In situ Vaccination Combined with Androgen Ablation and Regulatory T-Cell Depletion Reduces Castration-Resistant Tumor Burden in Prostate-Specific Pten Knockout Mice

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Abstract

There is no effective treatment for prostate cancer arising after androgen ablation. Previous studies have analyzed the short-term effects of androgen ablation on the immune system and suggest an abatement of immune suppression by hormone removal. Because castration-resistant disease can arise years after treatment, it is crucial to determine the duration of immune potentiation by castration. Because immunotherapeutic efficacy is determined by the balance of immune cell subsets and their location within the tumor, we assessed the acute and chronic effect of androgen ablation on the localization of T-cell subsets within castration-resistant murine prostate cancer. We observed a transient increase in CD4+ and CD8+ T-cell numbers at the residual tumor after androgen ablation. More than 2 months later, regulatory T cells (Treg) were increasingly found within prostate epithelium, whereas CTLs, which were evenly distributed before androgen ablation, became sequestered within stroma. Anti-CD25 antibody administration along with castration enhanced CTL access to cancerous glands but did not increase effector function. Intraprostatic injection of LIGHT-expressing tumor cells increased the proportion of CD8+ T cells with functional capacity within the cancerous gland. In addition, Treg depletion within the tumor was enhanced. Together, these manipulations significantly reduced castration-resistant tumor burden. Thus, our results indicate that immune modulations, which prevent Treg accumulation and augment effector cell infiltration of prostatic epithelium, may be effective in reducing tumor burden or preventing tumor recurrence after androgen ablation therapy.

Introduction

Androgen ablation therapy of prostate cancer causes apoptotic cell death, significantly reducing tumor burden (1). However, the benefit is often short-lived, and many patients develop fatal androgen-independent disease (2).

Systemic androgen removal modulates T-cell number and function, increasing peripheral T-lymphocyte numbers (3, 4) and reducing regulatory T-cell (Treg) numbers (5). Androgen ablation caused an early and transient increase in T-cell infiltration of human prostate tumors (6) and removed tolerance to prostate cancer antigens in a transgenic mouse model (7), suggesting that systemic removal of androgen can enhance prostate antitumor immunity.

The presence of lymphocytes within prostate tumors (8, 9) and circulating tumor-reactive T cells in the peripheral blood of prostate cancer patients (10–14) have been reported. Effector CD8+ T cells (6, 15), regulatory FoxP3+ cells (16), and Th17 cells (17) have been observed within prostate tumors. Whether the composition of lymphocytes favors effector or regulatory cells serves as a prognostic indicator of disease outcome (18–20).

In mouse models, dysfunctional T cells both systemically and at the tumor site (21–25) indicate that CTL may fail to become fully functional or may receive one or more suppressive signals. The presence of Tregs at the tumor site can inhibit effector cell trafficking and function. However, studies depleting Tregs have had mixed results in mouse models (26, 27). Human and animal studies suggest that androgen ablation may overcome some suppressive signals, resulting in increased effector cell presence at the tumor site. For the postcastration influx of lymphocytes to be advantageous, the balance should favor effector cells and be maintained over time. However, immune potentiation must be insufficient because the tumor recurs.
Malignant cells within prostate glands are surrounded by a stroma that impedes lymphocyte infiltration of the tumor and presents a significant barrier (28), which functional CTL must cross to access the tumor. Whereas a study in patients with non–small cell lung cancer showed high levels of epithelial infiltration by CD8+ cells and stromal infiltration by CD4+ cells and suggested both as independent, positive prognostic indicators of patient survival (18), such a study has not been reported for prostate cancer.

