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(54) Title: METHODS AND COMPOSITIONS COMPRISING VIRAL GENE THERAPY AND AN IMMUNE CHECKPOINT INHIBITOR FOR TREATMENT AND PREVENTION OF CANCER AND INFECTIOUS DISEASES

(57) Abstract: Provided herein are methods and compositions for treating cancer in an individual comprising administering to the individual an effective amount of at least one immune checkpoint inhibitor and a viral composition comprising one or more viruses engineered to comprise an N1L gene deletion, a matrix-degrading protein gene, an adenoviral death protein (ADP) gene, and/or a cytochrome p450 gene. Also provided herein are methods and compositions for treating cancer in an individual comprising administering to the individual an effective amount of a viral composition comprising two or more viruses engineered to comprise an N1L gene deletion, a matrix-degrading protein gene, an adenoviral death protein (ADP) gene, and/or a cytochrome p450 gene. Also provided herein are methods of enhancing antitumor efficacy by administering the agents described above in combination with other cancer therapies.

DESCRIPTION

METHODS AND COMPOSITIONS COMPRISING VIRAL GENE THERAPY AND AN IMMUNE CHECKPOINT INHIBITOR FOR TREATMENT AND PREVENTION OF CANCER AND INFECTIOUS DISEASES

[0001] The present application claims the priority benefit of United States Provisional Applications Serial No. 62/433,075, filed December 12, 2016, Serial No. 62/438,273, filed December 22, 2016, Serial No. 62/444,160, filed January 9, 2017, the entire contents of each application being hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates generally to the fields of biology and medicine. More particularly, it concerns methods and compositions that combine genetically engineered viruses which induce local and/or abscopal effects.

2. Description of Related Art

[0003] Current therapies for cancer involve locoregional treatments like surgery or radiation and systemically administered agents like chemotherapy and monoclonal antibodies.

[0004] The abscopal effect is an uncommon phenomenon in the treatment of metastatic cancer where localized treatment of a tumor causes regression of the treated tumor and additional tumors outside the scope of the localized treatment. This phenomenon was first defined in 1953 for radiation therapy by the physician R.H. Mole who proposed the term "abscopal" ('ab' - away from, 'scopus' - target) to refer to therapeutic effects at a distance from the treated volume but within the same organism (Mole, 1953).

[0005] Despite advances in both locoregional and systemic cancer treatments, it is estimated there will be approximately 500,000 deaths from cancer yearly in the United States. Hence, there is an unmet need for improved cancer therapies which can increase local and abscopal efficacy.

SUMMARY OF THE INVENTION

[0006] In certain embodiments, the present disclosure provides methods to treat cancer by administering a virus composition to treat a cancer in a subject. In one embodiment, the present disclosure provides methods and compositions of treating cancer in a subject comprising administering to the subject an effective amount of two or more viruses engineered to comprise an N1L gene deletion, a matrix-degrading protein gene, an adenoviral death protein (ADP) gene, and/or a cytochrome p450 gene. In certain aspects, the adenoviral death protein is overexpressed. In particular aspects, the virus engineered to comprise the N1L deletion is a vaccinia virus. In some aspects, the virus engineered to comprise the cytochrome p450 gene is a herpes simplex virus. In certain aspects, the viruses engineered to comprise the matrix-degrading protein and/or adenoviral death protein are adenoviruses.

[0007] In another embodiment, the present disclosure provides methods and compositions of treating cancer in a subject comprising administering to the subject an effective amount of (a) one or more viruses one or more viruses engineered to comprise an N1L gene deletion, a matrix-degrading protein gene, an adenoviral death protein (ADP) gene, and/or a cytochrome p450 gene, and (b) at least one immune checkpoint inhibitor. In certain aspects, more than one checkpoint inhibitor is administered. In particular aspects, one, two, three, or all four of the viruses are administered. In certain aspects, the adenoviral death protein is overexpressed. In particular aspects, the virus engineered to comprise the N1L deletion is a vaccinia virus. In some aspects, the virus engineered to comprise the cytochrome p450 gene is a herpes simplex virus. In certain aspects, the viruses engineered to comprise the matrix-degrading protein and/or adenoviral death protein are adenoviruses.

[0008] In one particular aspect, a virus composition in the above embodiments may comprise one, two, three, or four of the following viruses (a) a virus engineered to express the relaxin gene, (b) a virus engineered to overexpress the adenoviral death protein (ADP) gene, (c) a vaccinia virus engineered to delete the N1L gene, and (d) a herpes simplex virus engineered to express the rat cytochrome p450 2B1 gene.

[0009] In one embodiment, the present disclosure provides methods and compositions for treating or preventing cancer or an infectious disease in a subject comprising administering to the subject effective amounts of (a) a vaccinia virus that expresses at least one tumor associated or pathogen associated antigen, said virus comprising an N1L gene deletion, and (b)

at least a second virus, preferably an adenovirus, that expresses at least one tumor associated or pathogen associated antigen. In certain aspects, the tumor associated antigen is mesothelin, melanoma-associated gene (MAGE), carcinoembryonic antigen (CEA), mutated Ras, or mutated p53. In certain aspects, the pathogen associated antigen is an antigen expressed by an infectious viral, bacterial, fungal, prion, or parasitic organism. In some aspects, the at least one tumor associated or pathogen associated antigen expressed by the vaccinia virus and the at least one tumor associated or pathogen associated antigen expressed by the second virus are the same. In other aspects, the at least one tumor associated or pathogen associated antigen expressed by the vaccinia virus and the at least one tumor associated or pathogen associated antigen expressed by the second virus are different. In certain aspects, the second virus, preferably an adenovirus, is administered prior to administration of the N1L-deleted vaccinia virus that expresses at least one tumor associated or pathogen associated antigen. In certain aspects, the subject is administered the virus composition more than once, such as providing an initial priming vaccination following by one or more booster vaccination. In some aspects, the subject is further administered a tumor suppressor immune gene therapy (*see*, PCT/US2016/060833, which is incorporated herein by reference in its entirety).

[0010] In some aspects, the viruses of the above embodiments comprise an adenovirus, retrovirus, vaccinia virus, adeno-associated virus, herpes virus, vesicular stomatitis virus, and/or stomatitis virus. In certain aspects, the viruses comprise one or more adenoviruses.

[0011] In some aspects, the matrix-degrading protein is relaxin, hyaluronidase, or decorin. In particular aspects, the matrix-degrading protein is relaxin.

[0012] In certain aspects, the cytochrome p450 gene is the cytochrome p450 2B1 gene. In particular aspects, the cytochrome p450 2B1 gene is rat cytochrome p450 2B1 gene.

[0013] In some aspects, the virus composition induces local and/or abscopal effects. In some aspects, the virus composition induces local and abscopal effects.

[0014] In certain aspects, the viruses are replication competent or oncolytic. In certain aspects, the viruses are replication incompetent. In certain aspects, the virus composition comprises a combination of replication competent and replication incompetent viruses.

[0015] In some aspects, the virus engineered to express relaxin and/or the virus engineered to overexpress the adenoviral death protein (ADP) is an adenovirus, retrovirus,

vaccinia virus, adeno-associated virus, herpes virus, vesicular stomatitis virus, or stomatitis virus. In particular aspects, the virus engineered to express relaxin and/or the virus engineered to overexpress the adenoviral death protein (ADP) is an adenovirus.

[0016] In particular aspects, the treated subject is a mammal or human. In certain aspects, the treatment is provided to prevent or treat a pre-malignant or a malignant hyperproliferative condition. In certain aspects of prevention, the subject is a healthy subject. In other aspects of prevention, the subject comprises a pre-malignant lesion, such as, for example, a leukoplakia or a dysplastic lesion. In other aspects of prevention, the subject is at risk of developing cancer, such as, for example, by being a smoker or having a family history of cancer. In certain aspects, the treatment is for initial or recurrent hyperproliferative conditions. In some aspects, the treatment is administered to augment or reverse resistance to another therapy. In certain aspects, the resistance to treatment is known historically for a particular population of hyperproliferative condition patients. In certain aspects, the resistance to treatment is observed in individual hyperproliferative condition patients.

[0017] In certain aspects, the virus administered to the subject is engineered to express relaxin. In some aspects, the relaxin is full length relaxin. In other aspects, the relaxin is a fragment of relaxin molecule that retains biological activity (*e.g.,* described in U.S. Patent No. 5,023,321). In particular aspects, the relaxin is recombinant human relaxin (H2) or other active agents with relaxin-like activity, such as agents that competitively displace bound relaxin from a receptor.

[0018] In certain aspects, the virus engineered to overexpress ADP is a serotype 5 adenovirus termed VRX-007 (*i.e.,* an oncolytic adenoviral vector engineered to delete most of the E3 region and to overexpresses the E3-11.6K Adenovirus Death Protein (ADP)). VRX-007 may also be modified to express other therapeutic genes. The construction of VRX-007 is described previously (Doronin 2003; Tollefson 1996; Lichtenstein 2004).

[0019] In certain aspects, the vaccinia virus engineered to delete N1L is derived from the Western Reserve, Wyeth and Lister strains. Various deletion mutants of each of these strains have been created. In certain aspects, the N1L deletion derivatives VVL 15N1L employed are described in Wang *et al.*, 2015 (Patent WO2015/150809A1). VVL 15N1L vectors may also be modified to express therapeutic genes including but not limited to IL-12 and/or relaxin. In some aspects, the VVL 15N1L vectors are also combined with immune

checkpoint inhibitors and PI3K inhibitors. In a particular aspect, PI3Kdelta or PI3Kgamma/delta inhibitors are administered to enhance intravenous administration of viral vectors. In one particular method, the subject is administered the PI3K delta inhibitor prior to (*e.g.,* hours) the intravenous VVL 15N1L vectors.

[0020] In certain aspects, the herpes simplex virus engineered to express the rat cytochrome p450 2B1 gene has a deleted ICP6 gene and is termed rRp450 as further described in (Aghi *et al.,* 1999). The vector encodes for expression of the cyclophosphamide (CPA)-sensitive rat cytochrome p450 2B1, and the ganciclovir (GCV)-sensitive herpes simplex virus thymidine kinase (HSV-TK) gene. The expression of the cytochrome p450 and HSV-TK genes result, respectively, in the conversion of CPA and GCV prodrugs into their therapeutically active metabolites. In particular aspects, rRp450 is administered in combination with CPA and GCV.

[0021] In certain aspects, the at least one checkpoint inhibitor is selected from an inhibitor of CTLA-4, PD-1, PD-L1, PD-L2, LAG-3, BTLA, B7H3, B7H4, TIM3, KIR, or A2aR. In some aspects, the at least one immune checkpoint inhibitor is an anti-CTLA-4 antibody. In some aspects, the anti-CTLA-4 antibody is tremelimumab or ipilimumab. In certain aspects, the at least one immune checkpoint inhibitor is an anti-killer-cell immunoglobulin-like receptor (KIR) antibody. In some embodiments, the anti-KIR antibody is lirilumab. In some aspects, the inhibitor of PD-L1 is durvalumab, atezolizumab, or avelumab. In some aspects, the inhibitor of PD-L2 is rHIgM12B7. In some aspects, the LAG3 inhibitor is IMP321, or BMS-986016. In some aspects, the inhibitor of A2aR is PBF-509.

[0022] In some aspects, the at least one immune checkpoint inhibitor is a human programmed cell death 1 (PD-1) axis binding antagonist. In certain aspects, the PD-1 axis binding antagonist is selected from the group consisting of a PD-1 binding antagonist, a PDL1 binding antagonist and a PDL2 binding antagonist. In some aspects, the PD-1 axis binding antagonist is a PD-1 binding antagonist. In certain aspects, the PD-1 binding antagonist inhibits the binding of PD-1 to PDL1 and/or PDL2. In particular, the PD-1 binding antagonist is a monoclonal antibody or antigen binding fragment thereof. In some embodiments, the PD-1 binding antagonist is nivolumab, pembrolizumab, pidilizumab, AMP-514, REGN2810, CT-011, BMS 936559, MPDL328OA or AMP-224.

[0023] In some aspects, the virus composition is administered intratumorally, intraarterially, intravenously, intravascularly, intrapleuraly, intraperitoneally, intratracheally, intrathecally, intramuscularly, endoscopically, intralesionally, percutaneously, subcutaneously, regionally, stereotactically, or by direct injection or perfusion. In some aspects, administering is via continuous infusion, intratumoral injection, intravenous injection, intra-arterial injection, intra-peritoneal injection, intrapleural injection, or intra-thecal injection. In some aspects, the virus compositions is administered intradermally, subcutaneously, intramuscularly, intra-peritoneally, orally, by inhalation, or by other forms of mucosal exposure.

[0024] In certain aspects, the subject is administered the virus composition after the at least one immune checkpoint inhibitor. In certain aspects, the subject is administered the virus composition before the at least one immune checkpoint inhibitor. In certain aspects, the subject is administered the virus composition simultaneously with the at least one immune checkpoint inhibitor. In some aspects, the virus composition is administered to the subject locoregionally and induces abscopal effects on untreated distant tumors. In some aspects, the virus composition and at least one immune checkpoint inhibitor induce abscopal effects on distant tumors that are not injected with the virus composition.

[0025] In certain aspects, the cancer is melanoma, non-small cell lung, small-cell lung, lung, hepatocarcinoma, retinoblastoma, astrocytoma, glioblastoma, leukemia, neuroblastoma, head, neck, breast, pancreatic, prostate, renal, bone, testicular, ovarian, mesothelioma, cervical, gastrointestinal, urogenital, respiratory tract, hematopoietic, musculoskeletal, neuroendocrine, carcinoma, sarcoma, central nervous system, peripheral nervous system, lymphoma, brain, colon or bladder cancer. In some aspects, the cancer is metastatic.

[0026] In certain aspects, the virus composition is administered at between about 10^3 and about 10^{13} viral particles. In some aspects, the virus composition is administered to the subject intravenously, intraarterially, intravascularly, intrapleuraly, intraperitoneally, intratracheally, intratumorally, intrathecally, intramuscularly, endoscopically, intralesionally, percutaneously, subcutaneously, regionally, stereotactically, or by direct injection or perfusion. In certain aspects, the subject is administered the virus composition more than once. The virus composition may be administered to one or more tumors in a treated subject.

[0027] In some aspects, the virus composition is further engineered to express a therapeutic nucleic acid. In certain aspects, the therapeutic nucleic acid is a tumor suppressor gene, an immune stimulating gene, a radiation enhancing gene, or a chemotherapy enhancing gene. In certain aspects, the therapeutic nucleic acid may also regulate the expression of other genes, such as siRNA or miRNA. In some aspects, the therapeutic gene encodes p53 and/or IL-24 or variants thereof with similar or improved functions. In other aspects, methods to restore or enhance p53 or IL-24 function and these methods are known in the art and are also contemplated for use in the present embodiments.

[0028] In certain aspects, administering comprises a local or regional injection. In other aspects, administering is via continuous infusion, intratumoral injection, intravenous or intra-arterial injection.

[0029] In some aspects, the methods further comprise administering at least one additional anticancer treatment. In certain aspects, the at least one additional anticancer treatment is surgical therapy, chemotherapy (*e.g.,* administration of a protein kinase inhibitor or a EGFR-targeted therapy), embolization therapy, chemoembolization therapy, radiation therapy, cryotherapy, hyperthermia treatment, phototherapy, radioablation therapy, hormonal therapy, immunotherapy, small molecule therapy, receptor kinase inhibitor therapy, anti-angiogenic therapy, cytokine therapy or a biological therapies such as monoclonal antibodies, siRNA, miRNA, antisense oligonucleotides, ribozymes or gene therapy. In particular aspects, the at least one additional anticancer treatment is a protein kinase inhibitor, such as a tyrosine kinase inhibitor. In one specific aspect, the protein kinase inhibitor is a Bruton's tyrosine kinase (BTK) inhibitor (*e.g.,* ibrutinib, acalabrutinib (ACP-196), ONO-4059, spebrutinib (CC-292), HM-71224, CG-036806, GDC-0834, ONO-4049, RN-486, SNS-062, TAS-5567, AVL-101, AVL-291, PCI-45261, HCI-1684, PLS-123, or BGB-3111). In some aspects, one or more BTK inhibitors are administered in combination with the virus composition. In certain aspects, one or more BTK inhibitors are administered in combination with the virus composition and at least one immune checkpoint inhibitor. In some aspects, the at least one additional anticancer treatment is an inhibitor (*e.g.,* small molecule inhibitor) of HDM2 (also known as MDM2) and/or HDM4, such as to reverse its inhibition of p53 activity. In specific aspects, the small molecule inhibitor of HDM2 is HDM201, cis-imidazolines (*e.g.,* Nutlins), benzodiazepines (BDPs), spiro-oxindoles.

[0030] In some aspects, the immunotherapy comprises a cytokine. In particular aspects, the cytokine is granulocyte macrophage colony-stimulating factor (GM-CSF), an interleukin such as IL-2, and/or an interferon such as IFN-alpha. Additional approaches to boost tumor-targeted immune responses include additional immune checkpoint inhibition. In some aspects, the immune checkpoint inhibition includes anti-CTLA4, anti–PD-1, anti–PD-L1, anti-PD-L2, anti-TIM-3, anti–LAG-3, anti-A2aR, or anti-KIR antibodies. In some aspects, the immunotherapy comprises co-stimulatory receptor agonists such as anti-OX40 antibody, anti-GITR antibody, anti-CD137 antibody, anti-CD40 antibody, and anti-CD27 antibody. In certain aspects, the immunotherapy comprises suppression of T regulatory cells (Tregs), myeloid derived suppressor cells (MDSCs) and cancer associated fibroblasts (CAFs). In further aspects, the immunotherapy comprises stimulation of innate immune cells, such as natural killer (NK) cells, macrophages, and dendritic cells. Additional immune stimulatory treatments may include IDO inhibitors, TGF-beta inhibitors, IL-10 inhibitors, stimulator of interferon genes (STING) agonists, toll like receptor (TLR) agonists (*e.g.,* TLR7, TLR8, or TLR9), tumor vaccines (*e.g.,* whole tumor cell vaccines, peptides, and recombinant tumor associated antigen vaccines), and adoptive cellular therapies(ACT) (*e.g.,* T cells, natural killer cells, TILs, and LAK cells). In certain aspects, combinations of these agents may be used such as combining immune checkpoint inhibitors, checkpoint inhibition plus agonism of T-cell costimulatory receptors, and checkpoint inhibition plus TIL ACT. In certain aspects, additional anti-cancer treatment includes a combination of anti-PD-L1 immune checkpoint inhibitor (*e.g.,* Avelumab), a 4-1BB (CD-137) agonist (*e.g.* Utomilumab), and an OX40 (TNFRS4) agonist.

[0031] In some aspects, the chemotherapy comprises a DNA damaging agent. In some embodiments, the DNA damaging agent is gamma- irradiation, X-rays, UV-irradiation, microwaves, electronic emissions, adriamycin, 5- fluorouracil (5FU), capecitabine, etoposide (VP-16). camptothecin. actinomycin-D, mitomycin C, cisplatin (CDDP), or hydrogen peroxide. In particular aspects, the DNA damaging agent is 5FU or capecitabine. In some aspects, the chemotherapy comprises a cisplatin (CDDP), carboplatin, procarbazine, mechlorethamine, cyclophosphamide, camptothecin, ifosfamide, melphalan, chlorambucil, bisulfan, nitrosurea, dactinomycin, daunorubicin, doxombicin, bleomycin, plicomycin, mitomycin, etoposide (VP16), tamoxifen, taxotere, taxol, transplatinum, 5-fluorouracil, vincristin, vinblastin, methotrexate, an HDAC inhibitor or any analog or derivative variant thereof.

[0032] In some aspects, the at least one additional anticancer treatment is a replication competent or replication incompetent virus. In certain aspects, the replication competent or replication incompetent virus is an adenovirus, adeno-associated virus, retrovirus, lentivirus, herpes virus, pox virus, vaccinia virus, vesicular stomatitis virus, polio virus, Newcastle's Disease virus, Epstein-Barr virus, influenza virus, or reovirus. In particular aspects, the replication competent or replication incompetent virus is herpes simplex virus. In some aspects, the replication competent or replication incompetent virus is engineered to express a transgene, such as a a tumor suppressor (*e.g.,* p53) and/or a cytokine (*e.g.,* IL-24). In some embodiments, the cytokine is granulocyte-macrophage colony-stimulating factor (GM-CSF). In some embodiments, the replication competent or replication incompetent virus is further defined as talimogene laherparepvec (T-VEC) (*e.g.,* IMLYGIC™). In some embodiments, the additional replication competent or replication incompetent virus is administered before, simultaneously, or after the local/abscopal virus composition and immune checkpoint inhibitor.

[0033] In some aspects, the at least one additional cancer treatment is a protein kinase inhibitor or a monoclonal antibody that inhibits receptors involved in protein kinase or growth factor signaling pathways. For example, the protein kinase or receptor inhibitor can be an EGFR, VEGFR, AKT, Erb1, Erb2, ErbB, Syk, Bcr-Abl, JAK, Src, GSK-3, PI3K, Ras, Raf, MAPK, MAPKK, mTOR, c-Kit, eph receptor or BRAF inhibitor. In particular aspects, the protein kinase inhibitor is a PI3K inhibitor. In some embodiments, the PI3K inhibitor is a PI3K delta inhibitor. For example, the protein kinase or receptor inhibitor can be Afatinib, Axitinib, Bevacizumab, Bosutinib, Cetuximab, Crizotinib, Dasatinib, Erlotinib, Fostamatinib, Gefitinib, Imatinib, Lapatinib, Lenvatinib, Mubritinib, Nilotinib, Panitumumab, Pazopanib, Pegaptanib, Ranibizumab, Ruxolitinib, Saracatinib, Sorafenib, Sunitinib, Trastuzumab, Vandetanib, AP23451, Vemurafenib, CAL101, PX-866, LY294002, rapamycin, temsirolimus, everolimus, ridaforolimus, Alvocidib, Genistein, Selumetinib, AZD-6244, Vatalanib, P1446A-05, AG-024322, ZD1839, P276-00, GW572016, or a mixture thereof. In certain aspects, the protein kinase inhibitor is an AKT inhibitor (*e.g.,* MK-2206, GSK690693, A-443654, VQD-002, Miltefosine or Perifosine). In certain aspects, EGFR-targeted therapies for use in accordance with the embodiments include, but are not limited to, inhibitors of EGFR/ErbB1/HER, ErbB2/Neu/HER2, ErbB3/HER3, and/or ErbB4/HER4. A wide range of such inhibitors are known and include, without limitation, tyrosine kinase inhibitors active against the receptor(s) and EGFR-binding antibodies or aptamers. For instance, the EGFR inhibitor can be gefitinib, erlotinib, cetuximab, matuzumab, panitumumab, AEE788; CI-1033, HKI-272, HKI-357, or

EKB-569. The protein kinase inhibitor may be a BRAF inhibitor such as dabrafenib, or a MEK inhibitor such as trametinib.

[0034] In a further embodiment, there is provided a pharmaceutical composition comprising (a) one or more viruses engineered to comprise an N1L gene deletion, a matrix-degrading protein gene, an adenoviral death protein (ADP) gene, and/or a cytochrome p450 gene; and (b) at least one immune checkpoint inhibitor. In certain aspects, the adenoviral death protein is overexpressed. In particular aspects, the virus engineered to comprise the N1L deletion is a vaccinia virus. In some aspects, the virus engineered to comprise the cytochrome p450 gene is a herpes simplex virus. In certain aspects, the viruses engineered to comprise the matrix-degrading protein and/or adenoviral death protein are adenoviruses.

[0035] In one particular aspects the one or more viruses selected from the group consisting of a virus engineered to express the relaxin gene, a virus engineered to overexpress the adenoviral death protein (ADP) gene, a vaccinia virus engineered to delete the N1L gene, and a herpes simplex virus engineered to express the rat cytochrome p450 2B1 gene.

[0036] In some aspects, the viruses of the above embodiments comprise an adenovirus, retrovirus, vaccinia virus, adeno-associated virus, herpes virus, vesicular stomatitis virus, and/or stomatitis virus. In certain aspects, the viruses comprise one or more adenoviruses.

[0037] In some aspects, the matrix-degrading protein is relaxin, hyaluronidase, or decorin. In particular aspects, the matrix-degrading protein is relaxin.

[0038] In certain aspects, the cytochrome p450 gene is the cytochrome p450 2B1 gene. In particular aspects, the cytochrome p450 2B1 gene is rat cytochrome p450 2B1 gene.

[0039] In yet another embodiment, there is provided a pharmaceutical composition comprising two or more viruses engineered to comprise an N1L gene deletion, a matrix-degrading protein gene, an adenoviral death protein (ADP) gene, and/or a cytochrome p450 gene. In some aspects, the composition comprises three or four of the viruses.

[0040] In one particular aspect, the two or more viruses are selected from the group consisting of a virus engineered to express the relaxin gene, a virus engineered to overexpress the adenoviral death protein (ADP) gene, a vaccinia virus engineered to delete the N1L gene, and a herpes simplex virus engineered to express the rat cytochrome p450 2B1 gene.

[0041] In some aspects, the viruses comprise an adenovirus, retrovirus, vaccinia virus, adeno-associated virus, herpes virus, vesicular stomatitis virus, and/or stomatitis virus. In certain aspects, the viruses comprise one or more adenoviruses.

[0042] In some aspects, the matrix-degrading protein is relaxin, hyaluronidase, or decorin. In particular aspects, the matrix-degrading protein is relaxin.

[0043] In certain aspects, the cytochrome p450 gene is the cytochrome p450 2B1 gene. In particular aspects, the cytochrome p450 2B1 gene is rat cytochrome p450 2B1 gene.

[0044] In yet another embodiment, there are provided pharmaceutical compositions comprising (a) a vaccinia virus that expresses at least one tumor associated or pathogen associated antigen and an N1L gene deletion; and (b) at least a second virus that expresses at least one tumor associated or pathogen associated antigen. In certain aspects, the composition further comprises an immune adjuvant, such as an adjuvant known to increase anti-antigen immune responses. In some aspects, the tumor associated antigen is mesothelin, melanoma-associated gene (MAGE), carcinoembryonic antigen (CEA), mutated Ras, or mutated p53. In some aspects, the pathogen associated antigen is an antigen expressed by an infectious viral, bacterial, fungal, prion, or parasitic organism. In one aspect, the second virus that expresses at least one tumor associated or pathogen associated antigen is an adenovirus. In various aspects, the at least one tumor associated or pathogen associated antigen expressed by the vaccinia virus and the at least one tumor associated or pathogen associated antigen expressed by the second virus are the same or different.

[0045] Other objects, features and advantages of the present invention will become apparent from the following detailed description. It should be understood, however, that the detailed description and the specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0046] The following drawings form part of the present specification and are included to further demonstrate certain aspects of the present invention. The invention may be better

understood by reference to one or more of these drawings in combination with the detailed description of specific embodiments presented herein.

