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CD4+CD25+ Tregs control the TRAIL-dependent cytotoxicity of tumor-infiltrating DCs in rodent models of colon cancer

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Introduction
Tumor stroma is richly invaded by host cells, which include tumor-derived DCs in rodent models of colon cancer. Several therapeutic strategies were proposed to attempt to restore the ability of DCs to mediate an efficient antitumor immune response. For example, the Mycobacterium bovis Bacillus Calmette-Guérin–cell-wall skeleton (BCG-CWS) was shown to act as a potent inducer of ex vivo DC maturation via its TLR agonist activity (21). Moreover, preventive administration of BCG could delay tumor growth in vivo in a TLR2- and TLR4-dependent manner (22). Furthermore, TLR triggering together with IL-10 neutralization reverted tumor-induced TIDC paralysis and elicited an efficient antitumor immune response (10). A combination of IL-2 and Imatinib mesylate expands a subtype of tumor-infiltrating cells with NK functions and DC markers that kill tumor cells through TNF-related apoptosis-inducing ligand (TRAIL) and control tumor growth (23, 24). Thus, redirecting TIDCs from a tolerantergic to a pro-Th1 state or toward cytotoxic function might be an efficient strategy in tumor immunotherapy. However, mechanisms controlling the switch from tolerogenic to immunogenic TIDCs remain elusive.

In the present study, we demonstrate in 2 models of colon carcinoma in rodents that the combination of 2 treatments used in the clinic, low-dose cyclophosphamide (CTX) and M. bovis BCG, a mycobacterium that activates innate components of the immune system through TLR2, TLR4, and TLR9 (25, 26), induced an accumulation of cytotoxic myeloid TIDCs that kill tumor cells through TRAIL expression by the CD11b+ TIDCs was induced by BCG and dependent on signaling through TLR2, TLR4, and TLR9. In vivo transfer of Tregs abrogated the ability of BCG to induce CD11b+ TIDCs to express TRAIL and thereby nullified the efficacy of the CTX-BCG treatment. Our data have therefore delineated what we believe to be a novel mechanism by which Tregs inhibit the antitumor immune response.

Nonstandard abbreviations used: BCG, Bacillus Calmette-Guérin; BM-DC, BM-derived DC; CTX, cyclophosphamide; IFN-γ, IFN-γ-producing killer DC; iNOS, inducible NOS; iNOS, N-nitroso-arginine; MHC-II, MHC class II; Mo-DC, monocyte-derived DC; TCR, T-cell receptor; TIDCs, tumor-infiltrating DCs; TRAIL, TNF-related apoptosis-inducing ligand; Z-VAD-fmk, Z-valine-alanine-aspartate fluoromethyl ketone.

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Results
Synergistic antitumor effects of CTX and BCG. The treatment, consisting of 1 systemic injection of CTX followed by 2 intratumoral injections of BCG, was tested in 2 models of established subcutaneous tumors (PROb in BD-IX rats and CT26 in BALB/c mice). When administered alone, CTX and BCG therapies demonstrated...
Supplemental Figure 1; supplemental material available online

subcutaneous tumors were incubated with PROb and CT26 cells, respectively, at different effector/target ratios. Unexpectedly, only BCG were able to kill tumor cells in vitro (Figure 3, A and B, and Supplemental Figure 1; supplemental material available online with this article; doi:10.1172/JCI35890DS1). Extensive phenotypic analysis of DC subtypes revealed that the combined treatment mostly induced a large infiltration of CD11b+ DCs (3-fold increase over untreated control) negative for F4/80 (data not shown) and at a lower level of CD8α DCs. Of note, no significant tumor infiltration by Gr-1+, B220-, CD11cint, NK-p46+ plasmacytoid DCs or B220+, CD11c+, NK-p46+ IFN-γ-producing killer DCs (IKDCs) was induced by the combined treatment (Figure 3C).