We hypothesized that androgen ablation enhances antitumor immunity by transiently shifting the balance of lymphocyte subsets to favor effector CD8+ T cells and that, over time, the lymphocyte composition changes to favor cells that inhibit tumor rejection. We investigated this hypothesis in a prostate-specific Pten (phosphatase and tensin homologue on chromosome 10) knockout mouse model of prostate cancer, a model that recapitulates human prostate cancer development and progression (29). Androgen ablation in this model leads to apoptotic death in the primary tumor with persistence of invasive disease. We characterized the T-lymphocyte infiltrate within these androgen-independent prostate tumors and found an overall increase in both the number of T cells within the prostate and the ratio of CD8+/FoxP3+ T cells.

Using immunohistochemical analysis, we determined that although Treg depletion did not increase the percentage of functional CD8+ T cells, it increased their access to cancerous glands. Vaccination with tumor cells expressing the tumor necrosis factor (TNF) superfamily member LIGHT (lymphotoxin-like, exhibits inducible expression, and competes with herpes simplex virus glycoprotein D for HVEM, a receptor expressed by T lymphocytes; ref. 30) along with castration and anti-CD25 administration reduced tumor volume and sustained Treg depletion within the tumor. Thus, CTL infiltration of prostatic epithelium and in situ vaccination were crucial to an effective antitumor response.

Materials and Methods

Mice and cell lines. All animal work followed Wake Forest University Health Sciences (WFUHS) Institutional Animal Care and Use Committee regulations. PtenloxP/loxP mice were obtained from Dr. Yong Chen (WFUHS) with permission of Dr. Hong Wu (University of California at Los Angeles; ref. 29). A PB-Cre4 transgenic mouse breeding pair (31) was obtained from the National Cancer Institute Mouse Models of Human Cancer Consortium, and the line was maintained and intercrossed with PtenloxP/loxP mice to generate Pten−/− male mice as described previously (29).

Animals were killed at the indicated time points, and wet weights of pooled prostate lobes were obtained. Tumors and spleens were embedded in OCT medium. H&E-stained sections were evaluated for the presence of tumor by M.C.W. in a blinded fashion.

UV-8101-RE sarcoma cells (32) were maintained in DMEM + 10% fetal bovine serum (both from Lonza). Pten CaP8 cells were maintained in Pten medium, as described previously (33). TRAMP C-1 cells were maintained in TRAMP medium (34).

Castration. Mice were anesthetized with an i.p. injection of 100 μL/25 g of a ketamine/xylazine mixture (23.75 mg/mL ketamine + 1.25 mg/mL xylazine) and castrated by surgical removal of both testicles.

Treg depletion. Tregs were depleted by a single i.p. injection of 0.5 mg anti-CD25 antibody (ref. 35; clone PC61, BioXCell).

Antibody sources. The antibodies used are as follows: anti-CD4 (clone GK1.5), anti-FoxP3 (clone FJK-16s), and IgG2b isotype control (eBioscience); polyclonal rabbit anti-granzyme B and rabbit IgG (Abcam); anti-CD8 (clone 53-6.7), IgG2a isotype control, and goat anti-rat IgG (BD Biosciences); biotinylated donkey anti-rabbit and goat anti-mouse Fab (Jackson ImmunoResearch); and goat anti-rat-ASF46 and donkey anti-rat-ASF488 (Invitrogen).

Immunohistochemistry and immunofluorescence. Eight micrometer cryosections were stained using standard immunohistochemical techniques. For single staining, slides were incubated with anti-CD4 (5 μg/mL), anti-CD8 (5 μg/mL), or anti-Foxp3 (10 μg/mL) antibody for 1 hour and biotinylated goat anti-rat immunoglobulin (1:300). Signal was amplified using ABC kit (Vector Labs), developed with 3,3′-diaminobenzidine (DAB), and mounted using Permount (Fisher).

Granzyme B+/CD8+ cells were detected by immunohistochemical analysis or immunofluorescence double staining. CD8 staining was developed with DAB + nickel, followed by anti-granzyme B (5 μg/mL, 30 minutes), donkey anti-rabbit biotin (1:250), and avidin-biotin complex, developed with AEC (Vector Labs). For immunofluorescence, granzyme B was detected with red substrate 1 kit (Vector Labs), and CD8 was detected with Alexa Fluor-488 (1:100, Molecular Probes, Invitrogen Corp.).