[0047] FIG. 1: Ad-Relaxin + anti-PD-1 Local Efficacy: Tumor Volume. A graph showing tumor volume over time in rodents receiving either phosphate buffered saline (PBS) control, anti-PD-1, Ad-Relaxin, or the combination of Ad-Relaxin + anti-PD-1. There was severe tumor progression during anti-PD-1 therapy with reversal of anti-PD-1 resistance induced by Ad-Relaxin therapy. There was synergistically enhanced efficacy of Ad-Relaxin + anti-PD-1 treatment compared to either anti-PD-1 or Ad-Relaxin therapy alone. By day 8, the combined treatment with Ad-Relaxin + anti-PD-1 induced a large decrease in tumor volume, as compared to either anti-PD-1 or Ad-Relaxin therapy alone. T test statistical analysis determined the anti-tumor effects of Ad-Relaxin + anti-PD1 were significant compared to Ad-Relaxin alone (p-value 0.0254) or anti-PD-1 alone (p-value 0.0231). The increased efficacy of combined Ad-Relaxin and anti-PD-1 was more than additive compared to the modest effects of Ad-Relaxin and anti-PD-1 therapy alone which were not statistically different from treatment with the PBS control.

[0048] FIG. 2: Ad-Relaxin + anti-PD-1 Abscopal Efficacy: Contralateral Tumor Volume. Contralateral tumor volume over time in rodents whose primary tumor had received either Ad-Relaxin or a combination of Ad-Relaxin + anti-PD-1 treatment. A statistically significant abscopal effect by T test with decreased tumor growth compared to the growth rate of primary tumors treated with anti-PD-1 alone was also observed in the contralateral (secondary) tumors that did not receive viral therapy injections. These findings indicate that the viral treatment (Ad-Relaxin alone and Ad-Relaxin + anti-PD1) induced abscopal effects. Contralateral tumors in animals whose primary tumor had been treated with Ad-Relaxin alone showed significantly delayed tumor growth (p=0.0273) compared to the growth rate of primary tumors treated with anti-PD-1 alone. Consistent with the synergistic effect observed in the suppression of primary tumor growth, an even greater abscopal effect on contralateral tumor growth (p=0.0009) was observed in mice whose primary tumors were treated with combined Ad-Relaxin+anti-PD-1.

[0049] FIG. 3: Ad-Relaxin + anti-PD1 Efficacy: Survival. Kaplan-Meier survival curves for mice treated with either PBS, anti-PD-1, Ad-Relaxin or a combination of Ad-Relaxin+Anti-PD-1. There was a statistically significant increase in survival by the log rank test in mice whose primary tumors were treated with combined Ad-Relaxin+anti-PD-1

compared to treatment with anti-PD-1 alone (p=0.0010). The increase in median survival for the combined Ad-Relaxin+anti-PD-1 group was more than additive of the separate effects observed for Ad-Relaxin alone and anti-PD-1 alone. There was no statistically significant increase in survival for mice treated with Ad-Relaxin alone compared to anti-PD-1 alone. The more than additive Ad-Relaxin+anti-PD-1 increased survival findings are consistent with the synergistic effect observed in the suppression of primary tumor growth and the greater abscopal effect on contralateral tumor growth for the combined Ad-Relaxin+anti-PD-1 therapy and reflect unexpected synergistic effects of the combined treatment.

[0050] FIG. 4: VRX-007 Over Expressing Adenoviral Death Protein + anti-PD-L1 Efficacy: Tumor Volume. The efficacy of immune checkpoint inhibitor anti-PD-L1 treatment in combination with adenoviral death protein (ADP) gene therapy was evaluated in the ADS immunocompetent animal tumor model. VRX-007 is an adenovirus engineered to overexpress the ADP gene. Four treatment groups were compared including PBS vehicle control (N=10), anti-PD-L1 immune checkpoint inhibitor (N=10), VRX-007 (N=4) and VRX-007 + anti-PD-L1 (N=4). Treatment efficacy was evaluated by comparing the percentage change in tumor volume 15 days following the initiation of therapy (or at the time of animal sacrifice) relative to baseline values. A Kruskal–Wallis one-way analysis of variance (one-way ANOVA on ranks) demonstrated a statistically significant difference between the treatment groups (p-value = 0.0258). The statistically significant anti-tumor effect of combined VRX-007 + anti-PD-L1 therapy (p = 0.0047) was unexpected and surprisingly synergistic as neither VRX-007 (p = 0.1232) nor anti-PD-L1 (p=0.5866) separately were statistically different from treatment with the vehicle control. The increased efficacy of combined VRX-007 and anti-PD-L1 was more than additive and the combined treatment was also statistically superior to anti-PD-L1 therapy alone (p=0.0157). Furthermore, T test statistical analysis revealed the anti-tumor effects of VRX-007 + anti-PD1 were significant compared to VRX-007 alone (one sided p-value=0.0356). The efficacy and synergy of combined VRX-007 + anti-PD-L1 therapy was unexpected as neither treatment demonstrated statistically significant efficacy separately.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0051] It is well known that tumors evolve during their initiation and progression to evade destruction by the immune system. While the recent use of immune checkpoint inhibitors to reverse this resistance has demonstrated some success, the majority of patients do not respond these treatments. In certain embodiments, the present disclosure provides methods

and compositions for altering the microenvironment of tumors to overcome resistance and to enhance anti-tumor immune responses. In one embodiment, there is provided a method for the treatment of cancer by administering a virus composition alone or in combination with at least one immune checkpoint inhibitor. The virus composition may comprise one or more viruses engineered to comprise an N1L gene deletion, a matrix-degrading protein gene, an adenoviral death protein (ADP) gene, and/or a cytochrome p450 gene. In one method, the extracellular matrix degrading therapy is relaxin gene therapy, such as adenoviral relaxin. Particularly, the adenoviral relaxin is administered intratumorally or intraarterially.

[0052] In exemplary methods, the virus composition may comprise a virus engineered to express the relaxin gene, a virus engineered to overexpress the adenoviral death protein (ADP) gene, a vaccinia virus engineered to delete the N1L gene, and/or a herpes simplex virus engineered to express the rat cytochrome p450 2B1 gene.

[0053] Particularly, the virus compositions are replication competent or oncolytic. In certain aspects, the virus compositions are replication incompetent or comprise combinations of replication competent and replication incompetent viruses. In particular, the virus composition induces local and/or abscopal effects.

[0054] In one method, the virus composition is administered in combination with an immune checkpoint inhibitor such as an anti-PD1 antibody or an anti-KIR antibody to enhance innate anti-tumor immunity before the administration of the virus composition to induce adaptive anti-tumor immune responses. Alternatively, the virus composition could be administered concurrently with the immune checkpoint inhibitor.

[0055] Further, the methods of treatment can include additional anti-cancer therapies such as cytokines or chemotherapeutics to enhance the anti-tumor effect of the combination therapy provided herein. For example, the cytokine could be granulocyte macrophage colony-stimulating factor (GM-CSF) and the chemotherapy could be 5-fluorouracil (5FU) or capecitabine or cyclophosphamide or a PI3K inhibitor.

[0056] In the present studies, a loco-regional virus composition treatment reversed resistance to systemic immune checkpoint inhibitor therapy, demonstrated unexpected synergy with immune checkpoint inhibitor treatment and the combined therapies induced superior abscopal effects on distant tumors that were not treated with the virus composition. These unexpected systemic treatment effects were found to be enhanced in combination with

chemotherapy, cytokine therapy and agents known to modulate myeloid derived suppressor cells (MDSC), T-Regs and dendritic cells. Thus, the present disclosure provides methods of treating cancer by enhancing innate and adaptive anti-tumor immune responses as well as overcoming resistance to immune checkpoint therapy and inducing abscopal systemic treatment effects.

I. Definitions

[0057] As used herein, "essentially free," in terms of a specified component, is used herein to mean that none of the specified component has been purposefully formulated into a composition and/or is present only as a contaminant or in trace amounts. The total amount of the specified component resulting from any unintended contamination of a composition is therefore well below 0.05%, preferably below 0.01%. Most preferred is a composition in which no amount of the specified component can be detected with standard analytical methods.

[0058] As used herein the specification, "a" or "an" may mean one or more. As used herein in the claim(s), when used in conjunction with the word "comprising," the words "a" or "an" may mean one or more than one.

[0059] The use of the term "or" in the claims is used to mean "and/or" unless explicitly indicated to refer to alternatives only or the alternatives are mutually exclusive, although the disclosure supports a definition that refers to only alternatives and "and/or." As used herein "another" may mean at least a second or more.

[0060] Throughout this application, the term "about" is used to indicate that a value includes the inherent variation of error for the device, the method being employed to determine the value, or the variation that exists among the study subjects.

[0061] As used herein "wild-type" refers to the naturally occurring sequence of a nucleic acid at a genetic locus in the genome of an organism, and sequences transcribed or translated from such a nucleic acid. Thus, the term "wild-type" also may refer to the amino acid sequence encoded by the nucleic acid. As a genetic locus may have more than one sequence or alleles in a population of individuals, the term "wild-type" encompasses all such naturally occurring alleles. As used herein the term "polymorphic" means that variation exists (*i.e.*, two or more alleles exist) at a genetic locus in the individuals of a population. As used herein,

"mutant" refers to a change in the sequence of a nucleic acid or its encoded protein, polypeptide, or peptide that is the result of recombinant DNA technology.

[0062] The term "exogenous," when used in relation to a protein, gene, nucleic acid, or polynucleotide in a cell or organism refers to a protein, gene, nucleic acid, or polynucleotide that has been introduced into the cell or organism by artificial or natural means; or in relation to a cell, the term refers to a cell that was isolated and subsequently introduced to other cells or to an organism by artificial or natural means. An exogenous nucleic acid may be from a different organism or cell, or it may be one or more additional copies of a nucleic acid that occurs naturally within the organism or cell. An exogenous cell may be from a different organism, or it may be from the same organism. By way of a non-limiting example, an exogenous nucleic acid is one that is in a chromosomal location different from where it would be in natural cells, or is otherwise flanked by a different nucleic acid sequence than that found in nature.

[0063] By "expression construct" or "expression cassette" is meant a nucleic acid molecule that is capable of directing transcription. An expression construct includes, at a minimum, one or more transcriptional control elements (such as promoters, enhancers or a structure functionally equivalent thereof) that direct gene expression in one or more desired cell types, tissues or organs. Additional elements, such as a transcription termination signal, may also be included.

[0064] A "vector" or "construct" (sometimes referred to as a gene delivery system or gene transfer "vehicle") refers to a macromolecule or complex of molecules comprising a polynucleotide to be delivered to a host cell, either *in vitro* or *in vivo*.

[0065] A "plasmid," a common type of a vector, is an extra-chromosomal DNA molecule separate from the chromosomal DNA that is capable of replicating independently of the chromosomal DNA. In certain cases, it is circular and double-stranded.

[0066] An "origin of replication" ("ori") or "replication origin" is a DNA sequence, *e.g.*, in a lymphotrophic herpes virus, that when present in a plasmid in a cell is capable of maintaining linked sequences in the plasmid and/or a site at or near where DNA synthesis initiates. As an example, an ori for EBV includes FR sequences (20 imperfect copies of a 30 bp repeat), and preferably DS sequences; however, other sites in EBV bind EBNA-1, *e.g.*, Rep* sequences can substitute for DS as an origin of replication (Kirshmaier and Sugden, 1998).

Thus, a replication origin of EBV includes FR, DS or Rep* sequences or any functionally equivalent sequences through nucleic acid modifications or synthetic combination derived therefrom. For example, the present invention may also use genetically engineered replication origin of EBV, such as by insertion or mutation of individual elements, as specifically described in Lindner, *et. al.*, 2008.

[0067] A "gene," "polynucleotide," "coding region," "sequence," "segment," "fragment," or "transgene" that "encodes" a particular protein, is a nucleic acid molecule that is transcribed and optionally also translated into a gene product, *e.g.*, a polypeptide, *in vitro* or *in vivo* when placed under the control of appropriate regulatory sequences. The coding region may be present in either a cDNA, genomic DNA, or RNA form. When present in a DNA form, the nucleic acid molecule may be single-stranded (*i.e.*, the sense strand) or double-stranded. The boundaries of a coding region are determined by a start codon at the 5' (amino) terminus and a translation stop codon at the 3' (carboxy) terminus. A gene can include, but is not limited to, cDNA from prokaryotic or eukaryotic mRNA, genomic DNA sequences from prokaryotic or eukaryotic DNA, and synthetic DNA sequences. A transcription termination sequence will usually be located 3' to the gene sequence.

[0068] The term "control elements" refers collectively to promoter regions, polyadenylation signals, transcription termination sequences, upstream regulatory domains, origins of replication, internal ribosome entry sites (IRES), enhancers, splice junctions, and the like, which collectively provide for the replication, transcription, post-transcriptional processing, and translation of a coding sequence in a recipient cell. Not all of these control elements need be present so long as the selected coding sequence is capable of being replicated, transcribed, and translated in an appropriate host cell.

[0069] The term "promoter" is used herein in its ordinary sense to refer to a nucleotide region comprising a DNA regulatory sequence, wherein the regulatory sequence is derived from a gene that is capable of binding RNA polymerase and initiating transcription of a downstream (3' direction) coding sequence. It may contain genetic elements at which regulatory proteins and molecules may bind, such as RNA polymerase and other transcription factors, to initiate the specific transcription of a nucleic acid sequence. The phrases "operatively positioned," "operatively linked," "under control," and "under transcriptional control" mean that a promoter is in a correct functional location and/or orientation in relation

to a nucleic acid sequence to control transcriptional initiation and/or expression of that sequence.

[0070] By "enhancer" is meant a nucleic acid sequence that, when positioned proximate to a promoter, confers increased transcription activity relative to the transcription activity resulting from the promoter in the absence of the enhancer domain.

[0071] By "operably linked" or co-expressed" with reference to nucleic acid molecules is meant that two or more nucleic acid molecules (*e.g.*, a nucleic acid molecule to be transcribed, a promoter, and an enhancer element) are connected in such a way as to permit transcription of the nucleic acid molecule. "Operably linked" or "co-expressed" with reference to peptide and/or polypeptide molecules means that two or more peptide and/or polypeptide molecules are connected in such a way as to yield a single polypeptide chain, *i.e.*, a fusion polypeptide, having at least one property of each peptide and/or polypeptide component of the fusion. The fusion polypeptide is preferably chimeric, *i.e.*, composed of heterologous molecules.

[0072] "Homology" refers to the percent of identity between two polynucleotides or two polypeptides. The correspondence between one sequence and another can be determined by techniques known in the art. For example, homology can be determined by a direct comparison of the sequence information between two polypeptide molecules by aligning the sequence information and using readily available computer programs. Alternatively, homology can be determined by hybridization of polynucleotides under conditions that promote the formation of stable duplexes between homologous regions, followed by digestion with single strand-specific nuclease(s), and size determination of the digested fragments. Two DNA, or two polypeptide, sequences are "substantially homologous" to each other when at least about 80%, preferably at least about 90%, and most preferably at least about 95% of the nucleotides, or amino acids, respectively match over a defined length of the molecules, as determined using the methods above.

[0073] The term "nucleic aci"" will generally refer to at least one molecule or strand of DNA, RNA or a derivative or mimic thereof, comprising at least one nucleobase, such as, for example, a naturally occurring purine or pyrimidine base found in DNA (*e.g.,* adenine "A," guanine "G," thymine "T," and cytosine "C") or RNA (*e.g.* A, G, uracil "U," and C). The term "nucleic acid" encompasses the terms "oligonucleotide" and "polynucleotide." The term

"oligonucleotide" refers to at least one molecule of between about 3 and about 100 nucleobases in length. The term "polynucleotide" refers to at least one molecule of greater than about 100 nucleobases in length. These definitions generally refer to at least one single-stranded molecule, but in specific embodiments will also encompass at least one additional strand that is partially, substantially or fully complementary to the at least one single-stranded molecule. Thus, a nucleic acid may encompass at least one double-stranded molecule or at least one triple-stranded molecule that comprises one or more complementary strand(s) or "complement(s)" of a particular sequence comprising a strand of the molecule.

[0074] The term "therapeutic benefit" used throughout this application refers to anything that promotes or enhances the well-being of the patient with respect to the medical treatment of his cancer. A list of nonexhaustive examples of this includes extension of the patient's life by any period of time; decrease or delay in the neoplastic development of the disease; decrease in hyperproliferation; reduction in tumor growth; delay of metastases; reduction in the proliferation rate of a cancer cell or tumor cell; induction of apoptosis in any treated cell or in any cell affected by a treated cell; and a decrease in pain to the patient that can be attributed to the patient's condition.

[0075] An "effective amount" is at least the minimum amount required to effect a measurable improvement or prevention of a particular disorder. An effective amount herein may vary according to factors such as the disease state, age, sex, and weight of the patient, and the ability of the antibody to elicit a desired response in the individual. An effective amount is also one in which any toxic or detrimental effects of the treatment are outweighed by the therapeutically beneficial effects. For prophylactic use, beneficial or desired results include results such as eliminating or reducing the risk, lessening the severity, or delaying the onset of the disease, including biochemical, histological and/or behavioral symptoms of the disease, its complications and intermediate pathological phenotypes presenting during development of the disease. For therapeutic use, beneficial or desired results include clinical results such as decreasing one or more symptoms resulting from the disease, increasing the quality of life of those suffering from the disease, decreasing the dose of other medications required to treat the disease, enhancing effect of another medication such as via targeting, delaying the progression of the disease, and/or prolonging survival. In the case of cancer or tumor, an effective amount of the drug may have the effect in reducing the number of cancer cells; reducing the tumor size; inhibiting (*i.e.*, slow to some extent or desirably stop) cancer cell infiltration into peripheral

organs; inhibit (*i.e.*, slow to some extent and desirably stop) tumor metastasis; inhibiting to some extent tumor growth; and/or relieving to some extent one or more of the symptoms associated with the disorder. An effective amount can be administered in one or more administrations. For purposes of this invention, an effective amount of drug, compound, or pharmaceutical composition is an amount sufficient to accomplish prophylactic or therapeutic treatment either directly or indirectly. As is understood in the clinical context, an effective amount of a drug, compound, or pharmaceutical composition may or may not be achieved in conjunction with another drug, compound, or pharmaceutical composition. Thus, an "effective amount" may be considered in the context of administering one or more therapeutic agents, and a single agent may be considered to be given in an effective amount if, in conjunction with one or more other agents, a desirable result may be or is achieved.

[0076] As used herein, "carrier" includes any and all solvents, dispersion media, vehicles, coatings, diluents, antibacterial and antifungal agents, isotonic and absorption delaying agents, buffers, carrier solutions, suspensions, colloids, and the like. The use of such media and agents for pharmaceutical active substances is well known in the art. Except insofar as any conventional media or agent is incompatible with the active ingredient, its use in the therapeutic compositions is contemplated. Supplementary active ingredients can also be incorporated into the compositions.

[0077] The term "pharmaceutical formulation" refers to a preparation which is in such form as to permit the biological activity of the active ingredient to be effective, and which contains no additional components which are unacceptably toxic to a subject to which the formulation would be administered. Such formulations are sterile. "Pharmaceutically acceptable" excipients (vehicles, additives) are those which can reasonably be administered to a subject mammal to provide an effective dose of the active ingredient employed.

[0078] As used herein, the term "treatment" refers to clinical intervention designed to alter the natural course of the individual or cell being treated during the course of clinical pathology. Desirable effects of treatment include decreasing the rate of disease progression, ameliorating or palliating the disease state, and remission or improved prognosis. For example, an individual is successfully "treated" if one or more symptoms associated with cancer are mitigated or eliminated, including, but are not limited to, reducing the proliferation of (or destroying) cancerous cells, decreasing symptoms resulting from the disease, increasing the

quality of life of those suffering from the disease, decreasing the dose of other medications required to treat the disease, and/or prolonging survival of individuals.

[0079] An "anti-cancer" agent is capable of negatively affecting a cancer cell/tumor in a subject, for example, by promoting killing of cancer cells, inducing apoptosis in cancer cells, reducing the growth rate of cancer cells, reducing the incidence or number of metastases, reducing tumor size, inhibiting tumor growth, reducing the blood supply to a tumor or cancer cells, promoting an immune response against cancer cells or a tumor, preventing or inhibiting the progression of cancer, or increasing the lifespan of a subject with cancer.

[0080] The term "antibody" herein is used in the broadest sense and specifically covers monoclonal antibodies (including full length monoclonal antibodies), polyclonal antibodies, multispecific antibodies (*e.g.*, bispecific antibodies), and antibody fragments so long as they exhibit the desired biological activity.

[0081] The term "monoclonal antibody" as used herein refers to an antibody obtained from a population of substantially homogeneous antibodies, *e.g.*, the individual antibodies comprising the population are identical except for possible mutations, *e.g.,* naturally occurring mutations, that may be present in minor amounts. Thus, the modifier "monoclonal" indicates the character of the antibody as not being a mixture of discrete antibodies. In certain embodiments, such a monoclonal antibody typically includes an antibody comprising a polypeptide sequence that binds a target, wherein the target-binding polypeptide sequence was obtained by a process that includes the selection of a single target binding polypeptide sequence from a plurality of polypeptide sequences. For example, the selection process can be the selection of a unique clone from a plurality of clones, such as a pool of hybridoma clones, phage clones, or recombinant DNA clones. It should be understood that a selected target binding sequence can be further altered, for example, to improve affinity for the target, to humanize the target binding sequence, to improve its production in cell culture, to reduce its immunogenicity *in vivo*, to create a multispecific antibody, *etc.*, and that an antibody comprising the altered target binding sequence is also a monoclonal antibody of this invention. In contrast to polyclonal antibody preparations, which typically include different antibodies directed against different determinants (epitopes), each monoclonal antibody of a monoclonal antibody preparation is directed against a single determinant on an antigen. In addition to their specificity, monoclonal antibody preparations are advantageous in that they are typically uncontaminated by other immunoglobulins.

[0082] The term "immune checkpoint" refers to a molecule such as a protein in the immune system which provides inhibitory signals to its components in order to balance immune reactions. Known immune checkpoint proteins comprise CTLA-4, PD-l and its ligands PD-Ll and PD-L2 and in addition LAG-3, BTLA, B7H3, B7H4, TIM3, KIR. The pathways involving LAG3, BTLA, B7H3, B7H4, TIM3, and KIR are recognized in the art to constitute immune checkpoint pathways similar to the CTLA-4 and PD-1 dependent pathways (see *e.g.* Pardoll, 2012. Nature Rev Cancer 12:252-264; Mellman *et al.*, 2011. Nature 480:480- 489).

[0083] The term "PD-1 axis binding antagonist" refers to a molecule that inhibits the interaction of a PD-1 axis binding partner with either one or more of its binding partners, so as to remove T-cell dysfunction resulting from signaling on the PD-1 signaling axis - with a result being to restore or enhance T-cell function (*e.g.*, proliferation, cytokine production, target cell killing). As used herein, a PD-1 axis binding antagonist includes a PD-1 binding antagonist, a PD-Ll binding antagonist and a PD-L2 binding antagonist.

[0084] The term "PD-1 binding antagonist" refers to a molecule that decreases, blocks, inhibits, abrogates or interferes with signal transduction resulting from the interaction of PD-1 with one or more of its binding partners, such as PD-Ll and/or PD-L2. In some embodiments, the PD-1 binding antagonist is a molecule that inhibits the binding of PD-1 to one or more of its binding partners. In a specific aspect, the PD-1 binding antagonist inhibits the binding of PD-1 to PD-Ll and/or PD-L2. For example, PD-1 binding antagonists include anti-PD-1 antibodies, antigen binding fragments thereof, immunoadhesins, fusion proteins, oligopeptides and other molecules that decrease, block, inhibit, abrogate or interfere with signal transduction resulting from the interaction of PD-1 with PD-Ll and/or PD-L2. In one embodiment, a PD-1 binding antagonist reduces the negative co-stimulatory signal mediated by or through cell surface proteins expressed on T lymphocytes mediated signaling through PD-1 so as render a dysfunctional T-cell less dysfunctional (*e.g.,* enhancing effector responses to antigen recognition). In some embodiments, the PD-1 binding antagonist is an anti-PD-1 antibody. In a specific aspect, a PD-1 binding antagonist is MDX-1106 (nivolumab). In another specific aspect, a PD-1 binding antagonist is MK-3475 (pembrolizumab). In another specific aspect, a PD-1 binding antagonist is CT-011 (pidilizumab). In another specific aspect, a PD-1 binding antagonist is AMP-224.

[0085] The term "PD-L1 binding antagonist" refers to a molecule that decreases, blocks, inhibits, abrogates or interferes with signal transduction resulting from the interaction

of PD-L1 with either one or more of its binding partners, such as PD-1 or B7-1. In some embodiments, a PD-L1 binding antagonist is a molecule that inhibits the binding of PD-L1 to its binding partners. In a specific aspect, the PD-L1 binding antagonist inhibits binding of PD-L1 to PD-1 and/or B7-1. In some embodiments, the PD-L1 binding antagonists include anti-PD-Ll antibodies, antigen binding fragments thereof, immunoadhesins, fusion proteins, oligopeptides and other molecules that decrease, block, inhibit, abrogate or interfere with signal transduction resulting from the interaction of PD-L1 with one or more of its binding partners, such as PD-1 or B7-1. In one embodiment, a PD-L1 binding antagonist reduces the negative co-stimulatory signal mediated by or through cell surface proteins expressed on T lymphocytes mediated signaling through PD-L1 so as to render a dysfunctional T-cell less dysfunctional (*e.g.*, enhancing effector responses to antigen recognition). In some embodiments, a PD-L1 binding antagonist is an anti-PD-Ll antibody. In a specific aspect, an anti-PD-Ll antibody is YW243.55.S70. In another specific aspect, an anti-PD-Ll antibody is MDX-1105. In still another specific aspect, an anti-PD-Ll antibody is MPDL3280A. In still another specific aspect, an anti-PD-Ll antibody is MEDI4736.

[0086] The term "PD-L2 binding antagonist" refers to a molecule that decreases, blocks, inhibits, abrogates or interferes with signal transduction resulting from the interaction of PD-L2 with either one or more of its binding partners, such as PD-1. In some embodiments, a PD-L2 binding antagonist is a molecule that inhibits the binding of PD-L2 to one or more of its binding partners. In a specific aspect, the PD-L2 binding antagonist inhibits binding of PD-L2 to PD-1. In some embodiments, the PD-L2 antagonists include anti-PD-L2 antibodies, antigen binding fragments thereof, immunoadhesins, fusion proteins, oligopeptides and other molecules that decrease, block, inhibit, abrogate or interfere with signal transduction resulting from the interaction of PD-L2 with either one or more of its binding partners, such as PD-1. In one embodiment, a PD-L2 binding antagonist reduces the negative co-stimulatory signal mediated by or through cell surface proteins expressed on T lymphocytes mediated signaling through PD-L2 so as render a dysfunctional T-cell less dysfunctional (*e.g.*, enhancing effector responses to antigen recognition). In some embodiments, a PD-L2 binding antagonist is an immunoadhesin.

[0087] An "immune checkpoint inhibitor" refers to any compound inhibiting the function of an immune checkpoint protein. Inhibition includes reduction of function and full blockade. In particular the immune checkpoint protein is a human immune checkpoint protein.

