COMPOSITIONS AND METHODS FOR TREATING GLIOBLASTOMA GBM

FIELD AND BACKGROUND OF THE INVENTION

The present invention, in some embodiments thereof, relates to compositions and methods for treating malignant gliomas and, more particularly, but not exclusively, for treating Glioblastoma multiforme (GBM).

Malignant gliomas, the most common adult-onset neurological neoplasms, encompass a family of primary central nervous system tumors including glioblastoma, astrocytoma, oligodendroglioma, and ependymoma, along with the juvenile onset neoplasms such as juvenile pilocystic astrocytoma.

Malignant gliomas are typically characterized by over-expression of growth factors/tumor associated antigens believed to significantly contribute to the unchecked growth of such tumors. Various malignant gliomas, such as glioblastomas, exhibit epidermal growth factor receptor (EGFR) overexpression leading to increased aggressivenes and poor prognosis. Malignant gliomas may also display over-expression of platelet-derived growth factor receptor, a phenomenon which has also been correlated with increased malignancy and poor prognosis.

Malignant gliomas, the most common type of primary brain tumors, are aggressive, highly invasive, and neurologically destructive tumors which are among the deadliest of all human cancers. Of the estimated 17,000 new brain tumors diagnosed each year in the United States, about half are malignant gliomas. Malignant glioma cells produce very invasive brain tumors with infiltration of both white and gray matter. At the time of diagnosis, microscopic extension through much of the neural axis by malignant glioma is the rule. Such extension by motile invading cells underlies the incurability by surgery of most gliomas, even when they appear small and restricted in nature.

Glioblastoma multiforme (GBM), the most serious form of malignant glioma, are extremely aggressive brain tumors which generally arise in the upper brain (cerebrum), but which may also occur elsewhere in the central nervous system, such as in the spinal cord, cerebellum, brain stem, or optic chiasm. Low-grade gliomas, which include astrocytomas, oligodendrogliomas, and pilocytic astrocytomas, account for 25 % of all primary brain tumors, and over time most of these low-grade tumors

dedifferentiate into more malignant gliomas. Diffuse astrocytomas are predominantly located in the cerebral hemispheres of adults and have an inherent tendency to progress to anaplastic astrocytoma and (secondary) glioblastoma. The majority of glioblastomas develop de novo (primary glioblastomas), without an identifiable less-malignant precursor lesion.

Despite optimal therapy with surgery, radiotherapy, and temozolomide chemotherapy, the median survival of patients with glioblastomas is only 12–15 months. When these tumors recur, conventional salvage therapies produce minimal benefit, with only 8–15 % of patients alive and free from progression at 6 months (6M-PFS).

Neovascularization is a major feature of glioblastomas (Maher et al., 2001, Genes Dev. 15:1311–1333). Angiogenesis activators are extremely important in tumor growth, as reflected by the fact that neovascularization must occur for solid tumors to grow beyond a diameter of 2–3 mm (Goldbrunner et al., 2000, J. Neurooncol. 50:53–62). One of the molecules that regulates this process is the vascular endothelial growth factor (VEGF). VEGF mRNA is overexpressed in the highly vascularized glioblastoma multiform (Maher et al., 2001, Genes Dev. 15:1311–1333). It has been demonstrated that the transfection of antisense-VEGF–complementary-DNA as well VEGF antisense RNA encoding vectors result in down-regulation of the endogenous VEGF and inhibits growth of gliomas in mice (Sasaki et al., 1999, Int. J. Dev. Neurosci. 17:579–591; Zheng et al., 2000, Acta Pharmacol. Sin. 21:211–214). A similar effect was observed upon the local delivery of the angiogenesis inhibitor endostatin (Read et al., 2001, Nat. Biotechnol. 19:29–34). However, this strategy has a cytostatic effect. It is effective in inhibiting tumor growth but not in actually eliminating them.

Bevacizumab (Avastin®) is a humanized monoclonal antibody that binds VEGF, preventing it from activating its receptors, especially VEGFR2, abrogating subsequent biologic effects. This drug has shown benefit in colorectal, non-small cell lung, and breast cancers, and is approved by the Food and Drug Administration for these indications. Several studies have now evaluated the combination of bevacizumab and the chemotherapeutic agent irinotecan in recurrent malignant gliomas and the results have been more encouraging.

In one phase II study, the combination of bevacizumab and irinotecan produced a response rate of 67 % and 6M-PFS of 56 % in recurrent anaplastic gliomas, and a response rate of 57 % and a 6M-PFS of 46 % in recurrent glioblastomas.

These preliminary findings have been recently confirmed by a large multi-center randomized phase II study of 167 patients with recurrent GBM who were treated with bevacizumab alone or in combination with irinotecan [Cloughesy T, Prados M, Wen P, et al. Society for Neuro-Oncology 12th Annual Meeting, 2007].