To further characterize the function of these TIDCs, CD11c+ CD11b+ MHC-II+ TIDC (CD11b+ TIDC) or CD11c+CD8α+MHC-II+ TIDC (CD8α+ TIDC) cells were sorted and tested for their capacity to kill CT26 cells. Interestingly, only CD11b+ TIDCs exhibited cytotoxicity against tumor cells (Figure 3D). Moreover, we showed that CD11b+ TIDCs isolated from CTX-BCG–treated CT26 tumors could acquire a mature phenotype, as demonstrated by upregulation of CD80, CD86, CD40, and I-A/I-E molecules (Supplemental Figure 2A). When injected into the footpad of naive mice, these cells could trigger a specific IFN-γ production by tumor draining lymph node cells after an in vitro stimulation (Supplemental Figure 2B) and vaccinate naïve mice specifically against CT26 cells (Supplemental Figure 2C). In contrast, CD11b+ TIDCs obtained from either untreated groups or groups treated only with CTX or BCG alone were unable to do so. Similarly, TIDCs from CTX-BCG–treated rats could stimulate PROb specific lymphocytes in vitro (Supplemental Figure 2D) and vaccinate specifically naïve rats against PROb cells (Supplemental Figure 2E).

Altogether, these data demonstrate that the CTX-BCG combination promotes a tumor infiltration of CD11c+, CD11b+, MHC-II+ cells (CD11b+ TIDC) that kill tumor cells and exert APC functions. BCG induces TRAIL-dependent DC killing capacity through TLR2, TLR4, and TLR9 signaling. To determine which cytotoxic pathways were likely to be involved in the tumoricidal activity of CD11b+ TIDCs, we tested the killing activity of CD11b+ TIDCs
in the presence of Z-valine-alanine-aspartate-fluoromethyl ketone (Z-VAD-fmk), a pan-caspase inhibitor. As shown in Figure 4A, tumor cell death induced by CD11b⁺ TIDCs from CTX-BCG–treated mice is prevented by Z-VAD-fmk. We additionally observed that tumor cell death induced by CD11b⁺ TIDCs is blunted by an anti-TRAIL blocking mAb but not by an anti–Fas ligand blocking mAb, N-monomethyl-L-arginine (L-NMMA), which inhibits the inducible nitric oxide synthase, or concanamycin A, which inhibits the perforin/granzyme pathway (Figure 4A). We ruled out a role for TNF-α to account for the cytotoxicity of TIDCs as we noted that CT26 and PROb cells were intrinsically resistant to TNF-α–mediated cell death (data not shown). TRAIL expression was only detected at the surface of CD11b⁺ TIDCs sorted from treated mice and not on CD11b⁺ TIDCs from control mice (Figure 4B). In contrast, TRAIL was not detected at the surface of intratumoral T cells (data not shown). Furthermore, CD11b⁺ TIDCs sorted from untreated mice or DCs generated from the BM of mice (BM-DCs) incubated in vitro overnight with BCG induced TRAIL expression at their surface (Figure 4C) and triggered CT26 cell death in a TRAIL-dependent manner as demonstrated by the inhibitory effect of the blocking anti-TRAIL mAb (Figure 4D). BCG was recently reported to activate the immune system through TLR2, TLR4, and TLR9 (25, 26). We showed that TLR2, TLR4, and TLR9 ligands also enhanced BM-DC TRAIL expression while TLR3 ligand did not (Figure 4E). Using wild-type BM-DCs, wild-type BM-DCs treated with an oligodeoxynucleotide (IRS 954), which efficiently blocks TLR9 signaling, TRIF, Myd88, and TLR2- and TLR4-deficient BM-DCs, we observed by quantitative RT-PCR that the induction of Trail mRNA by BCG is dependent on TLR2, TLR4, and TLR9 molecules and on their shared adapter protein MyD88 but does not involve TRIF (and thus TLR3) signaling pathway (Supplemental Figure 3). To investigate the role of TLR in the antitumor effects mediated by CTX and BCG in vivo, we compared the ability of the combined treatment to promote antitumor effects in wild-type, TLR2–, TLR4–, and MyD88-deficient BALB/c mice bearing
CT26 tumors. While tumors grew at the same kinetic in wild-type and in TLR-deficient mice (Figure 4F), the antitumor effect of the combined treatment was significantly hampered in Tlr2−/−, Tlr4−/−, or Myd88−/− mice (Figure 4F). Similar results were achieved when wild-type mice were injected with an oligodeoxynucleotide (IRS 954), which efficiently blocks TLR9 signaling (data not shown), underlining the participation of TLR9 in the effects of CTX-BCG combination (Figure 4F).