Thus the immune checkpoint protein inhibitor in particular is an inhibitor of a human immune checkpoint protein.

[0088] An "extracellular matrix degradative protein" or "extracellular matrix degrading protein" refers any protein which acts on the integrity of the cell matrix, in particular exerting a total or partial degrading or destabilizing action on at least one of the constituents of the said matrix or on the bonds which unite these various constituents.

[0089] An "abscopal effect" is referred to herein as a shrinking of tumors outside the scope of the localized treatment of a tumor. For example, localized treatment with a virus composition provided herein in combination with systemic treatment with an immune checkpoint therapy can result in an abscopal effect at distant tumors that is not injected with the virus composition.

II. Virus Composition

[0090] Embodiments of the present disclosure concern a virus composition comprising a one or more viruses engineered to comprise an N1L gene deletion, a matrix-degrading protein gene, an adenoviral death protein (ADP) gene, and/or a cytochrome p450 gene. In particular aspects, the virus composition comprises a virus engineered to express the relaxin gene, a virus engineered to overexpress the adenoviral death protein (ADP) gene, a vaccinia virus engineered to delete the N1L gene, and/or a herpes simplex virus engineered to express the rat cytochrome p450 2B1 gene. A subject may be administered one, two, three, or four of these viruses to induce local and/or abscopal effects. The virus composition may be administered in combination with an immune checkpoint inhibitor.

A. Virus Expressing Extracellular Matrix Protein

[0091] In one aspect, the delivery of the gene therapy (*e.g.,* viral distribution) and tumor penetration are enhanced by a protein or agent which degrades the tumor cell extracellular matrix (ECM) or component thereof.

[0092] The extracellular matrix (ECM) is a collection of extracellular molecules secreted by cells that provides structural and biochemical support to the surrounding cells. Because multicellularity evolved independently in different multicellular lineages, the composition of ECM varies between multicellular structures; however, cell adhesion, cell-to-cell communication and differentiation are common functions of the ECM. Components of the

ECM that may be targeted by the extracellular matrix degradative protein include collagen, elastin, hyaluronic acid, fibronectin and laminin.

1. Relaxin

[0093] One extracellular matrix degrading protein that can be used in the methods provided herein is relaxin. Relaxin is a 6 kDa peptide hormone that is structurally related to insulin and insulin-like growth factors. It is predominantly produced in the corpus luteum and endometrium and its serum level greatly increases during pregnancy (Sherwood *et al.*, 1984). Relaxin is a potent inhibitor of collagen expression when collagen is overexpressed, but it does not markedly alter basal levels of collagen expression, in contrast to other collagen. It promotes the expression of various MMPs such as MMP2, MMP3, and MMP9 to degrade collagen, so that connective tissues and basal membranes are degraded to lead to the disruption of extracellular matrix of birth canal. In addition to this, the promotion of MMP 1 and MMP 3 expressions by relaxin is also observed in lung, heart, skin, intestines, mammary gland, blood vessel and spermiduct where relaxin plays a role as an inhibitor to prevent overexpression of collagen (Qin, X., *et al.*, 1997a; Qin, X., *et al.*, 1997b).

[0094] Administration of the relaxin protein or nucleic acid encoding the relaxin protein can induce the degradation of collagen, a major component of the extracellular matrix surrounding tumor cells, to disrupt connective tissue and basal membrane, thereby resulting in the degradation of extracellular matrix. In particular, when administered to tumor tissues enclosed tightly by connective tissue, the administration of the tumor suppressor gene therapy in combination with relaxin exhibits improved anti-tumor efficacy.

[0095] The relaxin protein can be full length relaxin or a portion of the relaxin molecule that retains biological activity as described in U.S. Patent No. 5,023,321. Particularly, the relaxin is recombinant human relaxin (H2) or other active agents with relaxin-like activity, such as agents that competitively displace bound relaxin from a receptor. Relaxin can be made by any method known to those skilled in the art, preferably as described in U.S. Patent No. 4,835,251. Relaxin analogs or derivatives thereof are described in U.S. Patent No. 5,811,395 and peptide synthesis is described in U.S. Patent Publication No. US20110039778.

[0096] An exemplary adenoviral relaxin that may be used in the methods provided herein is described by Kim *et al.* (2006). Briefly, a relaxin-expressing, replication-competent

(Ad-ΔE1B-RLX) adenovirus is generated by inserting a relaxin gene into the E3 adenoviral region.

2. Hyaluronidase

[0097] In some embodiments, any substance which is able to hydrolyze the polysaccharides which are generally present in extracellular matrices such as hyaluronic acid can be administered. Particularly, the extracellular matrix degrading protein used in the present invention can be hyaluronidase. Hyaluronan (or hyaluronic acid) is a ubiquitous constituent of the vertebrate extracellular matrix. This linear polysaccharide, which is based on glucuronic acid and glucosamine [D-glucuronic acid 1-β-3)N-acetyl-D-glucosamine(1-b-4)], is able to exert an influence on the physicochemical characteristics of the matrices by means of its property of forming very viscous solutions. Hyaluronic acid also interacts with various receptors and binding proteins which are located on the surface of the cells. It is involved in a large number of biological processes such as fertilization, embryonic development, cell migration and differentiation, wound-healing, inflammation, tumor growth and the formation of metastases.

[0098] Hyaluronic acid is hydrolyzed by hyaluronidase and its hydrolysis leads to disorganization of the extracellular matrix. Thus, it is contemplated that any substance possessing hyaluronidase activity is suitable for use in the present methods such as hyaluronidases as described in Kreil (Protein Sci., 1995, 4:1666-1669). The hyaluronidase can be a hyaluronidase which is derived from a mammalian, reptilian or hymenopteran hyaluronate glycanohydrolase, from a hyaluronate glycanohydrolase from the salivary gland of the leech, or from a bacterial, in particular streptococcal, pneumococcal and clostridial hyaluronate lyase. The enzymatic activity of the hyaluronidase can be assessed by conventional techniques such as those described in Hynes and Ferretti (Methods Enzymol., 1994, 235: 606-616) or Bailey and Levine (J. Pharm. Biomed. Anal., 1993, 11: 285-292).

3. Decorin

[0099] Decorin, a small leucine-rich proteoglycan, is a ubiquitous component of the extracellular matrix and is preferentially found in association with collagen fibrils. Decorin binds to collagen fibrils and delays the lateral assembly of individual triple helical collagen molecules, resulting in the decreased diameter of the fibrils. In addition, decorin can modulate the interactions of extracellular matrix components, such as fibronectin and thrombospondin,

with cells. Furthermore, decorin is capable of affecting extracellular matrix remodeling by induction of the matrix metalloproteinase collagenase. These observations suggest that decorin regulates the production and assembly of the extracellular matrix at several levels, and hence has a prominent role in remodeling connective tissues as described by Choi *et al.* (Gene Therapy, 17: 190–201, 2010) and by Xu *et al.* (Gene Therapy, 22(3) : 31–40, 2015).

[00100] An exemplary adenoviral decorin that may be used in the methods provided herein is described by Choi *et al.* (Gene Therapy, 17: 190–201, 2010). Briefly, a decorin-expressing, replication-competent (Ad-ΔE1B-DCNG) adenovirus is generated by inserting a decorin gene into the E3 adenoviral region. Another exemplary adenoviral decorin that may be used in the methods provided herein is described by Xu *et al.* (Gene Therapy, 22(3): 31–40, 2015). Similarly, a decorin-expressing, replication-competent (Ad.dcn) adenovirus is generated by inserting a decorin gene into the E3 adenoviral region.

[00101] Additional exemplary adenoviruses may be used in the methods which involve a modified TERT promoter oncolytic adenovirus as described in the U.S. Patent No. 8,067,567, an HRE-E2F-TERT hybrid promoter oncolytic adenovirus described in PCT/KR2011/004693, viruses expressing the decorin gene as described in the U.S. Patent Application No. 11/816,751, viruses expressing the relaxin gene as described in the U.S. Patent Application No. #10/599,521; all of which are incorporated by reference.

B. Virus with Overexpression of ADP

[00102] Certain embodiments of the present disclosure concern a virus engineered to overexpress adenovirus death protein (ADP) (*i.e.,* E3 11.6K protein).

[00103] Where the virus is a recombinant adenovirus, overexpression of ADP can be achieved in a multitude of ways (*e.g.,* described in US20100034776; incorporated herein by reference). In general, any type of deletion in the E3 region that removes a splice site for any of the E3 mRNAs will lead to overexpression of the mRNA for ADP, inasmuch as more of the E3 pre-mRNA molecules will be processed into the mRNA for ADP. Other means of achieving overexpression of ADP in Ad vectors include, but are not limited to: insertion of pre-mRNA splicing and cleavage/polyadenylation signals at sites flanking the gene for ADP; expression of ADP from another promoter, *e.g.* the human cytomegalovirus promoter, inserted into a variety of sites in the Ad genome; and insertion of the gene for ADP behind the gene for another Ad MRNA, together with a sequence on the 5′ side of the ADP sequence that allows

for internal initiation of translation of ADP, *e.g.* the Ad tripartite leader or a viral internal ribosome initiation sequence.

[00104] The ADP expressed by a vector according to the present disclosure is any polypeptide comprising a naturally-occurring full-length ADP amino acid sequence or variant thereof that confers upon a vector expressing the ADP the ability to lyse a cell containing the vector such that replicated copies of the vector are released from the infected cell. A preferred full-length ADP comprises the ADP amino acid sequence encoded by Ad1, Ad2, AdS or Ad6. ADP variants include fragments and deletion mutants of naturally-occurring adenovirus death proteins, as well as full-length molecules, fragments and deletion mutants containing conservative amino acid substitutions, provided that such variants retain the ability, when expressed by a vector inside a cell, to lyse the cell.

[00105] In certain aspects, the virus engineered to overexpress ADP is a serotype 5 adenovirus termed VRX-007 (*i.e.,* an oncolytic adenoviral vector engineered to delete most of the E3 region and to overexpresses the E3-11.6K Adenovirus Death Protein (ADP)). VRX-007 may also be modified to express other therapeutic genes. The construction of VRX-007 is described previously (Doronin 2003; Tollefson 1996; Lichtenstein 2004).

C. Vaccinia Virus with N1L Deletion

[00106] Certain embodiments of the present disclosure concern a vaccinia virus with an N1L deletion. In certain aspects, the vaccinia virus engineered to delete N1L is derived from the Western Reserve, Wyeth and Lister strains. Various deletion mutants of each of these strains have been created. In certain aspects, the N1L deletion derivatives VVL 15N1L employed are described in Wang *et al.*, 2015 (PCT Publication No. WO2015/150809A1). VVL 15N1L vectors may also be modified to express therapeutic genes including but not limited to IL-12 and/or relaxin. In some aspects, the VVL 15N1L vectors are also combined with immune checkpoint inhibitors and PI3K inhibitors. In a particular aspect, PI3Kdelta or PI3Kgamma/delta inhibitors are administered to enhance intravenous administration of viral vectors. In one particular method, the subject is administered the PI3K delta inhibitor prior to (*e.g.,* hours) the intravenous VVL 15N1L vectors.

D. Herpes Simplex Virus Expressing the Cytochrome p450 2B1 Gene

[00107] Embodiments of the present disclosure concern, in some aspects, a virus (*e.g.,* herpes simplex virus) expressing cytochrome p450 2B1 gene. In certain aspects, the

herpes simplex virus engineered to express the rat cytochrome p450 2B1 gene has a deleted ICP6 gene and is termed rRp450 as further described in (Aghi *et al* 1999). The vector encodes for expression of the cyclophosphamide (CPA)-sensitive rat cytochrome p450 2B1, and the ganciclovir (GCV)-sensitive herpes simplex virus thymidine kinase (HSV-TK) gene. The expression of the cytochrome p450 and HSV-TK genes result, respectively, in the conversion of CPA and GCV prodrugs into their therapeutically active metabolites. In particular aspects, rRp450 is administered in combination with CPA and GCV. Additional examples of herpes viruses that may be used are described in U.S. Patent No. 6,602,499; which is incorporated herein by reference.

III. Nucleic Acids

[00108] A nucleic acid may be made by any technique known to one of ordinary skill in the art. Non-limiting examples of a synthetic nucleic acid, particularly a synthetic oligonucleotide, include a nucleic acid made by in vitro chemical synthesis using phosphotriester, phosphite or phosphoramidite chemistry and solid phase techniques such as described in EP 266,032, or via deoxynucleoside H-phosphonate intermediates as described by Froehler *et al.*, 1986, and U.S. Patent No. 5,705,629. A non-limiting example of enzymatically produced nucleic acid includes one produced by enzymes in amplification reactions such as PCR™ (see for example, U.S. Patent No. 4,683,202 and U.S. Patent No. 4,682,195), or the synthesis of oligonucleotides described in U.S. Patent No. 5,645,897. A non-limiting example of a biologically produced nucleic acid includes recombinant nucleic acid production in living cells, such as recombinant DNA vector production in bacteria (see for example, Sambrook *et al.* 1989).

[00109] The nucleic acid(s), regardless of the length of the sequence itself, may be combined with other nucleic acid sequences, including but not limited to, promoters, enhancers, polyadenylation signals, restriction enzyme sites, multiple cloning sites, coding segments, and the like, to create one or more nucleic acid construct(s). The overall length may vary considerably between nucleic acid constructs. Thus, a nucleic acid segment of almost any length may be employed, with the total length preferably being limited by the ease of preparation or use in the intended recombinant nucleic acid protocol.

A. Nucleic Acid Delivery by Expression Vector

[00110] Vectors provided herein are designed, primarily, to express a therapeutic gene (*e.g.,* an immune stimulatory gene such as IL-12 and/or a prodrug converting gene like cytochrome p450 and/or a viral derived lysis promoting gene like ADP) and/or extracellular matrix degradative gene (*e.g.,* relaxin) under the control of regulated eukaryotic promoters (*i.e.,* constitutive, inducible, repressable, tissue-specific). In some aspects, the therapeutic genes may be co-expressed in a vector. In another aspect, the therapeutic genes may be co-expressed with an extracellular matrix degradative gene. Also, the vectors may contain a selectable marker if, for no other reason, to facilitate their manipulation *in vitro.*

[00111] One of skill in the art would be well-equipped to construct a vector through standard recombinant techniques (see, for example, Sambrook *et al.*, 2001 and Ausubel *et al.,* 1996, both incorporated herein by reference). Vectors include but are not limited to, plasmids, cosmids, viruses (bacteriophage, animal viruses, and plant viruses), and artificial chromosomes (*e.g.,* YACs), such as retroviral vectors (*e.g.* derived from Moloney murine leukemia virus vectors (MoMLV), MSCV, SFFV, MPSV, SNV *etc*), lentiviral vectors (*e.g.* derived from HIV-1, HIV-2, SIV, BIV, FIV *etc.*), adenoviral (Ad) vectors including replication competent, replication deficient and gutless forms thereof, adeno-associated viral (AAV) vectors, simian virus 40 (SV-40) vectors, bovine papilloma virus vectors, Epstein-Barr virus vectors, herpes virus vectors, vaccinia virus vectors, Harvey murine sarcoma virus vectors, murine mammary tumor virus vectors, Rous sarcoma virus vectors, parvovirus vectors, polio virus vectors, vesicular stomatitis virus vectors, maraba virus vectors and group B adenovirus enadenotucirev vectors.

1. Viral Vectors

[00112] Viral vectors encoding a therapeutic gene may be provided in certain aspects of the present disclosure. In generating recombinant viral vectors, non-essential genes are typically replaced with a gene or coding sequence for a heterologous (or non-native) protein. A viral vector is a kind of expression construct that utilizes viral sequences to introduce nucleic acid and possibly proteins into a cell. The ability of certain viruses to infect cells or enter cells via receptor-mediated endocytosis, and to integrate into host cell genomes and express viral genes stably and efficiently have made them attractive candidates for the transfer of foreign nucleic acids into cells (*e.g.*, mammalian cells). Non-limiting examples of virus

vectors that may be used to deliver a nucleic acid of certain aspects of the present invention are described below.

[00113] Lentiviruses are complex retroviruses, which, in addition to the common retroviral genes *gag, pol*, and *env*, contain other genes with regulatory or structural function. Lentiviral vectors are well known in the art (see, for example, Naldini *et al.*, 1996; Zufferey *et al.*, 1997; Blomer *et al.*, 1997; U.S. Patents 6,013,516 and 5,994,136).

[00114] Recombinant lentiviral vectors are capable of infecting non-dividing cells and can be used for both *in vivo* and *ex vivo* gene transfer and expression of nucleic acid sequences. For example, recombinant lentivirus capable of infecting a non-dividing cell—wherein a suitable host cell is transfected with two or more vectors carrying the packaging functions, namely gag, pol and env, as well as rev and tat—is described in U.S. Patent 5,994,136, incorporated herein by reference.

a. Adenoviral Vector

[00115] One method for delivery of the tumor suppressor and/or extracellular matrix degradative gene involves the use of an adenovirus expression vector. Although adenovirus vectors are known to have a low capacity for integration into genomic DNA, this feature is counterbalanced by the high efficiency of gene transfer afforded by these vectors. Adenovirus expression vectors include constructs containing adenovirus sequences sufficient to (a) support packaging of the construct and (b) to ultimately express a recombinant gene construct that has been cloned therein.

[00116] Adenovirus growth and manipulation is known to those of skill in the art, and exhibits broad host range *in vitro* and *in vivo*. This group of viruses can be obtained in high titers, *e.g.*, 109-1011 plaque-forming units per ml, and they are highly infective. The life cycle of adenovirus does not require integration into the host cell genome. The foreign genes delivered by adenovirus vectors are episomal and, therefore, have low genotoxicity to host cells. No side effects have been reported in studies of vaccination with wild-type adenovirus (Couch *et al.*, 1963; Top *et al.*, 1971), demonstrating their safety and therapeutic potential as *in vivo* gene transfer vectors.

[00117] Knowledge of the genetic organization of adenovirus, a 36 kb, linear, double-stranded DNA virus, allows substitution of large pieces of adenoviral DNA with foreign

sequences up to 7 kb (Grunhaus and Horwitz, 1992). In contrast to retrovirus, the adenoviral infection of host cells does not result in chromosomal integration because adenoviral DNA can replicate in an episomal manner without potential genotoxicity. Also, adenoviruses are structurally stable, and no genome rearrangement has been detected after extensive amplification.

[00118] Adenovirus is particularly suitable for use as a gene transfer vector because of its mid-sized genome, ease of manipulation, high titer, wide target-cell range and high infectivity. Both ends of the viral genome contain 100-200 base pair inverted repeats (ITRs), which are cis elements necessary for viral DNA replication and packaging. The early (E) and late (L) regions of the genome contain different transcription units that are divided by the onset of viral DNA replication. The E1 region (E1A and E1B) encodes proteins responsible for the regulation of transcription of the viral genome and a few cellular genes. The expression of the E2 region (E2A and E2B) results in the synthesis of the proteins for viral DNA replication. These proteins are involved in DNA replication, late gene expression and host cell shut-off (Renan, 1990). The products of the late genes, including the majority of the viral capsid proteins, are expressed only after significant processing of a single primary transcript issued by the major late promoter (MLP). The MLP, (located at 16.8 m.u.) is particularly efficient during the late phase of infection, and all the mRNA's issued from this promoter possess a 5'-tripartite leader (TPL) sequence which makes them particular mRNA's for translation.

[00119] A recombinant adenovirus provided herein can be generated from homologous recombination between a shuttle vector and provirus vector. Due to the possible recombination between two proviral vectors, wild-type adenovirus may be generated from this process. Therefore, a single clone of virus is isolated from an individual plaque and its genomic structure is examined.

[00120] The adenovirus vector may be replication competent, replication defective, or conditionally defective, the nature of the adenovirus vector is not believed to be crucial to the successful practice of the invention. The adenovirus may be of any of the 42 different known serotypes or subgroups A-F. Adenovirus type 5 of subgroup C is the particular starting material in order to obtain the conditional replication-defective adenovirus vector for use in the present invention. This is because Adenovirus type 5 is a human adenovirus about which a great deal of biochemical and genetic information is known, and it has historically

been used for most constructions employing adenovirus as a vector. However, other serotypes of adenovirus may be similarly utilized.

[00121] Nucleic acids can be introduced to adenoviral vectors as a position from which a coding sequence has been removed. For example, a replication defective adenoviral vector can have the E1-coding sequences removed. The polynucleotide encoding the gene of interest may also be inserted in lieu of the deleted E3 region in E3 replacement vectors as described by Karlsson *et al.* (1986) or in the E4 region where a helper cell line or helper virus complements the E4 defect.

[00122] Generation and propagation of replication deficient adenovirus vectors can be performed with helper cell lines. One unique helper cell line, designated 293, was transformed from human embryonic kidney cells by Ad5 DNA fragments and constitutively expresses E1 proteins (Graham *et al.*, 1977). Since the E3 region is dispensable from the adenovirus genome (Jones and Shenk, 1978), adenovirus vectors, with the help of 293 cells, carry foreign DNA in either the E1, the E3, or both regions (Graham and Prevec, 1991).

[00123] Helper cell lines may be derived from human cells such as human embryonic kidney cells, muscle cells, hematopoietic cells or other human embryonic mesenchymal or epithelial cells. Alternatively, the helper cells may be derived from the cells of other mammalian species that are permissive for human adenovirus. Such cells include, *e.g.*, Vero cells or other monkey embryonic mesenchymal or epithelial cells. As stated above, a particular helper cell line is 293.

[00124] Methods for producing recombinant adenovirus are known in the art, such as U.S. Patent No. 6740320, incorporated herein by reference. Also, Racher *et al.* (1995) have disclosed improved methods for culturing 293 cells and propagating adenovirus. In one format, natural cell aggregates are grown by inoculating individual cells into 1 liter siliconized spinner flasks (Techne, Cambridge, UK) containing 100-200 ml of medium. Following stirring at 40 rpm, the cell viability is estimated with trypan blue. In another format, Fibra-Cel microcarriers (Bibby Sterlin, Stone, UK) (5 g/l) are employed as follows. A cell inoculum, resuspended in 5 ml of medium, is added to the carrier (50 ml) in a 250 ml Erlenmeyer flask and left stationary, with occasional agitation, for 1 to 4 hours. The medium is then replaced with 50 ml of fresh medium and shaking initiated. For virus production, cells are allowed to grow to about 80% confluence, after which time the medium is replaced (to 25% of the final

volume) and adenovirus added at an MOI of 0.05. Cultures are left stationary overnight, following which the volume is increased to 100% and shaking commenced for another 72 hours.

b. Retroviral Vector

[00125] Additionally, the viral composition may comprise a retroviral vector. The retroviruses are a group of single-stranded RNA viruses characterized by an ability to convert their RNA to double-stranded DNA in infected cells by a process of reverse-transcription (Coffin, 1990). The resulting DNA then stably integrates into cellular chromosomes as a provirus and directs synthesis of viral proteins. The integration results in the retention of the viral gene sequences in the recipient cell and its descendants. The retroviral genome contains three genes, gag, pol, and env that code for capsid proteins, polymerase enzyme, and envelope components, respectively. A sequence found upstream from the gag gene contains a signal for packaging of the genome into virions. Two long terminal repeat (LTR) sequences are present at the 5' and 3' ends of the viral genome. These contain strong promoter and enhancer sequences and are also required for integration in the host cell genome (Coffin, 1990).

[00126] In order to construct a retroviral vector, a nucleic acid encoding a gene of interest is inserted into the viral genome in the place of certain viral sequences to produce a virus that is replication-defective. In order to produce virions, a packaging cell line containing the gag, pol, and env genes but without the LTR and packaging components is constructed (Mann *et al.*, 1983). When a recombinant plasmid containing a cDNA, together with the retroviral LTR and packaging sequences is introduced into this cell line (by calcium phosphate precipitation for example), the packaging sequence allows the RNA transcript of the recombinant plasmid to be packaged into viral particles, which are then secreted into the culture media (Nicolas and Rubenstein, 1988; Temin, 1986; Mann *et al.*, 1983). The media containing the recombinant retroviruses is then collected, optionally concentrated, and used for gene transfer. Retroviral vectors are able to infect a broad variety of cell types. However, integration and stable expression require the division of host cells (Paskind *et al.*, 1975).

[00127] Concern with the use of defective retrovirus vectors is the potential appearance of wild-type replication-competent virus in the packaging cells. This can result from recombination events in which the intact sequence from the recombinant virus inserts upstream from the gag, pol, env sequence integrated in the host cell genome. However,

packaging cell lines are available that should greatly decrease the likelihood of recombination (Markowitz *et al.,* 1988; Hersdorffer *et al.,* 1990).

c. Adeno-associated Viral Vector

[00128] Adeno-associated virus (AAV) is an attractive vector system for use in the present disclosure as it has a high frequency of integration and it can infect nondividing cells, thus making it useful for delivery of genes into mammalian cells (Muzyczka, 1992). AAV has a broad host range for infectivity (Tratschin, *et al.*, 1984; Laughlin, *et al.*, 1986; Lebkowski, *et al.*, 1988; McLaughlin, *et al.,* 1988), which means it is applicable for use with the present invention. Details concerning the generation and use of rAAV vectors are described in U.S. Patent No. 5,139,941 and U.S. Patent No. 4,797,368.

[00129] AAV is a dependent parvovirus in that it requires coinfection with another virus (either adenovirus or a member of the herpes virus family) to undergo a productive infection in cultured cells (Muzyczka, 1992). In the absence of coinfection with helper virus, the wild-type AAV genome integrates through its ends into human chromosome 19 where it resides in a latent state as a provirus (Kotin *et al.,* 1990; Samulski *et al.,* 1991). rAAV, however, is not restricted to chromosome 19 for integration unless the AAV Rep protein is also expressed (Shelling and Smith, 1994). When a cell carrying an AAV provirus is superinfected with a helper virus, the AAV genome is "rescued" from the chromosome or from a recombinant plasmid, and a normal productive infection is established (Samulski *et al.,* 1989; McLaughlin *et al.*, 1988; Kotin *et al.,* 1990; Muzyczka, 1992).

[00130] Typically, recombinant AAV (rAAV) virus is made by cotransfecting a plasmid containing the gene of interest flanked by the two AAV terminal repeats (McLaughlin *et al.*, 1988; Samulski *et al.*, 1989; each incorporated herein by reference) and an expression plasmid containing the wild-type AAV coding sequences without the terminal repeats, for example pIM45 (McCarty *et al.*, 1991). The cells are also infected or transfected with adenovirus or plasmids carrying the adenovirus genes required for AAV helper function. rAAV virus stocks made in such fashion are contaminated with adenovirus which must be physically separated from the rAAV particles (for example, by cesium chloride density centrifugation). Alternatively, adenovirus vectors containing the AAV coding regions or cell lines containing the AAV coding regions and some or all of the adenovirus helper genes could be used (Yang *et al.*, 1994; *Clark et al.,* 1995). Cell lines carrying the rAAV DNA as an integrated provirus can also be used (Flotte *et al.,* 1995).

d. Other Viral Vectors

[00131] Other viral vectors may be employed as constructs in the present disclosure. Vectors derived from viruses such as vaccinia virus (Ridgeway, 1988; Baichwal and Sugden, 1986; Coupar *et al.*, 1988) and herpesviruses may be employed. They offer several attractive features for various mammalian cells (Friedmann, 1989; Ridgeway, 1988; Baichwal and Sugden, 1986; Coupar *et al.,* 1988; Horwich *et al.,* 1990).

