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DESCRIPTION

Description

FIELD OF THE INVENTION

[0001] The present invention relates to the fields of life sciences and medicine. Specifically, the invention relates to cancer therapies of humans.

BACKGROUND OF THE INVENTION

[0002] Novel therapies are constantly developed for cancer treatment. Adoptive cell therapies (ACT) are a potent approach for treating cancer but also for treating other diseases such as infections and graft versus host disease. Adoptive cell transfer is the passive transfer of ex vivo grown cells, most commonly immune-derived cells, into a host with the goal of transferring the immunologic functionality and characteristics of the transplant. Adoptive cell transfer can be autologous, as is common in adoptive T-cell therapies, or allogeneic as typical for treatment of infections or graft-versus-host disease. Clinically, common embodiments of this approach include transfer of either immune-promoting or tolerogenic cells such as lymphocytes to patients to either enhance immunity against viruses and cancer or to promote tolerance in the setting of autoimmune disease, such as type I diabetes or rheumatoid arthritis.

[0003] With regard to cancer therapy, the ACT approach was conceived in the 1980s by a small number of groups working in the US, one of the leading group being Steven Rosenberg and colleagues working at the NCI. The adoptive transfer of autologous tumor infiltrating lymphocytes (TILs) or genetically re-directed peripheral blood mononuclear cells has been used to successfully treat patients with advanced solid tumors such as melanoma as well as patients with CD19-expressing hematologic malignancies. In ACT, the most commonly used cell types are the T-cells, sometimes sorted for CD8+, but other variations include CD4+ cells, NK-cells, delta-gamma T-cells, regulatory T-cells and peripheral blood mononuclear cells. Cells can be unmodified such as in TIL therapy or genetically modified. There are two common ways to achieve genetic targeting of T-cells to tumor specific targets. One is transfer of a T-cell receptor with known specificity (TCR therapy) and with matched human leukocyte antigen (HLA, known as major histocompatibility complex in rodents) type. The other is modification of cells with artificial molecules such as chimeric antigen receptors (CAR). This approach is not dependent on HLA and is more flexible with regard to targeting molecules. For example, single chain antibodies can be used and CARs can also incorporate costimulatory domains. However, the targets of CAR cells need to be on the membrane of target cells, while TCR modifications can utilize intracellular targets.

[0004] For the first decade of ACT development, the focus was on TILs. TILs are found in tumors, suggesting that tumors trigger an immune response in the host. This so-called tumor immunogenicity is mediated by tumor antigens. These antigens distinguish the tumor from healthy cells, thereby providing an immunological stimulus.

[0005] For example, US2003194804 A1 describes a method for enhancing the reactivity of a T cell toward a tumor cell by utilizing TILs. In US2003194804 A1 the T cells are exposed to an agent and re-introducing into the patient. The agent is capable of reducing or preventing expression or interaction of an endogenous Notch or Notch ligand in the T cell.

[0006] US5126132 A describes a method of treating cancer, wherein an effective amount of autologous TILs and a cytokine are used.

[0007] Diaz RM et al. (Cancer Res. 2007 Mar 15;67(6):2840-8) describe an increase of the circulating levels of tumor antigen-specific T cells by using adoptive T cell transfer therapy in combination with vesicular stomatitis virus intratumoral virotherapy. Diaz et al. used OT1 cells i.e. an artificial monoclonal cell line in adoptive T cell transfer therapy.

[0008] CN102154213 describes an oncolytic adenoviral vector comprising the sequence encoding the Interleukin-2 (IL-2) as therapeutic product, for its use in the treatment of cancer.

[0009] Ellebaek et al. (Journal of Translational Medicine, Biomed Central; 21 August 2012; 10(1):169) discloses the combination of IL-2 together with a separate adoptive cell therapy, by subcutaneous administration of Interleukin-2 (IL-2) and intravenous infusion of separate adoptive cell therapy (ACT).

[0010] CA2423091 describes the delivering of TNF-alpha and Interleukin-2 (IL-2) to tumors using an adenovirus for selective destruction of the tumor.

[0011] While even in early trials of ACTs there were dramatic examples of treatment benefits, and even cures, most patients did not benefit and many patients experienced severe side effects. During the first two decades of adoptive cell therapy, safety of cell transfer *per se* was generally good, but significant toxicities and even mortality was associated with the concomitant treatments used to enhance the therapy, including preconditioning chemotherapy and radiation, and the IL-2 used after transfer. Preconditioning is used to kill suppressive cells such as regulatory T-cells and myeloid derived suppressors in the host, to modulate the tumor microenvironment and to "make room" for the graft. IL2 is used post-transfer to reduce anergy of the graft and to propagate it.

[0012] With regard to efficacy, room is left for improvement. Increased specificity and sufficient tumor killing ability of cell therapies in general are warranted. In particular, in the ACT of the prior art the transferred cells fail to traffic to tumors, and even if they do, they often quickly become anergic, are otherwise unable to kill tumor cells or fail to propagate resulting in a rapid decline of cell numbers. Furthermore, cancers frequently down-regulate human leukocyte antigen (HLA) - known as major histocompatibility complex in animals - in tumor cells, thus resulting in inability of T-cells to kill, as HLA is required for presentation of tumor epitopes to the T-cell receptor.

BRIEF DESCRIPTION OF THE INVENTION

[0013] An object of the present invention is to provide simple methods and tools for overcoming the above problems of inefficient, unsafe and unpredictable cancer therapies. The invention is characterized by what is stated in the independent claims. The specific embodiments of the invention are disclosed in the dependent claims.

[0014] The present application describes construction of recombinant viral vectors.

[0015] The invention is based on the idea of combining oncolytic adenoviral vectors coding for cytokines IL-2 and TNFalphawith adoptive cell therapeutics for cancer treatment in a novel and inventive way. The invention is based on surprising effects, i.e. the following improvements in adoptive T-cell therapy: i) recruitment of transferred cells to the tumor, ii) propagation of transferred cells at the tumor, iii) enhanced reactivity of transferred cells at the tumor (Figure 20). Indeed, the said combination of viral vectors and cytokines IL-2 and TNFalpha with adoptive cell therapeutics provides more effective results on wider targets than could have been assumed. Effects of the said combination of viral vectors comprising cytokine transgenes IL-2 and TNFalpha with adoptive cell transfer are synergistic compared to the effects of only viral vectors comprising cytokine transgene or only adoptive cell transfers.

[0016] The advantages of the arrangements of the present invention are enhanced therapeutic effect and reduced side effects. Severe adverse events, even deaths are prevented, because enhancements in efficacy, and the antisuppressive effects of our approach, may reduce the need for preconditioning chemotherapy and/or radiation used in the prior art methods to "make room" for transferred cells and reduce tumor immunosuppression. Also, severe adverse events, even deaths are prevented, because separate addition of IL2 used in the prior art methods to propagate and sustain transferred cells after transferring them into a patient is not needed if the virus produces it while replicating in the tumor. Local production at the tumor can also enhance the sought-after effects of IL-2 (stimulation and propagation of the graft) while reducing systemic exposure which is the cause of adverse events.

[0017] Also, the present invention provides surprising therapeutic effects by: i) Providing trafficking signals to the tumor for example by injecting the virus vectors comprising recombinant cytokines IL-2 and TNFalpha into tumor. Virus injection results in production of cytokines IL-2 and TNFalpha relevant for this effect (in reaction to the virus binding to pathogen associated molecular pattern recognition receptors), but much higher effects can be achieved by additional production of cytokines IL-2 and TNFalpha as transgenes from the virus. ii) Reducing tolerance by increasing danger signals. Virus injection *per se* can achieve this by binding to pathogen associated molecular pattern recognition receptors, but the effect can be enhanced by additional production of IL-2 and TNFalpha as a transgenes from the virus. iii) Inducing HLA expression. Virus infection increases HLA expression, since cells attempt to present viral epitopes for mounting an anti-viral T-cell response. Unexpectedly, this can be used to enhance T-cell therapy against tumor epitopes, which requires HLA to work. The effect of the virus on HLA is mediated in part by cytokines IL-2 and TNFalpha; production of said cytokines from the virus can thus induce HLA expression also in nearby tumor cells. iv) Inducing propagation of cells by lifting immunosuppression, mediated by both the presence of the virus *per se* (again through the pathogen associated molecular pattern recognition receptors), but enhanced by production of cytokines (Figure 37). Thus, this approach can solve the critical obstacles currently hindering adaptive cell therapies.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] In the following the invention will be described in greater detail by means of specific embodiments with reference to the attached drawings, in which

Figure 1 shows that treatment with Ad5/3 chimeric oncolytic adenovirus increased cytokine and chemokine secretion in B16-OVA tumors. Interferon-γ can upregulate the expression of HLA (=MHC) class I, thus generating a tumor cell phenotype that can effectively be recognized by TILs. Various IFN-γ inducible chemokines (such as RANTES, MIP-1α and MCP-1) are involved in immune cell recruitment, which might promote TIL activation and proliferation. Also trafficking of TILs can be enhanced by up-regulation of these chemokines.

Figure 2 shows tumor growth control following multiple injections of 5/3 chimeric oncolytic adenovirus with or without adoptive cell transfer. Adenovirus treatment alone (A) had little effect on B16-OVA tumor growth compared to PBS treatment. Adoptive transfer of 500 000 (B) or 2 000 000 (C) tumor-specific OT-I lymphocytes in combination with virus injections resulted in significant tumor growth control. The poor therapeutic effect on tumor growth using adenovirus alone or OT-I cells in combination with PBS highlights the major shortcomings of oncolytic virus and adoptive cell transfer therapies used as single agents, supporting the purpose of the invention to enhance efficacy of adoptive cell therapy using adenovirus.

Figure 3 shows that adenovirus injections induce T cell trafficking into tumors, and increase proliferation of adoptively transferred T cells in tumors. A) Amount of adoptively transferred CD8+ CFSE+ cells increased in tumors and decreased in blood, draining lymph nodes and spleen of Ad treated mice at day 1 post-treatment, purportedly due to lymphocyte trafficking. The overall CD8+ T-cell count remained high in the adenovirus treated tumors throughout the experiment, suggesting resistance of these cells to the deleterious tumor microenvironment and/or increased proliferation of the CD8+ T cells. B) On days 6 and 14 the OT-I cell proliferation was enhanced in the Ad treated tumors when compared to the PBS group, seen as a greater fraction of cells that have undergone cell division (moved toward M7) than in the

PBS group. Consequently, treatment with oncolytic adenovirus induces trafficking and proliferation of adoptively transferred TILs. C) Example on how gating of CFSE-positive cells was done. M0 indicates cells that have not divided, M7 shows cells that have divided enough to dilute CFSE to below detectable limits (more than 7 times).

Figure 4 reveals data from humans treated with oncolytic adenovirus on days indicated by arrows. Virus injection into tumor resulted in a decrease of lymphocytes in blood, reflecting their trafficking to tumors.

Figure 5 reveals data that oncolytic adenovirus injection into a tumor of a human cancer patient caused influx of CD8+ T cells. Intratumoral injection of oncolytic adenovirus results in accumulation of CD8+ T-cells at the tumor assessed from needle biopsies before and after treatment.

Figure 6 shows results of adenovirus injections combined with adoptive transfer of T cells. Mice with subcutaneous B16-Ova tumors were adoptively transferred with 5×10^5 OT1 lymphocytes intraperitoneally and tumors were left untreated, or injected with PBS or Ad5/3 (see Examples Materials and methods). In an immunosuppressive B16-Ova model similar to human melanoma, adoptive transfer of anti-Ova OT1 cells does little. Adding virus injections increases efficacy dramatically (a). CD8+ T-cells increase (b). These cells are not anti-Ova T-cells (c).

Figure 7 reveals dramatic increase in the number of "natural" anti-tumor T-cells due to adoptive transfer and virus injection. Mice with subcutaneous B16-Ova tumors were adoptively transferred with 5×10^5 OT1 lymphocytes intraperitoneally and tumors were left untreated, or injected with PBS or Ad5/3 (see Examples Materials and methods). Adoptive transfer + virus injections acts act as catalyst for propagation of "other" T-cells at tumor and local lymph nodes. (a) Trp2 CD8+ cells at the tumor site. (b) Anti-gp100 CD8+ cell at the tumor site.

Figure 8 shows activated CD8+ cells in tumor and TIM-3 expression in the tumor on day 14. Mice with subcutaneous B16-Ova tumors were adoptively transferred with 5×10^5 OT1 lymphocytes intraperitoneally and tumors were left untreated, or injected with PBS or Ad5/3 (see Examples Materials and methods). Immunosuppression in immunotherapy: increase in T-cell number is not enough if immunosuppression is not removed. There are more activated T-cells in virus treated tumors and less immunosuppression.

Figure 9 shows that increase in anti-tumor T-cells and reduction of immunosuppression results in systemic immunity against tumor antigens. Mice with subcutaneous B16-Ova tumors were adoptively transferred with 5×10^5 OT1 (a) or 2×10^6 (b) OT1 lymphocytes intraperitoneally and tumors were left untreated, or injected with PBS or Ad5/3 (see Examples Materials and methods). Antigen presentation is enhanced by virus: T-cells work better. Systemic immunity against several tumor epitopes results. (a) expression of co-stimulatory molecules on dendritic cells (CD11 c+ CD80+ CD86+) in the tumor on day 14. (b) IFNg ELISPOT with splenocytes on day 14.

Figure 10 shows distribution of OTI T-cells following virus injection: trend for trafficking but not enough to explain efficacy. (a) diagram, (b) animal model, (c) tumor.

Figure 11 reveals that lifting immunosuppression can induce propagation of cells. Adenovirus treated tumors contained more tumor specific lymphocytes (OT-I cells). In PBS treated tumors OTI cells had arrested in M5 phase (left arrow), while in the Ad group they continued to proliferate (right arrow).

Figure 12 shows efficacy of recombinant cytokines (no virus) in combination with OT1 cells.

Figure 13 shows antitumor efficacy of cytokine-armed adenoviruses combined with adoptive T-cell transfer. C57BL/6 mice bearing subcutaneous B16-OVA melanoma tumors were treated with 1.5 × 10e6 CD8+ enriched OT-1 T-cells interaperitoneally on Day 1. Cytokine-coding adenoviruses or control virus Ad5-Luc1 were injected intratumorally on Day 1 and weekly thereafter (1 × 10e9 viral particles per tumor). Tumor volume was calculated as previously described (Bramante et al. Serotype chimeric oncolytic adenovirus coding for GMCSF for treatment of sarcoma in rodents and humans. Int J Cancer. 2013 Dec 24) and tumor sizes are indicated as percentage respective to Day 1, which was set as 100%. Number at risk figure: Number of animals remaining in each experimental group at a given timepoint. Animals were humanely sacrificed when the tumors had exceeded the maximum acceptable size or when any signs of pain or distress were evident.

Figure 14 shows effects of different viruses on tumor size.

Figure 15 shows excellent results of adenoviral vectors comprising mTNFa transgene in combination with OT1 T-cells on reducing the tumor size.

Figure 16 shows excellent results of adenoviral vectors comprising mIL3 transgene in combination with OT1 T-cells on reducing the tumor size.

Figure 17 shows a schematic of C5a or TNF-α expressing oncolytic adenoviruses. Shown are some important features of the viruses, including the site where the transgenes are inserted.

Figure 18 shows expression of TNF-α by oncolytic adenovirus in A549 cells. Cells were infected with 10 VP/cell, media was collected at indicated time points and ELISA was used to assess the amount of TNF-α in the media. Virus induces expression and secretion of TNF-α from infected cells.

Figure 19 shows biological activity of TNF-alpha produced by oncolytic TNF-alpha-armed oncolytic adenovirus. In this assay, supernatant from infected cells was used to challenge TNF-sensitive WEHI-13VAR cells, corroborating that oncolytic adenovirus drives expression of functional cytokines.

Figure 20 shows dose-dependent killing of human cancer cells by oncolytic adenovirus. As expected, in TNF-alpha insensitive oncolysis permissive human A549 or PC3 tumor cells, no difference was observed between unarmed control virus and TNF-alpha-expressing oncolytic adenovirus, as mere oncolysis was sufficient to kill cells. However, because human TNF-alpha is partially active in mouse cells, which are not permissive to oncolysis by human adenovirus, TNF-alpha contributed to the stronger cytotoxicity of the virus seen in B16-OVA mouse cells compared to unarmed virus. Replication-defective virus shows negligible cell-killing capacity.

Figure 21 shows that radiation therapy synergizes with TNF-alpha expressing virus. A) A schematic of the treatment schedule in this experiment. Radiation (XRT) was whole body irradiation at a dose of 2 X 2Gy and virus was 1 × 10^8 VP/tumor, where each nude mouse carried two A549 xenografts. B) TNF-alpha virus harbors greater anti-tumor potency than the unarmed parental virus. Because replication-defective (RD) virus did not kill A549 cells in culture (Figure 20), the anti-tumor effect afforded by RD virus in vivo is likely due to innate immune responses, including cytokines, NK cells and macrophages, elicited by virus injections. C) TNF-alpha-expressing virus causes greater anti-tumor effects when combined with clinically relevant doses of external beam irradiation, supporting the clinical translatability of cytokine-armed viruses. Importantly, these and previous experiments indicate that TNF-alpha-expressing oncolytic adenovirus is capable of replicating and killing cells, arguing that TNF-alpha does not exert antiviral effects against adenovirus.

Figure 22 shows anti-tumor efficacy of hTNF-alpha-encoding adenovirus on B16-OVA tumors. This experiment is analogous to the one depicted in Figure 26 with C5a virus, demonstrating that TNF-alpha-expression confers greater therapeutic advantage compared to unarmed virus.

Figure 23 shows enhanced induction/expansion of tumor-specific CD8+ T cells in tumors treated with cytokine armed virus (II). Tumors in the experiment depicted in Figure 20 were excised and processed for flow cytometric analysis, similar to as in Experiment 11. A greater induction/number of OVA-specific CD8+ T cells was detected in tumors treated with the TNF-encoding virus compared to unarmed control virus, suggesting together with C5a data that rationally selected cytokines expressed by oncolytic adenovirus together with the virus-induced inflammation make a unique tumor milieu that strongly supports expansion and activation of tumor-specific T cells-by inferral and comparison to Figures 2B,C also of adoptively transferred T cells.

Figure 24 shows expression of C5a in A549 cells. Cells were infected with 10 VP/cell, media was collected at indicated time points and ELISA was used to assess the amount of C5a in the media. Results of two individual experiments are shown.

Figure 25 shows results of an in vitro chemotaxis assay. The amount of THP1 human monocytes passing through a semi-permeable membrane into the lower chamber, as attracted by chemokines in the test supernatants, was quantified as per manufacturer's instructions (Millipore QCM kit). C5a-expressing virus elicits stronger chemoattractive factors from infected cells than control virus. Results argue in favor of using cytokine-armed virus rather than unarmed virus.

Figure 26 shows anti-tumor efficacy of AdD24-C5a in vivo. Established subcutaneous tumors were injected on day 0, 2 and 4 with 1 × 10^9 VP of each virus or with 50 ul PBS and tumor volumes were measured by caliper. C5a-expressing virus affords superior tumor control compared to control virus. As adenovirus does not replicate in or kill mouse cells, i.e. it is non-cytolytic in this model (Young AM et al. Mol Ther. 2012 Sep;20(9):1676-88, PMID: 22735379), these results underscore the robust ability of the cytokine-armed virus to enhance immunological anti-tumor effects, strongly supporting the concept of using it to enhance efficacy of adoptive cell therapy.

Figure 27 shows enhanced induction/expansion of tumor-specific CD8+ T cells in tumors treated with cytokine armed virus (I). Tumors in experiment depicted in Figure 26 were excised and processed for flow cytometric analysis. Single cell suspensions were stained with antibody against CD8 and with pentamer against anti-ova TCR. C5a-expression by non-cytolytic adenovirus induces greater OVA-specific CD8 T cell numbers in tumors compared to control viruses, unarmed adenovirus or virus expressing C5a antagonist, supporting the use of cytokine-armed virus to increase numbers of adoptively transferred T cells in tumors. Also see experiment 13.

Figure 28 shows a schematic of the adaptive T-cell response.

Figure 29 shows that adaptively transferred T-cells act as a catalyst ("spark") for pre-existing T-cells.

Figure 30 shows that adaptive "spark" results in increase in "natural" anti-tumor T-cells.

Figure 31 shows the method of adoptive cell transfer.

Figure 32 shows that with TILT technology of the present invention, toxic preconditioning (chemo+radiation) and post-conditioning (systemic IL2) can be avoided. (For mechanisms of TILT technology see Figure 37.)