We could establish in human settings that human DCs derived from monocytes (Mo-DCs) also expressed TRAIL after an in vitro BCG stimulation (Figure 5A) and became cytotoxic toward HCT116 human colon carcinoma cells (Figure 5B) and toward a panel of melanoma cell lines (Figure 5C). Moreover, their cytotoxicity could be blunted by an anti-TRAIL antibody or by Z-VAD-fmk, whereas l-NMMA and concanamycin A (Figure 5D) and anti–Fas ligand and anti–TNF-α antibodies were ineffective (data not shown).

Overall, these data demonstrate that BCG induces TRAIL expression at the surface of DCs, either CD11b+ TIDCs or BM-DCs, through TLR2, TLR4, or TLR9 signaling and promotes tumor cell killing in a TRAIL-dependent manner.

Tregs prevent BCG-induced TRAIL expression on CD11b+ TIDCs. We (18, 27) and others (28) demonstrated that CTX administration decreased the number and inhibited the function of Tregs in the lymphoid organs. We here extend these findings by demonstrating that CTX decreased the percentage of Tregs that infiltrated CT26 and PROb tumors (Figure 6A and data not shown). DAPI staining indicated that, 2 days after CTX treatment, a large part of tumor-infiltrating Tregs were dying cells (Figure 6A). Furthermore, mafosfamide, a metabolite of CTX, preferentially induces apoptosis of CD4+CD25+ Tregs in vitro compared with conventional CD4+CD25+ T cells (Tconv) (Supplemental Figure 4A). This cytotoxicity likely involved Foxp3 expression, as Foxp3 expression in Jurkat leukemic T cells sensitized these cells to mafosfamide (Supplemental Figure 4B). Finally, we demonstrated in CT26 tumor-bearing mice that the adoptive transfer of Tregs (but not Tconv) performed concomitantly with the first administration of BCG dramatically reduced the antitumor effects of the combined treatment (Figure 6B). Therefore, we investigated whether Tregs could hamper TRAIL-dependent cytotoxicity of CD11b+ TIDCs described above. In vitro, Tregs but not Tconv could prevent the upregulation of TRAIL molecules after BCG stimulation at the surface of CD11b+ TIDCs isolated from untreated or CTX-BCG–treated mice were incubated with 1 × 10^6 CT26 cells. Cytotoxic effect on the CT26 cells was determined using a crystal violet assay. For each experiment, values represent mean ± SEM. *P < 0.05.
CD11b+ TIDCs or conventional DCs and the subsequent tumoricidal activity of TRAIL expression.

**Tregs** compromise the success of CTX-BCG treatment via inhibition of TRAIL-dependent TIDC cytotoxicity. We next sought to analyze the direct cytotoxicity of TIDCs in vivo. Nude mice inoculated subcutaneously with CT26 cells were treated with intratumoral injections of BM-DCs stimulated or not with BCG. Importantly, the antitumor effects of BM-DCs were correlated to their level of TRAIL expression described in Figure 4C, as only TRAIL expressing BCG-stimulated BM-DCs significantly delayed tumor growth, while unstimulated BM-DCs had no impact on tumor growth (Figure 7A). Moreover, FACS analysis revealed that adoptive transfer of Tregs (but not Tconvs) inhibited the capacity of the combined treatment to induce TRAIL expression on CD11b+ TIDCs (Figure 7B). Finally, in vivo inhibition of TIDC-mediated cytotoxicity using systemic injection of TRAIL blocking mAb or intratumoral injection of Z-VAD-fmk could blunt the antitumor effects of the combined treatment in immunocompetent mice (Figure 7C).

**Discussion**

The present study demonstrates that mouse CD11b+ TIDCs and conventional mouse and human DCs could be rendered cytotoxic against tumor cells through induction of TRAIL expression. This cytotoxic property is induced by BCG, which activates TIDCs through TLR, and is tightly controlled by Tregs.

BCG is a consensual treatment of superficial bladder cancer (29), and its use as an adjuvant treatment reduces the rate of recurrence after colon cancer surgery (30). BCG modifies the immune response in vivo. Interestingly, our results highlight the role of Tregs in the regulation of TRAIL expression on TIDCs and their subsequent antitumor effects, which may have implications for the targeting of Tregs in immunotherapy strategies.
response through its effect on TLR2, TLR4 (25), and TLR9 (26) and induces IFN-γ production in human DCs via TLR2 (31). Some reports demonstrated that BCG could induce TRAIL expression on human neutrophil cell surface (32), and high TRAIL protein levels in the urine of bladder cancer patients treated with BCG were associated with a favorable response to treatment (33). TRAIL expression on human plasmacytoid DCs or Mo-DCs was described after TLR7 triggering or IFN-α stimulation, respectively (34, 35).