[00132] A molecularly cloned strain of Venezuelan equine encephalitis (VEE) virus has been genetically refined as a replication competent vaccine vector for the expression of heterologous viral proteins (Davis *et al.,* 1996). Studies have demonstrated that VEE infection stimulates potent CTL responses and has been suggested that VEE may be an extremely useful vector for immunizations (Caley *et al.*, 1997).

[00133] In further embodiments, the nucleic acid is housed within an infective virus that has been engineered to express a specific binding ligand. The virus particle will thus bind specifically to the cognate receptors of the target cell and deliver the contents to the cell. A novel approach designed to allow specific targeting of retrovirus vectors was recently developed based on the chemical modification of a retrovirus by the chemical addition of lactose residues to the viral envelope. This modification can permit the specific infection of hepatocytes via sialoglycoprotein receptors.

[00134] For example, targeting of recombinant retroviruses was designed in which biotinylated antibodies against a retroviral envelope protein and against a specific cell receptor were used. The antibodies were coupled via the biotin components by using streptavidin (Roux *et al.*, 1989). Using antibodies against major histocompatibility complex class I and class II antigens, they demonstrated the infection of a variety of human cells that bore those surface antigens with an ecotropic virus *in vitro* (Roux *et al.,* 1989).

2. Regulatory Elements

[00135] Expression cassettes included in vectors useful in the present disclosure in particular contain (in a 5'-to-3' direction) a eukaryotic transcriptional promoter operably linked to a protein-coding sequence, splice signals including intervening sequences, and a transcriptional termination/polyadenylation sequence. The promoters and enhancers that control the transcription of protein encoding genes in eukaryotic cells are composed of multiple genetic elements. The cellular machinery is able to gather and integrate the regulatory

information conveyed by each element, allowing different genes to evolve distinct, often complex patterns of transcriptional regulation. A promoter used in the context of the present invention includes constitutive, inducible, and tissue-specific promoters.

a. Promoter/Enhancers

[00136] The expression constructs provided herein comprise a promoter to drive expression of the tumor suppressor and/or extracellular matrix degradative gene. A promoter generally comprises a sequence that functions to position the start site for RNA synthesis. The best known example of this is the TATA box, but in some promoters lacking a TATA box, such as, for example, the promoter for the mammalian terminal deoxynucleotidyl transferase gene and the promoter for the SV40 late genes, a discrete element overlying the start site itself helps to fix the place of initiation. Additional promoter elements regulate the frequency of transcriptional initiation. Typically, these are located in the region 30-110 bp upstream of the start site, although a number of promoters have been shown to contain functional elements downstream of the start site as well. To bring a coding sequence "under the control of" a promoter, one positions the 5′ end of the transcription initiation site of the transcriptional reading frame "downstream" of (*i.e.*, 3′ of) the chosen promoter. The "upstream" promoter stimulates transcription of the DNA and promotes expression of the encoded RNA.

[00137] The spacing between promoter elements frequently is flexible, so that promoter function is preserved when elements are inverted or moved relative to one another. In the tk promoter, the spacing between promoter elements can be increased to 50 bp apart before activity begins to decline. Depending on the promoter, it appears that individual elements can function either cooperatively or independently to activate transcription. A promoter may or may not be used in conjunction with an "enhancer," which refers to a cis-acting regulatory sequence involved in the transcriptional activation of a nucleic acid sequence.

[00138] A promoter may be one naturally associated with a nucleic acid sequence, as may be obtained by isolating the 5′ non-coding sequences located upstream of the coding segment and/or exon. Such a promoter can be referred to as "endogenous." Similarly, an enhancer may be one naturally associated with a nucleic acid sequence, located either downstream or upstream of that sequence. Alternatively, certain advantages will be gained by positioning the coding nucleic acid segment under the control of a recombinant or heterologous promoter, which refers to a promoter that is not normally associated with a nucleic acid

sequence in its natural environment. A recombinant or heterologous enhancer refers also to an enhancer not normally associated with a nucleic acid sequence in its natural environment. Such promoters or enhancers may include promoters or enhancers of other genes, and promoters or enhancers isolated from any other virus, or prokaryotic or eukaryotic cell, and promoters or enhancers not "naturally occurring," *i.e.,* containing different elements of different transcriptional regulatory regions, and/or mutations that alter expression. For example, promoters that are most commonly used in recombinant DNA construction include the β-lactamase (penicillinase), lactose and tryptophan (trp) promoter systems. In addition to producing nucleic acid sequences of promoters and enhancers synthetically, sequences may be produced using recombinant cloning and/or nucleic acid amplification technology, including PCR™, in connection with the compositions disclosed herein (*see* U.S. Patent Nos. 4,683,202 and 5,928,906, each incorporated herein by reference). Furthermore, it is contemplated that the control sequences that direct transcription and/or expression of sequences within non-nuclear organelles such as mitochondria, chloroplasts, and the like, can be employed as well.

[00139] Naturally, it will be important to employ a promoter and/or enhancer that effectively directs the expression of the DNA segment in the organelle, cell type, tissue, organ, or organism chosen for expression. Those of skill in the art of molecular biology generally know the use of promoters, enhancers, and cell type combinations for protein expression, (*see*, for example Sambrook *et al.* 1989, incorporated herein by reference). The promoters employed may be constitutive, tissue-specific, inducible, and/or useful under the appropriate conditions to direct high level expression of the introduced DNA segment, such as is advantageous in the large-scale production of recombinant proteins and/or peptides. The promoter may be heterologous or endogenous.

[00140] Additionally, any promoter/enhancer combination (as per, for example, the Eukaryotic Promoter Data Base EPDB, through world wide web at epd.isb-sib.ch/) could also be used to drive expression. Use of a T3, T7 or SP6 cytoplasmic expression system is another possible embodiment. Eukaryotic cells can support cytoplasmic transcription from certain bacterial promoters if the appropriate bacterial polymerase is provided, either as part of the delivery complex or as an additional genetic expression construct.

[00141] Non-limiting examples of promoters include early or late viral promoters, such as, SV40 early or late promoters, cytomegalovirus (CMV) immediate early promoters, Rous Sarcoma Virus (RSV) early promoters; eukaryotic cell promoters, such as, *e.*

g., beta actin promoter (Ng, 1989; Quitsche *et al.*, 1989), GADPH promoter (Alexander *et al.*, 1988, Ercolani *et al.*, 1988), metallothionein promoter (Karin *et al.*, 1989; Richards *et al.*, 1984); and concatenated response element promoters, such as cyclic AMP response element promoters (cre), serum response element promoter (sre), phorbol ester promoter (TPA) and response element promoters (tre) near a minimal TATA box. It is also possible to use human growth hormone promoter sequences (*e.g.*, the human growth hormone minimal promoter described at Genbank, accession no. X05244, nucleotide 283-341) or a mouse mammary tumor promoter (available from the ATCC, Cat. No. ATCC 45007). In certain embodiments, the promoter is CMV IE, dectin-1, dectin-2, human CD11c, F4/80, SM22, RSV, SV40, Ad MLP, beta-actin, MHC class I or MHC class II promoter, however any other promoter that is useful to drive expression of the therapeutic gene is applicable to the practice of the present invention.

[00142] In certain aspects, methods of the disclosure also concern enhancer sequences, *i.e.*, nucleic acid sequences that increase a promoter's activity and that have the potential to act in cis, and regardless of their orientation, even over relatively long distances (up to several kilobases away from the target promoter). However, enhancer function is not necessarily restricted to such long distances as they may also function in close proximity to a given promoter.

b. Initiation Signals and Linked Expression

[00143] A specific initiation signal also may be used in the expression constructs provided in the present disclosure for efficient translation of coding sequences. These signals include the ATG initiation codon or adjacent sequences. Exogenous translational control signals, including the ATG initiation codon, may need to be provided. One of ordinary skill in the art would readily be capable of determining this and providing the necessary signals. It is well known that the initiation codon must be "in-frame" with the reading frame of the desired coding sequence to ensure translation of the entire insert. The exogenous translational control signals and initiation codons can be either natural or synthetic. The efficiency of expression may be enhanced by the inclusion of appropriate transcription enhancer elements.

[00144] In certain embodiments, the use of internal ribosome entry sites (IRES) elements are used to create multigene, or polycistronic, messages. IRES elements are able to bypass the ribosome scanning model of 5′ methylated Cap dependent translation and begin translation at internal sites (Pelletier and Sonenberg, 1988). IRES elements from two members of the picornavirus family (polio and encephalomyocarditis) have been described (Pelletier and

Sonenberg, 1988), as well an IRES from a mammalian message (Macejak and Sarnow, 1991). IRES elements can be linked to heterologous open reading frames. Multiple open reading frames can be transcribed together, each separated by an IRES, creating polycistronic messages. By virtue of the IRES element, each open reading frame is accessible to ribosomes for efficient translation. Multiple genes can be efficiently expressed using a single promoter/enhancer to transcribe a single message (see U.S. Patent Nos. 5,925,565 and 5,935,819, each herein incorporated by reference).

[00145] Additionally, certain 2A sequence elements could be used to create linked- or co-expression of genes in the constructs provided in the present disclosure. For example, cleavage sequences could be used to co-express genes by linking open reading frames to form a single cistron. An exemplary cleavage sequence is the F2A (Foot-and-mouth diease virus 2A) or a "2A-like" sequence (*e.g., Thosea asigna* virus 2A; T2A) (Minskaia and Ryan, 2013).

c. Origins of Replication

In order to propagate a vector in a host cell, it may contain one or more origins of replication sites (often termed "ori"), for example, a nucleic acid sequence corresponding to oriP of EBV as described above or a genetically engineered oriP with a similar or elevated function in programming, which is a specific nucleic acid sequence at which replication is initiated. Alternatively a replication origin of other extra-chromosomally replicating virus as described above or an autonomously replicating sequence (ARS) can be employed.

3. Selection and Screenable Markers

[00146] In some embodiments, cells containing a construct of the present disclosure may be identified *in vitro* or *in vivo* by including a marker in the expression vector. Such markers would confer an identifiable change to the cell permitting easy identification of cells containing the expression vector. Generally, a selection marker is one that confers a property that allows for selection. A positive selection marker is one in which the presence of the marker allows for its selection, while a negative selection marker is one in which its presence prevents its selection. An example of a positive selection marker is a drug resistance marker.

[00147] Usually the inclusion of a drug selection marker aids in the cloning and identification of transformants, for example, genes that confer resistance to neomycin,

puromycin, hygromycin, DHFR, GPT, zeocin and histidinol are useful selection markers. In addition to markers conferring a phenotype that allows for the discrimination of transformants based on the implementation of conditions, other types of markers including screenable markers such as GFP, whose basis is colorimetric analysis, are also contemplated. Alternatively, screenable enzymes as negative selection markers such as herpes simplex virus thymidine kinase (*tk*) or chloramphenicol acetyltransferase (CAT) may be utilized. One of skill in the art would also know how to employ immunologic markers, possibly in conjunction with FACS analysis. The marker used is not believed to be important, so long as it is capable of being expressed simultaneously with the nucleic acid encoding a gene product. Further examples of selection and screenable markers are well known to one of skill in the art.

B. Other Methods of Nucleic Acid Delivery

[00148] In addition to viral delivery of the nucleic acids encoding the therapeutic gene and/or extracellular matrix degradative gene, the following are additional methods of recombinant gene delivery to a given host cell and are thus considered in the present disclosure. Thus, other forms of gene therapy may be combined with the therapeutic viral compositions including gene editing methods such as meganucleases, zinc finger nucleases (ZFNs), transcription activator-like effector-based nucleases (TALEN), and the CRISPR-Cas system.

[00149] Introduction of a nucleic acid, such as DNA or RNA, may use any suitable methods for nucleic acid delivery for transformation of a cell, as described herein or as would be known to one of ordinary skill in the art. Such methods include, but are not limited to, direct delivery of DNA such as by ex vivo transfection (Wilson *et al.*, 1989, Nabel *et al*, 1989), by injection (U.S. Patent Nos. 5,994,624, 5,981,274, 5,945,100, 5,780,448, 5,736,524, 5,702,932, 5,656,610, 5,589,466 and 5,580,859, each incorporated herein by reference), including microinjection (Harland and Weintraub, 1985; U.S. Patent No. 5,789,215, incorporated herein by reference); by electroporation (U.S. Patent No. 5,384,253, incorporated herein by reference; Tur-Kaspa *et al.*, 1986; Potter *et al.*, 1984); by calcium phosphate precipitation (Graham and Van Der Eb, 1973; Chen and Okayama, 1987; Rippe *et al.*, 1990); by using DEAE-dextran followed by polyethylene glycol (Gopal, 1985); by direct sonic loading (Fechheimer *et al.*, 1987); by liposome mediated transfection (Nicolau and Sene, 1982; Fraley *et al.*, 1979; Nicolau *et al.*, 1987; Wong *et al.*, 1980; Kaneda *et al.*, 1989; Kato *et al.*, 1991) and receptor-mediated transfection (Wu and Wu, 1987; Wu and Wu, 1988); by microprojectile bombardment (PCT Application Nos. WO 94/09699 and 95/06128; U.S. Patent

Nos. 5,610,042; 5,322,783 5,563,055, 5,550,318, 5,538,877 and 5,538,880, and each incorporated herein by reference); by agitation with silicon carbide fibers (Kaeppler *et al.,* 1990; U.S. Patent Nos. 5,302,523 and 5,464,765, each incorporated herein by reference); by *Agrobacterium*-mediated transformation (U.S. Patent Nos. 5,591,616 and 5,563,055, each incorporated herein by reference); by desiccation/inhibition-mediated DNA uptake (Potrykus *et al.,* 1985), and any combination of such methods. Through the application of techniques such as these, organelle(s), cell(s), tissue(s) or organism(s) may be stably or transiently transformed.

1. Electroporation

[00150] In certain particular embodiments of the present disclosure, the gene construct is introduced into target hyperproliferative cells via electroporation. Electroporation involves the exposure of cells (or tissues) and DNA (or a DNA complex) to a high-voltage electric discharge.

[00151] Transfection of eukaryotic cells using electroporation has been quite successful. Mouse pre-B lymphocytes have been transfected with human kappa-immunoglobulin genes (Potter *et al.*, 1984), and rat hepatocytes have been transfected with the chloramphenicol acetyltransferase gene (Tur-Kaspa *et al.*, 1986) in this manner.

[00152] It is contemplated that electroporation conditions for hyperproliferative cells from different sources may be optimized. One may particularly wish to optimize such parameters as the voltage, the capacitance, the time and the electroporation media composition. The execution of other routine adjustments will be known to those of skill in the art. See *e.g.*, Hoffman, 1999; Heller *et al.*, 1996.

2. Lipid-Mediated Transformation

[00153] In a further embodiment, the tumor suppressor and/or extracellular matrix degradative gene may be entrapped in a liposome or lipid formulation. Liposomes are vesicular structures characterized by a phospholipid bilayer membrane and an inner aqueous medium. Multilamellar liposomes have multiple lipid layers separated by aqueous medium. They form spontaneously when phospholipids are suspended in an excess of aqueous solution. The lipid components undergo self-rearrangement before the formation of closed structures and entrap water and dissolved solutes between the lipid bilayers (Ghosh and Bachhawat, 1991). Also contemplated is a gene construct complexed with Lipofectamine (Gibco BRL).

[00154] Lipid-mediated nucleic acid delivery and expression of foreign DNA *in vitro* has been very successful (Nicolau and Sene, 1982; Fraley *et al.*, 1979; Nicolau *et al.*, 1987). Wong *et al.* (1980) demonstrated the feasibility of lipid-mediated delivery and expression of foreign DNA in cultured chick embryo, HeLa and hepatoma cells.

[00155] Lipid based non-viral formulations provide an alternative to adenoviral gene therapies. Although many cell culture studies have documented lipid based non-viral gene transfer, systemic gene delivery via lipid based formulations has been limited. A major limitation of non-viral lipid based gene delivery is the toxicity of the cationic lipids that comprise the non-viral delivery vehicle. The *in vivo* toxicity of liposomes partially explains the .discrepancy between *in vitro* and *in vivo* gene transfer results. Another factor contributing to this contradictory data is the difference in lipid vehicle stability in the presence and absence of serum proteins. The interaction between lipid vehicles and serum proteins has a dramatic impact on the stability characteristics of lipid vehicles (Yang and Huang, 1997). Cationic lipids attract and bind negatively charged serum proteins. Lipid vehicles associated with serum proteins are either dissolved or taken up by macrophages leading to their removal from circulation. Current *in vivo* lipid delivery methods use subcutaneous, intradermal, intratumoral, or intracranial injection to avoid the toxicity and stability problems associated with cationic lipids in the circulation. The interaction of lipid vehicles and plasma proteins is responsible for the disparity between the efficiency of *in vitro* (Felgner *et al.*, 1987) and *in vivo* gene transfer (Zhu el al., 1993; Philip *et al.*, 1993; Solodin *et al.*, 1995; Liu *et al.*, 1995; Thierry *et al.*, 1995; Tsukamoto *et al.*, 1995; Aksentijevich *et al.*, 1996).

[00156] Advances in lipid formulations have improved the efficiency of gene transfer *in vivo* (Templeton *et al.* 1997; WO 98/07408). A novel lipid formulation composed of an equimolar ratio of 1,2-bis(oleoyloxy)-3-(trimethyl ammonio)propane (DOTAP) and cholesterol significantly enhances systemic *in vivo* gene transfer, approximately 150 fold. The DOTAP:cholesterol lipid formulation forms unique structure termed a "sandwich liposome". This formulation is reported to "sandwich" DNA between an invaginated bi-layer or 'vase' structure. Beneficial characteristics of these lipid structures include a positive ρ, colloidal stabilization by cholesterol, two dimensional DNA packing and increased serum stability. Patent Application Nos. 60/135,818 and 60/133,116 discuss formulations that may be used with the present invention.

[00157] The production of lipid formulations often is accomplished by sonication or serial extrusion of liposomal mixtures after (I) reverse phase evaporation (II) dehydration-rehydration (III) detergent dialysis and (IV) thin film hydration. Once manufactured, lipid structures can be used to encapsulate compounds that are toxic (chemotherapeutics) or labile (nucleic acids) when in circulation. Lipid encapsulation has resulted in a lower toxicity and a longer serum half-life for such compounds (Gabizon *et al.*, 1990). Numerous disease treatments are using lipid based gene transfer strategies to enhance conventional or establish novel therapies, in particular therapies for treating hyperproliferative diseases.

IV. Immune Checkpoint Inhibitors

[00158] The present disclosure provides methods of combining the blockade of immune checkpoints with a virus composition. Immune checkpoints are molecules in the immune system that either turn up a signal (*e.g.*, co-stimulatory molecules) or turn down a signal. Inhibitory checkpoint molecules that may be targeted by immune checkpoint blockade include adenosine A2A receptor (A2AR), B7-H3 (also known as CD276), B and T lymphocyte attenuator (BTLA), cytotoxic T-lymphocyte-associated protein 4 (CTLA-4, also known as CD152), indoleamine 2,3-dioxygenase (IDO), killer-cell immunoglobulin (KIR), lymphocyte activation gene-3 (LAG3), programmed death 1 (PD-1), T-cell immunoglobulin domain and mucin domain 3 (TIM-3) and V-domain Ig suppressor of T cell activation (VISTA). In particular, the immune checkpoint inhibitors target the PD-1 axis and/or CTLA-4.

[00159] The immune checkpoint inhibitors may be drugs such as small molecules, recombinant forms of ligand or receptors, or, in particular, are antibodies, such as human antibodies (*e.g.*, International Patent Publication WO2015016718; Pardoll, 2012; both incorporated herein by reference). Known inhibitors of the immune checkpoint proteins or analogs thereof may be used, in particular chimerized, humanized or human forms of antibodies may be used. As the skilled person will know, alternative and/or equivalent names may be in use for certain antibodies mentioned in the present disclosure. Such alternative and/or equivalent names are interchangeable in the context of the present invention. For example it is known that lambrolizumab is also known under the alternative and equivalent names MK-3475 and pembrolizumab.

[00160] It is contemplated that any of the immune checkpoint inhibitors that are known in the art to stimulate immune responses may be used. This includes inhibitors that directly or indirectly stimulate or enhance antigen-specific T-lymphocytes. These immune checkpoint inhibitors include, without limitation, agents targeting immune checkpoint proteins and pathways involving PD-L2, LAG3, BTLA, B7H4 and TIM3. For example, LAG3 inhibitors known in the art include soluble LAG3 (IMP321, or LAG3-Ig disclosed in WO2009044273) as well as mouse or humanized antibodies blocking human LAG3 (*e.g.*, IMP701 disclosed in WO2008132601), or fully human antibodies blocking human LAG3 (such as disclosed in EP 2320940). Another example is provided by the use of blocking agents towards BTLA, including without limitation antibodies blocking human BTLA interaction with its ligand (such as 4C7 disclosed in WO2011014438). Yet another example is provided by the use of agents neutralizing B7H4 including without limitation antibodies to human B7H4 (disclosed in WO 2013025779, and in WO2013067492) or soluble recombinant forms of B7H4 (such as disclosed in US20120177645). Yet another example is provided by agents neutralizing B7-H3, including without limitation antibodies neutralizing human B7-H3 (*e.g.* MGA271 disclosed as BRCA84D and derivatives in US 20120294796). Yet another example is provided by agents targeting TIM3, including without limitation antibodies targeting human TIM3 (*e.g.* as disclosed in WO 2013006490 A2 or the anti-human TIM3, blocking antibody F38-2E2 disclosed by Jones *et al.*, 2008).

[00161] In addition, more than one immune checkpoint inhibitor (*e.g.*, anti-PD-1 antibody and anti-CTLA-4 antibody) may be used in combination with the local/abscopal virus compositions. For example, local/abscopal virus compositions and immune checkpoint inhibitors (*e.g.*, anti-KIR antibody and/or anti-PD-1 antibody) can be administered to enhance innate anti-tumor immunity followed by local/abscopal virus compositions and immune checkpoint inhibitors (*e.g.*, anti-PD-1 antibody) to induce adaptive anti-tumor immune responses.

A. PD-1 Axis Antagonists

[00162] T cell dysfunction or anergy occurs concurrently with an induced and sustained expression of the inhibitory receptor, programmed death 1 polypeptide (PD-1). Thus, therapeutic targeting of PD-1 and other molecules which signal through interactions with PD-1, such as programmed death ligand 1 (PD-Ll) and programmed death ligand 2 (PD-L2) is provided herein. PD-Ll is overexpressed in many cancers and is often associated with poor

prognosis (Okazaki T *et al.*, 2007). Thus, inhibition of the PD-Ll/PD-1 interaction in combination with local/abscopal virus composition therapy is provided herein such as to enhance $CD8^+$ T cell-mediated killing of tumors.

[00163] Provided herein is a method for treating or delaying progression of cancer in an individual comprising administering to the individual an effective amount of a PD-1 axis binding antagonist in combination with local/abscopal virus compositions. Also provided herein is a method of enhancing immune function in an individual in need thereof comprising administering to the individual an effective amount of a PD-1 axis binding antagonist and local/abscopal virus compositions.

[00164] For example, a PD-1 axis binding antagonist includes a PD-1 binding antagonist, a PDL1 binding antagonist and a PDL2 binding antagonist. Alternative names for "PD-1" include CD279 and SLEB2. Alternative names for "PDL1" include B7-H1, B7-4, CD274, and B7-H. Alternative names for "PDL2" include B7-DC, Btdc, and CD273. In some embodiments, PD-1, PDL1, and PDL2 are human PD-1, PDL1 and PDL2.

[00165] In some embodiments, the PD-1 binding antagonist is a molecule that inhibits the binding of PD-1 to its ligand binding partners. In a specific aspect, the PD-1 ligand binding partners are PDL1 and/or PDL2. In another embodiment, a PDL1 binding antagonist is a molecule that inhibits the binding of PDL1 to its binding partners. In a specific aspect, PDL1 binding partners are PD-1 and/or B7-1. In another embodiment, the PDL2 binding antagonist is a molecule that inhibits the binding of PDL2 to its binding partners. In a specific aspect, a PDL2 binding partner is PD-1. The antagonist may be an antibody, an antigen binding fragment thereof, an immunoadhesion, a fusion protein, or oligopeptide. Exemplary antibodies are described in U.S. Patent Nos. US8735553, US8354509, and US8008449, all incorporated herein by reference. Other PD-1 axis antagonists for use in the methods provided herein are known in the art such as described in U.S. Patent Application No. US20140294898, US2014022021, and US20110008369, all incorporated herein by reference.

[00166] In some embodiments, the PD-1 binding antagonist is an anti-PD-1 antibody (*e.g.*, a human antibody, a humanized antibody, or a chimeric antibody). In some embodiments, the anti-PD-1 antibody is selected from the group consisting of nivolumab, pembrolizumab, and CT-011. In some embodiments, the PD-1 binding antagonist is an immunoadhesin (*e.g.,* an immunoadhesin comprising an extracellular or PD-1 binding portion

of PDL1 or PDL2 fused to a constant region (*e.g.*, an Fc region of an immunoglobulin sequence). In some embodiments, the PD-1 binding antagonist is AMP- 224. Nivolumab, also known as MDX-1106-04, MDX-1106, ONO-4538, BMS-936558, and OPDIVO®, is an anti-PD-1 antibody described in WO2006/121168. Pembrolizumab, also known as MK-3475, Merck 3475, lambrolizumab, KEYTRUDA®, and SCH-900475, is an anti-PD-1 antibody described in WO2009/114335. CT-011, also known as hBAT or hBAT-1, is an anti-PD-1 antibody described in WO2009/101611. AMP-224, also known as B7-DCIg, is a PDL2-Fc fusion soluble receptor described in WO2010/027827 and WO2011/066342. Additional PD-1 binding antagonists include Pidilizumab, also known as CT-011, MEDI0680, also known as AMP-514, and REGN2810.

[00167] In some aspects, the immune checkpoint inhibitor is a PD-L1 antagonist such as Durvalumab, also known as MEDI4736, atezolizumab, also known as MPDL3280A, or avelumab, also known as MSB00010118C. In certain aspects, the immune checkpoint inhibitor is a PD-L2 antagonist such as rHIgM12B7. In some aspects, the immune checkpoint inhibitor is a LAG-3 antagonist such as, but not limited to, IMP321, and BMS-986016. The immune checkpoint inhibitor may be an adenosine A2a receptor (A2aR) antagonist such as PBF-509.

[00168] In some aspects, the antibody described herein (such as an anti-PD-1 antibody, an anti-PDLl antibody, or an anti-PDL2 antibody) further comprises a human or murine constant region. In a still further aspect, the human constant region is selected from the group consisting of IgGl, IgG2, IgG2, IgG3, IgG4. In a still further specific aspect, the human constant region is IgGl. In a still further aspect, the murine constant region is selected from the group consisting of IgGl, IgG2A, IgG2B, IgG3. In a still further specific aspect, the antibody has reduced or minimal effector function. In a still further specific aspect, the minimal effector function results from production in prokaryotic cells. In a still further specific aspect the minimal effector function results from an "effector-less Fc mutation" or aglycosylation.