Figure 33 shows a schematic of the new virus constructs expressing a single cytokine. The virus backbone is human adenovirus serotype 5, apart from the fiber knob, which is from serotype 3. Both single and double transgenes are under transcriptional control of the virus E3 promoter. Both transgenes are placed into the E3 region which is deleted for *gp19k* and *6.7k.* The E1A protein is deleted for 24 amino acids ("D24"), in constant region 2, rendering Rb binding defective. E1A expression is under regulation of the E2F promoter. Some virus gene regions are shown for reference.

Figure 34 shows a schematic of the new virus constructs expressing two cytokines. In one version, `ribosome shunt site'/'ribosome skipping site'/'cis-acting hydrolase element' (CHYSEL) is placed as in-frame fusions between each cytokine. The cytokine inserts will be synthesized as a single polyprotein that is co-translationally cleaved to yield both sytokines, resulting in addition of several additional amino acids at the 3' end of the first cytokine, and a single proline at the 5' of the latter cytokine, IL2). In another version, an IRES element separates the two cytokines, resulting in synthesis of cytokines with no additional amino acids.

Figure 35 shows nucleotide and amino acid sequences of 2A.

Figure 36 shows TILT Biotherapeutics intravenous adenovirus delivery technology. TILT adenoviruses descibed above will be given intratumorally to patients to enhance T-cell therapy (marked 4a, 5a). However, not all tumors can be reached through the intratumoral route. Thus, we have developed an Ad3 based delivery vehicle which can reach tumors through the intravenous route (marked as 4b, 5b).

Figure 37 shows mechanisms of enhancement of adoptive cell therapy by dual cytokine-expressing virus. Virus infection and innate sensing of virus particles induces danger signals, which includes upregulation of HLA/MHC class I molecules on cancer cells, activation and maturation of antigen presenting cells and secretion of immune cell-recruiting cytokines. Danger signals are further amplified by tumor cell death with oncolytic viruses, which also releases tumor antigens and increases recognition of tumor tissue by the immune system. Viruses express two cytokines: the T cell recruiting cytokine attracts adoptively transferred T cells into the tumor, and the T cell expanding cytokine, in a specific embodiment interleukin 2, increases and maintains their proliferation.

Figure 38 shows schematics of the trafficking experiment with recombinant mouse cytokines. B16-OVA bearing C57BL/6 female mice are adoptively transferred with $2{,}0*10^6$ CD8a+ enriched OT-I lymphocytes (box) i.p. on day 0 and treated with intratumoral injections of recombinant murine cytokines (triangles) on workdays. Tumor growth is monitored and recorded thrice a week (circles) by using electronic calipers. Mice are sacrificed (X) at two different time points (SAC1 and SAC2), tumors are harvested and samples are analyzed using OT-I qPCR and T-cell FACS analysis.

Figure 39 shows schematics of the trafficking experiment with adenoviruses coding for mouse cytokines. B16-OVA bearing C57BL/6 female mice are adoptively transferred with $2{,}0*10^6$ CD8a+ enriched OT-I lymphocytes (box) i.p. on day 0 and intratumorally treated with adenoviruses armed with different mouse cytokines (red triangles) on workdays. Tumor growth is monitored and recorded thrice a week (circles) by using electronic calipers. Mice are sacrificed (X) at two different time points (SAC1 and SAC2), tumors are harvested and samples analyzed using OT-I qPCR and T-cell FACS analysis.

Figure 40 shows schematics of the trafficking experiment with using 111In radiolabeled OT-I cells and SPECT/CT imaging. B16-OVA bearing C57BL/6 female mice are intratumorally injected with 1e9 VP of 5/3 chimeric virus (triangles) on six consecutive days. First group of mice will receive adoptive transfer of $2{,}0*10^6$ CD8a+ enriched, indium oxine labeled OT-I lymphocytes (box) i.v. on day 0 and the other group of mice on day 7. Accumulation of OT-I cells into tumors is quantitated by SPECT/CT imaging (circles). Mice are sacrificed (X) at two different time points (SAC1 and SAC2), tumors are harvested and their final radioactivity is measured.

DETAILED DESCRIPTION OF THE INVENTION

Adoptive cell therapy

[0019] The general approach of the present invention is the development of a treatment for patients with cancer using the transfer of immune lymphocytes that are capable of reacting with and destroying the cancer. Isolated tumor infiltrating lymphocytes are grown in culture to large numbers and infused into the patient. In the present invention adenoviral vectors coding for at least TNFalpha and IL-2 are utilized for increasing the effect of lymphocytes. Separate administrations of an adoptive cell therapeutic composition and adenoviral vectors are frequently preceded by myeloablating or non-myeloablating preconditioning chemotherapy and/or radiation. The adoptive cell therapy treatment is intended to reduce or eliminate cancer in the patient. (Figure 21)

[0020] This invention relates to therapies with an adoptive cell therapeutic composition, e.g. tumor infiltrating lymphocytes, TCR modified lymphocytes or CAR modified lymphocytes. This invention relates to T-cell therapies in particular, but also other adoptive therapies such as NK cell therapies or other cell therapies. Indeed, according to the present invention the adoptive cell therapeutic composition may comprise unmodified cells such as in TIL therapy or genetically modified cells. There are two common ways to achieve genetic targeting of T-cells to tumor specific targets. One is transfer of a T-cell receptor with known specificity (TCR therapy) and with matched human leukocyte antigen (HLA, known as major histocompatibility complex in rodents) type. The other is modification of cells with artificial molecules such as chimeric antigen receptors (CAR). This approach is not dependent on HLA and is more flexible with regard to targeting molecules. For example, single chain antibodies can be used and CARs can also incorporate costimulatory domains. However, the targets of CAR cells need to be on the membrane of target cells, while TCR modifications can utilize intracellular targets.

[0021] As used herein "adoptive cell therapeutic composition" refers to any composition comprising cells suitable for adoptive cell transfer. In one embodiment of the invention the adoptive cell therapeutic composition comprises a cell type selected from a group consisting of a tumor infiltrating lymphocyte (TIL), TCR (i.e. heterologous T-cell receptor) modified lymphocytes and CAR (i.e. chimeric antigen receptor) modified lymphocytes. In another embodiment of the invention, the adoptive cell therapeutic composition comprises a cell type selected from a group consisting of T-cells, CD8+ cells, CD4+ cells, NK-cells, delta-gamma T-cells, regulatory T-cells and peripheral blood mononuclear cells. In another embodiment, TILs, T-cells, CD8+ cells, CD4+ cells, NK-cells, delta-gamma T-cells, regulatory T-cells or peripheral blood mononuclear cells form the adoptive cell therapeutic composition. In one specific embodiment of the invention the adoptive cell therapeutic composition comprises T cells. As used herein "tumor-infiltrating lymphocytes" or TILs refer to white blood cells that have left the bloodstream and migrated into a tumor. Lymphocytes can be divided into three groups including B cells, T cells and natural killer cells. In another specific embodiment of the invention the adoptive cell therapeutic composition comprises T-cells which have been modified with target-specific chimeric antigen receptors or specifically selected T-cell receptors. As used herein "T-cells" refers to CD3+ cells, including CD4+ helper cells, CD8+ cytotoxic T-cells and γδ T cells.

[0022] In addition to suitable cells, adoptive cell therapeutic composition used in the present invention may comprise any other agents such as pharmaceutically acceptable carriers, buffers, excipients, adjuvants, additives, antiseptics, filling, stabilising and/or thickening agents, and/or any components normally found in corresponding products. Selection of suitable ingredients and appropriate manufacturing methods for formulating the compositions belongs to general knowledge of a man skilled in the art.

[0023] The adoptive cell therapeutic composition may be in any form, such as solid, semisolid or liquid form, suitable for administration. A formulation can be selected from a group consisting of, but not limited to, solutions, emulsions, suspensions, tablets, pellets and capsules. The compositions are not limited to a certain formulation, instead the composition can be formulated into any known pharmaceutically acceptable formulation. The pharmaceutical compositions may be produced by any conventional processes known in the art.

Viral vectors

[0024] The oncolytic adenoviral vectors used in the present invention can be any adenoviral vectors suitable for treating a human or animal. In one embodiment of the invention, the adenoviral vectors are vectors of human viruses, and can be selected from a group consisting of Ad5, Ad3 and Ad5/3 vectors. In another embodiment, the vector is Ad5 or Ad5/3 vector.

[0025] As used herein "an oncolytic adenoviral vector" refers to an adenoviral vector capable of infecting and killing cancer cells by selective replication in tumor versus normal cells.

[0026] The vectors may be modified in any way known in the art, e.g. by deleting, inserting, mutating or modifying any viral areas. The vectors are made tumor specific with regard to replication. For example, the adenoviral vector may comprise modifications in E1, E3 and/or E4 such as insertion of tumor specific promoters (eg. to drive E1), deletions of areas (e.g. the constant region 2 of E1 as used in "D24", E3/gp19k, E3/6.7k) and insertion of transgenes. Furthermore, fiber knob areas of the vector can be modified. In one embodiment of the invention the adenoviral vector is Ad5/3 comprising an Ad5 nucleic acid backbone and Ad3 fiber knob or Ad5/3 chimeric fiber knob.

[0027] As used herein, expression "adenovirus serotype 5 (Ad5) nucleic acid backbone" refers to the genome of Ad5. Similarly "adenovirus serotype 3 (Ad3) nucleic acid backbone" refers to the genome of Ad3. "Ad5/3 vector" refers to a chimeric vector having parts of both Ad5 and Ad3 vectors. In a specific embodiment of the invention, the capsid modification of the vector is Ad5/3 chimerism. As used herein, "Ad5/3 chimeric fiber knob" refers to a chimerism, wherein the knob part of the fiber is from Ad serotype 3, and the rest of the fiber is from Ad serotype 5. Specifically, in one embodiment, the construct has the fiber knob from Ad3 while the remainder of the genome is from Ad5. (See figures 17, 33 and 34)

[0028] One approach for generation of a tumor specific oncolytic adenovirus is engineering a 24 base pair deletion (D24) affecting the constant region 2 (CR2) of E1. In wild type adenovirus CR2 is responsible for binding the cellular Rb tumor suppressor/cell cycle regulator protein for induction of the synthesis (S) phase i.e. DNA synthesis or replication phase. The interaction between pRb and E1A requires eight amino acids 121 to 127 of the E1A protein conserved region, which are deleted in the present invention. The vector of the present invention comprises a deletion of nucleotides corresponding to amino acids 122-129 of the vector according to Heise C. et al. (2000, Nature Med 6, 1134-1139). Viruses with the D24 are known to have a reduced ability to overcome the G1-S checkpoint and replicate efficiently only in cells where this interaction is not necessary, e.g. in tumor cells defective in the Rb-p16 pathway, which includes most if not all human tumors. (See figures 17, 33 and 34)

[0029] It is also possible to replace E1A endogenous viral promoter for example by a tumor specific promoter. In a specific embodiment of the invention hTERT promoter is utilized in the place of E1A endogenous viral promoter.

[0030] The E3 region is nonessential for viral replication *in vitro,* but the E3 proteins have an important role in the regulation of host immune response i.e. in the inhibition of both innate and specific immune responses. The gp19k/6.7K deletion in E3 refers to a deletion of 965 base pairs from the adenoviral E3A region. In a resulting adenoviral construct, both gp19k and 6.7K genes are deleted (Kanerva A et al. 2005, Gene Therapy 12, 87-94). The gp19k gene product is known to bind and sequester major histocompatibility complex I (MHC1, known as HLA1 in humans) molecules in the endoplasmic reticulum, and to prevent the recognition of infected cells by cytotoxic T-lymphocytes. Since many tumors are deficient in HLA1/MHC1, deletion of gp19k increases tumor selectivity of viruses (virus is cleared faster than wild type virus from normal cells but there is no difference in tumor cells). 6.7K proteins are expressed on cellular surfaces and they take part in downregulating TNF-related apoptosis inducing ligand (TRAIL) receptor 2. (See figures 17, 33 and 34)

[0031] Both of these deletions provide an advantage. Since we are attempting to regain expression of HLA/MHC for presentation of tumor epitopes to the adoptively transferred T-cells, expression of the gp19k protein is counterproductive and in fact the upregulation of HLA/MHC requires deletion of gp19k. With regard to 6.7k, since an embodiment of our invention is production of TNFalpha and IL-2 from the virus, and one of TNFalpha's anti-tumor activities is a direct anti-tumor proapoptotic effect (on both transduced and non-transduced by-stander cells), the presence of 6.7k is counterproductive.

[0032] In one embodiment of the invention, the TNFalpha and IL-2 transgenes are placed into a gp19k/6.7k deleted E3 region, under the E3 promoter. This restricts transgene expression to tumor cells that allow replication of the virus and subsequent activation of the E3 promoter. E3 promoter may be any exogenous (e.g. CMV or E2F promoter) or endogenous promoter known in the art, specifically the endogenous E3 promoter. Although the E3 promoter is chiefly activated by replication, some expression occurs when E1 is expressed. As the selectivity of

D24 type viruses occurs post E1 expression (when E1 is unable to bind Rb), these viruses do express E1 also in transduced normal cells. Thus, it is of critical importance to regulate also E1 expression to restrict E3 promoter mediated transgene expression to tumor cells.

[0033] In another embodiment of the invention E3 gp19k/6.7k is kept in the vector but one or many other E3 areas have been deleted (e.g. E3 9-kDa, E3 10.2 kDa, E3 15.2 kDa and/or E3 15.3 kDa).

[0034] In a specific embodiment of the invention the oncolytic adenoviral vector is based on an adenovirus serotype 5 (Ad5) nucleic acid backbone comprising a 5/3 chimeric fiber knob, and comprising the following: E2F1 promoter for tumor specific expression of E1A, a 24 bp deletion (D24) in the Rb binding constant region 2 of adenoviral E1, a nucleic acid sequence deletion of viral gp19k and 6.7k reading frames, with a transgene insertion into the deleted region, resulting in replication-associated control of transgene expression under the viral E3 promoter, and a nucleic acid sequence encoding at least IL-2 and TNFalpha transgenes in the place of the deleted adenoviral genes *gp19k/6.7K* in the E3 region (figure 17). In one embodiment of the invention, the adenoviral vector is based on a human adenovirus. (See figures 17, 33 and 34)

[0035] The exact functions of the Early Region (E3) proteins in adenovirus 3 are not known. Generally in adenoviruses they do not seem to impair replication when deleted and they seem to affect anti-viral host response to adenoviruses (Wold et al., 1999). The E3 of the human adenovirus genome contains the highest level of genetic diversity among the six species (A-F) of adenoviruses found in humans. This diversity in genetic content is primarily located between the highly conserved E3-gp19K and E3-RIDα open reading frames (ORFs) where species-specific arrays of genes are encoded (Burgert and Blusch, 2000).

[0036] Cytotoxic T-cell mediated killing of viral-infected cells is modulated by E3-gp19K. This is accomplished by blocking transport of MHC class I to the plasma membrane, and inhibiting the TAP-MHC class I complex formation (Andersson et al., 1985; Andersson et al., 1987; Burgert and Kvist, 2002, Bennet et al., 1999).

[0037] Thus, in one aspect of the invention the important molecule E3-gp19K is comprised in the adenoviral vector to make virus replication more stealty and enable more time for oncolysis and its beneficial effects. Also, retaining E3-gp19K can reduce induction of anti-adenovirus-cytotoxic T-cells, resulting in more anti-tumor T-cells.

[0038] Cytokines participate in immune response by acting through various mechanisms including recruitment of T-cells towards the tumor. The nucleotide sequence encoding a cytokine transgene may be from any animal such as a human, ape, rat, mouse, hamster, dog or cat, but specifically it is encoded by a human sequence. The nucleotide sequence encoding the transgene may be modified in order to improve its effects, or unmodified i.e. of a wild type.

[0039] Particular embodiments of the present invention include viral vectors coding for at least

IL-2 and TNFalpha.

[0040] The viral vectors of the invention may code for two, three, four, five or more cytokines. In one embodiment of the invention the oncolytic adenoviral vector codes for IL-2 and TNFalpha, and a further cytokine or cytokines selected from a cytokine group consisting of interferon alpha, interferon beta, interferon gamma, complement C5a, GMCSF, CD40L, IL12, IL-23, IL15, IL17, CCL1, CCL11, CCL12, CCL13, CCL14-1, CCL14-2, CCL14-3, CCL15-1, CCL15-2, CCL16, CCL17, CCL18, CCL19, CCL19, CCL2, CCL20, CCL21, CCL22, CCL23-1, CCL23-2, CCL24, CCL25-1, CCL25-2, CCL26, CCL27, CCL28, CCL3, CCL3L1, CCL4, CCL4L1, CCL5, CCL6, CCL7, CCL8, CCL9, CCR10, CCR2, CCR5, CCR6, CCR7, CCR8, CCRL1, CCRL2, CX3CL1, CX3CR, CXCL1, CXCL10, CXCL11, CXCL12, CXCL13, CXCL14, CXCL15, CXCL16, CXCL2, CXCL3, CXCL4, CXCL5, CXCL6, CXCL7, CXCL8, CXCL9, CXCL9, CXCR1, CXCR2, CXCR4, CXCR5, CXCR6, CXCR7 and XCL2. The other cytokine functions by attracting and activating the T cells and reducing tumor immunosuppression, while IL-2 induces the propagation of the T-cell graft. Thus, IL-2 is produced locally at the tumor where it is needed, instead of injected systemically as is typically done in T-cell therapy, which can cause side effects, and therefore a major problem of the prior art therapies (i.e. toxicity of systemic IL-2) can be prevented by this embodiment.

[0041] The danger signaling provided by replication of the oncolytic virus, and activation of pathogen associated molecular pattern recognition receptors by viral DNA, together with the action of the transgene(s) may reduce tumor immunosuppression to such degree that preconditioning therapy can be omitted. Consequently, and major issue in prior art, toxicity due to preconditioning chemotherapy and radiation can be avoided.

[0042] In one embodiment of the invention the virus vector comprises an internal ribosomal entry site (IRES) or optionally a ribosome shunt site 2A between the two transgenes IL-2 and TNFalpha. As used herein "IRES" refers to a nucleotide sequence that enables initiation of the translation in the middle of a messenger RNA sequence in protein synthesis. IRES can be from any virus, but in one embodiment of the invention IRES is from encephalomyocarditis virus (EMCV). As used herein "a ribosome shunt site 2A" refers to a translation initiation site in which ribosomes physically bypass parts of the 5' untranslated region to reach the initiation codon. Both the IRES and the A2 enable viruses to produce two transgenes from one promoter (the E3 promoter).

[0043] Schematics of the general layouts of the virus genomes are shown in Figures 17, 33, and 34. Nucleotide sequences of the viral vectors comprising transgenes C5a, hCD40L, hIFNa2, hIFNb1, hIFNg1, hIL2 or TNFalpha are shown in SEQ ID NOs 1-7, respectively (Ad5/3-E2F-D24-transgene). Furthermore, nucleotide sequences of the viral vectors comprising two transgenes, the other one being IL-2 and the other one C5a, CD40L, IFNa2, IFNb, IFNg, GMCSF or TNFalpha, are shown in SEQ ID NOs 8-21 (SEQ ID NO: 8 C5a-2A-IL2, SEQ ID NO: 9 IFNa-2A-IL2, SEQ ID NO: 10 TNFalpha-2A-IL2, SEQ ID NO: 11 CD40L-2A-IL2, SEQ ID NO: 12 IFNb-2A-IL2, SEQ ID NO: 13 GMCSF-2A-IL2, SEQ ID NO: 14 IFNg-2A-IL2, SEQ ID NO: 15 C5a-IRES-IL2, SEQ ID NO: 16 IFNa-IRES-IL2, SEQ ID NO: 17 TNFalpha-

IRES-IL2, SEQ ID NO: 18 CD40L-IRES-IL2, SEQ ID NO: 19 IFNb-IRES-IL2, SEQ ID NO: 20 GMCSF-IRES-IL2, SEQ ID NO: 21 IFNg-IRES-IL2) (Ad5/3-E2F-D24-transgene-IRES/2A-transgene).

[0044] In summary, the key advantages of the present invention utilizing viral vectors comprising at least cytokines IL-2 and TNFalpha as transgenes are: i) the cytokines and virus *per se* cause a danger signal which recruits T cells and other immune cells to tumors, ii) the cytokines induce T cell proliferation both at the tumor and in local lymphoid organs, iii) the cytokines and virus per se are able to induce T cells (both the adoptive T-cell graft and natural, innate anti-tumor T-cells) to propagate at the tumor, iv) the cytokines and virus induce the upregulation of antigen-presenting molecules (HLA) on cancer cells, rendering them sensitive to recognition and killing by T cells, and v) the cytokines and virus replication favorably alter tumor microenvironment by reducing immunosuppression and cellular anergy.

[0045] The viral vectors utilized in the present inventions may also comprise other modifications than described above. Any additional components or modifications may optionally be used but are not obligatory for the present invention.