Patients receiving bevacizumab alone had a response rate of 20 % and a 6M-PFS of 35.1 %, while patients receiving the combination of bevacizumab in combination with irinotecan had a response rate of 34 % and 6M-PFS of 51 %.The median survival was 9.7 months for bevacizumab (Avastin) alone, and 8.7 months for the combination. In addition, treatment with bevacizumab was also associated with a significant reduction in peritumoral edema and the need for corticosteroids. As a result of these studies, the combination of bevacizumab with irinotecan is increasingly used for the treatment of patients with recurrent malignant gliomas.

Another agent proposed for the treatment of malignant gliomas is Aflibercept (VEGF-Trap). This is a soluble hybrid receptor, composed of portions of VEGFR-1 and VEGFR-2 fused to an immunoglobulin G1 Fc domain. Like bevacizumab, it is designed to deplete circulating VEGF, but has significantly greater affinity for VEGF than bevacizumab itself.

In addition, inhibitors of VEGF receptors have been proposed for the treatment of malignant gliomas. In a phase II trial study of a potent pan-VEGFR inhibitor, cediranib (AZD2171; Recentin) in patients with recurrent glioblastomas, response rates in excess of 50 % were observed and the 6M-PFS was increased to approximately 25 %. Studies with other inhibitors of VEGFR such as sorafenib (Nexavar), sunitinib (Sutent), vandetanib (ZD6474; Zactima), pazopanib (GW786034), and vatalanib (PTK787) in glioblastomas are also in progress.

In comparison with drugs targeting VEGF or VEGFR, agents inhibiting other angiogenic pathways have produced less success. Drugs that inhibit PDGF receptors such as imatinib mesylate (Gleevec) were ineffective, due partly to its poor penetration across the blood-brain barrier. Cilengitide, a drug that inhibits $\alpha v\beta 3$ and $\alpha v\beta 5$ integrins

has shown modest activity in glioblastomas and studies combining it with other agents are in progress.

The use of viral vectors as gene delivery agents has been proposed for the treatment of malignant gliomas. Such viruses may be engineered to produce anticancer activity by expressing transgenes whose products exert a tumoricidal effect.

Several of such approaches have shown anti-tumor efficiency in experimental studies, and the first clinical trials for the treatment of malignant glioma were conducted in the 1990s. HSV-tk gene therapy has been the pioneering and most commonly used approach, but oncolytic conditionally replicating adenoviruses and herpes simplex virus mutant vectors, p53, interleukins, interferons, and antisense oligonucleotides have also been used.

United States Patent 5,747,340 teaches use of a murine endothelial cell-specific promoter which shows selectivity towards angiogenic cells.

International Application WO/2008/132729 teaches viral vectors comprising endothelial cell specific promoters which directs expression of a transgene in angiogenic cells for the treatment of cancer.

SUMMARY OF THE INVENTION

According to an aspect of some embodiments of the present invention there is provided a use of a viral vector for preparation of a medicament for the treatment of a malignant glioma, the nucleic acid construct comprising:

(i) a first polynucleotide sequence encoding a Fas-chimera (Fas-c), the first polynucleotide sequence comprising SEQ ID NOs: 2 and 3; and

(ii) a second polynucleotide sequence encoding an endothelial cell-specific promoter or a periendothelial cell-specific promoter.

According to an aspect of some embodiments of the present invention there is provided a use of a viral vector for the treatment of a malignant glioma, the nucleic acid construct comprising:

(i) a first polynucleotide sequence encoding a Fas-chimera (Fas-c), the first polynucleotide sequence comprising SEQ ID NOs: 2 and 3; and

(ii) a second polynucleotide sequence encoding an endothelial cell-specific promoter or a periendothelial cell-specific promoter.

According to an aspect of some embodiments of the present invention there is provided a method of treating a malignant glioma in a subject in need therof, the method comprising administering to the subject a therapeutically effective amount of a viral vector comprising:

(i) a first polynucleotide sequence encoding a Fas-chimera (Fas-c), the first polynucleotide sequence comprising SEQ ID NOs: 2 and 3; and

(ii) a second polynucleotide sequence encoding an endothelial cell-specific promoter or a periendothelial cell-specific promoter, thereby treating the malignant glioma.

According to some embodiments of the present invention the promoter is set forth in SEQ ID NO: 12.

According to some embodiments of the present invention the promoter is set forth in SEQ ID NO: 13.

According to some embodiments of the present invention the viral vector is an adenoviral vector.

According to some embodiments of the present invention the adenoviral vector is a non- replicating adenoviral vector.

According to some embodiments of the present invention the promoter comprises at least one copy of a sequence set forth in SEQ ID NO: 6.

According to some embodiments of the present invention the promoter comprises at least two copies of a sequence set forth in SEQ ID NO: 6.

According to some embodiments of the present invention the promoter comprises a sequence as set forth in SEQ ID NO: 7.

According to some embodiments of the present invention the promoter comprises a sequence as set forth in SEQ ID NO: 8.