[00169] Accordingly, an antibody used herein can be aglycosylated. Glycosylation of antibodies is typically either N-linked or O-linked. N-linked refers to the attachment of the carbohydrate moiety to the side chain of an asparagine residue. The tripeptide sequences asparagine- X-serine and asparagine-X-threonine, where X is any amino acid except proline, are the recognition sequences for enzymatic attachment of the carbohydrate moiety to the asparagine side chain. Thus, the presence of either of these tripeptide sequences in a

polypeptide creates a potential glycosylation site. O-linked glycosylation refers to the attachment of one of the sugars N-aceylgalactosamine, galactose, or xylose to a hydroxy amino acid, most commonly serine or threonine, although 5- hydroxyproline or 5 -hydroxy lysine may also be used. Removal of glycosylation sites form an antibody is conveniently accomplished by altering the amino acid sequence such that one of the above-described tripeptide sequences (for N-linked glycosylation sites) is removed. The alteration may be made by substitution of an asparagine, serine or threonine residue within the glycosylation site another amino acid residue (*e.g.*, glycine, alanine or a conservative substitution).

[00170] The antibody or antigen binding fragment thereof, may be made using methods known in the art, for example, by a process comprising culturing a host cell containing nucleic acid encoding any of the previously described anti-PDLl, anti-PD-1, or anti-PDL2 antibodies or antigen-binding fragment in a form suitable for expression, under conditions suitable to produce such antibody or fragment, and recovering the antibody or fragment.

B. CTLA-4

[00171] Another immune checkpoint that can be targeted in the methods provided herein is the cytotoxic T-lymphocyte-associated protein 4 (CTLA-4), also known as CD152. The complete cDNA sequence of human CTLA-4 has the Genbank accession number L15006. CTLA-4 is found on the surface of T cells and acts as an "off" switch when bound to CD80 or CD86 on the surface of antigen-presenting cells. CTLA4 is a member of the immunoglobulin superfamily that is expressed on the surface of Helper T cells and transmits an inhibitory signal to T cells. CTLA4 is similar to the T-cell co-stimulatory protein, CD28, and both molecules bind to CD80 and CD86, also called B7-1 and B7-2 respectively, on antigen-presenting cells. CTLA4 transmits an inhibitory signal to T cells, whereas CD28 transmits a stimulatory signal. Intracellular CTLA4 is also found in regulatory T cells and may be important to their function. T cell activation through the T cell receptor and CD28 leads to increased expression of CTLA-4, an inhibitory receptor for B7 molecules.

[00172] In some embodiments, the immune checkpoint inhibitor is an anti-CTLA-4 antibody (*e.g.*, a human antibody, a humanized antibody, or a chimeric antibody), an antigen binding fragment thereof, an immunoadhesin, a fusion protein, or oligopeptide.

[00173] Anti-human-CTLA-4 antibodies (or VH and/or VL domains derived therefrom) suitable for use in the present methods can be generated using methods well known

in the art. Alternatively, art recognized anti-CTLA-4 antibodies can be used. For example, the anti-CTLA-4 antibodies disclosed in: US 8,119,129, WO 01/14424, WO 98/42752; WO 00/37504 (CP675,206, also known as tremelimumab; formerly ticilimumab), U.S. Patent No. 6,207,156; Hurwitz *et al.*, 1998; Camacho *et al.*, 2004; and Mokyr *et al.*, 1998 can be used in the methods disclosed herein. The teachings of each of the aforementioned publications are hereby incorporated by reference. Antibodies that compete with any of these art-recognized antibodies for binding to CTLA-4 also can be used. For example, a humanized CTLA-4 antibody is described in International Patent Application No. WO2001014424, WO2000037504, and U.S. Patent No. US8017114; all incorporated herein by reference.

[00174] An exemplary anti-CTLA-4 antibody is ipilimumab (also known as 10D1, MDX- 010, MDX- 101, and Yervoy®) or antigen binding fragments and variants thereof (see, *e.g.*, WOO 1/14424). In other embodiments, the antibody comprises the heavy and light chain CDRs or VRs of ipilimumab. Accordingly, in one embodiment, the antibody comprises the CDR1, CDR2, and CDR3 domains of the VH region of ipilimumab, and the CDR1, CDR2 and CDR3 domains of the VL region of ipilimumab. In another embodiment, the antibody competes for binding with and/or binds to the same epitope on CTLA-4 as the above-mentioned antibodies. In another embodiment, the antibody has at least about 90% variable region amino acid sequence identity with the above-mentioned antibodies (*e.g.*, at least about 90%, 95%, or 99% variable region identity with ipilimumab).

[00175] Other molecules for modulating CTLA-4 include CTLA-4 ligands and receptors such as described in U.S. Patent Nos. US5844905, US5885796 and International Patent Application Nos. WO1995001994 and WO1998042752; all incorporated herein by reference, and immunoadhesions such as described in U.S. Patent No. US8329867, incorporated herein by reference.

C. Killer Immunoglobulin-like Receptor (KIR)

[00176] Another immune checkpoint inhibitor for use in the present invention is an anti-KIR antibody. Anti-human-KIR antibodies (or VH/VL domains derived therefrom) suitable for use in the invention can be generated using methods well known in the art.

[00177] Alternatively, art recognized anti-KIR antibodies can be used. The anti-KIR antibody can be cross-reactive with multiple inhibitory KIR receptors and potentiates the cytotoxicity of NK cells bearing one or more of these receptors. For example, the anti-KIR

antibody may bind to each of KIR2D2DL1, KIR2DL2, and KIR2DL3, and potentiate NK cell activity by reducing, neutralizing and/or reversing inhibition of NK cell cytotoxicity mediated by any or all of these KIRs. In some aspects, the anti-KIR antibody does not bind KIR2DS4 and/or KIR2DS3. For example, monoclonal antibodies 1-7F9 (also known as IPH2101), 14F1, 1-6F1 and 1-6F5, described in WO 2006/003179, the teachings of which are hereby incorporated by reference, can be used. Antibodies that compete with any of these art-recognized antibodies for binding to KIR also can be used. Additional art-recognized anti-KIR antibodies which can be used include, for example, those disclosed in WO 2005/003168, WO 2005/009465, WO 2006/072625, WO 2006/072626, WO 2007/042573, WO 2008/084106, WO 2010/065939, WO 2012/071411 and WO/2012/160448.

[00178] An exemplary anti-KIR antibody is lirilumab (also referred to as BMS-986015 or IPH2102). In other embodiments, the anti-KIR antibody comprises the heavy and light chain complementarity determining regions (CDRs) or variable regions (VRs) of lirilumab. Accordingly, in one embodiment, the antibody comprises the CDR1, CDR2, and CDR3 domains of the heavy chain variable (VH) region of lirilumab, and the CDR1, CDR2 and CDR3 domains of the light chain variable (VL) region of lirilumab. In another embodiment, the antibody has at least about 90% variable region amino acid sequence identity with lirilumab.

V. Methods of Treatment

[00179] Provided herein are methods for treating, delaying progression of, or preventing cancer in an individual comprising administering to the individual an effective amount a virus composition alone or in combination with at least one immune checkpoint inhibitor (*e.g.,* PD-1 axis binding antagonist and/or CTLA-4 antibody).

[00180] In some embodiments, the treatment results in a sustained response in the individual after cessation of the treatment. The methods described herein may find use in treating conditions where enhanced immunogenicity is desired such as increasing tumor immunogenicity for the treatment of cancer. Also provided herein are methods of enhancing immune function such as in an individual having cancer comprising administering to the individual an effective amount of an immune checkpoint inhibitor (*e.g.,* PD-1 axis binding antagonist and/or CTLA-4 antibody) and local/abscopal virus composition therapy. In some embodiments, the individual is a human.

[00181] Examples of cancers contemplated for treatment include lung cancer, head and neck cancer, breast cancer, pancreatic cancer, prostate cancer, renal cancer, bone cancer, testicular cancer, cervical cancer, gastrointestinal cancer, lymphomas, pre-neoplastic lesions in the lung, colon cancer, melanoma, and bladder cancer.

[00182] In some embodiments, the individual has cancer that is resistant (has been demonstrated to be resistant) to one or more anti-cancer therapies. In some embodiments, resistance to anti-cancer therapy includes recurrence of cancer or refractory cancer. Recurrence may refer to the reappearance of cancer, in the original site or a new site, after treatment. In some embodiments, resistance to anti-cancer therapy includes progression of the cancer during treatment with the anti-cancer therapy. In some embodiments, the cancer is at early stage or at late stage.

[00183] The individual may have a cancer that expresses (has been shown to express *e.g.*, in a diagnostic test) PD-L1 biomarker. In some embodiments, the patient's cancer expresses low PD-L1 biomarker. In some embodiments, the patient's cancer expresses high PD-L1 biomarker. The PD-L1 biomarker can be detected in the sample using a method selected from the group consisting of FACS, Western blot, ELISA, immunoprecipitation, immunohistochemistry, immunofluorescence, radioimmunoassay, dot blotting, immunodetection methods, HPLC, surface plasmon resonance, optical spectroscopy, mass spectrometery, HPLC, qPCR, RT-qPCR, multiplex qPCR or RT-qPCR, RNA-seq, microarray analysis, SAGE, MassARRAY technique, and FISH, and combinations thereof.

[00184] The efficacy of any of the methods described herein (*e.g.*, combination treatments including administering an effective amount of a virus composition therapy alone or in combination with at least one immune checkpoint inhibitor) may be tested in various models known in the art, such as clinical or pre -clinical models. Suitable pre-clinical models are exemplified herein and further may include without limitation ID8 ovarian cancer, GEM models, B16 melanoma, RENCA renal cell cancer, CT26 colorectal cancer, MC38 colorectal cancer, and Cloudman melanoma models of cancer.

[00185] In some embodiments of the methods of the present disclosure, the cancer has low levels of T cell infiltration. In some embodiments, the cancer has no detectable T cell infiltrate. In some embodiments, the cancer is a non-immunogenic cancer (*e.g.*, non-immunogenic colorectal cancer and/or ovarian cancer). Without being bound by theory, the

combination treatment may increase T cell (*e.g.*, $CD4^+$ T cell, $CD8^+$ T cell, memory T cell) priming, activation and/or proliferation relative to prior to the administration of the combination.

[00186] In some embodiments of the methods of the present disclosure, activated CD4 and/or CD8 T cells in the individual are characterized by γ-IFN producing CD4 and/or CD8 T cells and/or enhanced cytolytic activity relative to prior to the administration of the combination. γ-IFN may be measured by any means known in the art, including, *e.g.*, intracellular cytokine staining (ICS) involving cell fixation, permeabilization, and staining with an antibody against γ-IFN. Cytolytic activity may be measured by any means known in the art, *e.g.*, using a cell killing assay with mixed effector and target cells.

[00187] The present disclosure is useful for any human cell that participates in an immune reaction either as a target for the immune system or as part of the immune system's response to the foreign target. The methods include ex vivo methods, *in vivo* methods, and various other methods that involve injection of polynucleotides or vectors into the host cell. The methods also include injection directly into the tumor or tumor bed as well as local or regional to the tumor.

A. Administration

[00188] The therapy provided herein comprises administration of an effective amount of a virus composition alone or in combination with at least one immune checkpoint inhibitor (*e.g.*, PD-1 axis binding antagonist and/or CTLA-4 antibody). The combination therapy may be administered in any suitable manner known in the art. For example, of an immune checkpoint inhibitor (*e.g.*, PD-1 axis binding antagonist and/or CTLA-4 antibody) and a virus composition may be administered sequentially (at different times) or concurrently (at the same time). In some embodiments, the one or more immune checkpoint inhibitors are in a separate composition as the local/abscopal virus composition therapy or expression construct thereof. In some embodiments, the immune checkpoint inhibitor is in the same composition as the local/abscopal virus composition therapy. In certain aspects, the subject is administered the nucleic acid encoding p53 and/or the nucleic acid encoding MDA-7 before, simultaneously, or after the at least one immune checkpoint inhibitor.

[00189] The one or more immune checkpoint inhibitors and the components of the virus composition therapy may be administered by the same route of administration or by

different routes of administration. In some embodiments, the immune checkpoint inhibitor is administered intravenously, intramuscularly, subcutaneously, topically, orally, transdermally, intraperitoneally, intraorbitally, by implantation, by inhalation, intrathecally, intraventricularly, or intranasally. In some embodiments, the local/abscopal virus composition therapy is administered intravenously, intramuscularly, subcutaneously, topically, orally, transdermally, intraperitoneally, intraorbitally, by implantation, by inhalation, intrathecally, intraventricularly, or intranasally. In some aspects, the administration is via continuous infusion, intratumoral injection, intravenous injection, intra-arterial injection, intra-peritoneal injection, intrapleural injection, or intra-thecal injection. An effective amount of the immune checkpoint inhibitor and the local/abscopal virus composition therapy may be administered for prevention or treatment of disease. The appropriate dosage of immune checkpoint inhibitor and/or the local/abscopal virus composition therapy may be determined based on the type of disease to be treated, severity and course of the disease, the clinical condition of the individual, the individual's clinical history and response to the treatment, and the discretion of the attending physician. In some embodiments, combination treatment with at least one immune checkpoint inhibitor (*e.g.,* PD-1 axis binding antagonist and/or CTLA-4 antibody) and a local/abscopal virus composition therapy are synergistic, whereby an efficacious dose of a local/abscopal virus composition therapy in the combination is reduced relative to efficacious dose of at the least one immune checkpoint inhibitor (*e.g.,* PD-1 axis binding antagonist and/or CTLA-4 antibody) as a single agent.

[00190] For example, the therapeutically effective amount of the immune checkpoint inhibitor, such as an antibody, and/or the p53 and/or MDA-7 encoding nucleic acid or expression construct thereof that is administered to a human will be in the range of about 0.01 to about 50 mg/kg of patient body weight whether by one or more administrations. In some embodiments, the antibody used is about 0.01 to about 45 mg/kg, about 0.01 to about 40 mg/kg, about 0.01 to about 35 mg/kg, about 0.01 to about 30 mg/kg, about 0.01 to about 25 mg/kg, about 0.01 to about 20 mg/kg, about 0.01 to about 15 mg/kg, about 0.01 to about 10 mg/kg, about 0.01 to about 5 mg/kg, or about 0.01 to about 1 mg/kg administered daily, for example. In some embodiments, the antibody is administered at 15 mg/kg. However, other dosage regimens may be useful. In one embodiment, an anti-PDLl antibody described herein is administered to a human at a dose of about 100 mg, about 200 mg, about 300 mg, about 400 mg, about 500 mg, about 600 mg, about 700 mg, about 800 mg, about 900 mg, about 1000 mg, about 1100 mg, about 1200 mg, about 1300 mg or about 1400 mg on day 1 of 21-day cycles.

The dose may be administered as a single dose or as multiple doses (*e.g.*, 2 or 3 doses), such as infusions. The progress of this therapy is easily monitored by conventional techniques.

[00191] Intratumoral injection, or injection into the tumor vasculature is specifically contemplated for discrete, solid, accessible tumors. Local, regional or systemic administration also may be appropriate. For tumors of >4 cm, the volume to be administered will be about 4-10 ml (in particular 10 ml), while for tumors of <4 cm, a volume of about 1-3 ml will be used (in particular 3 ml). Multiple injections delivered as single dose comprise about 0.1 to about 0.5 ml volumes. For example, adenoviral particles may advantageously be contacted by administering multiple injections to the tumor.

[00192] Treatment regimens may vary as well, and often depend on tumor type, tumor location, disease progression, and health and age of the patient. Obviously, certain types of tumors will require more aggressive treatment, while at the same time, certain patients cannot tolerate more taxing protocols. The clinician will be best suited to make such decisions based on the known efficacy and toxicity (if any) of the therapeutic formulations.

[00193] In certain embodiments, the tumor being treated may not, at least initially, be resectable. Treatments with therapeutic viral constructs may increase the resectability of the tumor due to shrinkage at the margins or by elimination of certain particularly invasive portions. Following treatments, resection may be possible. Additional treatments subsequent to resection will serve to eliminate microscopic residual disease at the tumor site.

[00194] The treatments may include various "unit doses." Unit dose is defined as containing a predetermined-quantity of the therapeutic composition. The quantity to be administered, and the particular route and formulation, are within the skill of those in the clinical arts. A unit dose need not be administered as a single injection but may comprise continuous infusion over a set period of time. Unit dose of the present invention may conveniently be described in terms of plaque forming units (pfu) for a viral construct. Unit doses range from 10^3, 10^4, 10^5, 10^6, 10^7, 10^8, 10^9, 10^{10}, 10^{11}, 10^{12}, 10^{13} pfu and higher. Alternatively, depending on the kind of virus and the titer attainable, one will deliver 1 to 100, 10 to 50, 100-1000, or up to about 1×10^4, 1×10^5, 1×10^6, 1×10^7, 1×10^8 , 1×10^9, 1×10^{10}, 1×10^{11}, 1×10^{12}, 1×10^{13}, 1×10^{14}, or 1×10^{15} or higher infectious viral particles (vp) to the patient or to the patient's cells.

B. Injectable Compositions and Formulations

[00195] One method for the delivery of a virus composition provided herein and/or the immune checkpoint inhibitor(s) to hyperproliferative cells in the present disclosure is via intratumoral injection. However, the pharmaceutical compositions disclosed herein may alternatively be administered parenterally, intravenously, intradermally, intramuscularly, transdermally or even intraperitoneally as described in U.S. Patent 5,543,158, U.S. Patent 5,641,515 and U.S. Patent 5,399,363, all incorporated herein by reference.

[00196] Injection of nucleic acid constructs may be delivered by syringe or any other method used for injection of a solution, as long as the expression construct can pass through the particular gauge of needle required for injection. A novel needleless injection system has been described (U.S. Patent 5,846,233) having a nozzle defining an ampule chamber for holding the solution and an energy device for pushing the solution out of the nozzle to the site of delivery. A syringe system has also been described for use in gene therapy that permits multiple injections of predetermined quantities of a solution precisely at any depth (U.S. Patent 5,846,225).

[00197] Solutions of the active compounds as free base or pharmacologically acceptable salts may be prepared in water suitably mixed with a surfactant, such as hydroxypropylcellulose. Dispersions may also be prepared in glycerol, liquid polyethylene glycols, and mixtures thereof and in oils. Under ordinary conditions of storage and use, these preparations contain a preservative to prevent the growth of microorganisms. The pharmaceutical forms suitable for injectable use include sterile aqueous solutions or dispersions and sterile powders for the extemporaneous preparation of sterile injectable solutions or dispersions (U.S. Patent 5,466,468). In all cases the form must be sterile and must be fluid to the extent that easy syringability exists. It must be stable under the conditions of manufacture and storage and must be preserved against the contaminating action of microorganisms, such as bacteria and fungi. The carrier can be a solvent or dispersion medium containing, for example, water, ethanol, polyol (*e.g.,* glycerol, propylene glycol, and liquid polyethylene glycol, and the like), suitable mixtures thereof, and/or vegetable oils. Proper fluidity may be maintained, for example, by the use of a coating, such as lecithin, by the maintenance of the required particle size in the case of dispersion and by the use of surfactants. The prevention of the action of microorganisms can be brought about by various antibacterial and antifungal agents, for example, parabens, chlorobutanol, phenol, sorbic acid, thimerosal, and the like. In

many cases, it will be preferable to include isotonic agents, for example, sugars or sodium chloride. Prolonged absorption of the injectable compositions can be brought about by the use in the compositions of agents delaying absorption, for example, aluminum monostearate and gelatin.

[00198] For parenteral administration in an aqueous solution, for example, the solution should be suitably buffered if necessary and the liquid diluent first rendered isotonic with sufficient saline or glucose. These particular aqueous solutions are especially suitable for intravenous, intramuscular, subcutaneous, intratumoral and intraperitoneal administration. In this connection, sterile aqueous media that can be employed will be known to those of skill in the art in light of the present disclosure. For example, one dosage may be dissolved in 1 ml of isotonic NaCl solution and either added to 1000 ml of hypodermoclysis fluid or injected at the proposed site of infusion, (see for example, "Remington's Pharmaceutical Sciences" 22md Edition). Some variation in dosage will necessarily occur depending on the condition of the subject being treated. The person responsible for administration will, in any event, determine the appropriate dose for the individual subject. Moreover, for human administration, preparations should meet sterility, pyrogenicity, general safety and purity standards as required by FDA Office of Biologics standards.

[00199] Sterile injectable solutions are prepared by incorporating the active compounds in the required amount in the appropriate solvent with various of the other ingredients enumerated above, as required, followed by filtered sterilization. Generally, dispersions are prepared by incorporating the various sterilized active ingredients into a sterile vehicle which contains the basic dispersion medium and the required other ingredients from those enumerated above. In the case of sterile powders for the preparation of sterile injectable solutions, the preferred methods of preparation are vaccuum-drying and freeze-drying techniques which yield a powder of the active ingredient plus any additional desired ingredient from a previously sterile-filtered solution thereof.

[00200] The compositions disclosed herein may be formulated in a neutral or salt form. Pharmaceutically-acceptable salts, include the acid addition salts (formed with the free amino groups of the protein) and which are formed with inorganic acids such as, for example, hydrochloric or phosphoric acids, or such organic acids as acetic, oxalic, tartaric, mandelic, and the like. Salts formed with the free carboxyl groups can also be derived from inorganic bases such as, for example, sodium, potassium, ammonium, calcium, or ferric hydroxides, and such

organic bases as isopropylamine, trimethylamine, histidine, procaine and the like. Upon formulation, solutions will be administered in a manner compatible with the dosage formulation and in such amount as is therapeutically effective. The formulations are easily administered in a variety of dosage forms such as injectable solutions, drug release capsules and the like.

C. Additional Anti-Cancer Therapies

[00201] In order to increase the effectiveness of the virus composition provided herein and, in some aspects, the at least one immune checkpoint inhibitor, they can be combined with at least one additional agent effective in the treatment of cancer. More generally, these other compositions would be provided in a combined amount effective to kill or inhibit proliferation of the cell. This process may involve contacting the cells with the virus composition and the agent(s) or multiple factor(s) at the same time. This may be achieved by contacting the cell with a single composition or pharmacological formulation that includes both agents, or by contacting the cell with two distinct compositions or formulations, at the same time, wherein one composition includes the virus composition and the other includes the second agent(s). Alternatively, the virus composition may contact the proliferating cell and the additional therapy may affect other cells of the immune system or the tumor microenvironment to enhance anti-tumor immune responses and therapeutic efficacy.

[00202] The at least one additional anticancer therapy may be, without limitation, a surgical therapy, chemotherapy (*e.g.,* administration of a protein kinase inhibitor or a EGFR-targeted therapy), radiation therapy, cryotherapy, hyperthermia treatment, phototherapy, radioablation therapy, hormonal therapy, immunotherapy, small molecule therapy, receptor kinase inhibitor therapy, anti-angiogenic therapy, cytokine therapy or a biological therapies such as monoclonal antibodies, siRNA, miRNA, antisense oligonucleotides, ribozymes or gene therapy. Without limitation the biological therapy may be a gene therapy, such as tumor suppressor gene therapy, a cell death protein gene therapy, a cell cycle regulator gene therapy, a cytokine gene therapy, a toxin gene therapy, an immunogene therapy, a suicide gene therapy, a prodrug gene therapy, an anti-cellular proliferation gene therapy, an enzyme gene therapy, or an anti-angiogenic factor gene therapy.

[00203] The gene therapy may precede or follow the other agent treatment by intervals ranging from minutes to weeks. In embodiments where the other agent and expression construct are applied separately to the cell, one would generally ensure that a significant period

of time did not expire between the time of each delivery, such that the agent and expression construct would still be able to exert an advantageously combined effect on the cell. In such instances, it is contemplated that one may contact the cell with both modalities within about 12-24 hours of each other and, more preferably, within about 6-12 hours of each other. In some situations, it may be desirable to extend the time period for treatment significantly, however, where several days (*e.g.*, 2, 3, 4, 5, 6 or 7) to several weeks (*e.g.*, 1, 2, 3, 4, 5, 6, 7 or 8) lapse between the respective administrations.

[00204] Various combinations may be employed, virus composition and, in some embodiments, an immune checkpoint inhibitor is "A" and the secondary agent, *i.e.* chemotherapy, is "B":

A/B/A B/A/B B/B/A A/A/B A/B/B B/A/A A/B/B/B B/A/B/B

B/B/B/A B/B/A/B A/A/B/B A/B/A/B A/B/B/A B/B/A/A

B/A/B/A B/A/A/B A/A/A/B B/A/A/A A/B/A/A A/A/B/A

1. Chemotherapy

[00205] Cancer therapies in general also include a variety of combination therapies with both chemical and radiation based treatments. Combination chemotherapies include, for example, cisplatin (CDDP), carboplatin, procarbazine, mechlorethamine, cyclophosphamide, camptothecin, ifosfamide, melphalan, chlorambucil, busulfan, nitrosurea, dactinomycin, daunorubicin, doxorubicin, bleomycin, plicomycin, mitomycin, etoposide (VP16), tamoxifen, raloxifene, estrogen receptor binding agents, taxol, gemcitabien, navelbine, famesyl-protein transferase inhibitors, transplatinum, 5-fluorouracil, vincristine, vinblastine and methotrexate, Temazolomide (an aqueous form of DTIC), or any analog or derivative variant of the foregoing. The combination of chemotherapy with biological therapy is known as biochemotherapy. The chemotherapy may also be administered at low, continuous doses which is known as metronomic chemotherapy.