In mice, BCG or TLR2 or TLR4 ligands were shown to induce TRAIL expression at the surface of peritoneal macrophages (36). Here we show for what we believe to be the first time that BCG induces TRAIL expression at the surface of mouse CD11b+ TIDCs and conventional DCs. We also demonstrate that human Mo-DCs also express TRAIL upon BCG stimulation and then kill colon carcinoma and melanoma cell lines in a TRAIL-dependent manner.

We previously demonstrated that Tregs controlled NK cell cytotoxicity in mouse and human tumor settings (20, 42). Tregs were also involved in the control of the cytotoxic functions of classical CTL (19) but, to the best of our knowledge, no studies on the ability of Tregs to alter the killing potential of DCs were previously carried out. Here, by performing CTX-induced Treg depletion and an adoptive transfer of Tregs, we delineate another mechanism used by Tregs to mediate immunosuppression. While up to now Tregs were only known to affect DC maturation, to our knowledge we are the first to demonstrate that Tregs can control the cytotoxic effect of TIDCs and conventional DCs. The mechanism by which Tregs inhibit DC cytotoxicity remains to be discovered. Many potential mechanisms by which Tregs mediate their function have been described (43). However, it is noteworthy that among all the described Treg inhibitory mediators only TGF-β was reported to possess an inhibitory effect on TRAIL expression. Indeed, the cytotoxicity of other killer cells such as NK cells and IKDCs is mainly dependent on TRAIL and could be blunted by TGF-β (44, 45). We can therefore hypothesize that Treg membrane-bound TGF-β could blunt DC cytotoxicity as previously reported for NK cells (20, 46).

The ability of DCs to foster antitumoral immunity by triggering tumor cell death is an emerging concept (47, 48). Rat splenic and BM-derived DCs can trigger tumor cell lysis in vitro through NKR-P1 and nitric oxide production, respectively.
Figure 6
Tregs are selectively killed by CTX and prevent TRAIL-dependent cytotoxicity of TIDCs. (A) FACS analysis of CD4+CD25+ (Treg) cells in the CD3+CD4+CD127− tumor-infiltrating T cell subsets. The percentage of Tregs and dead cells in tumors were determined by DAPI labeling 2 days after CTX injection. Numbers indicate the percentage of cells ± SD. (B) The day of the first BCG injection, 2 groups of mice were adoptively transferred with 1 × 10^6 Tregs or 1 × 10^6 CD4+CD25− (Tconv) cells (n = 5 in each group). (C) CD11b+ TIDCs from untreated CT26 tumor-bearing mice were incubated overnight with BCG and with Tregs or Tconvs at a ratio 1:1. TRAIL expression was determined by FACS analysis. (D) Same experiment as in C but using mouse BM-DCs instead of CD11b+ TIDCs. (E) Same experiment as in D but in some wells DCs were separated from T cells by a 0.4-μm Transwell insert. TRAIL and GAPDH mRNA levels were determined by quantitative RT-PCR on CD11c cells sorted by magnetic isolation. BM-DCs incubated with IFN-γ represent a positive control of TRAIL mRNA expression. Each value is expressed as fold increase from medium control after normalization with GAPDH. (F) CD11b+ TIDCs from untreated CT26 tumor-bearing animals were incubated overnight with BCG and with Tregs or Tconvs at a ratio 1:1. Then these cells (5 × 10^4 cells) were cultured with 1 × 10^4 CT26 cells for 48 hours. TIDC cytotoxicity on CT26 cells was determined using crystal violet staining. (G) Same experiment as in F but using mouse BM-DCs instead of CD11b+ TIDCs and M45 melanoma cells instead of CT26 cells. Values from 1 experiment out of 2 represent mean ± SEM. *P < 0.05.
Human cord blood CD34+ (51) and peripheral blood CD14+ -derived DCs (52) could also exert cytotoxic effects in vitro. Tumor-infiltrating cells with NK functions and DC markers called IKDCs were demonstrated to kill tumor cells through TRAIL and control tumor growth, although in contrast to conventional DCs and TIDCs described in our study, their ability to act as professional APCs and to induce a strong Th1 polarization remains to be established (23, 24, 53–55). Here cytotoxic TIDCs are capable of antigen presentation as they were able to upregulate MHC-II and costimulatory molecules upon the combined treatment and to prime naive T cells.