[0046] Insertion of exogenous elements may enhance effects of vectors in target cells. The use of exogenous tissue or tumor-specific promoters is common in recombinant vectors and they can also be utilized in the present invention.

[0047] In summary, the present invention reveals that the replication of oncolytic virus can recruit T-cells and induce danger signals at the tumor, reducing immunosuppression and cellular anergy. These effects are mediated through pathogen associated molecular pattern recognition receptors, an evolutionarily conserved mechanism for inducing immunity and not subject to tolerance. The present invention also reveals that an added benefit of the oncolytic platform, capable of replication in tumors but not normal cells, is self-amplification at the tumor. In addition, the oncolytic effect *per se* may add to the overall anti-tumor effect in humans.

Cancer

[0048] The recombinant vectors of the present invention are replication competent in tumor cells. In one embodiment of the invention the vectors are replication competent in cells, which have defects in the Rb-pathway, specifically Rb-p16 pathway. These defective cells include all tumor cells in animals and humans. As used herein "defects in the Rb-pathway" refers to mutations and/or epigenetic changes in any genes or proteins of the pathway. Due to these defects, tumor cells overexpress E2F and thus, binding of Rb by E1A CR2, that is normally needed for effective replication, is unnecessary. Further selectivity is mediated by the E2F promoter, which only activates in the presence of free E2F, as seen in Rb/p16 pathway defective cells. In the absence of free E2F, no transcription of E1A occurs and the virus does not replicate. Inclusion of the E2F promoter is important to prevent expression of E1A in normal tissues, which can cause toxicity both directly and indirectly through allowing transgene expression from the E3 promoter.

[0049] The present invention relates to approaches for treating cancer in a subject. In one embodiment of the invention, the subject is a human or an animal, specifically an animal or human patient, more specifically a human or an animal suffering from cancer.

[0050] The approach can be used to treat any cancers or tumors, including both malignant and benign tumors, both primary tumors and metastases may be targets of the approach. In one embodiment of the invention the cancer features tumor infiltrating lymphocytes. The tools of the present invention are particulary appealing for treatment of metastatic solid tumors featuring tumor infiltrating lymphocytes. In another embodiment the T-cell graft has been modified by a tumor or tissue specific T-cell receptor of chimeric antigen receptor.

[0051] As used herein, the term "treatment" or "treating" refers to administration of at least oncolytic adenoviral vectors or at least oncolytic adenoviral vectors and adoptive cell therapeutic composition to a subject, preferably a mammal or human subject, for purposes which include not only complete cure but also prophylaxis, amelioration, or alleviation of disorders or symptoms related to a cancer or tumor. Therapeutic effect may be assessed by monitoring the symptoms of a patient, tumor markers in blood or for example a size of a tumor or the length of survival of the patient

[0052] In another embodiment of the invention the cancer is selected from a group consisting of nasopharyngeal cancer, synovial cancer, hepatocellular cancer, renal cancer, cancer of connective tissues, melanoma, lung cancer, bowel cancer, colon cancer, rectal cancer, colorectal cancer, brain cancer, throat cancer, oral cancer, liver cancer, bone cancer, pancreatic cancer, choriocarcinoma, gastrinoma, pheochromocytoma, prolactinoma, T-cell leukemia/lymphoma, neuroma, von Hippel-Lindau disease, Zollinger-Ellison syndrome, adrenal cancer, anal cancer, bile duct cancer, bladder cancer, ureter cancer, brain cancer, oligodendroglioma, neuroblastoma, meningioma, spinal cord tumor, bone cancer, osteochondroma, chondrosarcoma, Ewing's sarcoma, cancer of unknown primary site, carcinoid, carcinoid of gastrointestinal tract, fibrosarcoma, breast cancer, Paget's disease, cervical cancer, colorectal cancer, rectal cancer, esophagus cancer, gall bladder cancer, head cancer, eye cancer, neck cancer, kidney cancer, Wilms' tumor, liver cancer, Kaposi's sarcoma, prostate cancer, lung cancer, testicular cancer, Hodgkin's disease, non-Hodgkin's lymphoma, oral cancer, skin cancer, mesothelioma, multiple myeloma, ovarian cancer, endocrine pancreatic cancer, glucagonoma, pancreatic cancer, parathyroid cancer, penis cancer, pituitary cancer, soft tissue sarcoma, retinoblastoma, small intestine cancer, stomach cancer, thymus cancer, thyroid cancer, trophoblastic cancer, hydatidiform mole, uterine cancer, endometrial cancer, vagina cancer, vulva cancer, acoustic neuroma, mycosis fungoides, insulinoma, carcinoid syndrome, somatostatinoma, gum cancer, heart cancer, lip cancer, meninges cancer, mouth cancer, nerve cancer, palate cancer, parotid gland cancer, peritoneum cancer, pharynx cancer, pleural cancer, salivary gland cancer, tongue cancer and tonsil cancer.

[0053] Before classifying a human or animal patient as suitable for the therapy of the present invention, the clinician may examine a patient. Based on the results deviating from the normal and revealing a tumor or cancer, the clinician may suggest treatment of the present invention for a patient.

Pharmaceutical composition

[0054] A pharmaceutical composition of the invention comprises at least one type of viral vectors of the invention. Furthermore, the composition may comprise at least two, three or four different vectors. In addition to the vector, a pharmaceutical composition may also comprise other therapeutically effective agents, any other agents such as pharmaceutically acceptable carriers, buffers, excipients, adjuvants, additives, antiseptics, filling, stabilising and/or thickening agents, and/or any components normally found in corresponding products. Selection of suitable ingredients and appropriate manufacturing methods for formulating the compositions belongs to general knowledge of a man skilled in the art.

[0055] The pharmaceutical composition may be in any form, such as solid, semisolid or liquid form, suitable for administration. A formulation can be selected from a group consisting of, but not limited to, solutions, emulsions, suspensions, tablets, pellets and capsules. The compositions of the current invention are not limited to a certain formulation, instead the composition can be formulated into any known pharmaceutically acceptable formulation. The pharmaceutical compositions may be produced by any conventional processes known in the art.

[0056] In one embodiment of the invention, the viral vector or pharmaceutical composition acts as an *in situ* vehicle for recruitment of T-cells, enhancing their therapeutic effect and allowing their propagation at the tumor.

[0057] A pharmaceutical kit of the present invention comprises an adoptive cell therapeutic composition and oncolytic adenoviral vectors coding for at least IL-2 and TNFalpha. The adoptive cell therapeutic composition is formulated in a first formulation and the oncolytic adenoviral vectors coding for at least IL-2 and TNFalpha are formulated in a second formulation. In another embodiment of the invention the first and the second formulations are for simultaneous or sequential, in any order, administration to a subject.

Administration

[0058] The vector or pharmaceutical composition of the invention may be administered to any eukaryotic subject selected from a group consisting of plants, animals and human beings. In a specific embodiment of the invention, the subject is a human or an animal. An animal may be selected from a group consisting of pets, domestic animals and production animals.

[0059] Any conventional method may be used for administration of the vector or composition to a subject. The route of administration depends on the formulation or form of the composition, the disease, location of tumors, the patient, comorbidities and other factors.

[0060] In one embodiment of the invention the separate administration(s) of adoptive cell therapeutic composition and oncolytic adenoviral vectors coding for at least IL-2 and TNFalpha to a subject is(are) conducted simultaneously or consecutively, in any order. As used herein "separate administration" or "separate" refers to a situation, wherein adoptive cell therapeutic composition and oncolytic adenoviral vectors are two different products or compositions distinct from each other.

[0061] Only one administration of adoptive cell therapeutic composition and oncolytic adenoviral vectors coding for at least IL-2 and TNFalpha of the invention may have therapeutic effects. There may be any period between the administrations depending for example on the patient and type, degree or location of cancer. In one embodiment of the invention there is a time period of one minute to four weeks, specifically 1 to 10 days, more specifically 1 to five days, between the consecutive administration of adoptive cell therapeutic composition and oncolytic adenoviral vectors coding for at least IL-2 and TNFalpha and/or there are several administrations of adoptive cell therapeutic composition and oncolytic adenoviral vectors. The numbers of administration times of adoptive cell therapeutic composition and oncolytic adenoviral vectors may also be different during the treatment period. Oncolytic adenoviral vectors or pharmaceutical or adoptive cell compositions may be administered for example from 1 to 10 times in the first 2 weeks, 4 weeks, monthly or during the treatment period. In one embodiment of the invention, administration of vectors or any compositions is done three to seven times in the first 2 weeks, then at 4 weeks and then monthly. In a specific embodiment of the invention, administration is done four times in the first 2 weeks, then at 4 weeks and then monthly. The length of the treatment period may vary, and for example may last from two to 12 months or more.

[0062] In a specific embodiment of the invention an adoptive cell therapeutic composition and oncolytic adenoviral vectors are administered on the same day and thereafter oncolytic adenoviral vectors are administered every week, two weeks, three weeks or every month during a treatment period which may last for example from one to 6 or 12 months or more.

[0063] In one embodiment of the invention, the administration of oncolytic virus is conducted through an intratumoral, intra-arterial, intravenous, intrapleural, intravesicular, intracavitary or peritoneal injection, or an oral administration. Any combination of administrations is also possible. The approach can give systemic efficacy despite local injection. Adoptive cell therapeutic composition may be administered intravenously or intratumorally. In one embodiment the administration of the adoptive cell therapeutic composition and/or oncolytic viral vectors coding for at least IL-2 and TNFalpha is conducted through an intratumoral, intra-arterial, intravenous, intrapleural, intravesicular, intracavitary or peritoneal injection, or an oral administration. In a specific embodiment of the invention TILs or T cells are administered intravenously and viral vectors intratumorally and/or intravenously. Of note, virus is delivered to the tumor separately from administration of T-cells; virus is not used to modify the T-cell graft ex vivo. In essence, the virus modifies the tumor in such a way that the T-cell graft can work better.

[0064] The effective dose of vectors depends on at least the subject in need of the treatment, tumor type, location of the tumor and stage of the tumor. The dose may vary for example from about 1×10^{8} viral particles (VP) to about 1×10^{14} VP, specifically from about 5×10^{9} VP to about 1×10^{13} VP and more specifically from about 8×10^{9} VP to about 1×10^{12} VP. In one embodiment oncolytic adenoviral vectors coding for at least IL-2 and TNFalpha are administered in an amount of 1×10^{10}- 1×10^{14} virus particles. In another embodiment of the invention the dose is in the range of about 5×10^{10} - 5×10^{11} VP.

[0065] The amount of cells transferred will also depend on the patient, but typical amounts range from 1×10^{9}- 1×10^{12} cells per injection. The number of injections also varies but typical embodiments include 1 or 2 rounds of treatment several (eg 2-4) weeks apart.

[0066] Any other treatment or combination of treatments may be used in addition to the therapies of the present invention. In a specific embodiment the method or use of the invention further comprises administration of concurrent or sequential radiotherapy, monoclonal antibodies, chemotherapy or other anticancer drugs or interventions (including surgery) to a subject.

[0067] The terms "treat" or "increase", as well as words stemming therefrom, as used herein, do not necessarily imply 100% or complete treatment or increase. Rather, there are varying degrees of which one of ordinary skill in the art recognizes as having a potential benefit or therapeutic effect. In this respect, the present inventive methods can provide any amount of increase in the efficacy of T-cell therapy or any degree of treatment or prevention of a disease.

[0068] Figures 28-32, 36 and 37 illustrate the methods and mechanisms of the present invention.

[0069] It will be obvious to a person skilled in the art that, as the technology advances, the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

EXAMPLES

Materials & methods

[0070] B16-OVA animal model: ovalbumin-expressing B16 cells (B16-OVA) were maintained in RPMI, 10% FBS, 5 mg/ml G418, 20 mM L-Glutamine, 1x Pen/Strep solution (GIBCO). 4-7-week-old C57BL/6 immunocompetent female mice were implanted subcutaneously with 2.5 × 10^5 B16-OVA cells in 50 ul RPMI, 0% FBS, in the right flank, one tumor per mouse. Roughly ten days post tumor implantation (when tumors became injectable, ~3 mm minimum diameter), mice were divided into groups and treated in some experiments on six consecutive days with intratumoral injections of either 50 ul PBS or 1 × 10^9viral particles (VPs) of oncolytic adenovirus in 50 ul PBS. In other experiments, three injections were given on days 0, 2 and 4. As murine cells are non-permissive to human adenovirus, multiple intratumoral virus injections were used to mimic virus replication-induced inflammation, (Blair et al., 1989).

[0071] Adoptive transfer: On the first day of the i.t. treatment, the mice also received by adoptive transfer in the intraperitoneal cavity 5 × 10^5 to 2 × 10^6 overnight-rested CD8a-enriched and expanded splenocytes from 4-8-week-old C57BL/6-Tg(TcraTcrb)1100Mjb/J (OT-1) mice, genetically engineered to have only ovalbumin (OVA)-specific CD8 T-cell receptors, in 100 ul RPMI, 0% FBS. CD8a-enrichment was performed by mouse CD8a (Ly-2) MicroBeads 5 days prior to transfer, per manufacturer's instructions (Miltenyi Biotech, USA, cat. no 130-049-401). Enriched cells were expanded in numbers for five days in lymphocyte medium (RPMI, 10 % FBS, 20 mM L-Glutamine, 1x Pen/Strep solution, 15 mM HEPES, 50 µM 2-mercaptoethanol, 1 mM Na pyruvate) in the presence of recombinant murine IL-2 (160 ng/ml) and soluble anti-mouse CD3ε antibody (0,3 ug/ml, Abcam, clone 145-2C11).

[0072] Tissue processing for flow cytometry: Mice were euthanized and spleens, draining lymph nodes and tumors were harvested in 1 to 10 ml RPMI, 10% FBS, and blood was collected by terminal heart bleed into the pleural cavity and transferred by disposable syringe into EDTA-containing microcentrifuge tubes, and processed for analysis: solid tissues were roughly dissociated by scalpel and triturated in a 10 ml disposable sterile pipette tip in 5 to 10 ml ACK lysing buffer (150 mM NH_4Cl, 10 mM KHCOs, 0.1 mM EDTA, pH 7.2) and incubated at room temperature (RT) for ~ 20 minutes, upon which cells were pelleted at 1200 rpm 5 min +4ºC, following which cells were re-suspended in 1 to 10 ml RPMI, 10% FBS, depending on the estimated amount of cells, and passed through a 40 µm sterile filter to create a single-cell solution. In some experiments, tumor tissue was instead processed directly after scalpel cutting (before addition of ACK) in 1 ml total volume of protease-coctail (RPMI supplemented with collagenase type A, H or P, Roche, at 1 mg/ml and benzonase, 125 units/ml final conc., Sigma, E1014-25KU) for 1-2 hours at 37°C, 5% CO_2, after which 10 ml ACK lysing buffer was added and cells were treated as above. 200 µl whole blood was pipetted into 5 ml ACK lysing buffer and treated as above. Cells were either incubated overnight at 37°C, 5% CO_2, or analyzed directly by immunostaining and flow cytometry.

[0073] Tissue processing for cytokine analysis: Mice were euthanized and ~2-10 mm^3 tumor pieces were frozen in 2 ml microcentrifuge tubes on dry ice and stored at -80°C. Tumor pieces were weighed and 200 µl ice-cold PBS added. Pieces were homogenized by Tissue Master 125 rotor, 1x protease inhibitor cocktail (Sigma) and 0.1 % BSA final conc. was added and tubes were kept on ice. Tumor homogenate was spun at 2000 rpm 10 min +4°C and the supernatant was analyzed with CBA Flex Set cytokine beads (BD, USA) on BD FACSArray, per manufacturer's instructions.

Reference examples and experiments supporting the invention

Experiment 1 (cytokines and chemokines induced by intratumoral adenovirus injection) (reference example):

[0074] To study whether adenovirus infection could result in cytokine and chemokine expression, we injected mice harboring subcutaneous B16-OVA tumors intratumorally with either PBS or 5/3 chimeric oncolytic adenovirus on days 0, 1, 2, 3, 4 and 5. Tumors from three mice per treatment group were extracted and processed for cytokine analysis on day 0 (before virus injection = baseline control), and from three other mice per time point on days 6, 10, 14 and 18.

[0075] Remarkably, the results showed a virus-induced increase in secretion of IFN-γ and subsequent up-regulation of IFN-γ inducible chemokines RANTES, MIP-1α and MCP-1 on day 10 (Figure 1).

[0076] For enhancing therapeutic efficacy of adoptive cell therapy, these findings are important

[0077] Based on this data, treatment with oncolytic cytokine-armed adenovirus results in favorable alteration of tumor microenvironment, increased chemotaxis of adoptively transferred immune cells and enhanced tumor cell recognition by cytotoxic CD8+ T-cells.

Experiment 2 (adenovirus-mediated enhancement of adoptive T cell therapy)(reference example):

[0078] To study the impact of adenovirus treatment on adoptive T cell therapy, murine B16-OVA melanoma tumors were treated with 5/3 chimeric oncolytic adenovirus alone or in combination with adoptive transfer of tumor-specific OT-I cells and compared to mice receiving intratumoral PBS injections. The results of three independent experiments summarized in Figure 2 reveal, on one hand, that virus injections on their own (keeping in mind that human adenovirus does not productively replicate in mouse cells) resulted in minor tumor growth control, lasting until day 14 post-treatment and diminishing after that (Figure 2A). On the other hand, when treated mice were adoptively transferred with 5×10^5 or 2×10^6 OT-I cells, statistically significant differences between PBS and Ad groups were obtained in two separate experiments (Figure 2B and 2C, respectively).

[0079] Thus, the presence of virus in the tumor had a strong enhancing effect on adoptive cell therapy. Six intratumoral virus injections at 1 × 10^9 VPs each in our hands gave in combination with adoptive transfer of OT-I cells equal or superior anti-tumor efficacy compared to what was reported by Song et al. (2011, Mol Ther) for a single intramuscular injection of 1 × 10^{10} VP of OVA-expressing replication-defective adenovirus (Ad-OVA) admixed with an equal amount of adenovirus co-expressing an A20-specific short-hairpin RNA and a secretory form of flagellin that stimulates toll-like receptor 5 (Ad-shAF) in the B16.OVA melanoma model (Song XT et al. Mol Ther. 2011 Jan;19(1):211-7, PMID: 20959814). In light of these results, a novel aspect of our invention is to target the virus injection into the tumor, where we can achieve even with unarmed virus superior tumor control to multi-immune-functional armed virus administered intramuscularly.

Experiment 3 (adenovirus-mediated alterations in quality and quantity of immune cell populations in vivo) (reference example):

[0080] To study the trafficking and proliferation of adoptively transferred cells of experiment 2, OT-I cells were stained ex vivo with 5 µM carboxyfluorescein succinimidyl ester (CFSE). This fluorescent cell staining dye is diluted with every cell division and therefore enables us to trace lymphocyte proliferation by flow cytometry by analyzing ~1/2 fractional reduction of fluorescence signal intensity at each cell division (up to 7 divisions, here labeled M0-7). On day 1 post-transfer the results showed virus-induced accumulation of transferred OT-I cells (CD8+ CFSE+ double positive population) in the tumors, concomitant with reduction of these cells in the blood (Figure 3A). At later time points, also the total CD8+ T-cell count appeared higher in the virus-treated tumors compared to PBS-injected tumors, and on day 14 the overall CD8+ T-cell count was increased in lymphoid organs of virus treated mice.

[0081] The amounts of OT-I cell divisions at different time points are depicted in Figure 3B. Since the proliferation status of OT-I cells was the same between both groups on day 1, differences in the CD8+ cell count in various organs were due to adenovirus-induced immune cell trafficking. At later time points, however, the situation had changed and the increase of OT-I cells in the adenovirus treated tumor was due to increased lymphocyte proliferation. On day 6 the majority of OT-I cells in PBS treated tumors were arrested in M5 phase, whereas transferred cells in adenovirus group continued to proliferate (divisions M6-M7). This data suggests that oncolytic virotherapy or non-cytolytic virus infection results in enhanced trafficking and proliferation of adoptively transferred lymphocytes through breaking the immune suppression in the tumors, attracting immune cells that contribute to CD8+ cell activation and/or through some other important mechanisms that help overcome T-cell anergy.

[0082] As support to our findings in animal models, we have observed transient depression of blood lymphocyte counts during the first day following oncolytic virus administration to patients with advanced cancer (Figure 4), suggesting mobilization of circulating T cells in response to acute adenovirus infection in the tumor.

[0083] Furthermore, in support of adenovirus infection recruiting T cells into tumors, we detected increased numbers of CD8+ T cells in tumor biopsy tissue sections after treatment than before (Figure 5).

[0084] Figure 6 shows results of adenovirus injections combined with adoptive transfer of T cells.

[0085] Figure 7 reveals dramatic increase in the number of "natural" anti-tumor T-cells due to adoptive transfer and virus injection.