For double staining of CD4/FoxP3, slides were fixed in ice-cold methanol, washed in PBS, and blocked with 1% bovine serum albumin/PBS. Endogenous mouse immunoglobulin was blocked with goat anti-mouse Fab (100 μg/mL, 30 minutes) washed, followed with rat anti-mouse FoxP3 (40 μg/mL, overnight, room temperature). Slides were developed with goat anti-rat AF546 (25 μg/mL), washed, and blocked, and anti-CD4 (25 μg/mL, 30 minutes) was followed by donkey anti-rat AF488 (25 μg/mL), counterstained with 4′,6-diamidino-2-phenylindole, and mounted in 90% glycerol/PBS.

Enumeration of T-cell subsets. Pictures of three to four fields per prostate were quantified using the ImageJ Cell Counter Plug-in (NIH). The total number of positive cells per field and the number of positive cells in the glands were determined. Pictures were taken by E.J.A. or P.D. Cell counts were blinded or independently verified by P.D.

Statistical analysis. One to four 8-μm sections of tissue were measured on each mouse. The analysis used all of the measurements and accounted for the correlation of having repeated measures in a mouse by using a mixed effects model, with a random mouse effect. Differences in prostate tumor weight and the number of cells at each time point and treatment were compared using pairwise comparisons from...
the mixed effects ANOVA model. Differences within mice in the percentage of cells expressing granzyme B+, granzyme B+ percentage in stroma versus gland, and the density (cells/mm²) of CD4+, CD8+, and FoxP3+ in stroma versus gland were compared with 0 using a t test contrast in the mixed effects ANOVA model. All analyses were performed in SAS (v 9.2), with a two-sided \( \alpha \) level of 0.05. Data are shown as mean ± SEM and are compiled from at least five animals per group.

**Flow cytometry.** Splenocytes were dissociated into a single-cell suspension and stained using the mouse Treg staining kit (eBioscience), following the manufacturer’s instructions. Cells were analyzed on a FACSCalibur using Cellquest PRO software (BD Biosciences).

**MLTC and \( ^{51} \)Cr release assay.** MLTC cultures were set up, and lytic activity was assayed, as described previously (32), and assessed on days 6 to 7 of culture. Supernatant was harvested and measured after 4.5 hours.

**Results**

Deletion of exon 5 of the Pten tumor suppressor gene in the prostate causes invasive prostate adenocarcinoma in 100% of the mice (29) by 9 weeks of age. Although castration at 16 weeks of age induced apoptosis within the primary tumor, invasive adenocarcinoma was maintained in the residual tissue. We analyzed animals between 2.5 and 10 weeks postcastration to span different stages of androgen-independent prostate growth. Prostate weights did not change significantly over time (Fig. 1A), and carcinoma was detected at all time points by H&E staining (Supplementary Fig. S1).

**T-lymphocyte ratios favor CD8+ T cells early after castration.** Previous studies (6, 15) reported an increase in lymphocyte numbers at the prostate 1 to 4 weeks after hormone ablation. To determine the effect of castration on the number and proportion of T lymphocytes, we analyzed the prostates of Pten knockout mice by immunohistochemical analysis (Fig. 1B). Quantitative analysis showed that compared with intact 8- to 16-week-old mice, 2.5 weeks after castration, there were ~6-fold and 4-fold increases in the number of CD8+ and CD4+ T cells in the prostate, respectively (Fig. 1C). However, by 5 weeks postcastration, the numbers of both subsets were not significantly different from precastration numbers (Fig. 1C), suggesting that the effects of hormone removal on the immune system are acute. The small number of FoxP3+ T cells present did not change significantly throughout tumor progression (Fig. 1C).