In conclusion, this report emphasizes the remarkable efficacy of a combination of CTX and BCG in treating colon carcinomas in 2 rodent models. These findings illustrate 2 steps that are required for achieving eradication of established tumors by immunotherapy. The first step is to relieve the immune system from the tumor-dependent immune tolerance mediated by Treg, which prevents the development of an efficient antitumor immune response. The second step is the activation of the immune response. Implementing this strategy in the clinic may represent a new challenge for the next years. By acting directly on CD11b+ TIDCs through their TLRs, BCG intratumoral injections may achieve their activation, making these cells cytotoxic against tumor cells and able to acquire antigen-presenting function. We propose that Treg depletion followed by activation of TIDCs to transform them into tumor cell killers and efficient APCs might be a new and powerful way to build vaccine against established tumors.

Methods

Animals. Inbred BD-IX strain rats, used at 10–12 weeks of age, were bred at Centre de Zootechnologie. BALB/c (H-2d) mice were purchased from Janvier and male nude swiss mice were obtained from the animal facility of the Gustave Roussy Institute and used at 8–12 weeks of age. Tlr4−/−, Tlr2−/−, Trif−/−, and Myd88−/− mice (backcrossed 10 times on a BALB/c background) were provided by Grégoire Lauvau. Animal use and handling were approved by the Comité régionale d’éthique animale, Dijon, France, and experiments were performed following European laws for animal experimentation.

Cell lines. PROb cells were established from a 1,2-dimethylhydrazine–induced colon carcinoma in BD-IX rats (56). PROb cells transfected with a cDNA encoding H2B-GFP (BD) were obtained after selection with blasticidine (20 μg/ml; Invitrogen). Mouse CT26 colon and TS/A mammary adenocarcinoma cancer cell lines and rat PROb and G1V1A1 glioma cell lines were cultured at 37°C under 5% CO₂ in RPMI 1640 complete medium. Jurkat cells were obtained from ATCC (catalog no. TIB-152; ATCC) and stably transfected with Foxp3 full-length cDNA plasmid, which was kindly provided by Steven Ziegler (Benaroya Research Institute, Seattle, Washington, USA). Human HCT116 colon carcinoma, Jurkat leukemia cells, and melanomas (Beur, M45, and M110; kindly
Tumor models and immunotherapy. PROb tumors and CT26 tumors were obtained by subcutaneously injecting 1 × 106 cells in the thoracic wall of BD-IX rats and 5 × 104 cells in the flank of BALB/c mice. One i.p. injection of CTX (Sigma-Aldrich) was performed at 30 mg/kg body weight on day 28 for rats and 100 mg/kg body weight on day 7 for mice after tumor cell injection. Then rats received, and 14 days later, 2 intratumoral injections of 8 × 106 CFU of BCG (Pasteur-Merieux) while mice received, 2 and 7 days later, 2 intratumoral injections of 8 × 106 CFU of BCG in 100 μl of isotonic NaCl solution. Control groups of tumor-bearing rats and mice received CTX alone, BCG alone, or saline injections. In vivo blockade of TRAIL was performed by injecting mice i.p. 3 times a week with 250 μg of a neutralizing TRAIL-specific antibody (clone N2B2) obtained from H. Yagita (Juntendo University School of Medicine) (57). Intratumoral injections of Z-VAD-fmk (10 μl of a 100 μM solution), a pan-caspase inhibitor, were performed twice. TLR9 from wild-type mice was blocked by 3 weekly i.p. injections of 50 μg of IRS 954, an immunoregulatory DNA sequence inhibitor kindly provided by F.J. Barrat from Dynavax Technologies, Berkeley, California, USA (58).