[0086] Figure 8 shows activated CD8+ cells in tumor and TIM-3 expression in the tumor on day 14.

[0087] Figure 9 shows that increase in anti-tumor T-cells and reduction of immunosuppression results in systemic immunity against tumor antigens.

[0088] Figure 10 shows distribution of OTI T-cells following virus injection.

[0089] Figure 11 reveals that lifting immunosuppression can induce propagation of cells.

[0090] Figure 12 shows efficacy of recombinant cytokines (no virus) in combination with OT1 cells.

Experiment 4 (Adoptively transferred T-cells + murine cytokine-armed Ad5 adenovirus):

[0091]

Model:
C57BL/6 with B16-OVA (0,25 × 10e6 cells per animal)

Groups:

No injection

Ad5-Luc

Ad5-CMV-mTNFa

Ad5-CMV-mIFNg

Ad5-CMV-mIL2

Ad5-CMV-mIFNb1

No injection + OT1

Ad5-Luc + OT1

Ad5-CMV-mTNFa + OT1

Ad5-CMV-mIFNg + OT1

Ad5-CMV-mIL2 + OT1

Ad5-CMV-mIFNb1 + OT1

[0092] Ad5 vector is a vector of non-replicative human adenovirus coding for a mouse transgene. The constructs were made with AdEasy technology (Agilent Inc); the transgene cassette (driven by a CMV promoter) is in the deleted E1 region (see e.g. Diaconu I et al. Cancer Res. 2012 May 1 ;72(9):2327-38).

Group size:
n= 7, 12x7=84 (+ extra 20% = 100)

Treatment schedule:
OT1 cells: 2 × 10e6 per animal i.p. on Day 1

Virus injections: 1 × 10e9 virus particles (OD260) on Day 1 and weekly thereafter

Endpoint:

Tumor volume (measured every 2 days for the first week and then every 3 days)

Collection of tumors and spleens when mice die or are killed; for FACS and/or ELISPOT (focus on assays most relevant according to Siri data).

[0093] The best transgenes in combination with T-cell therapy were TNFalpha and IL2 (Figure 13). Strengthening the data, the same cytokines were implicated in the experiment without virus.

[0094] Figure 14 shows the results of different viruses (without T-cell therapy) on tumor size (Figure 14).

[0095] Figure 15 shows the excellent results of T-cell therapy in combination with Ad5-CMV-mTNFalpha-vector.

[0096] Figure 16 shows the excellent results of T-cell therapy in combination with Ad5-CMV-mIL2-vector.

Novel virus constructs

[0097] The following new virus constructs are presented as examples of our proposed technology:

C5a and TNF-α expressing oncolytic viruses

[0098] We generated new oncolytic Ad5/3 adenoviruses carrying the active portion of complement component C5a or human TNF-α as transgenes instead of 6.7K/gp19 gene regions (Figure 17).

Experiment 5 (transgene expression from C5a-encoding adenovirus vector)(reference example):

[0099] In order to confirm-as proof-of-concept-that oncolytic adenoviruses are able to express the chosen cytokines proposed to augment adoptive cell therapy, we infected human A549 cells in culture at 10 VP / cell of adenovirus encoding C5a (Figure 24), and assessed C5a levels in cell culture supernatant at different time points post infection by ELISA. Results indeed validate the assumption and support the generation of proprietary adenovirus constructs harboring selected cytokines.

Experiment 6 (effect on monocyte migration by novel adenovirus vectors)(reference example):

[0100] We tested the C5a capability of recruiting monocytes using an in vitro chemotaxis assay: A549 cells were infected either with adenovirus expressing C5a or with unarmed control virus (10 VP / cell - infectious units between viruses similar), or were treated with PBS, and media was collected 48h post infection and was used to recruit human monocytic cell line THP1 in a transwell chemotaxis assay per manufacturer's instructions (Millipore QCM, cat. no. ECM512). Results reveal significantly greater attraction of monocytes by supernatant from C5a-expressing virus-infected cells than by medium from non-infected cells or cells infected with unarmed control virus (Figure 25).

Experiment 7 (anti-tumor efficacy of C5a-armed adenovirus)(reference example):

[0101] To assess the anti-tumor potency of C5a in the context of non-cytolytic tumor infection, we treated established B16-OVA tumors in C57BL/6 mice on days 0, 2 and 4 with either PBS, C5a-expressing- or with unarmed control viruses. Results reveal strong anti-tumor effect by the C5a-expressing virus (Figure 26).

Experiment 8 (increased anti-tumor T cell expansion by C5a-virus)(reference example):

[0102] To assess whether the observed increase in anti-tumor efficacy of C5a-expressing virus (Figure 24) was related to T cells, tumors were analyzed by flow cytometry for ovalbumin-specific CD8+ T cells, detected by staining with APC-conjugated pentamer specific for TCR recognizing MHC I loaded with immunodominant ovalbumin peptide SIINFEKL (ProImmune, USA). Indeed, tumors in the C5a-virus group contained a significantly greater fraction of tumor-specific CD8 T cells than tumors injected with control virus or PBS (Figure 27).

Experiment 9 (transgene expression from TNF-α-encoding adenovirus):

[0103] Similar to the C5a virus (Figure 24 and Experiment 5), we tested the ability of hTNF-α-expressing oncolytic adenovirus to mediate secretion of the transgene of choice. Results confirm expression (Figure 18).

Experiment 10 (biological effect of expressed transgene is retained in oncolytic adenovirus):

[0104] In order to assess whether the adenovirus-expressed transgene retains its biological effects, virus-free (100kD-filtered) supernatant from A549 cells infected with control unarmed virus or with TNF-alpha-expressing virus (varying VPs / cell, 72 h p.i.) was applied onto WEHI-13VAR (ATCC CRL-2148) cells, which are sensitive to TNF-alpha, and these cells were assessed for viability 72 hours after exposure to the supernatant. (For example Espevik T et al. J Immunol Methods. 1986; 95(1): 99-105 describes the method.) Results reveal that TNF-alpha expressed from oncolytic adenovirus retains potent biological effects (Figure 19).

Experiment 11 (oncolytic cytokine-expressing viruses retain cell-killing ability in vitro):

[0105] Because TNF-alpha may have antiviral effects, it was important to confirm that oncolytic effect of adenovirus expressing TNF-α retains its ability to infect and kill cancer cells. Several cancer cell lines in culture were infected with TNF-alpha-expressing or with control viruses and assessed for viability by CelltiterGlo AQ MTS assay, as per manufacturer's instructions (Promega, USA). Results show the virus is oncolytic in vitro (Figures 19-20).

Experiment 12 (synergy between radiotherapy and oncolytic virus expressing TNF alpha):

[0106] We treated nude mice carrying subcutaneous A549 xenografts intratumorally with viruses with or without concomitant focused external beam radiation (XRT) (Figure 21). RD indicates replication deficient virus and unarmed virus is an oncolytic virus without TNFalpha.

Experiment 13 (increased anti-tumor efficacy of TNF-alpha-expressing adenovirus in immunocompetent hosts):

[0107] To test whether oncolytic adenovirus, which does not replicate in murine cells, might still be able to cause anti-tumor effects in vivo in immunocompetent mice, mice with established B16.OVA tumors were injected intratumorally with TNF-alpha-expressing or unarmed control virus or PBS, in a manner similar to as in Figure 26. Results show greater overall tumor control with TNF-alpha-expressing virus compared to controls (Figure 22), suggesting that human TNF-alpha is partially active in mice and supporting the notion of arming viruses to achieve greater anti-tumor effects.

Experiment 14 (increased anti-tumor T cell expansion by TNFα-virus):

[0108] Similar to Experiment 11, we wanted to test whether the observed anti-tumor effect of the TNF-alpha-expressing virus was associated with induction of tumor-specific cytolytic T cell responses. We extracted tumors and processed them for flow cytometric analysis, as in Experiment 11. Results (Figure 23) indeed confirm that also TNF-alpha expression facilitates expansion of tumor-specific T cells at the tumor site, strongly arguing in favor of the proposed technology.
Figures 28-32, 36 and 37 illustrate the methods and mechanisms of the present invention.

Experiment 15 (combination experiment with two different adenoviral vectors and OT1(<u>Ad-mTNFa/Ad-mIL2 + OT1</u>)):

[0109]

Model:
C57BL/6 with B16-OVA (0.25 × 10e6 cells per animal)

Groups:

Ad5-CMV-mTNFa (1 × 10e9 VP)

Ad5-CMV-mIL2 (1 × 10e9 VP)

Ad5-CMV-mTNFa + Ad5-CMV-mIL2 (0.5 + 0.5 × 10e9 VP)

Ad5-CMV-mTNFa + OT1

Ad5-CMV-mIL2 + OT1

Ad5-CMV-mTNFa + Ad5-CMV-mIL2 + OT1

Ad5Luc1 + OT1

No injection (mock-mock)

Ad5 vector is a vector of non-replicative human adenovirus coding for a mouse transgene. The constructs were made with AdEasy technology (Agilent Inc); the transgene cassette (driven by a CMV promoter) is in the deleted E1 region (see e.g. Diaconu I et al. Cancer Res. 2012 May 1;72(9):2327-38).

Group size:

n= 9

100 ordered

Treatment schedule:

OT1 cells: 1.5 × 10e6 per animal i.p. on Day 1 (same amount as in previous experiment, not 2x10e6)

Virus injections: for single agents: 1 × 10e9 virus particles (OD260) on Day 1 and weekly thereafter; for combination: 0.5 × 10e9 VP + 0.5 × 10e9 VP on Day 1 and weekly thereafter

Endpoint: Tumor volume (measured every 2 days for the first week and then every 3 days)

Further experiments supporting the invention:

[0110] Several animal experiments support the invention. First we screened optimal cytokine candidates to combine with adoptive T-cell transfer using recombinant murine forms of cytokines (Figure 38). A cytokine(s) is(are) selected from the following group: interferon alpha, interferon beta, interferon gamma, complement C5a, GMCSF, IL-2, TNFalpha, CD40L, IL12, IL-23, IL15, IL17, CCL1, CCL11, CCL12, CCL13, CCL14-1, CCL14-2, CCL14-3, CCL15-1, CCL15-2, CCL16, CCL17, CCL18, CCL19, CCL19, CCL2, CCL20, CCL21, CCL22, CCL23-1, CCL23-2, CCL24, CCL25-1, CCL25-2, CCL26, CCL27, CCL28, CCL3, CCL3L1, CCL4, CCL4L1, CCL5, CCL6, CCL7, CCL8, CCL9, CCR10, CCR2, CCR5, CCR6, CCR7, CCR8, CCRL1, CCRL2, CX3CL1, CX3CR, CXCL1, CXCL10, CXCL11, CXCL12, CXCL13, CXCL14, CXCL15, CXCL16, CXCL2, CXCL3, CXCL4, CXCL5, CXCL6, CXCL7, CXCL8, CXCL9, CXCL9, CXCR1, CXCR2, CXCR4, CXCR5, CXCR6, CXCR7 and XCL2. A schematic of the general layout of the virus genome comprising the cytokine transgene or two transgenes are shown in Figures 33 and 34. Figure 35 shows nucleotide and amino acid sequences of 2A. Nucleotide sequences of the viral vectors comprising transgenes C5a, hCD40L, hIFNa2, hIFNb1, hIFNg1, hIL2 or TNFa are shown in SEQ ID NOs 1-7, respectively (Ad5/3-E2F-D24-transgene). Furthermore, nucleotide sequences of the viral vectors comprising two transgenes, the other one being IL-2 and the other one C5a, CD40L, IFNa2, IFNb, IFNg, GMCSF or TNFa, are shown in SEQ ID NOs 8-21 (SEQ ID NO: 8 C5a-2A-IL2, SEQ ID NO: 9 IFNa-2A-IL2, SEQ ID NO: 10 TNFa-2A-IL2, SEQ ID NO: 11 CD40L-2A-IL2, SEQ ID NO: 12 IFNb-2A-IL2, SEQ ID NO: 13 GMCSF-2A-IL2, SEQ ID NO: 14 IFNg-2A-IL2, SEQ ID NO: 15 C5a-IRES-IL2, SEQ ID NO: 16 IFNa-IRES-IL2, SEQ ID NO: 17 TNFa-IRES-IL2, SEQ ID NO: 18 CD40L-IRES-IL2, SEQ ID NO: 19 IFNb-IRES-IL2, SEQ ID NO: 20 GMCSF-IRES-IL2, SEQ ID NO: 21 IFNg-IRES-IL2) (Ad5/3-E2F-D24-transgene-IRES/2A-transgene).

[0111] Several of the best candidates were chosen for a cytokine/virus combination experiment, where regimen roughly stay the same and all the mice receive intraperitoneal injection of CD8a+ enriched OT-I lymphocytes and intratumoral treatments of chosen cytokine mixed with adenovirus. In addition, a separate trafficking experiment was conducted using our existing replication deficient adenoviruses coding for either mouse cytokines or human cytokines with proven activity in mice (Figure 39). RD indicates replication deficient virus. Based on these experiments a final cytokine candidate or candidates can be chosen and analyzed further, even in the clinic.

[0112] Results of the experiments indicate that a) virus injection into tumors results in enhanced trafficking of T-cell to the tumor, b) virus injection results in enhanced MHC1 expression in tumors, c) danger signaling is activated resulting in less tolerance and immunosuppression, d) T-cells propagate at the tumor following virus injections. Importantly, adding a cytokine as a transgene enhanced each of these effects. Of note, dual transgenes enhanced the effect further. Thus, intratumoral injection of cytokine armed oncolytic adenovirus enhanced the effect of adoptive cell transfer in a synergistic manner, over what could be achieved with either virus vectors or adoptive cell transfer alone.

[0113] To study T cell trafficking and biodistribution after adoptive transfer, a SPECT/CT imaging experiment was conducted (Figure 40). CD8a+ enriched OT-I lymphocytes were radiolabeled with 111In and adoptively transferred into recipient mice.

[0114] Since the half-life of indium oxine is relatively short (2,83 days), the maximum surveillance period for the imaging was limited to 7 days. Due to this restriction, cells were labeled in two batches and transferred into mice at two different time points. The imaging data from the first batch covers trafficking events from days 0-7, whereas the second batch enables us to observe events in tumors during days 8-14 post-virus.

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P a t e n t k r a v

1. Onkolytisk adenoviral vektor, der koder for mindst IL-2 og TNF-alpha sammen med separat adoptiv celleterapeutisk sammensætning til anvendelse ved behandling af cancer.

2. Onkolytisk adenoviral vektor til anvendelse ifølge krav 1, hvor den adoptive celleterapeutiske sammensætning omfatter en celletype valgt fra en gruppe bestående af en tumorinfiltrerende lymfocyt (TIL), T-cellereceptor-modificerede lymfocytter og kimære antigenreceptor-modificerede lymfocytter.

3. Onkolytisk adenoviral vektor til anvendelse ifølge et hvilket som helst af kravene 1-2, hvor den adoptive celleterapeutiske sammensætning omfatter en celletype valgt fra en gruppe bestående af T-celler, CD8+-celler, CD4+-celler, NK-celler, delta-gamma-T-celler, regulatoriske T-celler og mononukleære celler fra perifert blod.

4. Onkolytisk adenoviral vektor til anvendelse ifølge et hvilket som helst af kravene 1-3, hvor den adoptive celleterapeutiske sammensætning omfatter T-celler.

5. Onkolytisk adenoviral vektor til anvendelse ifølge et hvilket som helst af kravene 1-4, hvor canceren er valgt fra en gruppe bestående af næsesvælgscancer, synovial cancer, hepatocellulær cancer, nyrecancer, cancer i bindevæv, melanom, lungecancer, tarmcancer, koloncancer, rektal cancer, kolorektal cancer, hjernecancer, halscancer, oralcancer, levercancer, knoglecancer, bygspytkirtel-cancer, choriokarcinom, gastrinom, phæochromocytom, prolactinom, T-celle-leukæmi/lymfom, neurom, von Hippel-Lindau-sygdom, Zollinger-Ellison-syndrom, binyrecancer, analcancer, galdevejscancer, urinblærecancer, urinleder-cancer, hjernecancer, oligodendrogliom, neuroblastom, meningiom, rygmarvstumor, knoglecancer, osteochondrom, chondrosarcom, Ewings sarcom, cancer med ukendt primært sted, karcinoid, karcinoid af fordøjelseskanalen, fibrosarkom, brystcancer, Pagets sygdom, livmoderhalskræft, kolorektal cancer, rektal cancer, spiserørs-cancer, galdeblærecancer, hovedcancer, øjecancer, nakkecancer, nyrecancer, Wilms tumor, levercancer, Kaposis sarcom, prostatacancer, lungecancer, testikelcancer, Hodgkins sygdom, non-Hodgkin-lymfom, oralcancer, hudcancer, mesotheliom, myelomatose, æggestokcancer, endokrin bygspytkirtel-cancer, glucagonom, bygspytkirtel-cancer, parathyroidcancer, peniscancer, hypofysecancer, blødtvævssarcom, retinoblastom, tyndtarmscancer, mavecancer, thymuscancer, skjoldbruskkirtel-cancer, trophoblastcancer, molasygdom, livmodercancer, endometri-cancer, vaginacancer, vulvacancer, akustisk neurom, mykosis fungoides, insulinom, carcinoidsyndrom, somatostatinom, tandkødscancer, hjertecancer, læbecancer, hjernehindecancer, mundcancer, nervecancer, ganecancer, ørespytkirtelcancer, bughindecancer, svælgcancer, pleural cancer, spytkirtelcancer, tungecancer og kræft i mandlerne.

6. Onkolytisk adenoviral vektor til anvendelse ifølge et hvilket som helst af kravene 1-5, hvor den adoptive celleterapeutiske sammensætning og de onkolytiske virale vektorer, der koder for mindst IL-2 og TNF-alpha til et individ, skal indgives samtidigt eller efter hinanden i en hvilken som helst rækkefølge.

7. Onkolytisk adenoviral vektor til anvendelse ifølge krav 6, hvor der er et tidsrum på et minut til fire uger mellem den konsekutive indgivelse af den adoptive celleterapeutiske sammensætning og de onkolytiske virale vektorer, der koder for mindst IL-2 og TNF-alpha, og/eller der er adskillige indgivelser af den adoptive celleterapeutiske sammensætning og de onkolytiske virale vektorer.

8. Onkolytisk adenoviral vektor til anvendelse ifølge et hvilket som helst af kravene 1-7, hvor den adoptive celleterapeutiske sammensætning og/eller de onkolytiske virale vektorer, der koder for mindst IL-2 og TNF-alpha, skal indgives gennem en intratumoral, intra-arterel, intravenøs, intrapleural, intravesikulær, intrakavitær eller peritoneal injektion, eller en oral indgivelse.

9. Onkolytisk adenoviral vektor til anvendelse ifølge et hvilket som helst af kravene 1-8, hvor den adenovirale vektor er valgt blandt Ad5, Ad3 eller Ad5/3.

10. Onkolytisk adenoviral vektor til anvendelse ifølge krav 9, hvor den adenovirale vektor er Ad5/3 omfattende en Ad5-nukleinsyre-backbone og en Ad3-fiberknop eller en kimær Ad5/3-fiberknop.

11. Onkolytisk adenoviral vektor til anvendelse ifølge et hvilket som helst af kravene 1-10, hvor den onkolytiske virale vektor koder for mere end to cytokiner.

12. Onkolytisk adenoviral vektor til anvendelse ifølge krav 11, hvor den onkolytiske virale vektor koder for IL-2 og TNF-alpha og et cytokin eller cytokiner valgt fra en cytokingruppe bestående af interferon alfa, interferon beta, interferon gamma, komplement C5a, GMCSF, CD40L IL12, IL-23, IL15, IL17, CCL1, CCL11, CCL12, CCL13, CCL14-1, CCL14-2, CCL14-3, CCL15-1, CCL15-2, CCL16, CCL17, CCL18, CCL19, CCL2, CCL20, CCL21, CCL22, CCL23-1, CCL23-2, CCL24, CCL25-1, CCL25-2, CCL26, CCL27, CCL28, CCL3, CCL3L1, CCL4, CCL4L1, CCL5, CCL6, CCL7, CCL8, CCL9, CCR10, CCR2, CCR5, CCR6, CCR7, CCR8, CCRL1, CCRL2, CX3CL1, CX3CR, CXCL1, CXCL10, CXCL11, CXCL12, CXCL13, CXCL14, CXCL15, CXCL16, CXCL2, CXCL3, CXCL4, CXCL5, CXCL6, CXCL7, CXCL8, CXCL9, CXCR1, CXCR2, CXCR4, CXCR5, CXCR6, CXCR7 og XCL2.