The ratio of CD8+ to FoxP3+ T cells within the tumor is a prognostic indicator of immune efficacy (20, 36, 37). Although not statistically significant, we observed an ~7-fold increase in the CD8+/FoxP3+ T-cell ratio at 2.5 weeks after castration (data not shown), showing that androgen ablation had an immune potentiating effect that favored effector cells.

Excluded from this analysis were distinct lymphoid aggregates, which were found in approximately one-third of the samples (Supplementary Fig. S2), because their functional status may be different from tumor-infiltrating lymphocytes (38–40).

**Figure 1.** Castration induces a transient increase in T-cell localization to the prostate without altering prostate tumor weight. A, prostate wet weights at indicated time points. B, CD8, CD4, and FoxP3 staining at pre-castration (pre-Cx) and 2.5, 5, and 10 wks after castration. Scale bars, 100 μm (pre-Cx to 10 wks) and 10 μm (high magnification). Arrows mark FoxP3+ cells. C, CD8+ and CD4+ T-cell numbers increased at 2.5 wks postcastration. Quantification was performed as described in Materials and Methods. □, Pre-Cx; ■, 2.5 wks; □, 5 wks; □, 10 wks; #, \( P < 0.05 \) versus precastration, 5 wks, and 10 wks; a, \( P < 0.05 \) versus precastration and 10 wks.
For most tumors, rejection is mediated by effector CTL. Therefore, we evaluated the functional status of the CD8+ T cells infiltrating the prostate gland after castration to assess whether there was an increase in functional cells. The proportion of CD8+ T cells that expressed granzyme B, a marker of lytic capacity, was evaluated (Fig. 2A) and was not significantly different before castration and at 2.5 weeks following castration (Fig. 2B). Because CD8+ T-cell numbers increased, the number of granzyme B+ cells increased ∼10-fold (data not shown). However there was no effect on tumor volume. By 10 weeks postcastration, the percentage of granzyme B+ cells in the tumor had declined significantly (Fig. 2B), indicating that enhancement of immune function was not sustained. Notably, about one-third of the CD8+ T cells at the tumor site before castration expressed granzyme B, suggesting that the growing tumor may have elicited a CTL response.

**Effector T cells localized to the prostate do not efficiently access tumor epithelium.** Random distribution of lymphocytes within a tissue may indicate that they are not actively involved in immune responses (41). There was no preferential localization of CD8+ and CD4+ cells within the prostate at any time point (Fig. 3A). In contrast to the CD4+ population, FoxP3+ cells were predominantly located in the tumor stroma early after castration (Fig. 3A). However, as the tumor progressed, Tregs were increasingly detected in the epithelium, suggesting that glandular localization of Tregs may be one hallmark of prostate cancer progression.

To assess whether functional CD8+ T cells were able to overcome the stromal barrier, we calculated the percentage of CD8+ T cells within stroma and gland that expressed granzyme B. Whereas there was no difference in the location of granzyme B+CD8+ cells in noncastrated mice, at both 2.5 and 5 weeks following castration, there was a significantly higher proportion of functional cells in the tumor-associated stroma than in the glands (Fig. 3B). In addition, the majority of functional cells were excluded from the prostate glands at all time points examined (Fig. 3C). Thus, whereas androgen ablation induced a substantial increase in lymphocyte numbers in the prostate, their location within the organ was not conducive for targeting of malignant epithelial cells.

**Systemic PC61 administration does not deplete Tregs within the prostate tumor.** Persistence of Tregs may be an immune suppression mechanism critical to prostate cancer progression. Therefore, we hypothesized that depletion of Tregs at the time of castration would enhance T-cell localization to function within the prostate epithelium.