Lymphocyte and TIDC isolation. Tregs (CD4CD25) or Tconvs (CD4CD25) were isolated from the spleen of CT26 tumor-bearing mice using a magnetic bead selection (Miltenyi Biotec) according to the manufacturer’s protocol. About 90% of the positively selected Tregs were CD4CD25 based on FACs analysis. Tregs were incubated overnight with 5 μg/ml of anti-CD3 and anti-CD28 mAbs, 100 μl/ml of IL2, and 1 ng/ml of TGF-β. Tconvs were cultured in a similar way without TGF-β. For tumor-infiltrating cell isolation, tumors were mechanically dissociated, then incubated 2 times with 0.5 mg/ml collagenase (Sigma-Aldrich) for 30 minutes at 37°C on a rocking platform. Populations of TIDCs and CD8+ T cells were either enriched using anti-CD11c or anti-CD8 microbeads according to the manufacturer’s protocol (Miltenyi Biotec) or sorted on a MoFlo instrument (Dako) after staining for CD45, CD11c, CD11b, and MHC-II. The purity of cell preparation exceeded 90% when cells were sorted and 70% when they were magnetically selected, based on flow cytometry analysis.

Immunofluorescence staining and flow cytometry. We purchased all mouse antibodies (Percp anti-CD8e, APC anti-CD11c, FITC anti-I-A/I-E, FITC anti-CD11b, FITTC anti-Gr1, APC-Cy7 anti-B220, FITC anti-CD19, PE anti-CD4, PE anti-CD80, PE anti-CD86, APC anti-CD3, PE-Cy7 anti-CD4, PE anti-CD25, FITC anti-CD127), from BD Biosciences — Pharmingen, except PE anti-TRAIL and PE-Cy7 anti-CD11c, which were purchased from eBioscience. Anti-NKp46 antibody was kindly provided by E. Vivier (CIIML, Marseille, France). Human PE anti-TRAIL and PE-Cy7 anti-CD11c were from eBioscience and BD Biosciences — Pharmingen, respectively. We incubated cells with antibodies for 30 minutes at 4°C and after a wash step we analyzed them with an LSRII (BD) and a FACS Diva software (BD). DAPI (Sigma-Aldrich) was added immediately before acquisition to exclude dead cells in tumors. We analyzed data with FlowJo 7.2 software (Tree Star Inc.).

Tumor immunohistochemical analysis. PROb tumors from treated rats were surgically removed, embedded in Tissue-Tek (Miles Inc.), and snap-frozen in methylbutane cooled in liquid nitrogen. Frozen sections (10μm) were thawed, fixed in acetone at 4°C, and incubated with various specific mAbs obtained from Serotec or BD Biosciences — Pharmingen as previously described (59).

BM- and Mo-DC generation and TLR ligand stimulation. Murine BM-DCs were propagated as already described (37) in Iscove’s medium (Sigma-Aldrich) containing 5% of supernatant from J558 cell culture and used when the proportion of DCs within the culture was above 75% as determined by CD11c and MHC-II labeling. TLR ligands, such as Pam3CSK4 (10 μg/ml; Invivo- gen), LPS (1 μg/ml; Sigma-Aldrich), poly(I-C) (5 μg/ml; Sigma-Aldrich), Cpg 1668 (5 μg/ml; MWG Biotech), were incubated overnight with BM-DCs or TIDCs. Human monocytes (CD14+), Tregs (CD4+CD25+CD127+), and Tconvs (CD4+CD127+) were isolated by sorting PBMCs of healthy volunteers on a MoFlo instrument (Dako) after staining with the following mAbs: FITC anti-CD127 (eBioscience), PE anti-CD25 (Miltenyi Biotec), PE-Cy7 anti-CD4 (BD Biosciences — Pharmingen), and APC anti-CD14 (BD Biosciences — Pharmingen). All donors gave written informed consent. The purity of each cell population was about 90%. CD14+ cells were cultured for 4 days with GM-CSF (1,000 U/ml; R&D Systems) and IFN-γ (1,000 U/ml; Introna Schering Plough), and Tregs and Tconvs were maintained in vitro with 1 CD3/CD28 bead (Dynal Biotech ASA) per T cell, 100 μl of IL-2, and 5 ng/ml of TGF-β for Trex culture.