13. Onkolytisk adenoviral vektor til anvendelse ifølge krav 11 eller 12, hvor den adenovirale vektor omfatter et internt ribosomalt indgangssted (IRES) eller eventuelt et ribosom-shuntsted 2A mellem transgenerne.

14. Farmaceutisk kit omfattende en adoptiv terapeutisk cellesammensætning og onkolytiske adenovirale vektorer, der koder for mindst Il-2 og TNF-alpha, hvor den adoptive terapeutiske cellesammensætning er formuleret i en første formulering, og de onkolytiske adenovirale vektorer, der koder for mindst IL-2 og TNF-alpha, er formuleret i en anden formulering.

15. Onkolytisk adenoviral vektor, der koder for mindst IL-2 og TNF-alpha.

DRAWINGS

Drawing

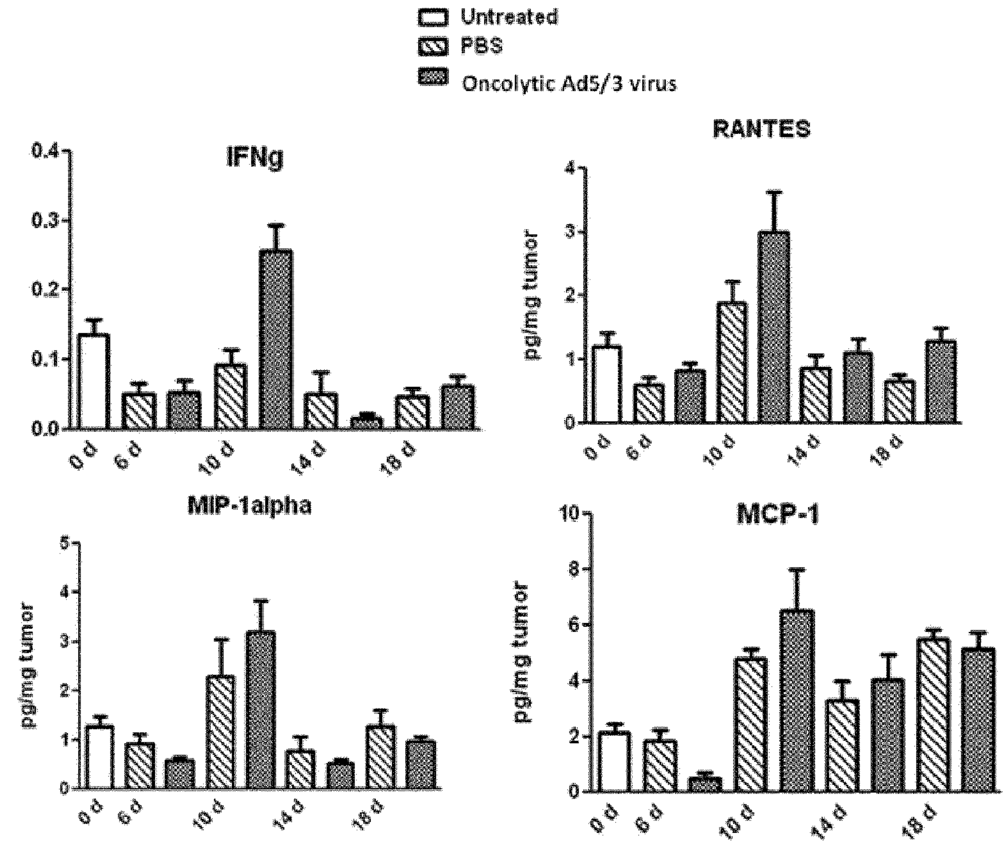


Figure 1.

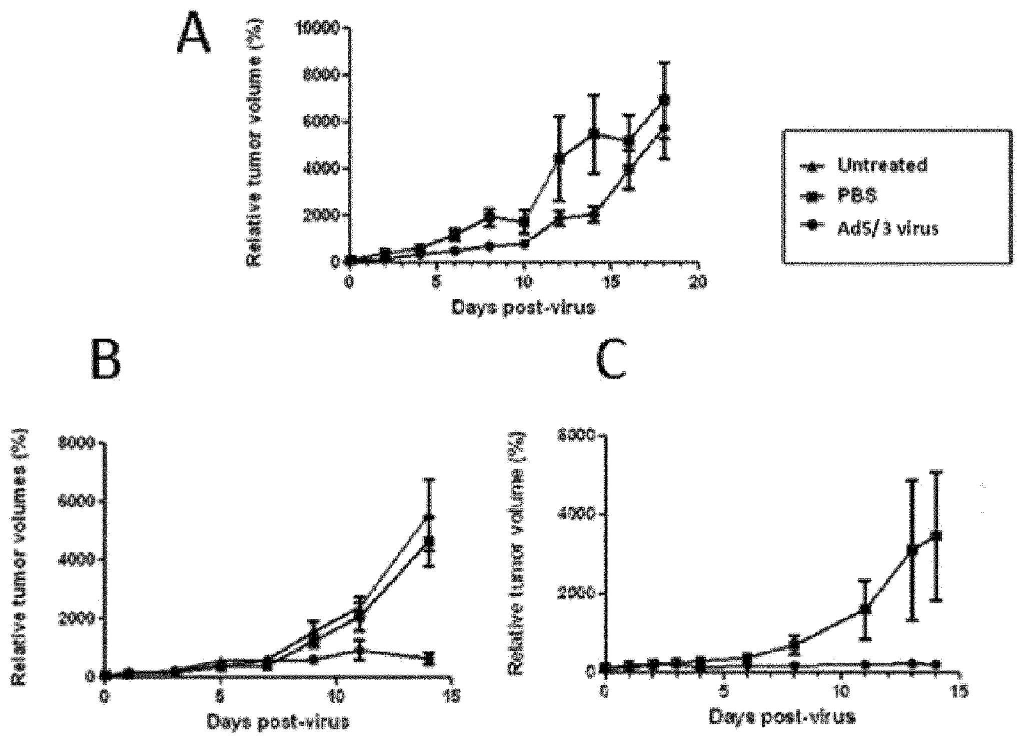

A
Relative tumor volume (%)
10000
8000
6000
4000
2000
0
0
5
10
15
20
Days post-virus
Untreated
PBS
Ad5/3 virus
B
Relative tumor volumes (%)
8000
6000
4000
2000
0
0
5
10
15
Days post-virus
C
Relative tumor volume (%)
6000
4000
2000
0
0
5
10
15
Days post-virus

Figure 2.

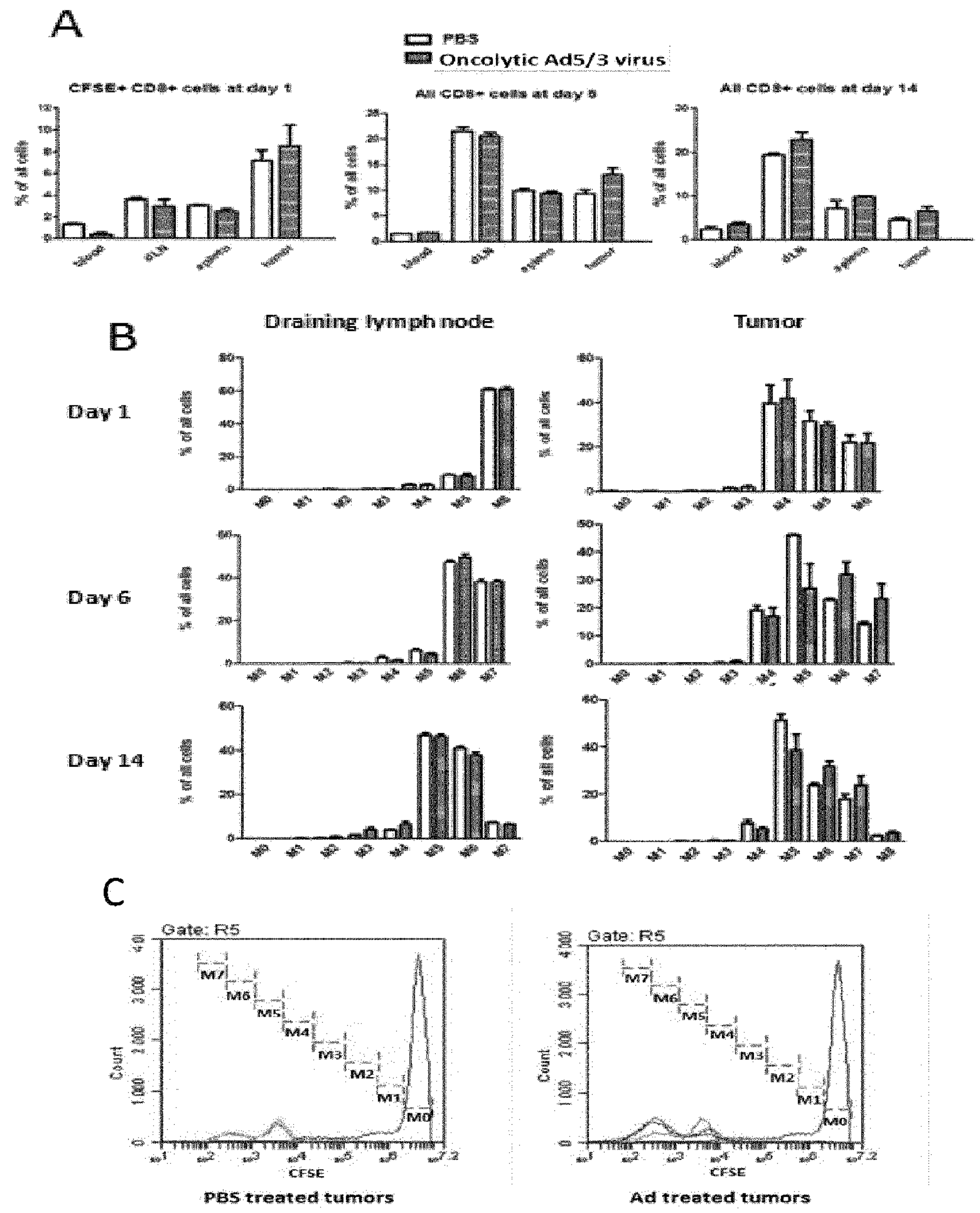

A
PBS
Oncolytic Ad5/3 virus
CFSE+ CD8+ cells at day 1
All CD8+ cells at day 5
All CD8+ cells at day 14
% of all cells
blood
dLN
spleen
tumor
B
Draining lymph node
Tumor
Day 1
Day 6
Day 14
C
Gate: R5
Count
CFSE
M7
M6
M5
M4
M3
M2
M1
M0
PBS treated tumors
Ad treated tumors

Figure 3.

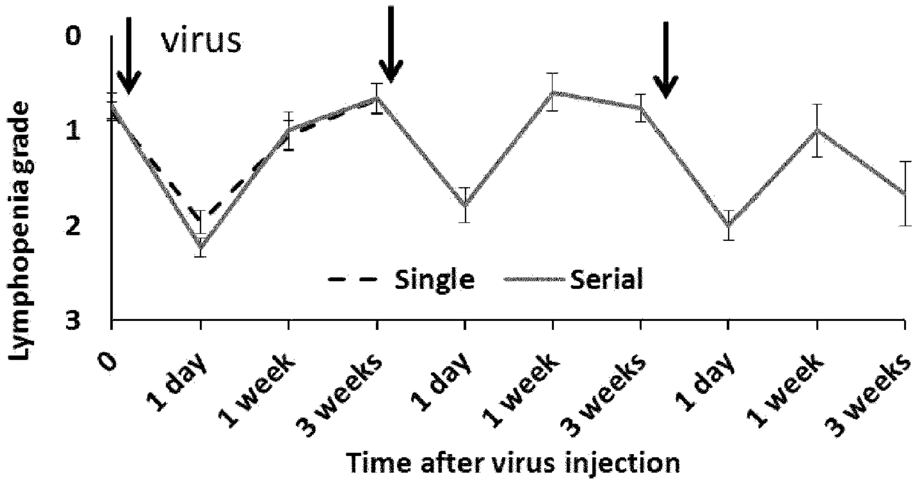


Figure 4.

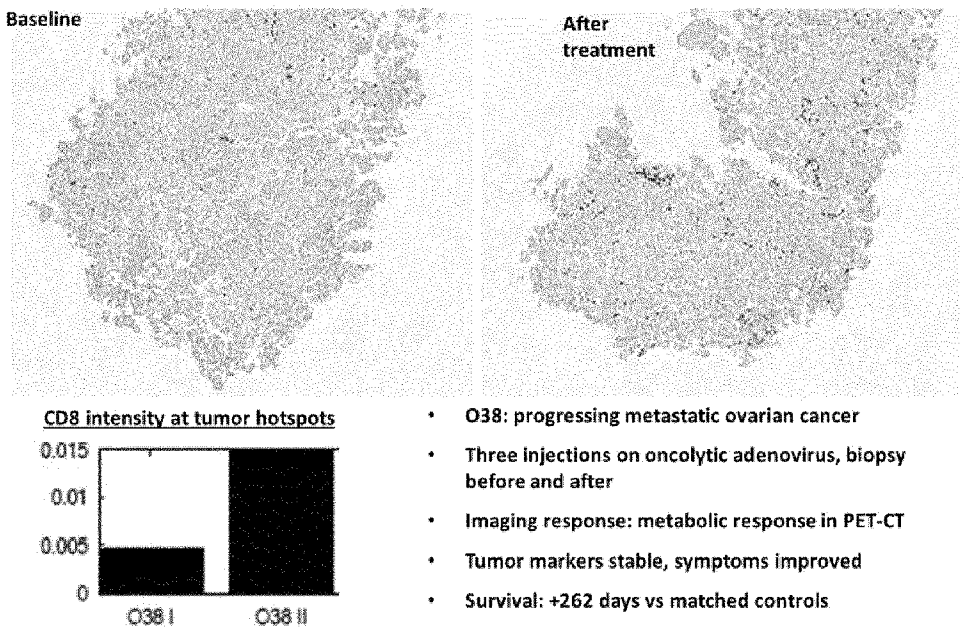
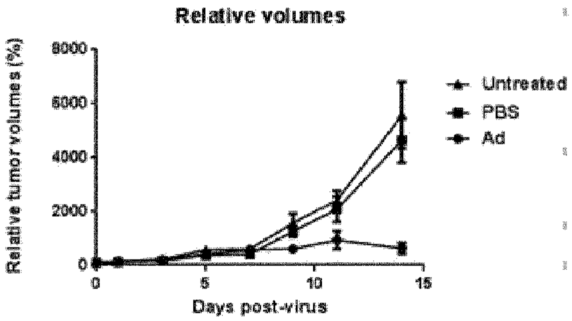
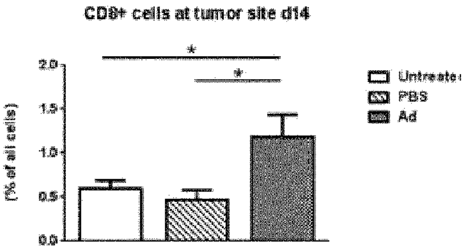


Figure 5.

a)


Relative volumes
Relative tumor volumes (%)
8000
6000
4000
2000
0
0
5
10
15
Days post-virus
Untreated
PBS
Ad

b)


CD8+ cells at tumor site d14
CD8+
(% of all cells)
2.0
1.5
1.0
0.5
0.0
*
*
Untreate
PBS
Ad

c)

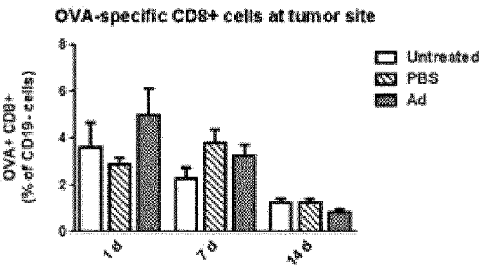

OVA-specific CD8+ cells at tumor site
OVA+ CD8+
(% of CD19- cells)
8
6
4
2
0
1 d
7 d
14 d
Untreated
PBS
Ad

Figure 6.

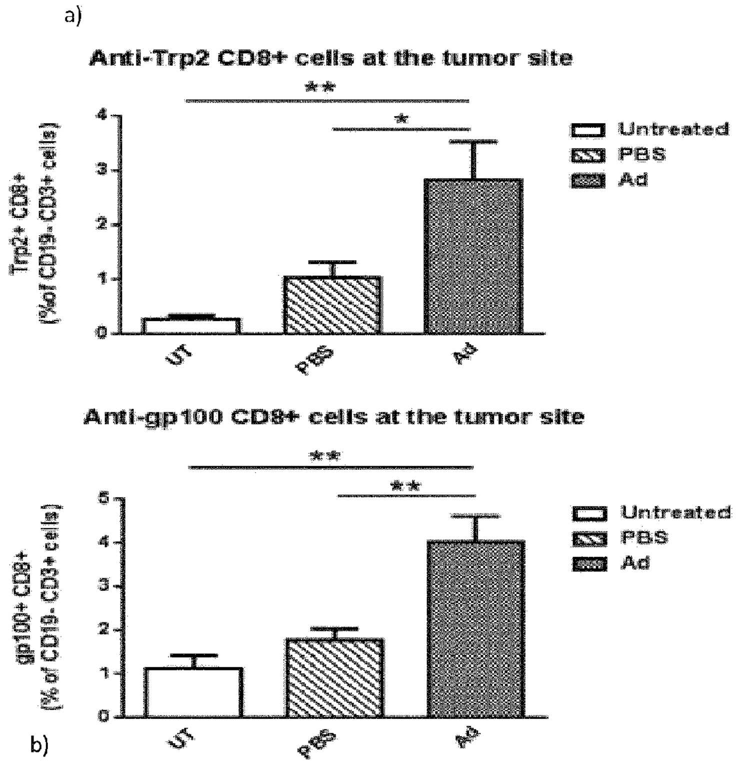


Figure 7.