In a melanoma model, prophylactic anti-CD25 treatment promoted tumor rejection, whereas therapeutic anti-CD25 treatment did not increase CD8+ T cell/Treg ratio or enhance tumor infiltration by effector T cells (42). Because androgen ablation results in death of the majority of existing tumor cells, we reasoned that concurrent PC61 treatment would mimic the prophylactic phenomenon; therefore, we gave the anti-CD25 antibody, PC61, i.p. 2 days before castration (35). Flow cytometry analysis of splenocytes showed that Tregs were depleted systemically 48 hours later (Fig. 4A).

Because changes in lymphocyte function and number were most evident at 2.5 weeks postcastration, we evaluated the effect of a single anti-CD25 treatment at that time point. The number of CD4+ and CD8+ T cells that infiltrated the prostate was not different from untreated animals (Fig. 4B). Surprisingly, FoxP3+ T cell numbers were significantly higher than castrated animals that were not treated with antibody (Fig. 4B), suggesting that PC61 administration did not deplete intratumoral Tregs or that compensatory mechanisms within the tumor maintained Tregs at the tumor site.

**Figure 2.** Androgen ablation does not alter granzyme B+ CD8+ T-cell proportions. A, representative sections of granzyme B+ cells (red) and CD8+ cells (black) at each time point. B, the percentage of granzyme B+ CD8+ cells was calculated (#, P < 0.05 versus 10 wks); Pre-Cx; ▪, 2.5 wks; □, 5 wks; ▲, 10 wks. Scale bar, 100 μm.
analyzed prostate tumors 3 days after antibody administration and found that Treg numbers within the prostate tumor were similar to those of untreated animals (Fig. 4B), suggesting that systemic antibody administration did not deplete intratumoral Tregs.

Fluorescent double staining (Fig. 4C) showed that the FoxP3+ cells within the tumor were also CD4+, indicating the accumulation and maintenance of classic Tregs at the tumor site (43).

**Treg depletion augments effector cell infiltration of tumor epithelium without increasing effector cell function.** We also examined the effect of PC61 treatment on the localization of T cells within the prostate microenvironment. Whereas the CD8+ cells continued to be randomly distributed throughout the organ, CD4+ cells were preferentially localized within tumor stroma (Fig. 4D).

Interestingly, the FoxP3+ cells were enriched in the glands, in contrast to prior significant enrichment in the stroma (Fig. 4D). Thus, PC61 treatment accelerated localization of Tregs to the epithelium, which occurred by 10 weeks postcastration in the absence of antibody treatment.

The percentage of granzyme B+ CD8+ T cells was significantly lower in antibody-treated mice (Fig. 5A). Because CD8+ T-cell numbers did not decrease after antibody treatment, systemic anti-CD25 administration may have prevented acquisition of full effector function.

CD8+ cells expressing granzyme B were evenly distributed between stroma and gland after PC61 administration, suggesting that removal of Tregs facilitated tumor infiltration by effector cells (Fig. 5B). However, compensatory movement of regulatory cells to the same compartment may keep effector function in check and prevent tumor rejection.

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**Figure 3.** Both effector CD8+ T cells and FoxP3+ T cells are localized to prostate tumor stroma after androgen ablation. A, FoxP3+ cells are preferentially localized to tumor stroma after androgen ablation and shift to the cancerous glands over time (*, \( P < 0.05 \) compared with gland or stroma at the same time point). B, the percentage of CD8+ cells in stroma or gland expressing granzyme B was determined (*, \( P < 0.05 \) versus gland at the same time point). C, the distribution of granzyme B+/CD8+ T cells in stroma or gland was determined (*, \( P \leq 0.05 \) versus gland at the same time point). ▪, stroma; □, gland.
Enhanced T-cell localization in the tumor stroma after androgen removal.

Figure 4. Treg depletion changes T-cell distribution within the prostate tumor microenvironment. A, Tregs were detected by flow cytometry as described in Materials and Methods. Top right quadrant, CD25+ FoxP3+ T cells (%). B, FoxP3+ cells are not depleted in the prostate after systemic PC61 administration, whereas CD8+ and CD4+ T cell numbers are unchanged. □, 2.5 wks; □, 2.5 wks postcastration + PC61 administration; □, 3 d postadministration of PC61. *, P < 0.05 compared with gland at the same time point; □, 3 d postadministration of PC61. P < 0.05 compared with gland at the same time point; □, 3 d postadministration of PC61.