[00206] Yet further combination chemotherapies include, for example, alkylating agents such as thiotepa and cyclosphosphamide; alkyl sulfonates such as busulfan, improsulfan and piposulfan; aziridines such as benzodopa, carboquone, meturedopa, and uredopa; ethylenimines and methylamelamines including altretamine, triethylenemelamine, trietylenephosphoramide, triethiylenethiophosphoramide and trimethylolomelamine; acetogenins (especially bullatacin and bullatacinone); a camptothecin (including the synthetic

analogue topotecan); bryostatin; callystatin; CC-1065 (including its adozelesin, carzelesin and bizelesin synthetic analogues); cryptophycins (particularly cryptophycin 1 and cryptophycin 8); dolastatin; duocarmycin (including the synthetic analogues, KW-2189 and CB1-TM1); eleutherobin; pancratistatin; a sarcodictyin; spongistatin; nitrogen mustards such as chlorambucil, chlornaphazine, cholophosphamide, estramustine, ifosfamide, mechlorethamine, mechlorethamine oxide hydrochloride, melphalan, novembichin, phenesterine, prednimustine, trofosfamide, uracil mustard; nitrosureas such as carmustine, chlorozotocin, fotemustine, lomustine, nimustine, and ranimnustine; antibiotics such as the enediyne antibiotics (*e.g.,* calicheamicin, especially calicheamicin gammaII and calicheamicin omegaI1; dynemicin, including dynemicin A; bisphosphonates, such as clodronate; an esperamicin; as well as neocarzinostatin chromophore and related chromoprotein enediyne antiobiotic chromophores, aclacinomysins, actinomycin, authrarnycin, azaserine, bleomycins, cactinomycin, carabicin, carminomycin, carzinophilin, chromomycinis, dactinomycin, daunorubicin, detorubicin, 6-diazo-5-oxo-L-norleucine, doxorubicin (including morpholino-doxorubicin, cyanomorpholino-doxorubicin, 2-pyrrolino-doxorubicin and deoxydoxorubicin), epirubicin, esorubicin, idarubicin, marcellomycin, mitomycins such as mitomycin C, mycophenolic acid, nogalarnycin, olivomycins, peplomycin, potfiromycin, puromycin, quelamycin, rodorubicin, streptonigrin, streptozocin, tubercidin, ubenimex, zinostatin, zorubicin; anti-metabolites such as methotrexate and 5-fluorouracil (5-FU); folic acid analogues such as denopterin, pteropterin, trimetrexate; purine analogs such as fludarabine, 6-mercaptopurine, thiamiprine, thioguanine; pyrimidine analogs such as ancitabine, azacitidine, 6-azauridine, carmofur, cytarabine, dideoxyuridine, doxifluridine, enocitabine, floxuridine; androgens such as calusterone, dromostanolone propionate, epitiostanol, mepitiostane, testolactone; anti-adrenals such as mitotane, trilostane; folic acid replenisher such as frolinic acid; aceglatone; aldophosphamide glycoside; aminolevulinic acid; eniluracil; amsacrine; bestrabucil; bisantrene; edatraxate; defofamine; demecolcine; diaziquone; elformithine; elliptinium acetate; an epothilone; etoglucid; gallium nitrate; hydroxyurea; lentinan; lonidainine; maytansinoids such as maytansine and ansamitocins; mitoguazone; mitoxantrone; mopidanmol; nitraerine; pentostatin; phenamet; pirarubicin; losoxantrone; podophyllinic acid; 2-ethylhydrazide; procarbazine; PSK polysaccharide complex; razoxane; rhizoxin; sizofiran; spirogermanium; tenuazonic acid; triaziquone; 2,2',2"-trichlorotriethylamine; trichothecenes (especially T-2 toxin, verracurin A, roridin A and anguidine); urethan; vindesine; dacarbazine; mannomustine; mitobronitol; mitolactol; pipobroman; gacytosine; arabinoside ("Ara-C"); cyclophosphamide; taxoids, *e.g.*, paclitaxel and docetaxel gemcitabine; 6-thioguanine;

mercaptopurine; platinum coordination complexes such as cisplatin, oxaliplatin and carboplatin; vinblastine; platinum; etoposide (VP-16); ifosfamide; mitoxantrone; vincristine; vinorelbine; novantrone; teniposide; edatrexate; daunomycin; aminopterin; xeloda; ibandronate; irinotecan (*e.g.*, CPT-11); topoisomerase inhibitor RFS 2000; difluorometlhylornithine (DMFO); retinoids such as retinoic acid; capecitabine; carboplatin, procarbazine, plicomycin, gemcitabien, navelbine, farnesyl-protein transferase inhibitors, transplatinum; and pharmaceutically acceptable salts, acids or derivatives of any of the above. In certain embodiments, the compositions provided herein may be used in combination with histone deacetylase inhibitors. In certain embodiments, the compositions provided herein may be used in combination with gefitinib. In other embodiments, the present embodiments may be practiced in combination with Gleevec (*e.g.*, from about 400 to about 800 mg/day of Gleevec may be administered to a patient). In certain embodiments, one or more chemotherapeutic may be used in combination with the compositions provided herein.

2. Radiotherapy

[00207] Other factors that cause DNA damage and have been used extensively include what are commonly known as y-rays, X-rays, and/or the directed delivery of radioisotopes to tumor cells. Other forms of DNA damaging factors are also known such as microwaves and UV-irradiation. It is most likely that all of these factors effect a broad range of damage on DNA, on the precursors of DNA, on the replication and repair of DNA, and on the assembly and maintenance of chromosomes. Dosage ranges for X-rays range from daily doses of 50 to 200 roentgens for prolonged periods of time (3 to 4 wk), to single doses of 2000 to 6000 roentgens. Dosage ranges for radioisotopes vary widely, and depend on the half-life of the isotope, the strength and type of radiation emitted, and the uptake by the neoplastic cells.

3. Immunotherapy

[00208] Immunotherapeutics, generally, rely on the use of immune effector cells and molecules to target and destroy cancer cells. The immune effector may be, for example, an antibody specific for some marker on the surface of a tumor cell. The antibody alone may serve as an effector of therapy or it may recruit other cells to actually effect cell killing. The antibody also may be conjugated to a drug or toxin (chemotherapeutic, radionuclide, ricin A chain, cholera toxin, pertussis toxin, etc.) and serve merely as a targeting agent. Alternatively, the effector may be a lymphocyte carrying a surface molecule that interacts, either directly or indirectly, with a tumor cell target. Various effector cells include cytotoxic T cells and NK

cells as well as genetically engineered variants of these cell types modified to express chimeric antigen receptors.

[00209] It will be appreciated by those skilled in the art of cancer immunotherapy that other complementary immune therapies may be added to the regimens described above to further enhance their efficacy including but not limited to GM-CSF to increase the number of myeloid derived innate immune system cells, low dose cyclophosphamide or PI3K inhibitors (e.g., PI3K delta inhibitors) to eliminate T regulatory cells that inhibit innate and adaptive immunity and 5FU (*e.g.,* capecitabine), PI3K inhibitors or histone deacetylase inhibitors to remove inhibitory myeloid derived suppressor cells. For example, PI3K inhibitors include, but are not limited to, LY294002, Perifosine, BKM120, Duvelisib, PX-866, BAY 80-6946, BEZ235, SF1126, GDC-0941, XL147, XL765, Palomid 529, GSK1059615, PWT33597, IC87114, TG100-15, CAL263, PI-103, GNE-477, CUDC-907, and AEZS-136. In some aspects, the PI3K inhibitor is a PI3K delta inhibitor such as, but not limited to, Idelalisib, RP6530, TGR1202, and RP6503. Additional PI3K inhibitors are disclosed in U.S. Patent Application Nos. US20150291595, US20110190319, and International Patent Application Nos. WO2012146667, WO2014164942, WO2012062748, and WO2015082376. The immunotherapy may also comprise the administration of an interleukin such as IL-2, or an interferon such as INFα.

[00210] Examples of immunotherapies that can be combined with the local/abscopal virus composition therapy and immune checkpoint inhibitor are immune adjuvants (e.g., Mycobacterium bovis, Plasmodium falciparum, dinitrochlorobenzene and aromatic compounds) (U.S. Patent 5,801,005 ; U.S. Patent 5,739,169 ; Hui and Hashimoto, 1998; Christodoulides et al., 1998), cytokine therapy (*e.g.*, interferons α, β and γ; interleukins (IL-1, IL-2), GM-CSF and TNF) (Bukowski et al., 1998; Davidson et al., 1998; Hellstrand et al., 1998) gene therapy (e.g., TNF, IL-1, IL-2, p53) (Qin et al., 1998; Austin-Ward and Villaseca, 1998; U.S. Patent 5,830,880 and U.S. Patent 5,846,945) and monoclonal antibodies (e.g., anti-ganglioside GM2, anti-HER-2, anti-p185) (Pietras et al., 1998; Hanibuchi et al., 1998; U.S. Patent 5,824,311). Herceptin (trastuzumab) is a chimeric (mouse-human) monoclonal antibody that blocks the HER2-neu receptor. It possesses anti-tumor activity and has been approved for use in the treatment of malignant tumors (Dillman, 1999). Combination therapy of cancer with herceptin and chemotherapy has been shown to be more effective than

the individual therapies. Thus, it is contemplated that one or more anti-cancer therapies may be employed with the Ad-mda7 therapy described herein.

[00211] Additional immunotherapies that may be combined with the local/abscopal virus composition therapy and immune checkpoint inhibitor include a co-stimulatory receptor agonist, a stimulator of innate immune cells, or an activator of innate immunity. The co-stimulatory receptor agonist may be an anti-OX40 antibody (*e.g.,* MEDI6469, MEDI6383, MEDI0562, and MOXR0916), anti-GITR antibody (*e.g.,* TRX518, and MK-4166), anti-CD137 antibody (*e.g.,* Urelumab, and PF-05082566), anti-CD40 antibody (*e.g.,* CP-870,893, and Chi Lob 7/4), or an anti-CD27 antibody (*e.g.,* Varlilumab, also known as CDX-1127). The stimulators of innate immune cells include, but are not limited to, a KIR monoclonal antibody (*e.g.,* lirilumab), an inhibitor of a cytotoxicity-inhibiting receptor (*e.g.,* NKG2A, also known as KLRC and as CD94, such as the monoclonal antibody monalizumab, and anti-CD96,also known as TACTILE), and a toll like receptor (TLR) agonist. The TLR agonist may be BCG, a TLR7 agonist (*e.g.,* poly0ICLC, and imiquimod), a TLR8 agonist (*e.g.,* resiquimod), or a TLR9 agonist (*e.g.,* CPG 7909). The activators of innate immune cells, such as natural killer (NK) cells, macrophages, and dendritic cells, include IDO inhibitors, TGFβ inhibitor, IL-10 inhibitor. An exemplary activator of innate immunity is Indoximod. In some aspects, the immunotherapy is a stimulator of interferon genes (STING) agonist (Corrales *et al.,* 2015).

[00212] Other immunotherapies contemplated for use in methods of the present disclosure include those described by Tchekmedyian *et al.,* 2015, incorporated herein by reference. The immunotherapy may comprise suppression of T regulatory cells (Tregs), myeloid derived suppressor cells (MDSCs) and cancer associated fibroblasts (CAFs). In some embodiments, the immunotherapy is a tumor vaccine (*e.g.,* whole tumor cell vaccines, peptides, and recombinant tumor associated antigen vaccines), or adoptive cellular therapies (ACT) (*e.g.,* T cells, natural killer cells, TILs, and LAK cells). The T cells may be engineered with chimeric antigen receptors (CARs) or T cell receptors (TCRs) to specific tumor antigens. As used herein, a chimeric antigen receptor (or CAR) may refer to any engineered receptor specific for an antigen of interest that, when expressed in a T cell, confers the specificity of the CAR onto the T cell. Once created using standard molecular techniques, a T cell expressing a chimeric antigen receptor may be introduced into a patient, as with a technique such as adoptive cell transfer. In some aspects, the T cells are activated CD4 and/or CD8 T cells in the individual

which are characterized by γ-IFN " producing CD4 and/or CD8 T cells and/or enhanced cytolytic activity relative to prior to the administration of the combination. The CD4 and/or CD8 T cells may exhibit increased release of cytokines selected from the group consisting of IFN- γ, TNF-αand interleukins. The CD4 and/or CD8 T cells can be effector memory T cells. In certain embodiments, the CD4 and/or CD8 effector memory T cells are characterized by having the expression of $CD44^{hlgh}$ $CD62L^{low}$.

[00213] In certain aspects, two or more immunotherapies may be combined with the local/abscopal virus composition therapy and immune checkpoint inhibitor including additional immune checkpoint inhibitors in combination with agonists of T-cell costimulatory receptors, or in combination with TIL ACT. Other combinations include T-cell checkpoint blockade plus costimulatory receptor agonists, T-cell checkpoint blockade to improve innate immune cell function, checkpoint blockade plus IDO inhibition, or checkpoint blockade plus adoptive T-cell transfer. In certain aspects, immunotherapy includes a combination of an anti-PD-L1 immune checkpoint inhibitor (*e.g.,* Avelumab), a 4-1BB (CD-137) agonist (*e.g.* Utomilumab), and an OX40 (TNFRS4) agonist. The immunotherapy may be combined with histone deacetylase (HDAC) inhibitors such as 5-azacytidine and entinostat.

[00214] The immunotherapy may be a cancer vaccine comprising one or more cancer antigens, in particular a protein or an immunogenic fragment thereof, DNA or RNA encoding said cancer antigen, in particular a protein or an immunogenic fragment thereof, cancer cell lysates, and/or protein preparations from tumor cells. As used herein, a cancer antigen is an antigenic substance present in cancer cells. In principle, any protein produced in a cancer cell that has an abnormal structure due to mutation can act as a cancer antigen. In principle, cancer antigens can be products of mutated Oncogenes and tumor suppressor genes, products of other mutated genes, overexpressed or aberrantly expressed cellular proteins, cancer antigens produced by oncogenic viruses, oncofetal antigens, altered cell surface glycolipids and glycoproteins, or cell type-specific differentiation antigens. Examples of cancer antigens include the abnormal products of ras and p53 genes. Other examples include tissue differentiation antigens, mutant protein antigens, oncogenic viral antigens, cancer-testis antigens and vascular or stromal specific antigens. Tissue differentiation antigens are those that are specific to a certain type of tissue. Mutant protein antigens are likely to be much more specific to cancer cells because normal cells shouldn't contain these proteins. Normal cells will display the normal protein antigen on their MHC molecules, whereas cancer cells will display

the mutant version. Some viral proteins are implicated in forming cancer, and some viral antigens are also cancer antigens. Cancer-testis antigens are antigens expressed primarily in the germ cells of the testes, but also in fetal ovaries and the trophoblast. Some cancer cells aberrantly express these proteins and therefore present these antigens, allowing attack by T-cells specific to these antigens. Exemplary antigens of this type are CTAG1 B and MAGEA1 as well as Rindopepimut, a 14-mer intradermal injectable peptide vaccine targeted against epidermal growth factor receptor (EGFR) vlll variant. Rindopepimut is particularly suitable for treating glioblastoma when used in combination with an inhibitor of the CD95/CD95L signaling system as described herein. Also, proteins that are normally produced in very low quantities, but whose production is dramatically increased in cancer cells, may trigger an immune response. An example of such a protein is the enzyme tyrosinase, which is required for melanin production. Normally tyrosinase is produced in minute quantities but its levels are very much elevated in melanoma cells. Oncofetal antigens are another important class of cancer antigens. Examples are alphafetoprotein (AFP) and carcinoembryonic antigen (CEA). These proteins are normally produced in the early stages of embryonic development and disappear by the time the immune system is fully developed. Thus self-tolerance does not develop against these antigens. Abnormal proteins are also produced by cells infected with oncoviruses, e.g. EBV and HPV. Cells infected by these viruses contain latent viral DNA which is transcribed and the resulting protein produces an immune response. A cancer vaccine may include a peptide cancer vaccine, which in some embodiments is a personalized peptide vaccine. In some embodiments, the peptide cancer vaccine is a multivalent long peptide vaccine, a multi -peptide vaccine, a peptide cocktail vaccine, a hybrid peptide vaccine, or a peptide-pulsed dendritic cell vaccine

[00215] The immunotherapy may be an antibody, such as part of a polyclonal antibody preparation, or may be a monoclonal antibody. The antibody may be a humanized antibody, a chimeric antibody, an antibody fragment, a bispecific antibody or a single chain antibody. An antibody as disclosed herein includes an antibody fragment, such as, but not limited to, Fab, Fab′ and F(ab′)2, Fd, single-chain Fvs (scFv), single-chain antibodies, disulfide-linked Fvs (sdfv) and fragments including either a VL or VH domain. In some aspects, the antibody or fragment thereof specifically binds epidermal growth factor receptor (EGFR1, Erb-B1), HER2/neu (Erb-B2), CD20, Vascular endothelial growth factor (VEGF), insulin-like growth factor receptor (IGF-1R), TRAIL-receptor, epithelial cell adhesion

molecule, carcino-embryonic antigen, Prostate-specific membrane antigen, Mucin-1, CD30, CD33, or CD40.

[00216] Examples of monoclonal antibodies that may be used in combination with the compositions provided herein include, without limitation, trastuzumab (anti-HER2/neu antibody); Pertuzumab (anti-HER2 mAb); cetuximab (chimeric monoclonal antibody to epidermal growth factor receptor EGFR); panitumumab (anti-EGFR antibody); nimotuzumab (anti-EGFR antibody); Zalutumumab (anti-EGFR mAb); Necitumumab (anti-EGFR mAb); MDX-210 (humanized anti-HER-2 bispecific antibody); MDX-210 (humanized anti-HER-2 bispecific antibody); MDX-447 (humanized anti-EGF receptor bispecific antibody); Rituximab (chimeric murine/human anti-CD20 mAb); Obinutuzumab (anti-CD20 mAb); Ofatumumab (anti-CD20 mAb); Tositumumab-I131 (anti-CD20 mAb); Ibritumomab tiuxetan (anti-CD20 mAb); Bevacizumab (anti-VEGF mAb); Ramucirumab (anti-VEGFR2 mAb); Ranibizumab (anti-VEGF mAb); Aflibercept (extracellular domains of VEGFR1 and VEGFR2 fused to IgG1 Fc); AMG386 (angiopoietin-1 and -2 binding peptide fused to IgG1 Fc); Dalotuzumab (anti-IGF-1R mAb); Gemtuzumab ozogamicin (anti-CD33 mAb); Alemtuzumab (anti-Campath-1/CD52 mAb); Brentuximab vedotin (anti-CD30 mAb); Catumaxomab (bispecific mAb that targets epithelial cell adhesion molecule and CD3); Naptumomab (anti-5T4 mAb); Girentuximab (anti-Carbonic anhydrase ix); or Farletuzumab (anti-folate receptor). Other examples include antibodies such as Panorex™ (17-1A) (murine monoclonal antibody); Panorex (@ (17-1A) (chimeric murine monoclonal antibody); BEC2 (ami-idiotypic mAb, mimics the GD epitope) (with BCG); Oncolym (Lym-1 monoclonal antibody); SMART M195 Ab, humanized 13′ 1 LYM-1 (Oncolym), Ovarex (B43.13, anti-idiotypic mouse mAb); 3622W94 mAb that binds to EGP40 (17-1A) pancarcinoma antigen on adenocarcinomas; Zenapax (SMART Anti-Tac (IL-2 receptor); SMART M195 Ab, humanized Ab, humanized); NovoMAb-G2 (pancarcinoma specific Ab); TNT (chimeric mAb to histone antigens); TNT (chimeric mAb to histone antigens); Gliomab-H (Monoclonals—Humanized Abs); GNI-250 Mab; EMD-72000 (chimeric-EGF antagonist); LymphoCide (humanized IL.L.2 antibody); and MDX-260 bispecific, targets GD-2, ANA Ab, SMART IDIO Ab, SMART ABL 364 Ab or ImmuRAIT-CEA. Examples of antibodies include those disclosed in U.S. Pat. No. 5,736,167, U.S. Pat. No. 7,060,808, and U.S. Pat. No. 5,821,337.

[00217] Further examples of antibodies include Zanulimumab (anti-CD4 mAb), Keliximab (anti-CD4 mAb); Ipilimumab (MDX-101; anti-CTLA-4 mAb); Tremilimumab

(anti-CTLA-4 mAb); (Daclizumab (anti-CD25/IL-2R mAb); Basiliximab (anti-CD25/IL-2R mAb); MDX-1106 (anti-PD1 mAb); antibody to GITR; GC1008 (anti-TGF-β antibody); metelimumab/CAT-192 (anti-TGF-β antibody); lerdelimumab/CAT-152 (anti-TGF-β antibody); ID11 (anti-TGF-β antibody); Denosumab (anti-RANKL mAb); BMS-663513 (humanized anti-4-1BB mAb); SGN-40 (humanized anti-CD40 mAb); CP870,893 (human anti-CD40 mAb); Infliximab (chimeric anti-TNF mAb; Adalimumab (human anti-TNF mAb); Certolizumab (humanized Fab anti-TNF); Golimumab (anti-TNF); Etanercept (Extracellular domain of TNFR fused to IgG1 Fc); Belatacept (Extracellular domain of CTLA-4 fused to Fc); Abatacept (Extracellular domain of CTLA-4 fused to Fc); Belimumab (anti-B Lymphocyte stimulator); Muromonab-CD3 (anti-CD3 mAb); Otelixizumab (anti-CD3 mAb); Teplizumab (anti-CD3 mAb); Tocilizumab (anti-IL6R mAb); REGN88 (anti-IL6R mAb); Ustekinumab (anti-IL-12/23 mAb); Briakinumab (anti-IL-12/23 mAb); Natalizumab (anti-α4 integrin); Vedolizumab (anti-α4 β7 integrin mAb); T1 h (anti-CD6 mAb); Epratuzumab (anti-CD22 mAb); Efalizumab (anti-CD11a mAb); and Atacicept (extracellular domain of transmembrane activator and calcium-modulating ligand interactor fused with Fc).

a. Passive Immunotherapy

[00218] A number of different approaches for passive immunotherapy of cancer exist. They may be broadly categorized into the following: injection of antibodies alone; injection of antibodies coupled to toxins or chemotherapeutic agents; injection of antibodies coupled to radioactive isotopes; injection of anti-idiotype antibodies; and finally, purging of tumor cells in bone marrow.

[00219] Preferably, human monoclonal antibodies are employed in passive immunotherapy, as they produce few or no side effects in the patient. Human monoclonal antibodies to ganglioside antigens have been administered intralesionally to patients suffering from cutaneous recurrent melanoma (Irie & Morton, 1986). Regression was observed in six out of ten patients, following, daily or weekly, intralesional injections. In another study, moderate success was achieved from intralesional injections of two human monoclonal antibodies (Irie et al., 1989).

[00220] It may be favorable to administer more than one monoclonal antibody directed against two different antigens or even antibodies with multiple antigen specificity. Treatment protocols also may include administration of lymphokines or other immune

enhancers as described by Bajorin et al. (1988). The development of human monoclonal antibodies is described in further detail elsewhere in the specification.

b. Active Immunotherapy

[00221] In active immunotherapy, an antigenic peptide, polypeptide or protein, or an autologous or allogenic tumor cell composition or "vaccine" is administered, generally with a distinct bacterial adjuvant (Ravindranath & Morton, 1991; Morton & Ravindranath, 1996; Morton et al., 1992; Mitchell et al., 1990; Mitchell et al., 1993). In melanoma immunotherapy, those patients who elicit high IgM response often survive better than those who elicit no or low IgM antibodies (Morton et al., 1992). IgM antibodies are often transient antibodies and the exception to the rule appears to be anti-ganglioside or anticarbohydrate antibodies.

c. Adoptive Immunotherapy

[00222] In adoptive immunotherapy, the patient's circulating lymphocytes, or tumor infiltrated lymphocytes, are isolated in vitro, activated by lymphokines such as IL-2 or transduced with genes for tumor necrosis, and readministered (Rosenberg et al., 1988; 1989). To achieve this, one would administer to an animal, or human patient, an immunologically effective amount of activated lymphocytes in combination with an adjuvant-incorporated antigenic peptide composition as described herein. The activated lymphocytes will most preferably be the patient's own cells that were earlier isolated from a blood or tumor sample and activated (or "expanded") in vitro. This form of immunotherapy has produced several cases of regression of melanoma and renal carcinoma, but the percentage of responders were few compared to those who did not respond. More recently, higher response rates have been observed when such adoptive immune cellular therapies have incorporated genetically engineered T cells that express chimeric antigen receptors (CAR) termed CAR T cell therapy. Similarly, natural killer cells both autologous and allogenic have been isolated, expanded and genetically modified to express receptors or ligands to facilitate their binding and killing of tumor cells.

4. Other Agents

[00223] It is contemplated that other agents may be used in combination with the compositions provided herein to improve the therapeutic efficacy of treatment. These additional agents include immunomodulatory agents, agents that affect the upregulation of cell

surface receptors and GAP junctions, cytostatic and differentiation agents, inhibitors of cell adhesion, or agents that increase the sensitivity of the hyperproliferative cells to apoptotic inducers. Immunomodulatory agents include tumor necrosis factor; interferon alpha, beta, and gamma; IL-2 and other cytokines; F42K and other cytokine analogs; or MIP-1, MIP-1beta, MCP-1, RANTES, and other chemokines. It is further contemplated that the upregulation of cell surface receptors or their ligands such as Fas / Fas ligand, DR4 or DR5 / TRAIL would potentiate the apoptotic inducing abilities of the compositions provided herein by establishment of an autocrine or paracrine effect on hyperproliferative cells. Increases intercellular signaling by elevating the number of GAP junctions would increase the anti-hyperproliferative effects on the neighboring hyperproliferative cell population. In other embodiments, cytostatic or differentiation agents can be used in combination with the compositions provided herein to improve the anti-hyerproliferative efficacy of the treatments. Inhibitors of cell adhesion are contemplated to improve the efficacy of the present invention. Examples of cell adhesion inhibitors are focal adhesion kinase (FAKs) inhibitors and Lovastatin. It is further contemplated that other agents that increase the sensitivity of a hyperproliferative cell to apoptosis, such as the antibody c225, could be used in combination with the compositions provided herein to improve the treatment efficacy.

[00224] In further embodiments, the other agents may be one or more oncolytic viruses, such as an oncolytic viruses engineered to express a gene other than p53 and/or IL24, such as a cytokine. Examples of oncolytic viruses include adenoviruses, adeno-associated viruses, retroviruses, lentiviruses, herpes viruses, pox viruses, vaccinia viruses, vesicular stomatitis viruses, polio viruses, Newcastle's Disease viruses, Epstein-Barr viruses, influenza viruses and reoviruses. In a particular embodiment, the other agent is talimogene laherparepvec (T-VEC) which is an oncolytic herpes simplex virus genetically engineered to express GM-CSF. Talimogene laherparepvec, HSV-1 [strain JS1] ICP34.5-/ICP47-/hGM-CSF, (previously known as OncoVEX$^{GM\ CSF}$), is an intratumorally delivered oncolytic immunotherapy comprising an immune-enhanced HSV-1 that selectively replicates in solid tumors. (Lui *et al.*, *Gene Therapy*, 10:292-303, 2003; U.S. Patent No. 7,223,593 and U.S. Patent No. 7,537,924; incorporated herein by reference). In October 2015, the US FDA approved T-VEC, under the brand name IMLYGIC™, for the treatment of melanoma in patients with inoperable tumors. The characteristics and methods of administration of T-VEC are described in, for example, the IMLYGIC™ package insert (Amgen, 2015) and U.S. Patent Publication No. US2015/0202290; both incorporated herein by reference. For example, talimogene laherparepvec is typically

administered by intratumoral injection into injectable cutaneous, subcutaneous, and nodal tumors at a dose of up to 4.0 ml of 10^6 plaque forming unit/mL (PFU/mL) at day 1 of week 1 followed by a dose of up to 4.0 ml of 10^8 PFU/mL at day 1 of week 4, and every 2 weeks (± 3 days) thereafter. The recommended volume of talimogene laherparepvec to be injected into the tumor(s) is dependent on the size of the tumor(s) and should be determined according to the injection volume guideline. While T-VEC has demonstrated clinical activity in melanoma patients, many cancer patients either do not respond or cease responding to T-VEC treatment. In one embodiment, the local/abscopal virus composition and the at least one immune checkpoint inhibitor may be administered after, during or before T-VEC therapy, such as to reverse treatment resistance. Exemplary oncolytic viruses include, but are not limited to, Ad5-yCD/mutTKSR39rep-hIL12, Cavatak™, CG0070, DNX-2401, G207, HF10, IMLYGIC™, JX-594, MG1-MA3, MV-NIS, OBP-301, Reolysin®, Toca 511, Oncorine, and RIGVIR. Other exemplary oncolytic viruses are described, for example, in International Patent Publication Nos. WO2015/027163, WO2014/138314, WO2014/047350, and WO2016/009017; all incorporated herein by reference.