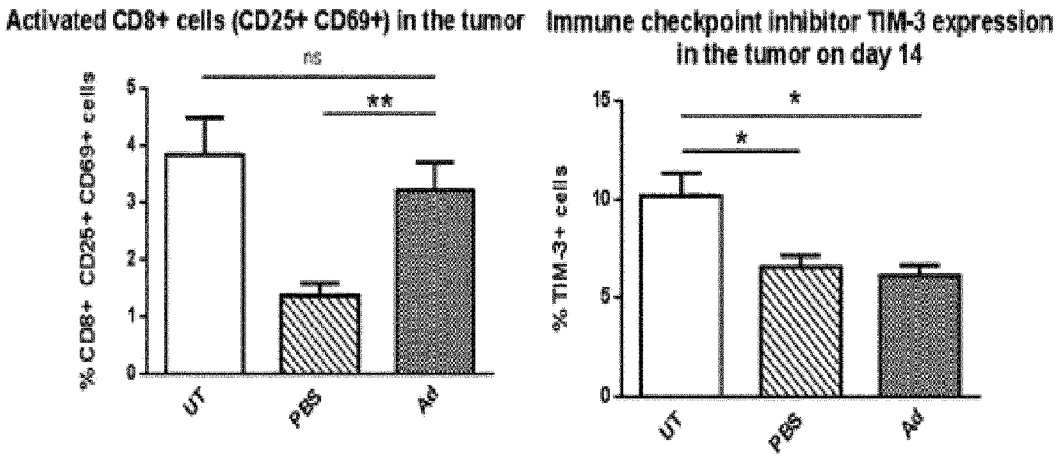
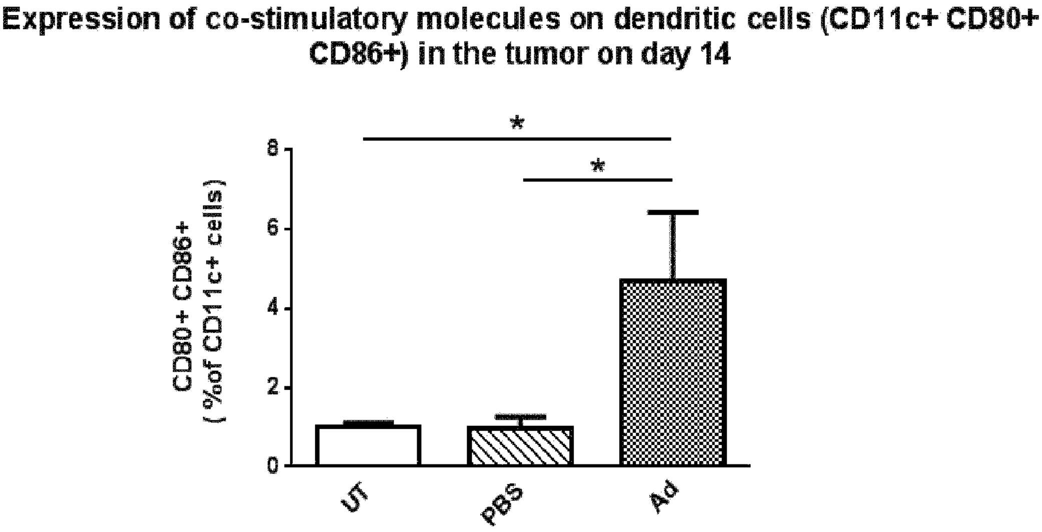


Figure 8.

a)


Expression of co-stimulatory molecules on dendritic cells (CD11c+ CD80+ CD86+) in the tumor on day 14
*
*
CD80+ CD86+
(%of CD11c+ cells)
8
6
4
2
0
UT
PBS
Ad

b)

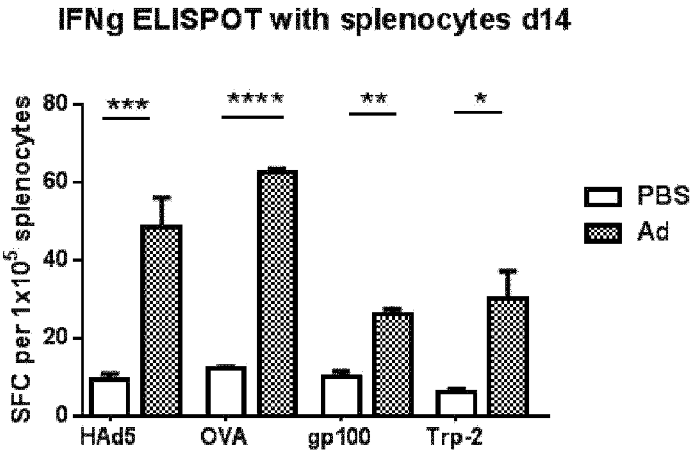
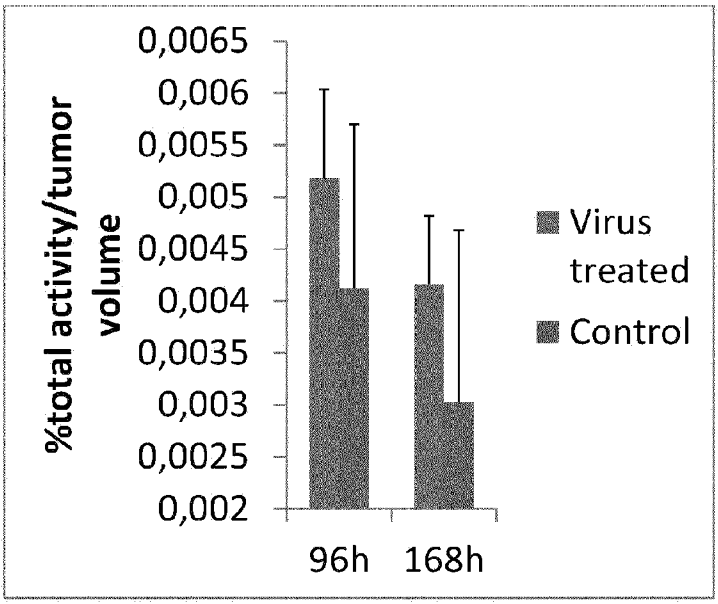
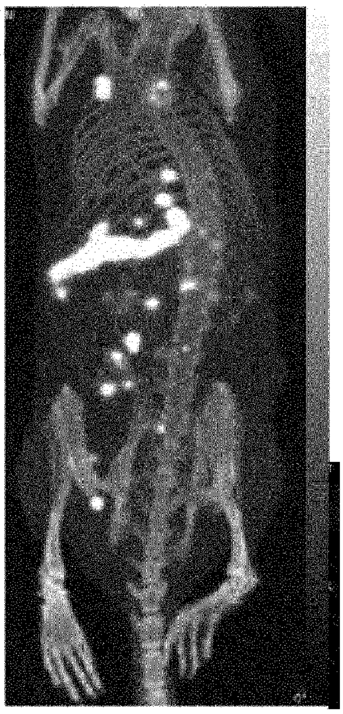

IFNg ELISPOT with splenocytes d14
***
****
**
*
SFC per 1x10^5 splenocytes
80
60
40
20
0
HAd5
OVA
gp100
Trp-2
PBS
Ad

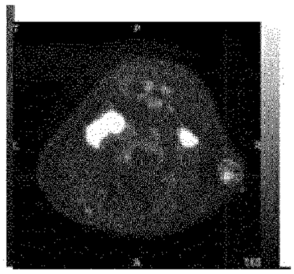
Figure 9.

a)





Uptake in normal lymphatic organs



Minor uptake in tumor

b)

c)

Figures 10a-c.

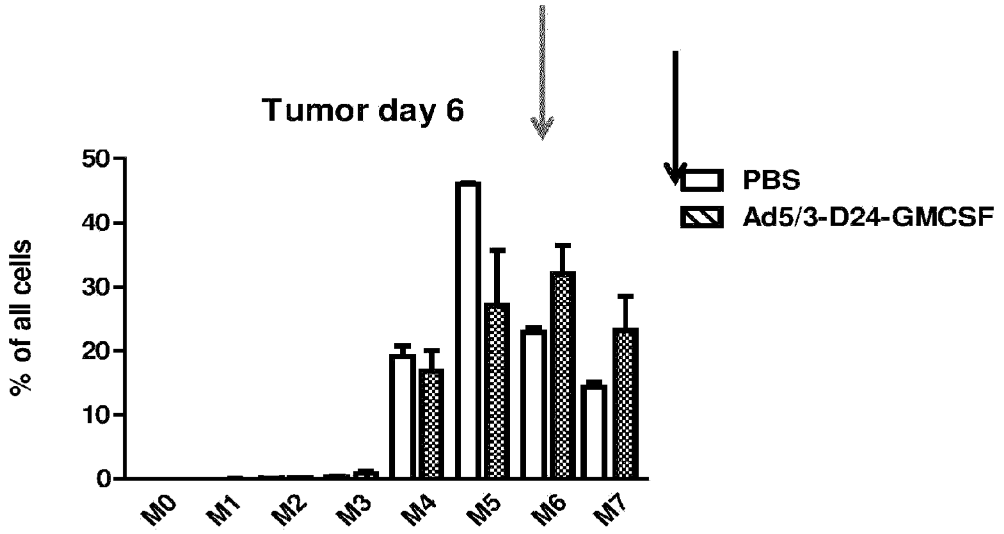


Figure 11.

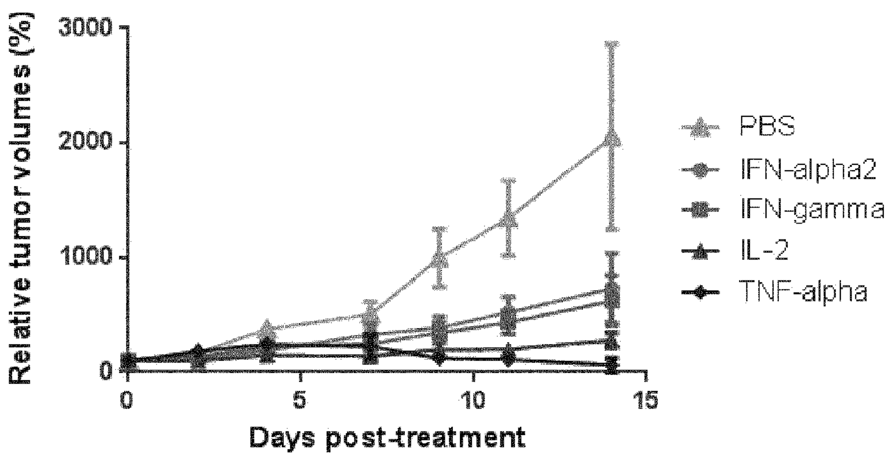
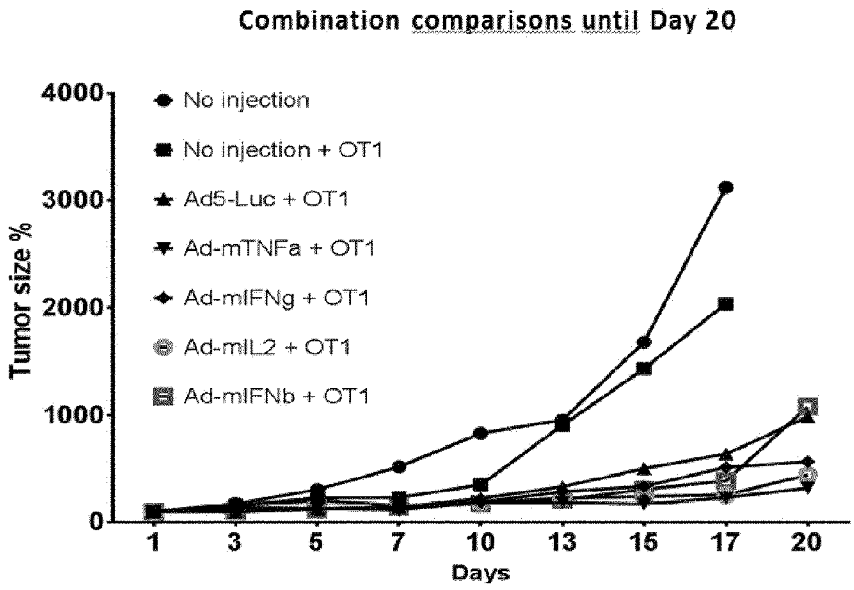
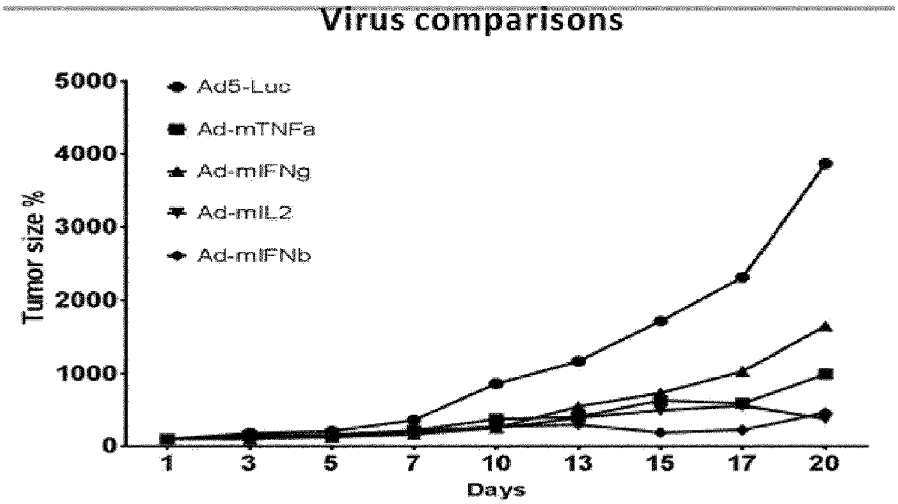


Figure 12.



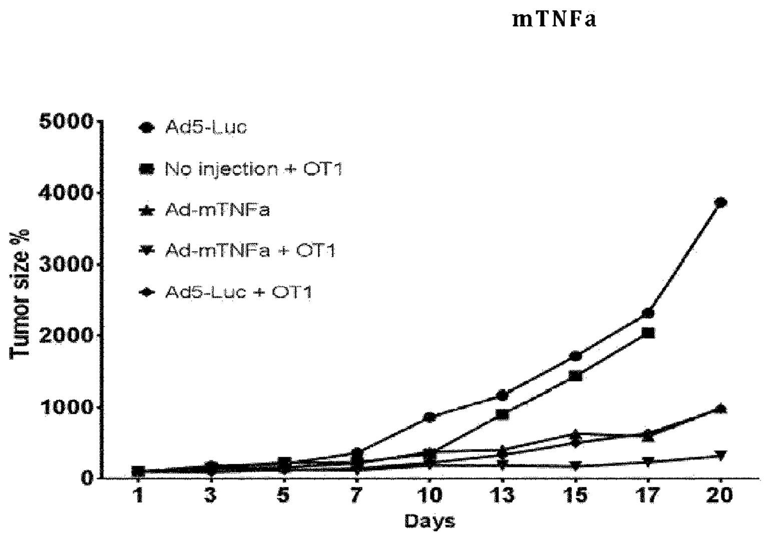
	Number at risk								
	Day 1	Day 3	Day 5	Day 7	Day 10	Day 13	Day 15	Day 17	Day 20
No injection	6	6	6	6	6	5	5	5	2
No injection + OT1	6	6	6	6	5	5	5	5	3
Ad5-Luc + OT1	5	5	5	5	5	5	5	4	4
Ad-mTNFa + OT1	6	6	6	6	5	5	4	4	4
Ad-mIFNg + OT1	5	5	5	5	5	5	5	5	4
Ad-mIL2 + OT1	5	5	5	5	4	4	4	4	4
Ad-mIFNb + OT1	5	5	5	5	5	5	5	5	5

Figure 13.



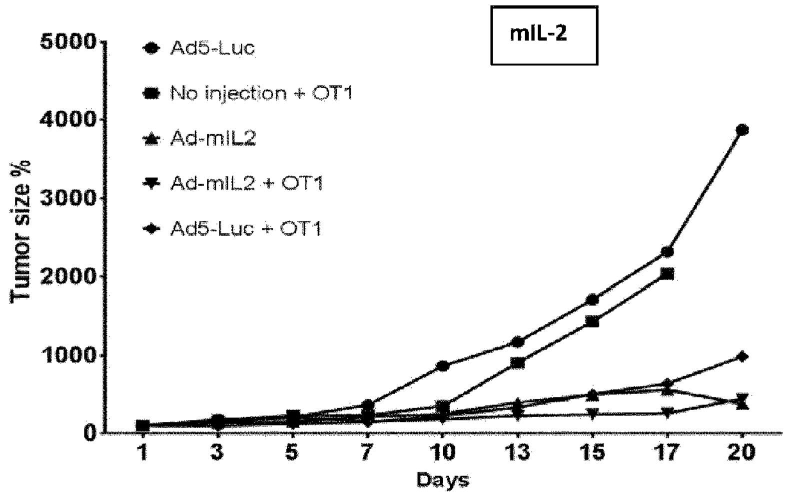
	Number at risk								
	Day 1	Day 3	Day 5	Day 7	Day 10	Day 13	Day 15	Day 17	Day 20
Ad5-Luc	6	6	6	6	6	6	5	5	4
Ad-mTNFa	5	5	5	5	4	4	4	3	3
Ad-mIFNg	5	5	5	5	5	5	5	5	5
Ad-mIL2	5	5	5	5	5	5	5	5	4
Ad-mIFNb	5	5	5	5	5	5	4	4	4

Figure 14.



	Number at risk								
	Day 1	Day 3	Day 5	Day 7	Day 10	Day 13	Day 15	Day 17	Day 20
Ad5-Luc	6	6	6	6	6	6	5	5	4
No injection + OT1	6	6	6	6	5	5	5	5	3
Ad-mTNFa	5	5	5	5	4	4	4	3	3
Ad-mTNFa + OT1	6	6	6	6	5	5	4	4	4
Ad5-Luc + OT1	5	5	5	5	5	5	5	4	4

Figure 15.



	Number at risk								
	Day 1	Day 3	Day 5	Day 7	Day 10	Day 13	Day 15	Day 17	Day 20
Ad5-Luc	6	6	6	6	6	6	5	5	4
No injection + OT1	6	6	6	6	5	5	5	5	3
Ad-mIL2	5	5	5	5	5	5	5	5	4
Ad-mIL2 + OT1	5	5	5	5	4	4	4	4	4
Ad5-Luc + OT1	5	5	5	5	5	5	5	4	4

Figure 16.

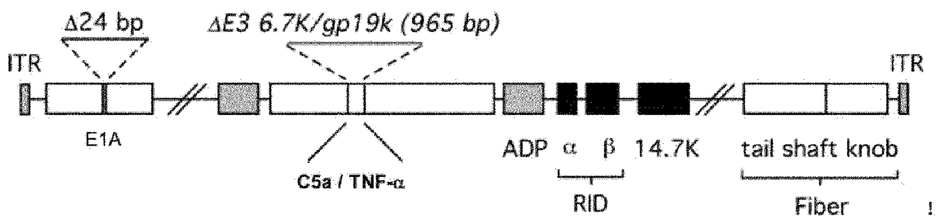


Figure 17.

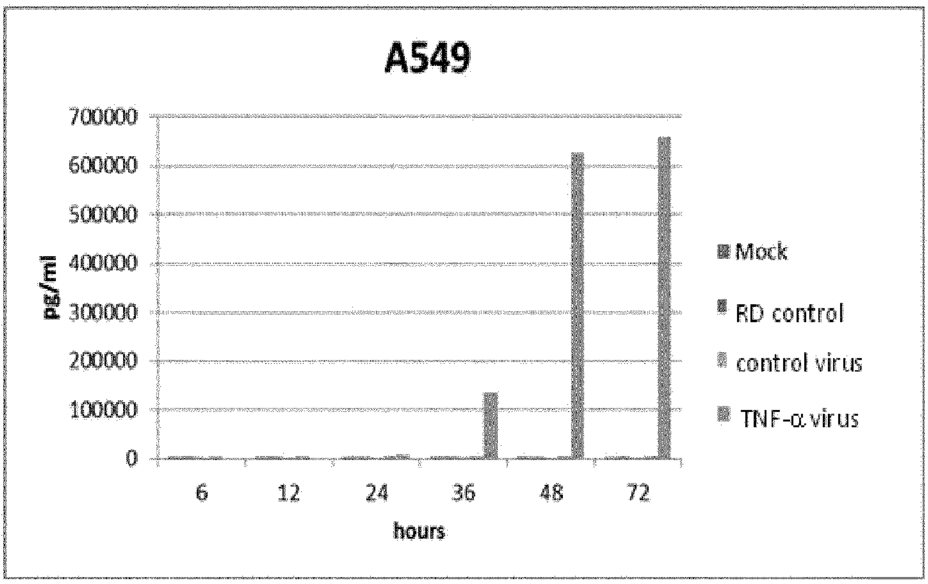


Figure 18.

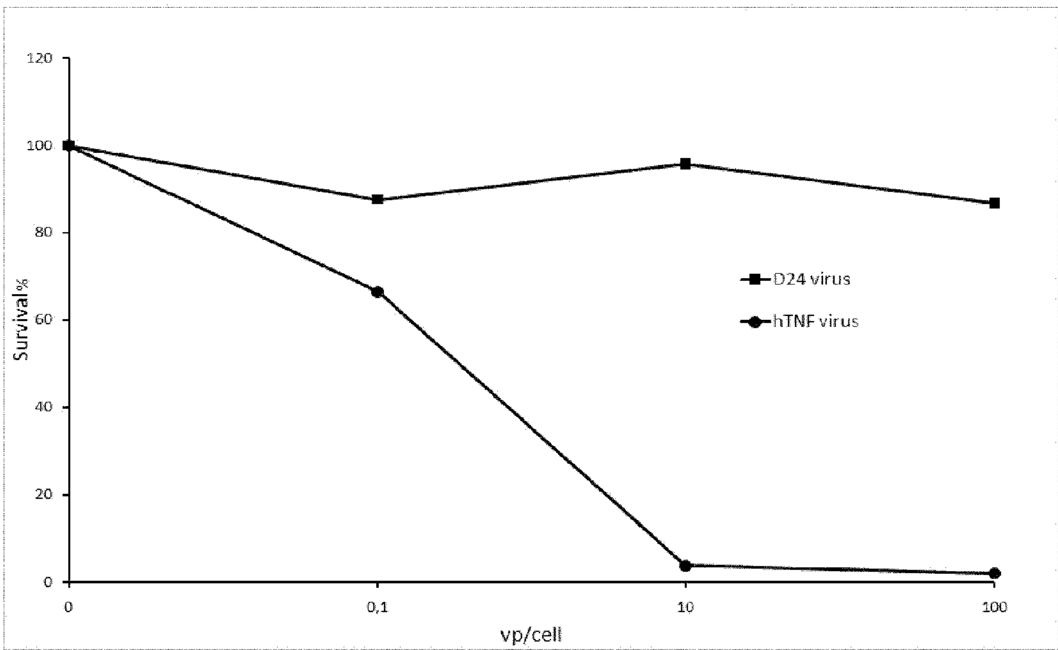


Figure 19.