Discussion

We evaluated the short-term and long-term effect of androgen ablation on the localization of T-cell subsets to prostate tumors in a prostate-specific Pten knockout mouse model. Pten deletion is frequently observed in human prostate cancers (44). Therefore, evaluation of the effects of immune modulations in a model that has parallels to human disease is a particular strength of our studies.

Previous studies in human and mouse models have reported that androgen ablation, the preferred first-line therapy visible. At the time of harvest, seminal vesicles were shrunken and prostate lobes were reduced in size (data not shown).

Mixed lymphocyte tumor cell cultures of spleens from immunized mice showed that both UV-8101-RE–vaccinated and UV-8101-RE-mLIGHT–vaccinated mice elicited a strong and specific lytic response by 2.5 weeks postvaccination, which was indistinguishable from that of wild-type non–tumor-bearing mice (Fig. 6A). Tumor wet weights from animals injected with UV-8101-mLIGHT were significantly smaller compared with weights of tumors from animals that were castrated and treated with PC61 antibody (Fig. 6B) and approaching significance compared with animals 2.5 weeks after castration alone. In contrast, although Pten knockout mice injected with UV-8101-RE cells also mounted a specific CTL response to the vaccine, there was no significant reduction in prostate tumor weight.

Although CD8+ T-cell numbers in the tumors of vaccinated mice were unchanged (Fig. 6C), the number of FoxP3+ T cells significantly decreased within tumors vaccinated with UV-8101-RE-mLIGHT or UV-8101-RE alone (Fig. 6C). Thus, generation of a strong and productive CTL response within the tumor may augment Treg depletion initiated by PC61 treatment.

The proportion of CD8+ cells expressing granzyme B was significantly increased in the prostate glands of mice vaccinated with UV-8101-RE cells, with or without the addition of LIGHT (Fig. 6D), likely due to the generation of a strong CTL response against the UV-8101 tumor-specific antigen. Nevertheless, only vaccination with LIGHT-expressing tumor cells reduced tumor burden, suggesting that introduction of LIGHT in an immunogenic context may enhance bystander CTL responses to prostate tumor antigens. Two of five mice vaccinated with UV-8101-RE-mLIGHT also lysed Pten CaP8 cells, a tumor cell line derived from a Pten knockout mouse prostate tumor (one example shown in Fig. 6A, top left), whereas mice vaccinated with UV-8101-RE cells did not lyse Pten CaP8 cells (Fig. 6A, top right).
Figure 6. Vaccination with LIGHT-expressing tumor cells together with castration and PC61 administration reduced prostate tumor weight. A, splenocytes from vaccinated mice were stimulated in vitro with UV-8101-LIGHT or UV-8101-RE. ▪, UV-8101-RE-LIGHT; ♦, UV-8101-RE; ▲, Pten CaP8; ▴, TRAMP C-1. B, prostate wet weight of mice was determined. \( P = 0.057 \) between 2.5 wks and 2.5 wks + PC61 + UV-8101-LIGHT. \( P = 0.03 \) between 2.5 wks + PC61 and 2.5 wks + PC61 + UV-8101-RE-LIGHT. C, FoxP3+ cells are significantly decreased in the tumor after vaccination with immunogenic sarcoma cells. ■, 2.5 wks; □, 2.5 wks + PC61 treatment; △, 2.5 wks + PC61 + UV-8101-RE-LIGHT; ▼, 2.5 wks + PC61 + UV-8101-RE. *, \( P < 0.05 \) compared with 2.5 wks and 2.5 wks + PC61; a, \( P < 0.05 \) compared with castration and PC61 treatment alone. D, proportion of granzyme B+ cells within the prostate glands is significantly increased after intraprostatic vaccination. ■, stroma; □, gland. *, \( P < 0.05 \) compared with gland at the same time point; #, \( P < 0.05 \) compared with gland at 2.5 wks and 2.5 wks + PC61 treatment. Data for 2.5 wks and 2.5 wks + PC61 are the same as in Figs. 1 and 4.
for localized prostate cancer, increases the number and functional status of T cells at the tumor site. However, this effect must be transient, because the tumor continues to grow. The increase in functional cell density we observed was not a result of smaller prostate volume, because tumor weights early and late after castration were similar. Androgen ablation alone was insufficient to prevent tumor recurrence, perhaps because the effector cells remained sequestered in the stroma.