[00225] In certain embodiments, hormonal therapy may also be used in conjunction with the present embodiments or in combination with any other cancer therapy previously described. The use of hormones may be employed in the treatment of certain cancers such as breast, prostate, ovarian, or cervical cancer to lower the level or block the effects of certain hormones such as testosterone or estrogen. This treatment is often used in combination with at least one other cancer therapy as a treatment option or to reduce the risk of metastases.

[00226] In some aspects, the at least one additional anticancer treatment is an inhibitor (*e.g.,* small molecule inhibitor) of HDM2 (also known as MDM2) and/or HDM4, such as to block p53 activity. In specific aspects, the small molecule inhibitor of HDM2 is HDM201, cis-imidazolines (*e.g.,* Nutlins), benzodiazepines (BDPs), and spiro-oxindoles. Other exemplary HDM2 and/or HDM4 inhibitors for use in the present methods are described in, for example, Carry *et al.,* 2013; Patel and Player, 2008; U.S. Patent No. 8,846,657; International Patent Publication No. WO2014123882; U.S. Patent No. 9,073,898; and International Patent Publication No. WO2014115080; all incorporated herein by reference.

[00227] In some aspects, the additional anti-cancer agent is a protein kinase inhibitor or a monoclonal antibody that inhibits receptors involved in protein kinase or growth

factor signaling pathways such as an EGFR, VEGFR, AKT, Erb1, Erb2, ErbB, Syk, Bcr-Abl, JAK, Src, GSK-3, PI3K, Ras, Raf, MAPK, MAPKK, mTOR, c-Kit, eph receptor or BRAF inhibitors. Nonlimiting examples of protein kinase or growth factor signaling pathways inhibitors include Afatinib, Axitinib, Bevacizumab, Bosutinib, Cetuximab, Crizotinib, Dasatinib, Erlotinib, Fostamatinib, Gefitinib, Imatinib, Lapatinib, Lenvatinib, Mubritinib, Nilotinib, Panitumumab, Pazopanib, Pegaptanib, Ranibizumab, Ruxolitinib, Saracatinib, Sorafenib, Sunitinib, Trastuzumab, Vandetanib, AP23451, Vemurafenib, MK-2206, GSK690693, A-443654, VQD-002, Miltefosine, Perifosine, CAL101, PX-866, LY294002, rapamycin, temsirolimus, everolimus, ridaforolimus, Alvocidib, Genistein, Selumetinib, AZD-6244, Vatalanib, P1446A-05, AG-024322, ZD1839, P276-00, GW572016 or a mixture thereof. In certain aspects, the additional anti-cancer agent is a tyrosine kinase inhibitor, such as a Bruton's tyrosine kinase (BTK) inhibitor. In some aspects, a small molecule BTK inhibitor as employed herein refers to a chemically synthesized molecule, generally with a molecular weight of 500 Daltons or less, which inhibits (*e.g.,* irreversibly) the BTK protein. Exemplary BTK inhibitors include ibrutinib, acalabrutinib (ACP-196), ONO-4059, spebrutinib (CC-292), HM-71224, CG-036806, GDC-0834, ONO-4049, RN-486, SNS-062, TAS-5567, AVL-101, AVL-291, PCI-45261, HCI-1684, PLS-123, and BGB-3111. Additional BTK inhibitors for use in the present methods are described, for example, in PCT Publication Nos. WO2014210255, WO2016087994, WO2013010380, WO2015061247, WO2013067274, and WO1999054286 and U.S. Patent No. 6,160,010; all incorporated herein by reference in their entirety.

[00228] In some aspects, the PI3K inhibitor is selected from the group of PI3K inhibitors consisting of buparlisib, idelalisib, BYL-719, dactolisib, PF-05212384, pictilisib, copanlisib, copanlisib dihydrochloride, ZSTK-474, GSK-2636771 , duvelisib, GS-9820, PF-04691502, SAR-245408, SAR-245409, sonolisib, Archexin, GDC-0032, GDC-0980, apitolisib, pilaralisib, DLBS 1425, PX-866, voxtalisib, AZD-8186, BGT-226, DS-7423, GDC-0084, GSK-21 26458, INK-1 1 17, SAR-260301 , SF-1 1 26, AMG-319, BAY-1082439, CH-51 32799, GSK-2269557, P-71 70, PWT-33597, CAL-263, RG-7603, LY-3023414, RP-5264, RV-1729, taselisib, TGR-1 202, GSK-418, INCB-040093, Panulisib, GSK-105961 5, CNX-1351 , AMG-51 1 , PQR-309, 17beta-Hydroxywortmannin, AEZS-129, AEZS-136, HM-5016699, IPI-443, ONC-201 , PF-4989216, RP-6503, SF-2626, X-339, XL- 499, PQR-401 , AEZS-132, CZC-24832, KAR-4141 , PQR-31 1 , PQR-316, RP- 5090, VS-5584, X-480, AEZS-126, AS-604850, BAG-956, CAL-130, CZC- 24758, ETP-46321 , ETP-471 87, GNE-317, GS-548202, HM-032, KAR-1 139, LY-294002, PF-04979064, PI-620, PKI-402, PWT-

143, RP-6530, 3-HOI-BA-01 , AEZS-134, AS-041 164, AS-252424, AS-605240, AS-605858, AS- 606839, BCCA-621 C, CAY-10505, CH-5033855, CH-51 08134, CUDC-908, CZC-1 9945, D-106669, D-87503, DPT-NX7, ETP-46444, ETP-46992, GE-21 , GNE-123, GNE-151 , GNE-293, GNE-380, GNE-390, GNE-477, GNE-490, GNE- 493, GNE-614, HMPL-51 8, HS-104, HS-1 06, HS-1 16, HS-173, HS-196, IC- 486068, INK-055, KAR 1 141 , KY-1 2420, Wortmannin, Lin-05, NPT-520-34, PF- 04691503, PF-06465603, PGNX-01 , PGNX-02, PI 620, PI-103, PI-509, PI-516, PI-540, PIK-75, PWT-458, RO-2492, RP-5152, RP-5237, SB-201 5, SB-2312, SB-2343, SHBM-1009, SN 32976, SR-13179, SRX-2523, SRX-2558, SRX-2626, SRX-3636, SRX-5000, TGR-5237, TGX-221 , UCB-5857, WAY-266175, WAY-266176, EI-201 , AEZS-131 , AQX-MN100, KCC-TGX, OXY-1 1 1 A, PI-708, PX-2000, and WJD-008.

[00229] It is contemplated that the additional cancer therapy can comprise an antibody, peptide, polypeptide, small molecule inhibitor, siRNA, miRNA or gene therapy which targets, for example, epidermal growth factor receptor (EGFR, EGFR1, ErbB-1, HER1), ErbB-2 (HER2/neu), ErbB-3/HER3, ErbB-4/HER4, EGFR ligand family; insulin-like growth factor receptor (IGFR) family, IGF-binding proteins (IGFBPs), IGFR ligand family (IGF-1R); platelet derived growth factor receptor (PDGFR) family, PDGFR ligand family; fibroblast growth factor receptor (FGFR) family, FGFR ligand family, vascular endothelial growth factor receptor (VEGFR) family, VEGF family; HGF receptor family: TRK receptor family; ephrin (EPH) receptor family; AXL receptor family; leukocyte tyrosine kinase (LTK) receptor family; TIE receptor family, angiopoietin 1, 2; receptor tyrosine kinase-like orphan receptor (ROR) receptor family; discoidin domain receptor (DDR) family; RET receptor family; KLG receptor family; RYK receptor family; MuSK receptor family; Transforming growth factor alpha (TGF-α), TGF-α receptor; Transforming growth factor-beta (TGF-β), TGF-β receptor; Interleukin 13 receptor alpha2 chain (1L13Ralpha2), Interleukin-6 (IL-6), 1L-6 receptor, Interleukin-4, IL-4 receptor, Cytokine receptors, Class I (hematopoietin family) and Class II (interferon/1L-10 family) receptors, tumor necrosis factor (TNF) family, TNF-α, tumor necrosis factor (TNF) receptor superfamily (TNTRSF), death receptor family, TRAIL-receptor; cancer-testis (CT) antigens, lineage-specific antigens, differentiation antigens, alpha-actinin-4, ARTC1, breakpoint cluster region-Abelson (Bcr-abl) fusion products, B-RAF, caspase-5 (CASP-5), caspase-8 (CASP-8), beta-catenin (CTNNB1), cell division cycle 27 (CDC27), cyclin-dependent kinase 4 (CDK4), CDKN2A, COA-1, dek-can fusion protein, EFTUD-2, Elongation factor 2 (ELF2), Ets variant gene 6/acute myeloid leukemia 1 gene ETS (ETC6-AML1) fusion

protein, fibronectin (FN), GPNMB, low density lipid receptor/GDP-L fucose: beta-Dgalactose 2-alpha-Lfucosyltraosferase (LDLR/FUT) fusion protein, HLA-A2, arginine to isoleucine exchange at residue 170 of the alpha-helix of the alpha2-domain in the HLA-A2 gene (HLA-A*201-R170I), MLA-A11, heat shock protein 70-2 mutated (HSP70-2M), KIAA0205, MART2, melanoma ubiquitous mutated 1, 2, 3 (MUM-1, 2, 3), prostatic acid phosphatase (PAP), neo-PAP, Myosin class 1, NFYC, OGT, OS-9, pml-RARalpha fusion protein, PRDX5, PTPRK, K-ras (KRAS2), N-ras (NRAS), HRAS, RBAF600, SIRT2, SNRPD1, SYT-SSX1 or -SSX2 fusion protein, Triosephosphate Isomerase, BAGE, BAGE-1, BAGE-2,3,4,5, GAGE-1,2,3,4,5,6,7,8, GnT-V (aberrant N-acetyl giucosaminyl transferase V, MGAT5), HERV-K-MEL, KK-LC, KM-HN-1, LAGE, LAGE-1, CTL-recognixed antigen on melanoma (CAMEL), MAGE-A1 (MAGE-1), MAGE-A2, MAGE-A3, MAGE-A4, MAGE-AS, MAGE-A6, MAGE-A8, MAGE-A9, MAGE-A10, MAGE-A11, MAGE-A12, MAGE-3, MAGE-B1, MAGE-B2, MAGE-B5, MAGE-B6, MAGE-C1, MAGE-C2, mucin 1 (MUC1), MART-1/Melan-A (MLANA), gp100, gp100/Pme117 (S1LV), tyrosinase (TYR), TRP-1, HAGE, NA-88, NY-ESO-1, NY-ESO-1/LAGE-2, SAGE, Sp17, SSX-1,2,3,4, TRP2-1NT2, carcino-embryonic antigen (CEA), Kallikfein 4, mammaglobm-A, OA1, prostate specific antigen (PSA), prostate specific membrane antigen, TRP-1/gp75, TRP-2, adipophilin, interferon inducible protein absent in nielanorna 2 (AIM-2), BING-4, CPSF, cyclin D1, epithelial cell adhesion molecule (Ep-CAM), EpbA3, fibroblast growth factor-5 (FGF-5), glycoprotein 250 (gp250intestinal carboxyl esterase (iCE), alpha-feto protein (AFP), M-CSF, mdm-2, MUCI, p53 (TP53), PBF, FRAME, PSMA, RAGE-1, RNF43, RU2AS, SOX10, STEAP1, survivin (BIRCS), human telomerase reverse transcriptase (hTERT), telomerase, Wilms' tumor gene (WT1), SYCP1, BRDT, SPANX, XAGE, ADAM2, PAGE-5, LIP1, CTAGE-1, CSAGE, MMA1, CAGE, BORIS, HOM-TES-85, AF15q14, HCA66I, LDHC, MORC, SGY-1, SPO11, TPX1, NY-SAR-35, FTHLI7, NXF2 TDRD1, TEX 15, FATE, TPTE, immunoglobulin idiotypes, Bence-Jones protein, estrogen receptors (ER), androgen receptors (AR), CD40, CD30, CD20, CD19, CD33, CD4, CD25, CD3, cancer antigen 72-4 (CA 72-4), cancer antigen 15-3 (CA 15-3), cancer antigen 27-29 (CA 27-29), cancer antigen 125 (CA 125), cancer antigen 19-9 (CA 19-9), beta-human chorionic gonadotropin, 1-2 microglobulin, squamous cell carcinoma antigen, neuron-specific enoJase, heat shock protein gp96, GM2, sargramostim, CTLA-4, 707 alanine proline (707-AP), adenocarcinoma antigen recognized by T cells 4 (ART-4), carcinoembryogenic antigen peptide-1 (CAP-1), calcium-activated chloride channel-2 (CLCA2), cyclophilin B (Cyp-B), human signet ring tumor-2 (HST-2), Human papilloma virus (HPV) proteins (HPV-E6, HPV-E7, major or minor capsid antigens, others), Epstein-Barr

vims (EBV) proteins (EBV latent membrane proteins—LMP1, LMP2; others), Hepatitis B or C virus proteins, and HIV proteins.

VI. Articles of Manufacture or Kits

[00230] An article of manufacture or a kit is provided comprising a virus composition and, in some embodiments, at least one immune checkpoint inhibitor (*e.g.,* anti-PD-1 antibody and/or anti-CTlA-4 antibody) is also provided herein. The article of manufacture or kit can further comprise a package insert comprising instructions for using the at least one checkpoint inhibitor in conjunction with the virus composition to treat or delay progression of cancer in an individual or to enhance immune function of an individual having cancer. Any of the immune checkpoint inhibitor and virus compositions described herein may be included in the article of manufacture or kits.

[00231] In some embodiments, the at least one immune checkpoint inhibitor (*e.g.,* anti-PD-1 antibody and/or anti-CTLA-4 antibody) and the virus composition are in the same container or separate containers. Suitable containers include, for example, bottles, vials, bags and syringes. The container may be formed from a variety of materials such as glass, plastic (such as polyvinyl chloride or polyolefin), or metal alloy (such as stainless steel or hastelloy). In some embodiments, the container holds the formulation and the label on, or associated with, the container may indicate directions for use. The article of manufacture or kit may further include other materials desirable from a commercial and user standpoint, including other buffers, diluents, filters, needles, syringes, and package inserts with instructions for use. In some embodiments, the article of manufacture further includes one or more of another agent (*e.g.,* a chemotherapeutic agent, and anti-neoplastic agent). Suitable containers for the one or more agent include, for example, bottles, vials, bags and syringes.

VII. Examples

[00232] The following examples are included to demonstrate preferred embodiments of the invention. It should be appreciated by those of skill in the art that the techniques disclosed in the examples which follow represent techniques discovered by the inventor to function well in the practice of the invention, and thus can be considered to constitute preferred modes for its practice. However, those of skill in the art should, in light of the present disclosure, appreciate that many changes can be made in the specific embodiments

which are disclosed and still obtain a like or similar result without departing from the spirit and scope of the invention.

Example 1 –Relaxin Viral Therapy in Combination with Immune Checkpoint Inhibitor Treatment for Induction of Local and Abscopal Effects and Reversal of Resistance to Prior Immunotherapy

[00233] The efficacy of Relaxin Viral Therapy for the induction of local and abscopal effects for tumors resistant to prior immunotherapy was demonstrated in immunocompetent animal tumor models. The following treatment methods, doses, and schedules were utilized:

[00234] Animals, tumor inoculation and measurements: C57BL/6 (B6) mice (6-8 weeks of age) were utilized. Animals were injected into the right flank, subcutaneously, with B16F10 melanoma cells (ATCC, 5 x 10^5 cells/mouse) to form the "Primary Tumor". Primary local tumor treatment was begun when tumors had reached approximately 50 mm^3 in size and this was termed treatment Day 1. Abscopal treatment effects were determined by evaluating the growth of subsequently implanted contralateral tumors that did not receive virus treatment injections. Tumor growth was monitored by measuring the length (L) and width (w) of the tumor, and tumor volume calculated using the following formula: volume = $0.523L(w)^2$. Animals were monitored for up to 60 days, and sacrificed when tumors reached approximately 2000 mm^3.

[00235] Viral vectors: The relaxin-expressing virus used was as described by Kim *et al.,* 2006. Briefly, a relaxin-expressing, replication-competent (Ad-ΔE1B-RLX) adenovirus is generated by inserting a relaxin gene into the E3 adenoviral region. Four doses of the viral vectors were administered intra-tumorally at 48 hour intervals. Each viral dose contained 5 x 10^{10} viral particles in a volume of 50 µl.

[00236] Immune Checkpoint Inhibitors: To mimic the common clinical condition of tumor progression during immune checkpoint inhibitor therapy, anti-PD1 treatment, at a dose of 10 mg/kg, was begun intraperitoneally on Day 1 and administered every 3 days up to day 31. In some experiments, to evaluate the effects of tumor suppressor therapy in tumors resistant to prior immunotherapy, tumor suppressor treatment was initiated after tumor progression on anti-PD-1 therapy with the first tumor suppressor therapy dose being given 2 to 3 days after the initiation of anti-PD-1 treatment. In other experiments, tumor

suppressor therapy was initiated concurrently with immune checkpoint inhibitors as initial treatment. These studies were performed in tumors known to be highly resistant to immune checkpoint inhibitor therapy. The B16F10 melanoma model is known to be highly resistant to immunotherapy. In these models, tumors progress on immune checkpoint inhibitor therapy similarly to control treatment with Phosphate Buffered Saline (PBS). The anti-mouse PD-1 antibody (CD279) specifically produced for use *in vivo* was purchased from BioXcell (catalog # BE0146) as were antibodies to anti-PD-L1 and the immune modulator anti-LAG-3. Surprisingly, loco-regional relaxin viral treatment reversed resistance to systemic immune checkpoint inhibitor therapy, demonstrated unexpected synergy with immune checkpoint inhibitor treatment and the combined therapies induced superior abscopal effects on distant tumors that were not treated with viral therapy. These unexpected treatment effects were found to be enhanced when combined with surgery, radiation, chemotherapy, cytokine therapy and agents known to modulate myeloid derived suppressor cells (MDSC), T-Regs and dendritic cells.

[00237] Ad-Relaxin plus checkpoint inhibitors in tumors progressing on prior immunotherapy: Treatment efficacy of Ad-Relaxin in combination with anti-PD-1 was evaluated by tumor volume (in primary and contralateral tumors), and survival. With regards to primary tumor volume (FIG. 1), there was severe tumor progression in animals treated with anti-PD-1 monotherapy with little difference from the growth observed in the PBS treated controls. In contrast, reversal of anti-PD-1 resistance was observed when the animals were treated with the combination therapy (Ad-Relaxin + anti-PD-1). By day 8, the combined treatment with Ad-Relaxin + anti-PD-1 induced a large decrease in tumor volume, as compared to either anti-PD-1 or Ad-Relaxin therapy alone. T test statistical analysis determined the anti-tumor effects of Ad-Relaxin + anti-PD1 were significant compared to Ad-Relaxin alone (p-value 0.0254) or anti-PD-1 alone (p-value 0.0231). The increased efficacy of combined Ad-Relaxin and anti-PD-1 was more than additive compared to the modest effects of Ad-Relaxin and anti-PD-1 therapy alone which were not statistically different from treatment with the PBS control.

[00238] The abscopal efficacy Ad-Relaxin + anti-PD-1 is shown in FIG. 2 where the contralateral tumor volume over time was assessed in rodents whose primary tumor had received either Ad-Relaxin or a combination of Ad-Relaxin + anti-PD-1 treatment. A statistically significant abscopal effect by T test with decreased tumor growth compared to the

growth rate of primary tumors treated with anti-PD-1 alone was also observed in the contralateral (secondary) tumors that did not receive viral therapy injections. These findings indicate that the viral treatment (Ad-Relaxin alone and Ad-Relaxin + anti-PD1) induced abscopal effects. Contralateral tumors in animals whose primary tumor had been treated with Ad-Relaxin alone showed significantly delayed tumor growth (p=0.0273) compared to the growth rate of primary tumors treated with anti-PD-1 alone. Consistent with the synergistic effect observed in the suppression of primary tumor growth, an even greater abscopal effect on contralateral tumor growth (p=0.0009) was observed in mice whose primary tumors were treated with combined Ad-Relaxin+anti-PD-1.

[00239] Increased survival efficacy for combined Ad-Relaxin + anti-PD1 therapy is shown in FIG. 3 which depicts Kaplan-Meier survival curves for mice treated with either PBS, anti-PD-1, Ad-Relaxin or a combination of Ad-Relaxin+Anti-PD-1. There was a statistically significant increase in survival by the log rank test in mice whose primary tumors were treated with combined Ad-Relaxin+anti-PD-1 compared to treatment with anti-PD-1 alone (p=0.0010). The increase in median survival for the combined Ad-Relaxin+anti-PD-1 group was more than additive of the separate effects observed for Ad-Relaxin alone and anti-PD-1 alone. There was no statistically significant increase in survival for mice treated with Ad-Relaxin alone compared to anti-PD-1 alone. The more than additive Ad-Relaxin+anti-PD-1 increased survival findings are consistent with the synergistic effect observed in the suppression of primary tumor growth and the greater abscopal effect on contralateral tumor growth for the combined Ad-Relaxin+anti-PD-1 therapy and reflect unexpected synergistic effects of the combined treatment.

[00240] It is important to point out that the contralateral tumors were not injected with any therapeutic agents. Taken together, these results demonstrate that combining loco-regional treatment with the specified virus combined with immune checkpoint inhibitor therapy reversed resistance to systemic immune checkpoint inhibitors, demonstrated unexpected synergy with immune checkpoint inhibitor treatment and the combined therapies induced superior abscopal effects on distant tumors that were not treated with viral therapy.

Example 2 – VRX-007 (an adenovirus engineered to overexpress ADP) in Combination with Immune Checkpoint Inhibitor Treatment for Reversal of Resistance to Immunotherapy

[00241] The efficacy of immune checkpoint inhibitor treatment in combination with adenoviral death protein (ADP) gene therapy was evaluated in an immunocompetent animal tumor model. VRX-007 is an adenovirus engineered to overexpress the ADP gene. The following treatment methods, doses, and schedules were utilized:

[00242] Animals, tumor inoculation and measurements: The ADS immunocompetent tumor model (Zhang et al 2015) was utilized for these studies. To assess and compare the effects of VRX-007 and VRX-007 + anti-PD-L1 treatment in large, well established tumors, animals in the VRX-007 treated groups had tumors greater than 100 mm^3 in size. Four treatment groups were compared including PBS vehicle control (N=10), anti-PD-L1 immune checkpoint inhibitor (N=10), VRX-007 (N=4) or VRX-007 + anti-PD-L1 (N=4). VRX-007 gene therapy was given intratumorally at a dose of 10^9 plaque forming units (pfu) daily for a total of 3 administrations. Animals in the groups treated with anti-PD-L1 received 200 µg, injected intraperitoneally (i.p.) every three days. The anti-mouse PD-L1 antibody (CD274) was purchased from BioXcell (catalog # BE0101).

[00243] Treatment efficacy was evaluated by comparing the percentage change in tumor volume 15 days following the initiation of therapy (or at the time of animal sacrifice) relative to baseline values (FIG. 4). Owing to the small number of animals in the VRX-007 treatment groups, a Kruskal–Wallis one-way analysis of variance (one-way ANOVA on ranks) was used and demonstrated a statistically significant difference between the treatment groups (p-value = 0.0258). The statistically significant anti-tumor effect of combined VRX-007 + anti-PD-L1 therapy (p = 0.0047) was unexpected and surprisingly synergistic as neither VRX-007 (p = 0.1232) nor anti-PD-L1 (p=0.5866) separately were statistically different from treatment with the vehicle control (FIG 4). The increased efficacy of combined VRX-007 and anti-PD-L1 was more than additive and the combined treatment was also statistically superior to anti-PD-L1 therapy alone (p=0.0157). Furthermore, T test statistical analysis revealed the anti-tumor effects of VRX-007 + anti-PD1 were significant compared to VRX-007 alone (one sided p-value 0.0356). Hence, the efficacy and synergy of combined VRX-007 + anti-PD-L1 therapy was unexpected as neither treatment demonstrated statistically significant efficacy alone.

[00244] Based upon the findings in the above Example 1 and Example 2, clinical applications of virus composition therapies are applied as initial cancer treatment or they are administered following the development of resistance to other therapies including immunotherapies such as TVEC or immune checkpoint inhibitor therapies, or cytokine or interleukin or adoptive cellular therapies or radiation or chemotherapy or small molecule therapies.

[00245] Summary: The animal studies described in the Examples use highly aggressive models of cancer, known to be resistant to checkpoint inhibitor therapy. Surprisingly, loco-regional administration of the virus composition treatment reversed resistance to systemic immune checkpoint inhibitor therapy, demonstrated unexpected synergy with immune checkpoint inhibitor treatment and the combined therapies induced superior abscopal effects on distant tumors that were not treated with the virus composition therapy. These unexpected systemic treatment effects are found to be enhanced when combined with additional therapies including radiation, surgery, chemotherapy, cytokine therapy, targeted therapies and agents known to modulate myeloid derived suppressor cells (MDSC) (5FU), T-Regs (CTX) and dendritic cells (anti-PD-1 and anti-LAG-3).

[00246] All the methods disclosed and claimed herein can be made and executed without undue experimentation considering the present disclosure. While the compositions and methods of this invention have been described in terms of preferred embodiments, it will be apparent to those of skill in the art that variations may be applied to the methods and in the steps or in the sequence of steps of the method described herein without departing from the concept, spirit and scope of the invention. More specifically, it will be apparent that certain agents which are both chemically and physiologically related may be substituted for the agents described herein while the same or similar results would be achieved. All such similar substitutes and modifications apparent to those skilled in the art are deemed to be within the spirit, scope and concept of the invention as defined by the appended claims.

* * *

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CLAIMS

What Is Claimed Is:

1. A method of treating cancer in a subject comprising administering to the subject an effective amount of:

(a) one or more viruses engineered to comprise an N1L gene deletion, a matrix-degrading protein gene, an adenoviral death protein (ADP) gene, and/or a cytochrome p450 gene; and

(b) at least one immune checkpoint inhibitor.

2. A method of treating cancer in a subject comprising administering to the subject an effective amount of two or more viruses engineered to comprise an N1L gene deletion, a matrix-degrading protein gene, an adenoviral death protein (ADP) gene, and/or a cytochrome p450 gene.

3. A method of treating or preventing cancer or an infectious disease in a subject comprising administering to the subject effective amounts of:

(a) a vaccinia virus that expresses at least one tumor associated or pathogen associated antigen, said virus comprising an N1L gene deletion; and

(b) at least a second virus that expresses at least one tumor associated or pathogen associated antigen.

4. The method of claim 3, wherein the tumor associated antigen is mesothelin, melanoma-associated gene (MAGE), carcinoembryonic antigen (CEA), mutated Ras, or mutated p53.