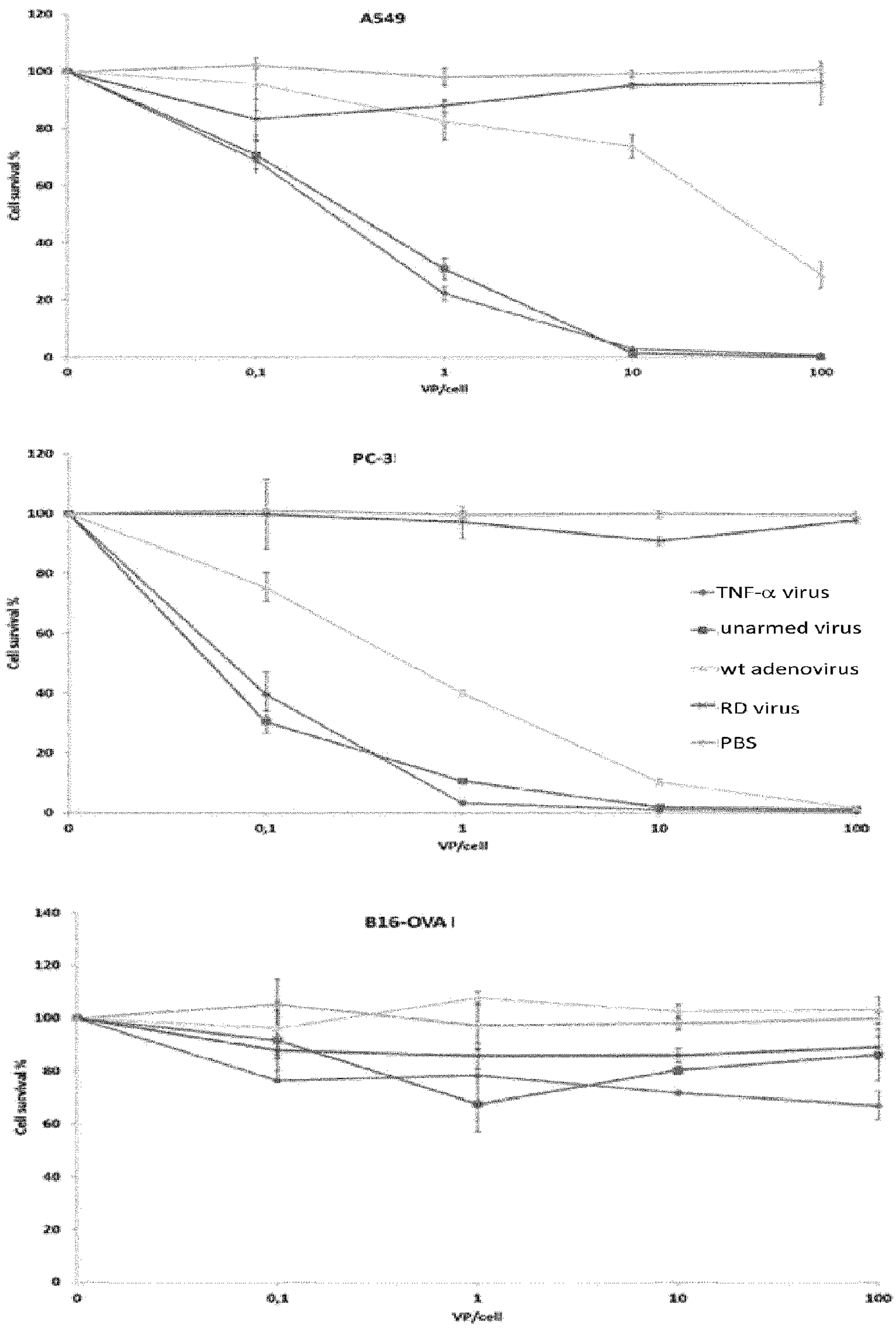

A549
Cell survival %
VP/cell
PC-3
TNF-α virus
unarmed virus
wt adenovirus
RD virus
PBS
B16-OVA

Figure 20.

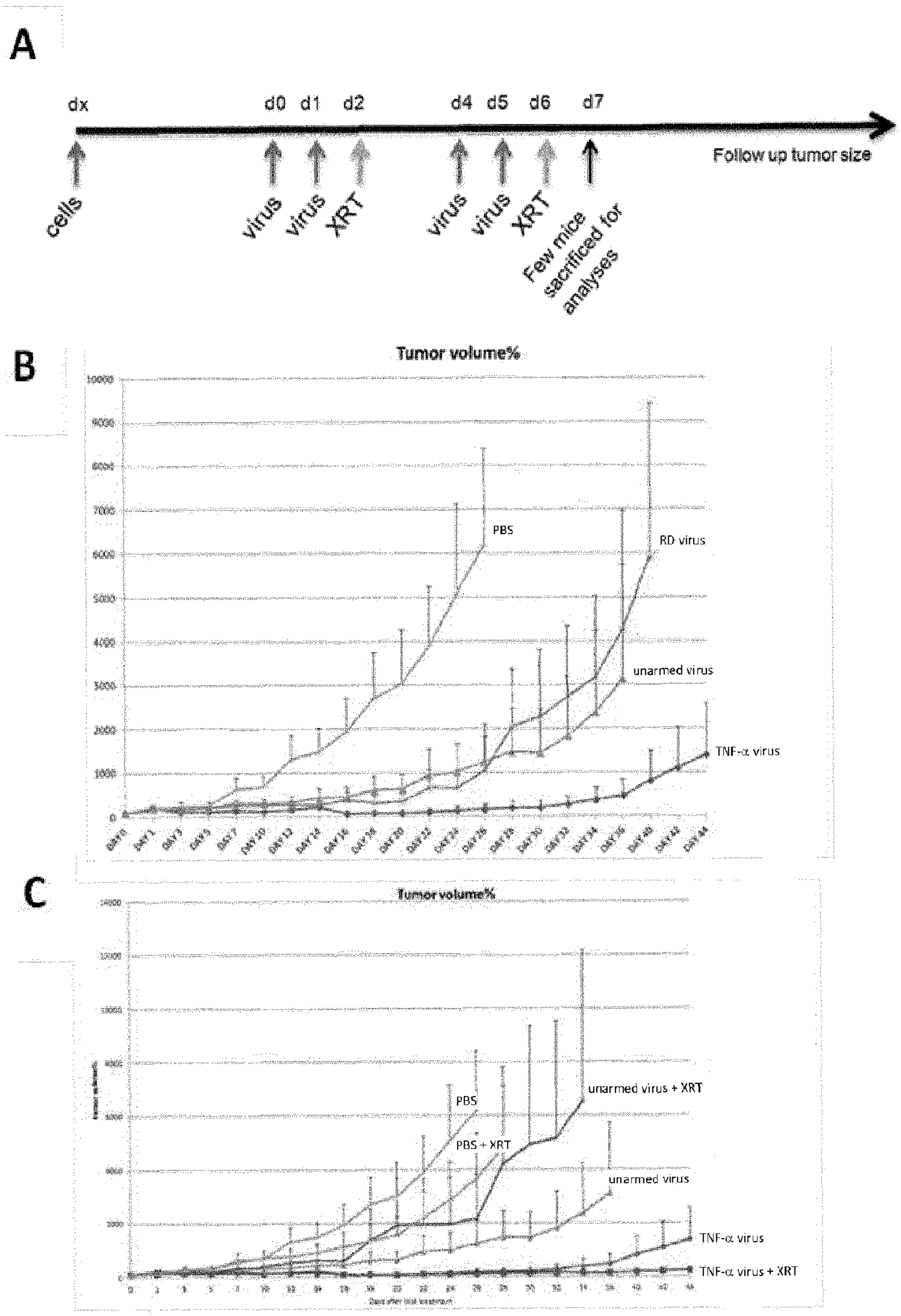

A
dx
d0
d1
d2
d4
d5
d6
d7
Follow up tumor size
cells
virus
virus
XRT
virus
virus
XRT
Few mice sacrificed for analyses
B
Tumor volume%
PBS
RD virus
unarmed virus
TNF-α virus
C
Tumor volume%
PBS
PBS + XRT
unarmed virus + XRT
unarmed virus
TNF-α virus
TNF-α virus + XRT

Figure 21.

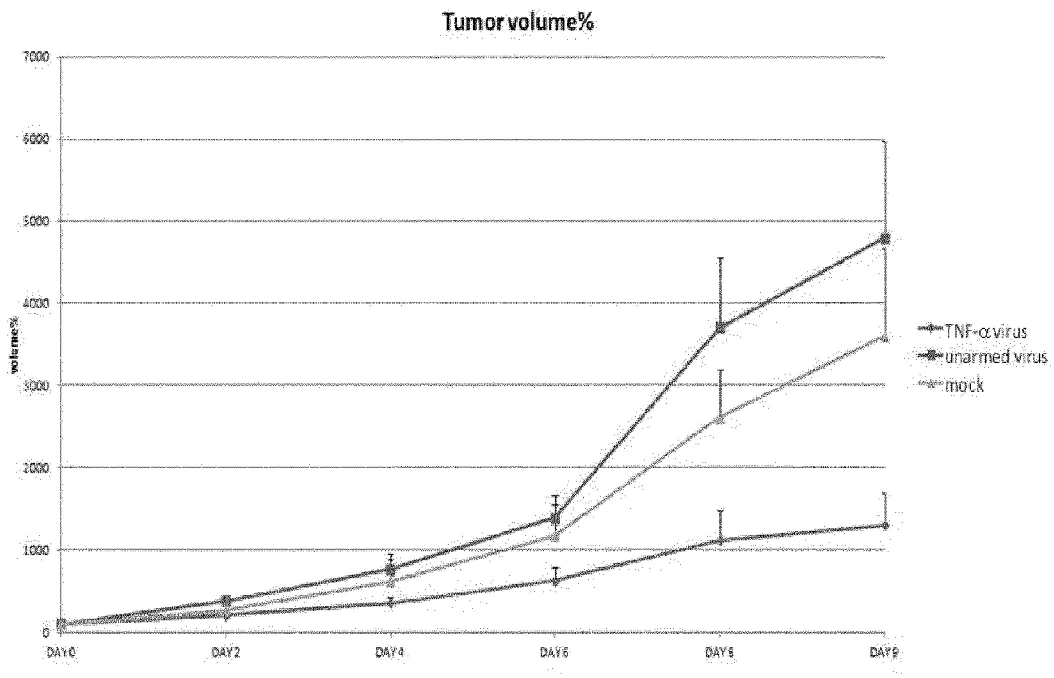


Figure 22.

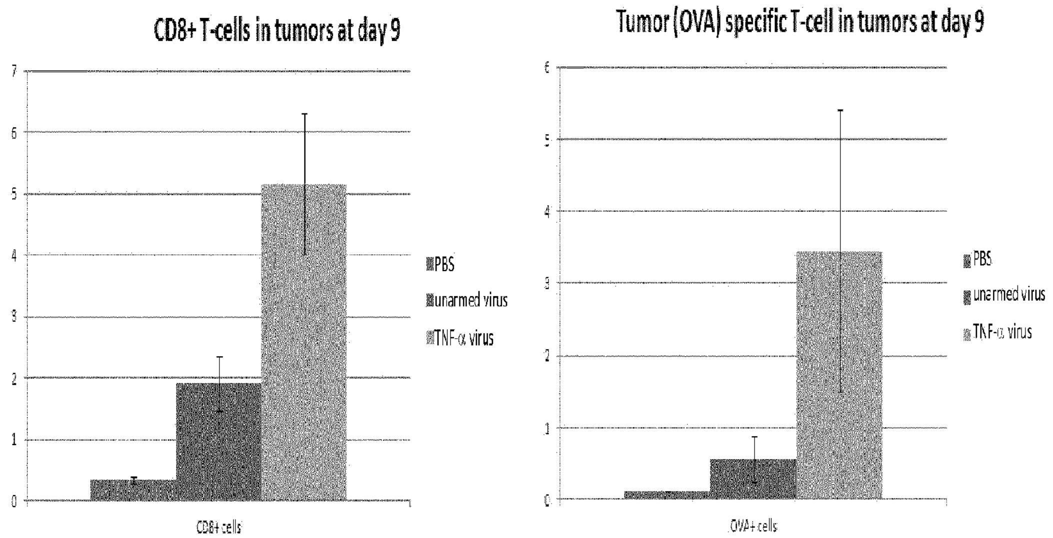


Figure 23.

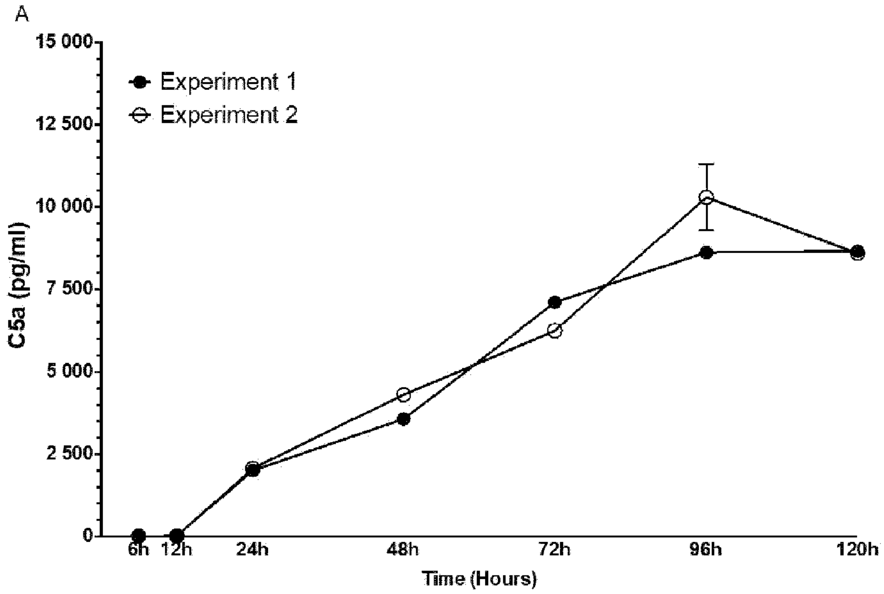


Figure 24.

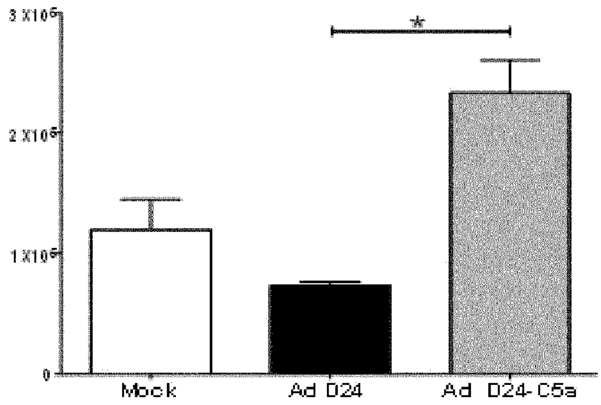


Figure 25.

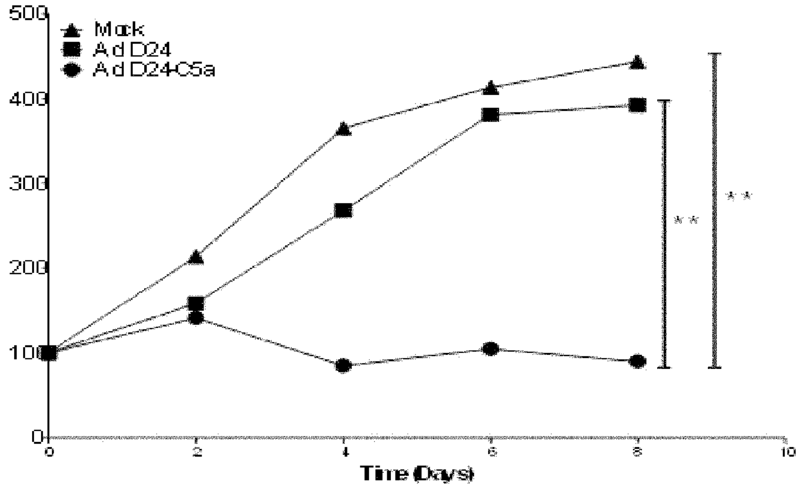


Figure 26.

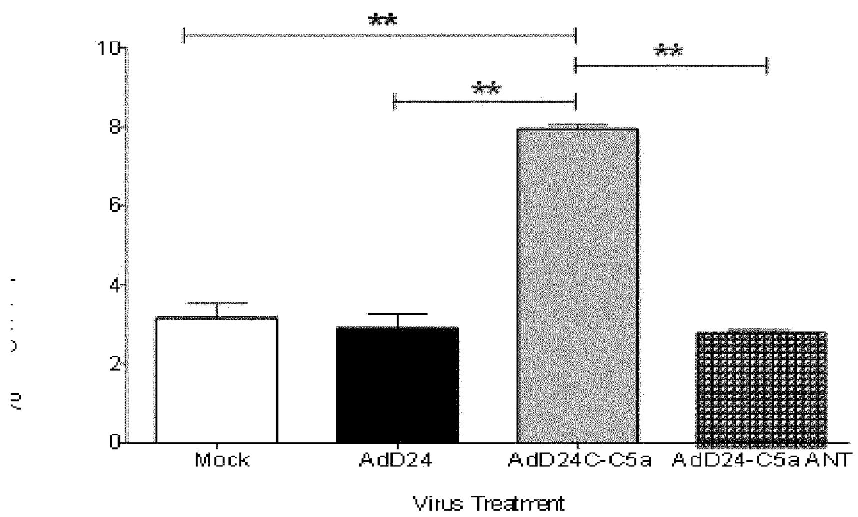


Figure 27.

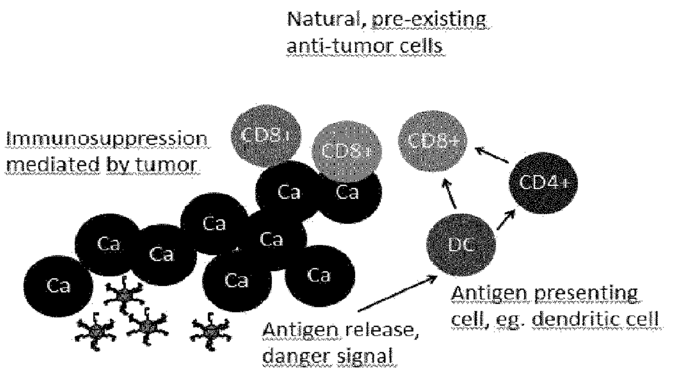


Figure 28.

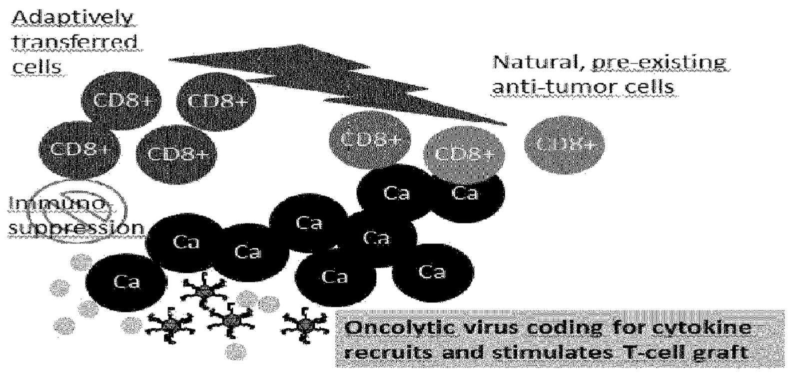


Figure 29.

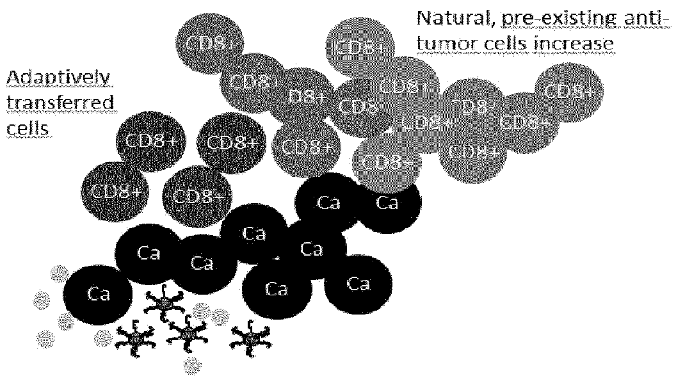


Figure 30.