The timing and dosage of anti-CD25 treatment is critical, because CD25+ effector cells may also be depleted. In a previous study, only prophylactic anti-CD25 administration augmented effector cell function (42). We reasoned that anti-CD25 administration, along with castration, would be a prophylactic treatment for residual castration-resistant disease. Because Tregs in the prostate tumor were not significantly depleted despite near complete systemic Treg depletion, intratumoral injection of PC61 may be necessary to deplete Tregs within the tumor.

PC61 administration increased granzyme B+ CD8+ T-cell access to the cancerous gland. However, CD8+ T-cell numbers were slightly (but not significantly) reduced at the tumor site, indicating that CTL proliferation did not increase within the tumor. In addition, the percentage of granzyme B+ cells within the tumor was significantly decreased, either due to depletion of effector cells or incomplete acquisition of effector function by CD8+ T cells. Thus, systemic administration of anti-CD25 antibody may be detrimental to the antitumor response even when delivered in the setting of minimal residual disease. A study using a transplantable model of glioblastoma showed that Treg depletion by systemic PC61 treatment reduced tumor burden when the tumors were small. Later administration of PC61 did not affect tumor burden and also depleted effector cells (45).

One potential explanation for the inability of CD8+ T cells at the tumor site to mount a rejection response is the lack of costimulation that is necessary for acquisition of full effector function. Transduction of tumor cells with molecules, such as B7-1 (46) and 4-1-BB ligand (47), provides costimulation in situ and augments effector function. Subcutaneous challenge of mice with tumor cells expressing the costimulatory molecule LIGHT increased the immunogenicity of the transduced tumor and activated T cells specific for an antigenically unrelated tumor present at a distant site within the same animal (30). Furthermore, introduction of LIGHT in the tumor microenvironment increased effector T-cell infiltration of the tumor.

We chose a highly immunogenic cell line as the vaccine to deliver LIGHT to elicit a strong immune response within the prostate tumor. Reduction in prostate tumor weight was only observed when LIGHT-expressing tumor cells were used as a vaccine, indicating that introduction of a potent immunogen alone is insufficient to elicit a rejection response against undefined antigens expressed by the endogenous prostate tumor. As reported previously (30), we also observed that LIGHT can enhance function of bystander T cells within antigenically and histologically unrelated tumor types. Approximately half of the injected cells expressed LIGHT, and a further increase in retroviral transduction of the vaccine may increase the bystander effect. To our knowledge, our study is the first to show that LIGHT immunization has potential as a therapeutic manipulation for endogenous tumors.

Elicitation of a strong CTL response against the vaccine may have resulted in movement of Tregs out of the organ or alternately may have enhanced Treg depletion initiated by anti-CD25 antibody treatment. We did not test whether LIGHT vaccination alone may be sufficient to deplete Tregs. Additional experiments in this tumor model will address whether repeated vaccinations with LIGHT-expressing tumor cells can sustain Treg depletion and increased effector function within the tumor, further reducing tumor burden.

In conclusion, our results imply that combination immunotherapy, which leads to an increased proportion of functional T cells that can efficiently access the cancerous glands, may be most effective at eliminating or preventing the development of castration-resistant prostate cancer.

Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.

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