5. The method of claim 3, wherein the pathogen associated antigen is an antigen expressed by an infectious viral, bacterial, fungal, prion, or parasitic organism.

6. The method of claim 3, wherein the at least one tumor associated or pathogen associated antigen expressed by the vaccinia virus and the at least one tumor associated or pathogen associated antigen expressed by the second virus are the same.

7. The method of claim 3, wherein the at least one tumor associated or pathogen associated antigen expressed by the vaccinia virus and the at least one tumor associated or pathogen associated antigen expressed by the second virus are different.

8. The method of claim 1 or claim 2, wherein the viruses induce local and/or abscopal effects.

9. The method of claim 2 or claim 3, further comprising administering at least one immune checkpoint inhibitor.

10. The method of claim 1 or claim 2 or claim 3, wherein two, three, or four viruses are administered.

11. The method of claim 1 or claim 2, wherein the viruses comprise an adenovirus, retrovirus, vaccinia virus, adeno-associated virus, herpes virus, vesicular stomatitis virus, and/or stomatitis virus.

12. The method of claim 1 or claim 2, wherein the viruses comprise one or more adenoviruses.

13. The method of claim 3, wherein the second virus that expresses at least one tumor associated or pathogen associated antigen is an adenovirus, retrovirus, vaccinia virus, adeno-associated virus, herpes virus, vesicular stomatitis virus, and/or stomatitis virus.

14. The method of claim 13, wherein the second virus that expresses at least one tumor associated or pathogen associated antigen is an adenovirus.

15. The method of claim 14, wherein the adenovirus is administered prior to administration of the N1L-deleted vaccinia virus that expresses at least one tumor associated or pathogen associated antigen.

16. The method of claim 1 or claim 2, wherein the adenoviral death protein gene is overexpressed.

17. The method of claim 1 or claim 2, wherein the matrix-degrading protein gene is relaxin, hyaluronidase, or decorin.

18. The method of claim 1 or claim 2, wherein the matrix-degrading protein gene is relaxin.

19. The method of claim 1 or claim 2, wherein the cytochrome p450 gene is the cytochrome p450 2B1 gene.

20. The method of claim 19, wherein the cytochrome p450 2B1 gene is rat cytochrome p450 2B1 gene.

21. The method of claim 1 or claim 2, wherein the virus engineered to comprise the N1L deletion is a vaccinia virus.

22. The method of claim 1 or claim 2, wherein the virus engineered to comprise the cytochrome p450 gene is a herpes simplex virus.

23. The method of claim 16, wherein the viruses engineered to comprise the matrix-degrading protein and/or adenoviral death protein gene are adenoviruses.

24. The method of claim 1 or claim 2 or claim 3, wherein the viruses are further engineered to express a therapeutic nucleic acid.

25. The method of claim 24, wherein the therapeutic nucleic acid encodes p53 and/or IL-24.

26. The method of claim 1 or claim 2, further comprising restoring or enhancing p53 and/or IL-24 function.

27. The method of claim 1 or claim 9, wherein the at least one checkpoint inhibitor is selected from an inhibitor of CTLA-4, PD-1, PD-L1, PD-L2, LAG-3, BTLA, B7H3, B7H4, TIM3, KIR, or A2aR.

28. The method of claim 1 or claim 9, wherein the at least one immune checkpoint inhibitor is a human programmed cell death 1 (PD-1) axis binding antagonist.

29. The method of claim 28, wherein the PD-1 axis binding antagonist is selected from the group consisting of a PD-1 binding antagonist, a PDL1 binding antagonist and a PDL2 binding antagonist.

30. The method of claim 28, wherein the PD-1 axis binding antagonist is a PD-1 binding antagonist.

31. The method of claim 29, wherein the PD-1 binding antagonist inhibits the binding of PD-1 to PDL1 and/or PDL2.

32. The method of claim 29, wherein the PD-1 binding antagonist is a monoclonal antibody or antigen binding fragment thereof.

33. The method of claim 29, wherein the PD-1 binding antagonist is nivolumab, pembrolizumab, pidillizumab, AMP-514, REGN2810, CT-011, BMS 936559, MPDL328OA or AMP-224.

34. The method of claim 1 or claim 9, wherein the at least one immune checkpoint inhibitor is an anti-CTLA-4 antibody.

35. The method of claim 34, wherein the anti-CTLA-4 antibody is tremelimumab or ipilimumab.

36. The method of claim 1 or claim 9, wherein the at least one immune checkpoint inhibitor is an anti-killer-cell immunoglobulin-like receptor (KIR) antibody.

37. The method of claim 36, wherein the anti-KIR antibody is lirilumab.

38. The method of claim 1 or claim 9, wherein more than one checkpoint inhibitor is administered.

39. The method of claim 1 or claim 9, wherein the immune checkpoint inhibitor is administered systemically.

40. The method of claim 1 or claim 2 or claim 3, wherein the viruses are replication competent or oncolytic.

41. The method of claim 1 or claim 2 or claim 3, wherein the viruses are replication incompetent.

42. The method of claim 1 or claim 2 or claim 3, wherein the viruses comprise a combination of replication competent and replication incompetent viruses.

43. The method of claim 1 or claim 9, wherein the viruses and/or the at least one checkpoint inhibitor are administered intratumorally, intraarterially, intravenously, intravascularly, intrapleuraly, intraperitoneally, intratracheally, intrathecally, intramuscularly, endoscopically,

intralesionally, percutaneously, subcutaneously, regionally, stereotactically, or by direct injection or perfusion.

44. The method of claim 1 or claim 2, wherein the viruses are administered intratumorally.

45. The method of claim 3, wherein the viruses are administered intradermally, subcutaneously, intramuscularly, intra-peritoneally, orally, by inhalation, or by other forms of mucosal exposure.

46. The method of claim 1 or claim 2, wherein the cancer is melanoma, non-small cell lung, small-cell lung, lung, hepatocarcinoma, retinoblastoma, astrocytoma, glioblastoma, leukemia, neuroblastoma, head, neck, breast, pancreatic, prostate, renal, bone, testicular, ovarian, mesothelioma, cervical, gastrointestinal, urogenital, respiratory tract, hematopoietic, musculoskeletal, neuroendocrine, carcinoma, sarcoma, central nervous system, peripheral nervous system, lymphoma, brain, colon or bladder cancer.

47. The method of claim 1 or claim 2, wherein the cancer is metastatic.

48. The method of claim 1 or claim 9, wherein the viruses and/or the at least one immune checkpoint inhibitor induce abscopal effects.

49. The method of claim 1 or claim 9, wherein the subject is administered the viruses and/or the at least one immune checkpoint inhibitor more than once.

50. The method of claim 1 or claim 9, wherein the subject is administered the viruses before, simultaneously, or after the at least one immune checkpoint inhibitor.

51. The method of claim 1 or claim 2, wherein administering comprises a local or regional injection.

52. The method of claim 1 or claim 2, wherein administering is via continuous infusion, intratumoral injection, intravenous injection, intra-arterial injection, intra-peritoneal injection, intrapleural injection, or intra-thecal injection.

53. The method of claim 1 or claim 2, wherein the subject is a human.

54. The method of claim 3, wherein the subject is a healthy subject.

55. The method of claim 3, wherein the subject comprises a pre-malignant lesion.

56. The method of claim 55, wherein the pre-malignant lesion is a leukoplakia or a dysplastic lesion.

57. The method of claim 3, wherein the subject is at risk of developing cancer.

58. The method of claim 57, wherein the subject is a smoker.

59. The method of claim 57, wherein the subject has a family history of cancer.

60. The method of claim 3, further comprising administering an effective amount of an immune adjuvant.

61. The method of claim 1 or claim 2 or claim 3, further comprising administering at least one additional anticancer treatment.

62. The method of claim 61, wherein the at least one additional anticancer treatment is surgical therapy, chemotherapy, radiation therapy, hormonal therapy, immunotherapy, small molecule therapy, receptor kinase inhibitor therapy, anti-angiogenic therapy, cytokine therapy, cryotherapy or a biological therapy.

63. The method of claim 62, wherein the biological therapy is a monoclonal antibody, siRNA, miRNA, antisense oligonucleotide, ribozyme or gene therapy.

64. The method of claim 61, wherein the at least one additional anticancer treatment is a protein kinase inhibitor.

65. The method of claim 64, wherein the protein kinase inhibitor is a tyrosine kinase inhibitor.

66. The method of claim 65, wherein the tyrosine kinase inhibitor is further defined as a Bruton's tyrosine kinase (BTK) inhibitor.

67. The method of claim 66, wherein the BTK inhibitor is selected from the group consisting of ibrutinib, acalabrutinib (ACP-196), ONO-4059, spebrutinib (CC-292), HM-71224, CG-036806, GDC-0834, ONO-4049, RN-486, SNS-062, TAS-5567, AVL-101, AVL-291, PCI-45261, HCI-1684, PLS-123, and BGB-3111.

68. The method of claim 61, wherein the at least one additional anticancer treatment is an inhibitor of HDM2 and/or HDM4.

69. The method of claim 68, wherein the inhibitor of HDM2 is HDM201.

70. The method of claim 61, wherein the at least one additional anticancer treatment is a replication competent or replication incompetent virus.

71. The method of claim 70, wherein the replication competent or replication incompetent virus is an adenovirus, adeno-associated virus, retrovirus, lentivirus, herpes virus, pox virus, vaccinia virus, vesicular stomatitis virus, polio virus, Newcastle's Disease virus, Epstein-Barr virus, influenza virus or reovirus.

72. The method of claim 70, wherein the replication competent or replication incompetent virus is engineered to express a therapeutic nucleic acid.

73. The method of claim 72, wherein the therapeutic nucleic acid encodes p53 and/or IL-24.

74. The method of claim 70, wherein the replication competent or replication incompetent virus is herpes simplex virus.

75. The method of claim 70, wherein the replication competent or replication incompetent virus is engineered to express a cytokine.

76. The method of claim 75, wherein the cytokine is granulocyte-macrophage colony-stimulating factor (GM-CSF).

77. The method of claim 70, wherein the replication competent or replication incompetent virus is further defined as talimogene laherparepvec (T-VEC).

78. The method of claim 61, wherein the at least one additional anticancer treatment is a protein kinase or growth factor signaling pathways inhibitor.

79. The method of claim 78, wherein the protein kinase or growth factor signaling pathways inhibitor is Afatinib, Axitinib, Bevacizumab, Bosutinib, Cetuximab, Crizotinib, Dasatinib, Erlotinib, Fostamatinib, Gefitinib, Imatinib, Lapatinib, Lenvatinib, Mubritinib, Nilotinib, Panitumumab, Pazopanib, Pegaptanib, Ranibizumab, Ruxolitinib, Saracatinib, Sorafenib, Sunitinib, Trastuzumab, Vandetanib, AP23451, Vemurafenib, CAL101, PX-866, LY294002, rapamycin, temsirolimus, everolimus, ridaforolimus, Alvocidib, Genistein, Selumetinib, AZD-6244, Vatalanib, P1446A-05, AG-024322, ZD1839, P276-00 or GW572016.

80. The method of claim 78, wherein the protein kinase inhibitor is a PI3K inhibitor.

81. The method of claim 80, wherein the PI3K inhibitor is a PI3K delta inhibitor.

82. The method of claim 62, wherein the immunotherapy comprises a cytokine.

83. The method of claim 82, wherein the cytokine is granulocyte macrophage colony-stimulating factor (GM-CSF).

84. The method of claim 82, wherein the cytokine is an interleukin and/or an interferon.

85. The method of claim 84, wherein the interleukin is IL-2.

86. The method of claim 84, wherein the interferon is IFNα.

87. The method of claim 62, wherein the immunotherapy comprises a co-stimulatory receptor agonist, a stimulator of innate immune cells, or an activator of innate immunity.

88. The method of claim 87, wherein the co-stimulatory receptor agonist is an anti-OX40 antibody, anti-GITR antibody, anti-CD137 antibody, anti-CD40 antibody, or an anti-CD27 antibody.

89. The method of claim 87, wherein the stimulator of immune cells is an inhibitor of a cytotoxicity-inhibiting receptor or an agonist of immune stimulating toll like receptors (TLR).

90. The method of claim 89, wherein the cytotoxicity-inhibiting receptor is an inhibitor of NKG2A/CD94 or CD96 TACTILE.

91. The method of claim 89, wherein the TLR agonist is a TLR7 agonist, TLR8 agonist, or TLR9 agonist.

92. The method of claim 62, wherein the immunotherapy comprises a combination of a PD-L1 inhibitor, a 4-1BB agonist, and an OX40 agonist.

93. The method of claim 62, wherein the immunotherapy comprises a stimulator of interferon genes (STING) agonist.

94. The method of claim 87, wherein the activator of innate immunity is an IDO inhibitor, TGFβ inhibitor, or IL-10 inhibitor.

95. The method of claim 62, wherein the chemotherapy comprises a DNA damaging agent.

96. The method of claim 94, wherein the DNA damaging agent is gamma- irradiation, X-rays, UV-irradiation, microwaves, electronic emissions, adriamycin, 5-fluorouracil (5FU), capecitabine, etoposide (VP-16), camptothecin, actinomycin-D, mitomycin C, cisplatin (CDDP), or hydrogen peroxide.

97. The method of claim 94, wherein the DNA damaging agent is 5FU or capecitabine.

98. The method of claim 62, wherein the chemotherapy comprises a cisplatin (CDDP), carboplatin, procarbazine, mechlorethamine, cyclophosphamide, camptothecin, ifosfamide, melphalan, chlorambucil, bisulfan, nitrosurea, dactinomycin, daunorubicin, doxombicin, bleomycin, plicomycin, mitomycin, etoposide (VP16), tamoxifen, taxotere, taxol, transplatinum, 5-fluorouracil, vincristine, vinblastine, methotrexate, or any analog or derivative variant thereof.

99. A pharmaceutical composition comprising (a) one or more viruses engineered to comprise an N1L gene deletion, a matrix-degrading protein gene, an adenoviral death protein (ADP) gene, and/or a cytochrome p450 gene; and (b) at least one immune checkpoint inhibitor.

100. The composition of claim 99, wherein the one or more viruses are selected from the group consisting of a virus engineered to express relaxin, a virus engineered to overexpress the adenoviral death protein (ADP) gene, a vaccinia virus engineered to delete the N1L gene, and a herpes simplex virus engineered to express the rat cytochrome p450 2B1 gene.

101. A pharmaceutical composition comprising two or more viruses engineered to comprise an N1L gene deletion, a matrix-degrading protein gene, an adenoviral death protein (ADP) gene, and/or a cytochrome p450 gene.

102. The composition of claim 101, wherein the two or more viruses are selected from the group consisting of a virus engineered to express relaxin, a virus engineered to overexpress the adenoviral death protein (ADP) gene, a vaccinia virus engineered to delete the N1L gene, and a herpes simplex virus engineered to express the rat cytochrome p450 2B1 gene.

103. The composition of claim 99 or claim 101, wherein the viruses comprise an adenovirus, retrovirus, vaccinia virus, adeno-associated virus, herpes virus, vesicular stomatitis virus, and/or stomatitis virus.

104. The composition of claim 99 or claim 101, wherein the viruses comprise one or more adenoviruses.

105. The composition of claim 99 or claim 101, wherein the adenoviral death protein is overexpressed.

106. The composition of claim 99 or claim 101, wherein the matrix-degrading protein is relaxin, hyaluronidase, or decorin.

107. The composition of claim 99 or claim 101, wherein the matrix-degrading protein is relaxin.

108. The composition of claim 99 or claim 101, wherein the cytochrome p450 gene is the cytochrome p450 2B1 gene.

109. The composition of claim 108, wherein the cytochrome p450 2B1 gene is rat cytochrome p450 2B1 gene.

110. The composition of claim 99 or claim 101, wherein the virus engineered to comprise the N1L deletion is a vaccinia virus.

111. The composition of claim 99 or claim 101, wherein the virus engineered to comprise the cytochrome p450 gene is a herpes simplex virus.

112. The composition of claim 105, wherein the viruses engineered to comprise the matrix-degrading protein and/or adenoviral death protein are adenoviruses.

113. A pharmaceutical composition comprising (a) a vaccinia virus that expresses at least one tumor associated or pathogen associated antigen and an N1L gene deletion; and (b) at least a second virus that expresses at least one tumor associated or pathogen associated antigen.

114. The composition of claim 113, wherein the tumor associated antigen is mesothelin, melanoma-associated gene (MAGE), carcinoembryonic antigen (CEA), mutated Ras, or mutated p53.

115. The composition of claim 113, wherein the pathogen associated antigen is an antigen expressed by an infectious viral, bacterial, fungal, prion, or parasitic organism.

116. The composition of claim 113, wherein the second virus that expresses at least one tumor associated or pathogen associated antigen is an adenovirus.

117. The composition of claim 113, wherein the at least one tumor associated or pathogen associated antigen expressed by the vaccinia virus and the at least one tumor associated or pathogen associated antigen expressed by the second virus are the same.

118. The composition of claim 113, wherein the at least one tumor associated or pathogen associated antigen expressed by the vaccinia virus and the at least one tumor associated or pathogen associated antigen expressed by the second virus are different.

119. The composition of claim 113, further comprising an immune adjuvant.

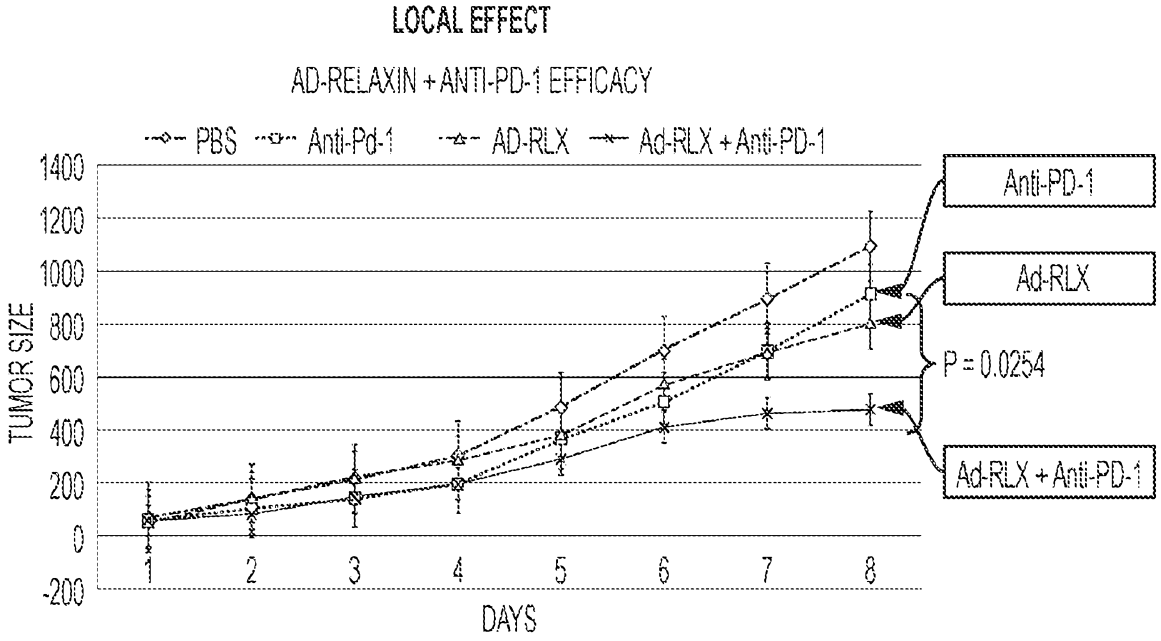
LOCAL EFFECT
AD-RELAXIN + ANTI-PD-1 EFFICACY
PBS
Anti-Pd-1
AD-RLX
Ad-RLX + Anti-PD-1
TUMOR SIZE
1400
1200
1000
800
600
400
200
0
-200
1
2
3
4
5
6
7
8
DAYS
Anti-PD-1
Ad-RLX
P = 0.0254
Ad-RLX + Anti-PD-1

FIG. 1

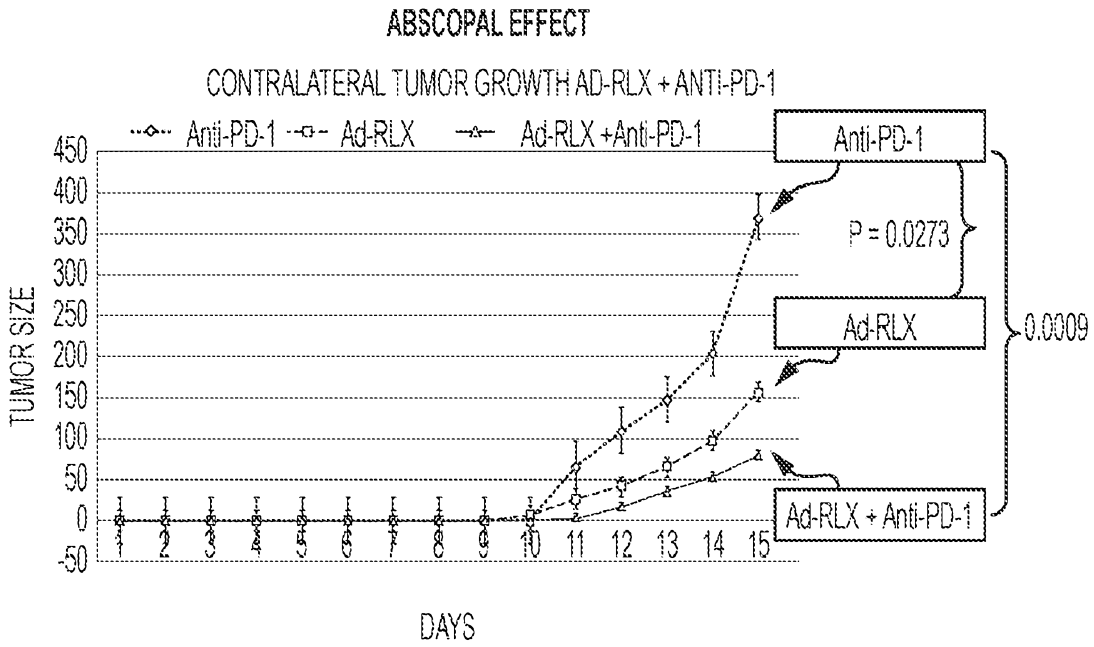
ABSCOPAL EFFECT
CONTRALATERAL TUMOR GROWTH AD-RLX + ANTI-PD-1
Anti-PD-1
Ad-RLX
Ad-RLX + Anti-PD-1
TUMOR SIZE
450
400
350
300
250
200
150
100
50
0
-50
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
DAYS
Anti-PD-1
P = 0.0273
Ad-RLX
0.0009
Ad-RLX + Anti-PD-1

FIG. 2

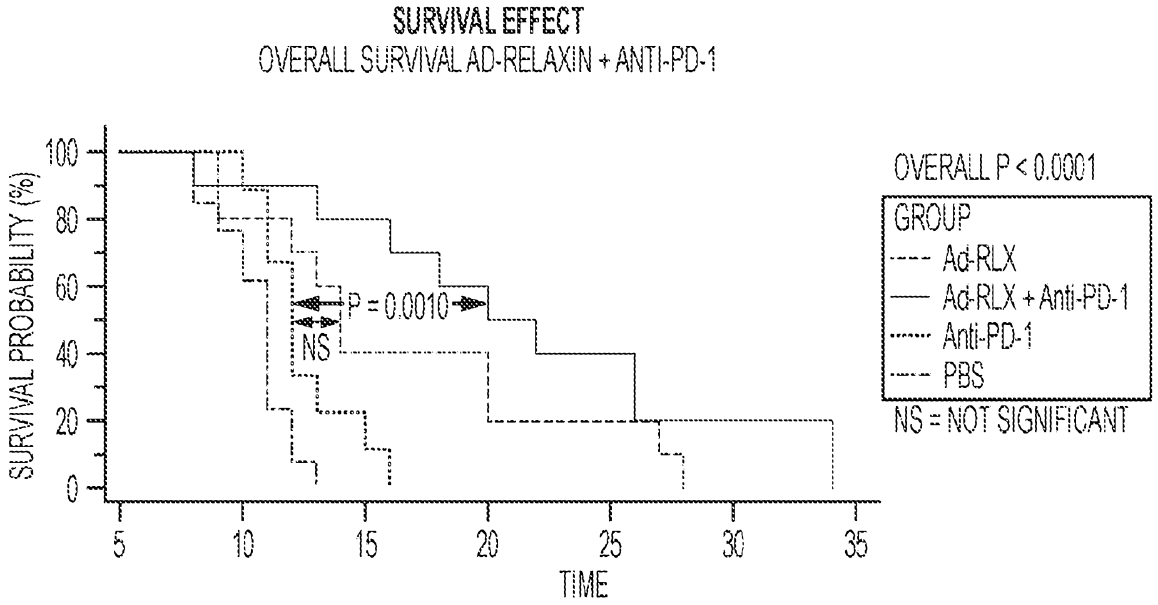
SURVIVAL EFFECT
OVERALL SURVIVAL AD-RELAXIN + ANTI-PD-1
SURVIVAL PROBABILITY (%)
100
80
60
40
20
0
5
10
15
20
25
30
35
TIME
P = 0.0010
NS
OVERALL P < 0.0001
GROUP
Ad-RLX
Ad-RLX + Anti-PD-1
Anti-PD-1
PBS
NS = NOT SIGNIFICANT

FIG. 3

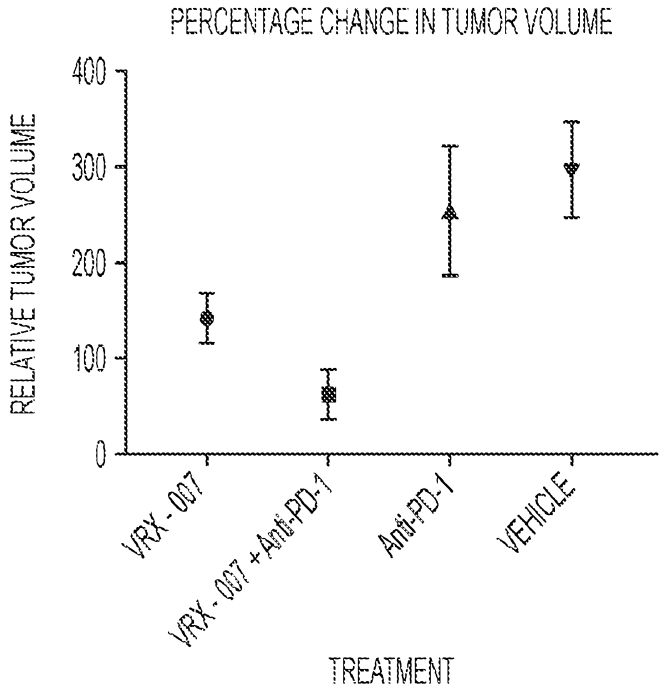
PERCENTAGE CHANGE IN TUMOR VOLUME
RELATIVE TUMOR VOLUME
400
300
200
100
0
VRX - 007
VRX - 007 + Anti-PD-1
Anti-PD-1
VEHICLE
TREATMENT

FIG. 4