumor environmental plasmacytoid dendritic cells induce CD8 regulatory T cells remain to be defined, we have identified four characteristics for these plasmacytoid dendritic cell–induced IL-10+CD8+ T cells; (a) induction of CD8+ regulatory T cells is independent on CD4+ regulatory T cells; (b) CD8+ regulatory T cells significantly suppress myeloid dendritic cell–mediated tumor-associated antigen–specific T cell effector functions through IL-10; (c) tumor myeloid dendritic cells cannot recover the suppressive functions; (d) CD8+ regulatory T cells express functional CCR7 and efficiently migrate with lymphoid homing chemokine MIP-3β. Furthermore, primary functional IL-10+CCR7+CD8+ T cells are found in blood, malignant ascites, and tumor-draining lymph nodes in patients with ovarian cancers. The data suggests that tumor plasmacytoid dendritic cells may induce IL-10+CCR7+CD8+ regulatory T cells in vivo.

CCR7 was used to categorize central memory T cells (CD45RO+CCR7+) versus effector memory T cells (CD45RO−CCR7−; ref. 28). Simultaneous staining of peripheral blood cells with CD45RO and CCR7 reveals a high heterogeneity in distribution of these markers (29). Functional variables are suggested to describe different T cell subsets (30). We show that tumor plasmacytoid dendritic cell–induced IL-10+ T cells exhibit a central memory T cell phenotype (CCR7+CD45RO−; ref. 28). These cells are functionally suppressive and migrate in response to MIP-3β. Furthermore, the in vivo primary counterpart (IL-10+CD8+CD45RO−CCR7+ T cells) is found in patients with ovarian cancers. Analogously,

![Diagram](Image)

**Figure 3.** Tumor plasmacytoid dendritic cells induced functionally suppressive IL-10+CCR7+CD8+ T cells. A, primary tumor ascites T cells (5 × 10^6/mL) received two rounds of stimulation with autologous tumor-associated antigen–plasmacytoid dendritic cells (10^7/mL). Different concentrations of these tumor-associated antigen–plasmacytoid dendritic cell–stimulated T cells were added into autologous tumor-associated antigen–myeloid dendritic cells (10^5/mL) and primary T cell (5 × 10^5/mL) coculture, and were further cultured for 6 days. T cell proliferation was detected by thymidine incorporation. Ratio, plasmacytoid dendritic cell–activated T cells/primary tumor ascites T cells (n = 4, *P < 0.05; **P < 0.01, compared with the group without plasmacytoid dendritic cell–activated T cells). B and C, anti-human IL-10 receptor was added into the coculture as described above. On day 6, T cell proliferation (B) and IFN-γ (C) production were detected as described. The ratio between primary tumor ascites T cells and tumor-associated antigen–plasmacytoid dendritic cell–stimulated T cells was 1:1 (n = 4, *P < 0.01, compared with the group with anti-human IL-10R). D and E, 5,6-carboxyfluorescein diacetate succinimidyl ester–labeled autologous tumor T cells (5 × 10^5/mL) were divided into three groups. Group 1 received only tumor-associated antigen–myeloid dendritic cell (10^5/mL) stimulation. Group 2 initially received tumor-associated antigen–plasmacytoid dendritic cell (10^5/mL) stimulation, and followed with tumor-associated antigen–myeloid dendritic cell (10^5/mL) stimulation. Group 3 received only tumor-associated antigen–plasmacytoid dendritic cell (10^5/mL) stimulation. D, T cell proliferation was determined by thymidine incorporation. E, T cell IFN-γ expression and cell divisions were shown when autologous tumor T cells (5 × 10^5/mL) were stimulated with 10^5/mL tumor-associated antigen–dendritic cells. One of four independent experiments is shown.
Primary tumor CCR7+CD45RO+CD8+ T cells are suppressive. Primary C, anti-CD3 (2.5 A lymph nodes. Activated T cells, normal blood T cells were stimulated with blood).

In summary, our study indicates that tumors manipulate tumor environmental dendritic cell subset distribution and functions to subvert tumor immunity (8). Multiple cellular and molecular layers of the suppressive network have been imposed in the tumor microenvironment in patients with cancers (8, 35–42). We suggest that a combination therapy with subverting immunosuppressive mechanisms, including blocking plasmacytoid dendritic cell tumor trafficking or function, is a promising, yet little-studied strategy for treating human cancers.

Acknowledgments
Received 11/11/2004; revised 3/14/2005; accepted 3/30/2005.

Grant support: The Department of Defense (OC020173), the National Cancer Institute (CA092562, CA100227), and the Louisiana Cancer Research Consortium.

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We thank Roy Weiner and Jules Puschett for their constant support.

References


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