TRAIL expression by quantitative RT-PCR. RNA isolation from BM-DCs was performed with the RNeasy Mini kit (Qiagen) following the manufacturer’s recommendations. Total RNA (500 μg) was reverse-transcribed in a 20 μl volume reaction. The cDNAs were then diluted 1:20 in nuclease-free water. cDNAs equivalent to 6.25 ng total RNA were used to carry out PCR for TRAIL, with ready to use Gene Expression Product (Applied Biosystems) in a unique PCR master mix (Applied Biosystems). Quantitative PCR was developed on an ABI Prism 7700 Sequence Detector (Applied Biosystems). For each experiment, amplification of GAPDH cDNA was carried out simultaneously as an endogenous control of the total RNA quantity in the reaction. We incubated BM-DCs overnight with 1,000 U/ml of IFN-γ (eBioscience) as a positive control of TRAIL mRNA expression (60).

Cytotoxicity assays. Human, rat, or mouse isolated DCs were mixed with target cells at different effector/target ratios in a 96-well plate in triplicates. After a 48-hour mixed culture, live tumor cells were killed after a crystal violet incubation as previously reported (59). Caspase-dependent cytotoxicity was evaluated by adding Z-VAD-fmk to a final concentration of 100 μM in wells. Mechanisms of TRAIL, Fas ligand, perforin, or NO-dependent cytotoxicity were appreciated by adding mouse neutralizing anti-TRAIL (10 μg/ml; clone N2B2), anti-Fas ligand (10 μg/ml; eBioscience), or isotype controls (10 μg/ml) human anti-TRAIL (50 ng/ml; Abcam) or isotype control (50 ng/ml); and concanamycin A (100 nM; Sigma-Aldrich) or l-NMMA (1 mM; Sigma-Aldrich) in triplicate wells.

For the chromium release assay, cell cytotoxicity was measured in a standard 6-hour 51Cr release assay at 37°C. Specific cytotoxicity was calculated as percentage 51Cr release = 100 × (cpm experimental – cpm spontaneous release)/(cpm maximum release – cpm spontaneous release). For annexin V/7-aminomethylcoumarin D (7-AAD) labelling, spontaneously detached cells or adherent cells collected after detachment with trypsin and EDTA were incubated 15 minutes with annexin V-PE (BD Biosciences — Pharmingen) at 20°C, then stained 10 minutes with 7-AAD (BD Biosciences — Pharmingen), and then analyzed by flow cytometry.

Priming and vaccination by TIDCs. To study the capacity of TIDCs to prime T cells, 5 × 104 purified CD11b+ TIDCs were injected into the footpad of mice and 5 days later draining popliteal lymph nodes were harvested, seeded in 96 U-well plates (5 × 104 cells per well), and restimulated with killed CT26 for 3 days before the collection of the supernatants. Rat TIDCs (105 cells) were incubated 2 days with 104 lymphocytes isolated from the spleen of rats immunized against killed PROb cells as previously described (18). IFN-γ production was measured in the supernatants by ELISA (OptEIA ELISA Kit; BD Biosciences). The ability of TIDCs to immunize mice was studied by injecting 3 × 106 CD11b+ TIDCs into the footpads of mice and by challenging these animals 7 days later with 5 × 104 CT26 cells. After 20 days, mice were challenged with the same amount of TSA/irrelevant syngeneic cells. Vaccination of rats was studied by injecting 5 × 104 TIDCs into footpads and by challenging these animals 7 days later with 106 PROb cells or G1V1A1 irrelevant syngeneic cells.
Cancer


1. Cai, X.Y., et al. 2006. Dendritic cell infiltration and animal facility for help in breeding transgenic mice. We received grant support from Fondation pour la Recherche Médicale (to S. Roux and L. Apetoh), Association pour la Recherche contre le Cancer (to G. Mignot), and Institut National de la Santé et de la Recherche Médicale (to F. Ghihringhelli). This work was supported by special grants from the Ligue contre le Cancer de Bourgogne and the Association pour la Recherche contre le Cancer.

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1. Cai, X.Y., et al. 2006. Dendritic cell infiltration and animal facility for help in breeding transgenic mice. We received grant support from Fondation pour la Recherche Médicale (to S. Roux and L. Apetoh), Association pour la Recherche contre le Cancer (to G. Mignot), and Institut National de la Santé et de la Recherche Médicale (to F. Ghihringhelli). This work was supported by special grants from the Ligue contre le Cancer de Bourgogne and the Association pour la Recherche contre le Cancer.
M.C. 1997. Rat spleen dendritic cells express natural killer cell receptor protein 1 (NKR-P1) and have cytotoxic activity to select targets via a Ca2+-dependent mechanism. J. Exp. Med. 186:467–472.