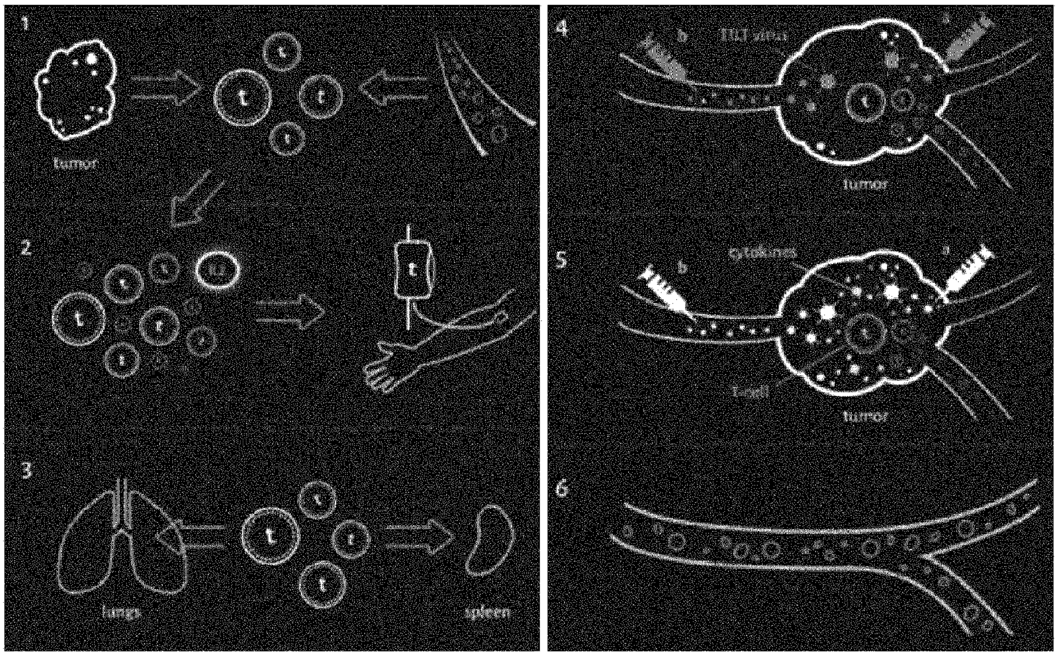


Figure 31.

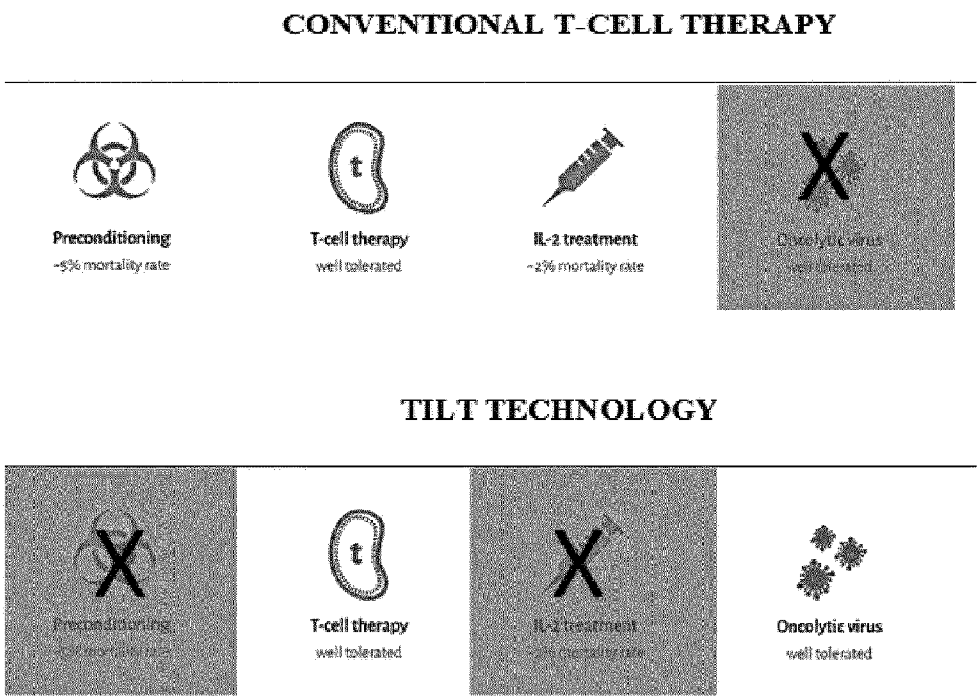


Figure 32.

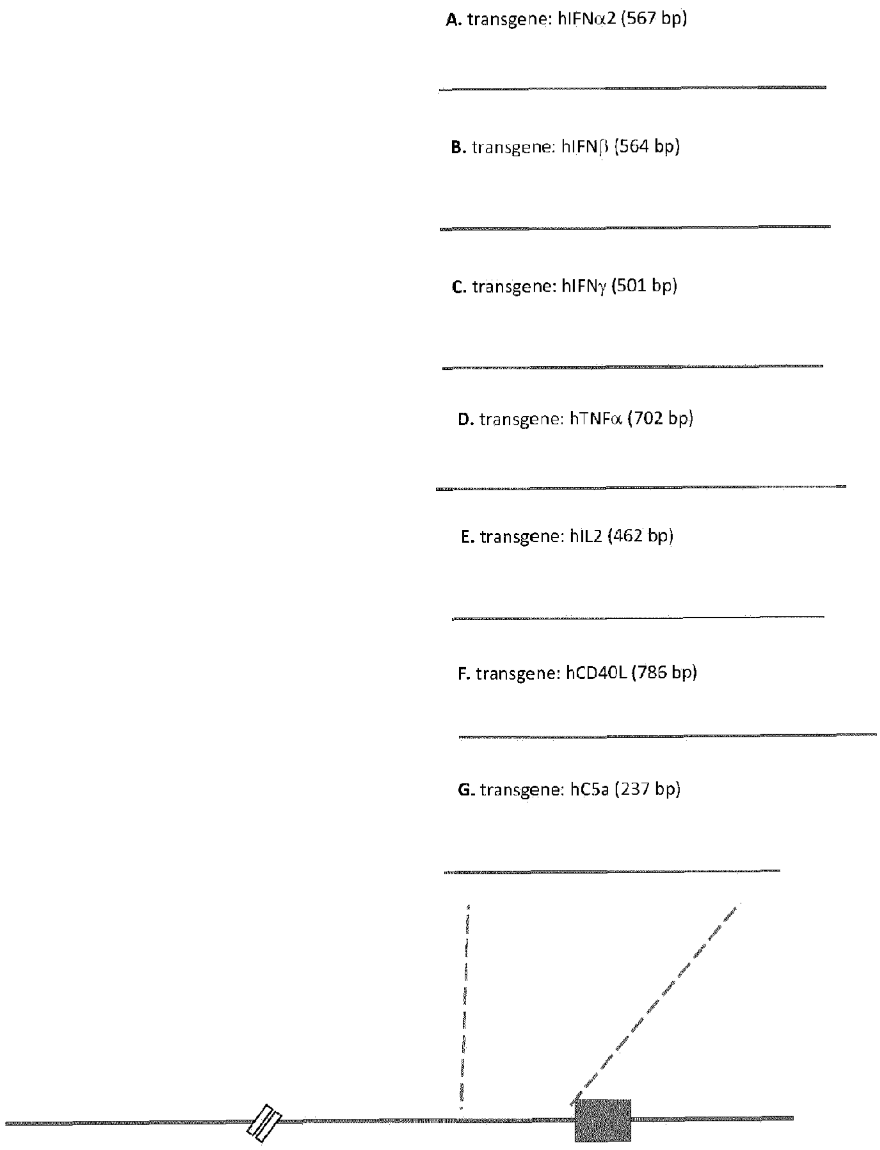

A. transgene: hIFNα2 (567 bp)
B. transgene: hIFNβ (564 bp)
C. transgene: hIFNγ (501 bp)
D. transgene: hTNFα (702 bp)
E. transgene: hIL2 (462 bp)
F. transgene: hCD40L (786 bp)
G. transgene: hC5a (237 bp)

Figure 33.

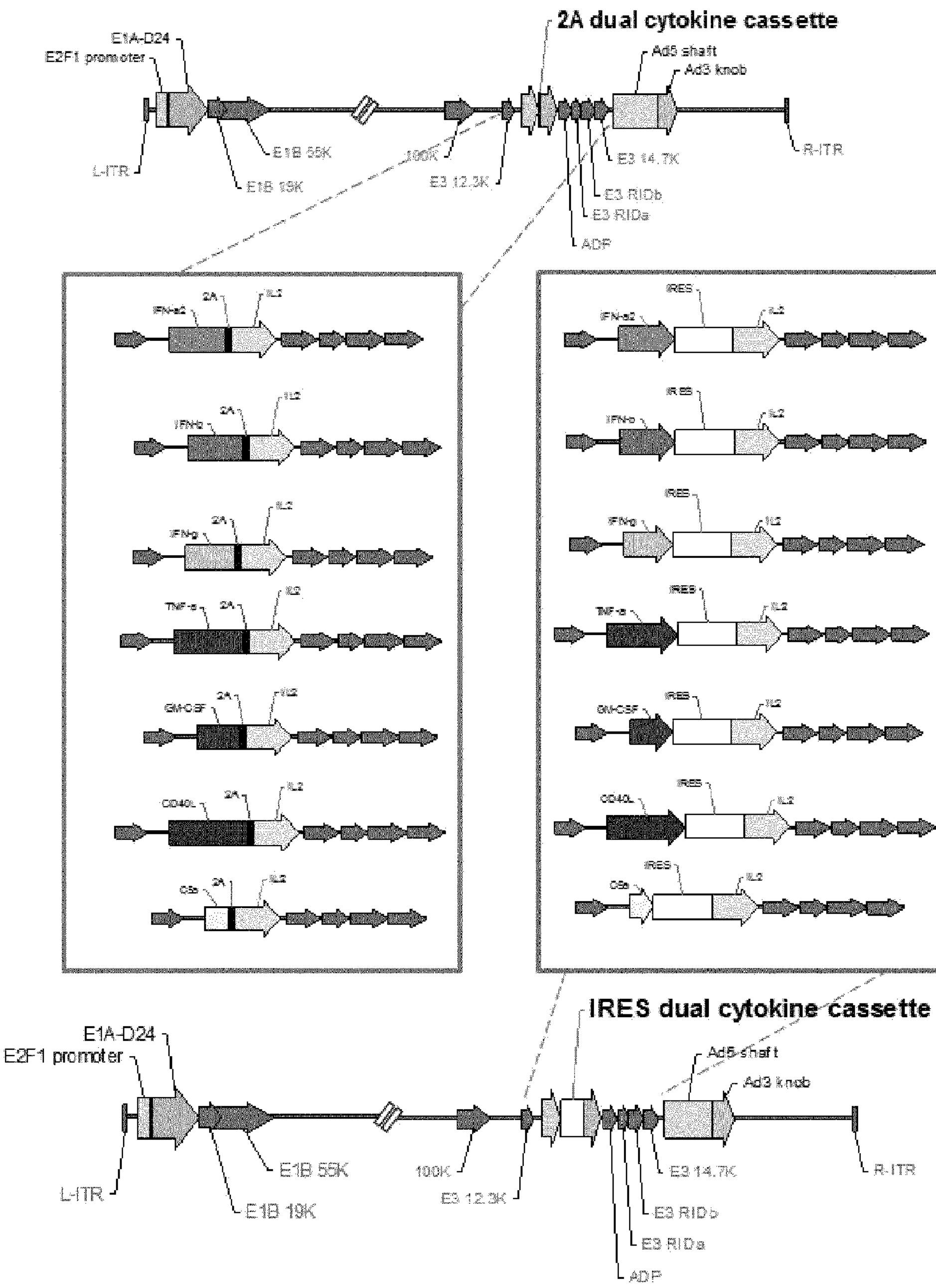

2A dual cytokine cassette
E1A-D24
E2F1 promoter
Ad5 shaft
Ad3 knob
L-ITR
E1B 55K
E1B 19K
100K
E3 12.3K
E3 14.7K
E3 RIDb
E3 RIDa
ADP
R-ITR
IRES dual cytokine cassette

Figure 34.

'ribosome shunt site', 'ribosome skipping site', 'cis-acting hydrolase element' (CHYSEL), '2A-like':

Foot & mouth disease virus (FMDV) 2A peptide:

nucleotide sequence: gtgaaaCAGCTGTTGAATTTTGACCTTCTTAAGCTTGCGGGAGACGTCGAGTCCAACCCCGGGCCC

translation: VKQLLNFDLLKLAGDVESNPG P

Porcine teshcovirus 1 (TV1) 2A peptide:

nucleotide sequence: ggcagcggcGCCACGAACTTCTCTCTGTTAAAGCAAGCAGGAGATGTTGAAGAAAACCCCGGGCCT

translation: GSGATNFSLLKQAGDVEENPG P (The GSG spacer improves cleavage; Holst et al., 2006, Nat Prot)

Thosea asigna virus (TAV) 2A peptide:

nucleotide sequence: GAGGGCAGAGGAAGTCTTCTAACATGCGGTGACGTGGAGGAGAATCCCGGCCCT

EGRGSLLTCGDVEENPG P

Figure 35.

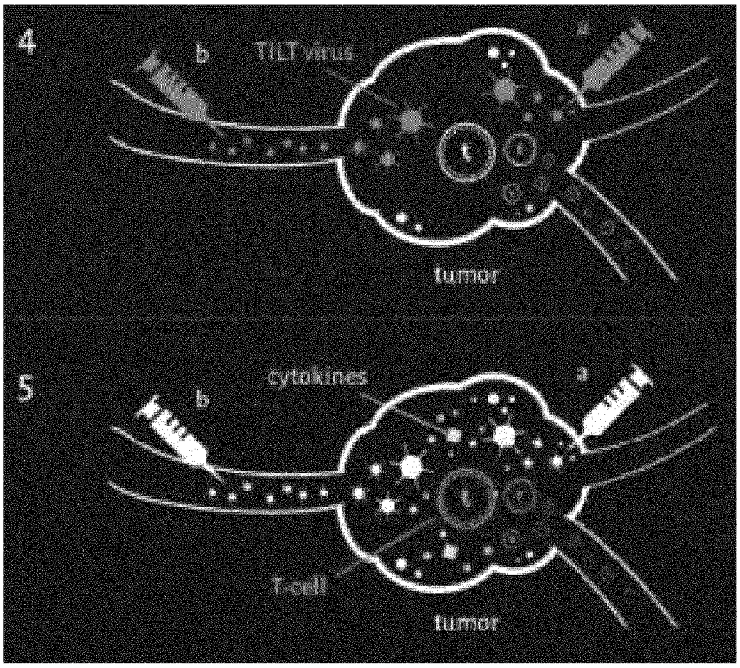


Figure 36.

.

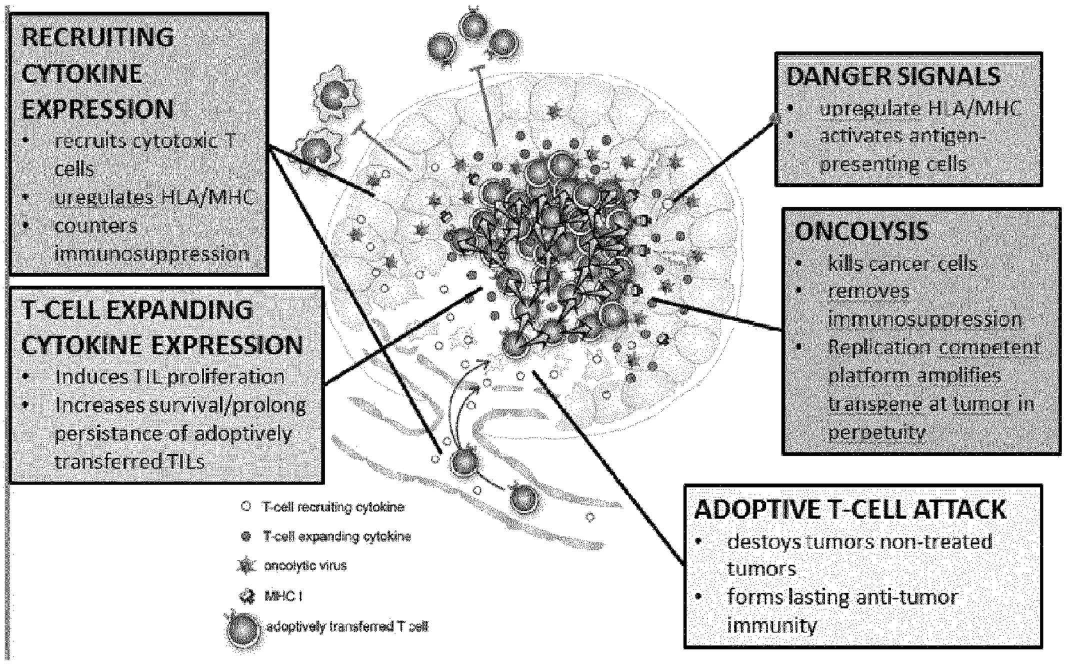


Figure 37.

Groups	SAC 1	SAC 2
PBS	5	5
IFN-α2a	5	5
IFN-β	5	5
IFN-γ	5	5
IL-2	5	5
GMCSF	5	5
CD40L	5	5
TNF-α	5	5
C5a	5	5
	45	45

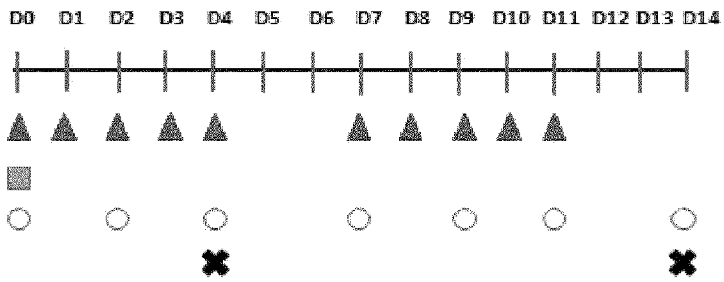


Figure 38.

GROUP	SAC1	SAC2	SAC3
PBS	5	5	5
unarmed RD control virus	5	5	5
unarmed oncolytic virus	5	5	5
C5a oncolytic virus	5	5	5
TNFa oncolytic virus	5	5	5
CD40L RD virus	5	5	5
IFNg RD virus	5	5	5
	35	**35**	**35**

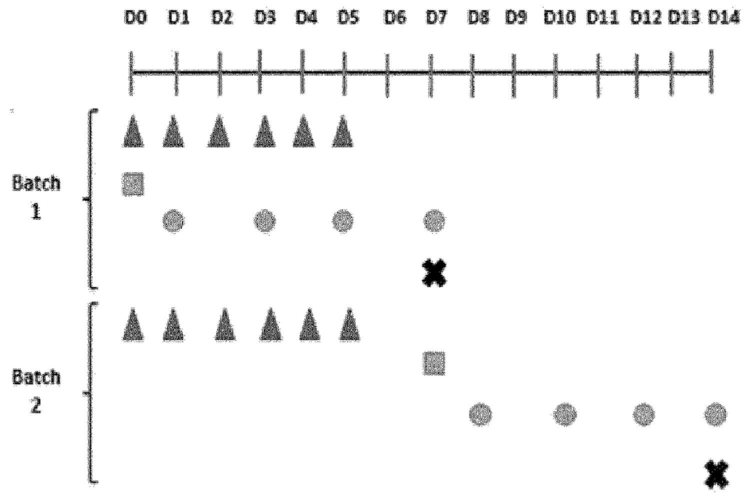


Figure 39.

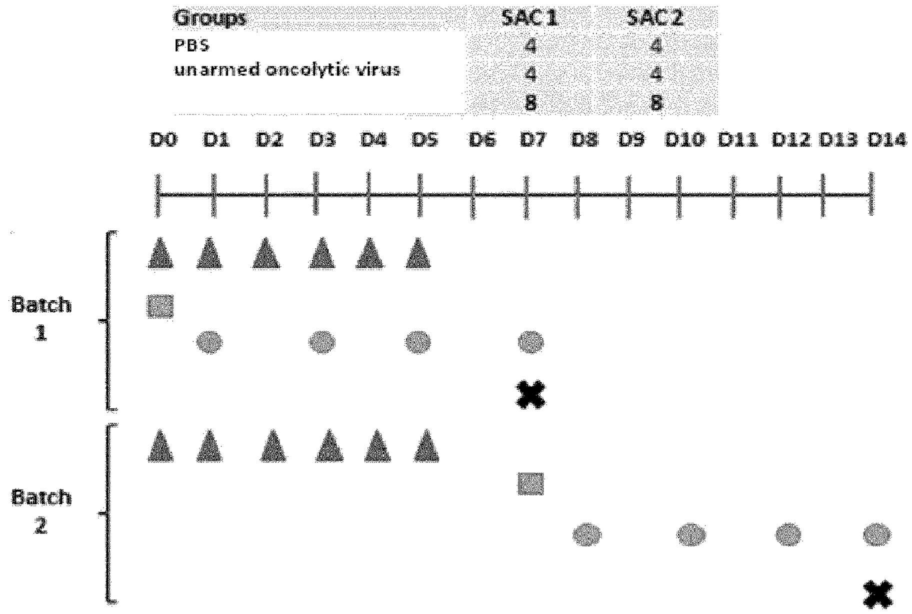

Groups
SAC 1
SAC 2
PBS
4
4
unarmed oncolytic virus
4
4
8
8
D0
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
D12
D13
D14
Batch 1
Batch 2

Figure 40.

SEKVENSLISTE

Sekvenslisten er udeladt af skriftet og kan hentes fra det Europæiske Patent Register.

The Sequence Listing was omitted from the document and can be downloaded from the European Patent Register.