According to some embodiments of the present invention the promoter comprises a hypoxia response element (HRE) as set forth in SEQ ID NO: 5.

According to some embodiments of the present invention the the viral vector consists of a sequence as set forth in SEQ ID NO: 9 or SEQ ID NO: 10.

According to some embodiments of the present invention the malignant glioma is selected from the group consisting of glioblastoma, astrocytoma, oligodendroglioma, and ependymoma, and juvenile pilocystic astrocytoma.

According to some embodiments of the present invention the therapeutically effective amount of the nucleic acid construct is about 10^3 to about 10^{16} virus particles.

According to some embodiments of the present invention the therapeutically effective amount of the nucleic acid construct is about 10^5 to about 10^{13} virus particles.

According to some embodiments of the present invention the therapeutically effective amount of the nucleic acid construct is about 10^7 to about 10^{12} virus particles.

According to some embodiments of the present invention the therapeutically effective amount of the nucleic acid construct is about $1x10^{12}$ to about $5\ x10^{12}$ virus particles.

According to some embodiments of the present invention the therapeutically effective amount of the nucleic acid construct is about $1x10^{13}$ to about $5\ x10^{13}$ virus particles.

According to some embodiments of the present invention the administering comprises intravenous administration.

According to some embodiments of the present invention the administering comprises local administration.

According to some embodiments of the present invention the administering is in at least two, or at least three or more doses of said viral vector.

Unless otherwise defined, all technical and/or scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention pertains. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of embodiments of the invention, exemplary methods and/or materials are described below. In case of conflict, the patent specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and are not intended to be necessarily limiting.

BRIEF DESCRIPTION OF THE DRAWINGS

Some embodiments of the invention are herein described, by way of example only, with reference to the accompanying drawings and images. With specific reference now to the drawings and images in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of embodiments of the

invention. In this regard, the description taken with the drawings makes apparent to those skilled in the art how embodiments of the invention may be practiced.

In the drawings:

FIG. 1 is a time chart illustrating an exemplary treatment schedule to measure the in-vivo effects of VB-111 in nude rats pre-inoculated with U87 tumor cells.

FIG. 2 is a graph illustrating the effect of VB-111 on survival of rats pre-inoculated with U87 tumor cells.

FIG. 3 is a graph illustrating the effect of VB-111 on tumor size (as measured by luciferase activity) of rats pre-inoculated with U87 tumor cells.

FIG. 4 is a graph illustrating the effect of VB-111 on tumor size (as measured by MRI) of rats pre-inoculated with U87 tumor cells.

FIGs. 5A-F are photographs of brain slices illustrating the effect of VB-111 on tumor size (as measured by MRI) of rats pre-inoculated with U87 tumor cells.

DESCRIPTION OF SPECIFIC EMBODIMENTS OF THE INVENTION

The present invention, in some embodiments thereof, relates to compositions and methods for treating malignant gliomas and, more particularly, but not exclusively, for treating Glioblastoma multiforme (GBM).

Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not necessarily limited in its application to the details set forth in the following description or exemplified by the Examples. The invention is capable of other embodiments or of being practiced or carried out in various ways.

Malignant gliomas, the most common subtype of primary brain tumors, are aggressive, highly invasive, and neurologically destructive tumors. These tumors are considered to be among the deadliest of all human cancers. In its most aggressive form, glioblastoma (GBM), median survival ranges from 9 to 12 months. Despite several decades of technological advances in neurosurgery and radiation therapy there has been no significant change in the overall statistics.

Gene therapy approaches for the treatment of malignant gliomas have been attempted. However, while these approaches have proved successful in vitro and in animal models, these strategies have met with limited success in clinical trials. It is believed that the low in vivo infection efficiency of the vectors is connected to the

histological structure of the glioblastomas. These are very solid tumors, which are almost completely impermeable to diffusion of big particles such as viruses.

The present inventors surprisingly found that treatment of glioblastomas in animals could be carried out effectively using viral vectors encoding a toxic molecule (Fas-chimera (Fas-c)) under the control of a promoter which directs transcription in endothelial cells.

Using an animal model of glioblastoma whereby rats were pre-inoculated with U87 tumor cells, the present inventors showed that administration of such viral vectors decreased the size of the luciferase-tagged tumors as measured by luciferase activity (Figure 3) and MRI (Figures 4 and 5). The present inventors further showed that administration of such viral vectors increased survival of the rats (Figure 2).

Thus, according to one aspect of the present invention, there is provided a method of treating a malignant glioma in a subject in need therof, the method comprising administering to the subject a therapeutically effective amount of a viral vector comprising:

(i) a first polynucleotide sequence encoding a Fas-chimera (Fas-c); and

(ii) a second polynucleotide sequence encoding an endothelial cell-specific promoter or a periendothelial cell-specific promoter, thereby treating the malignant glioma.

As used herein, the phrase "malignant glioma" refers to a primary central nervous system tumor typically characterized by over-expression of growth factor receptors and/or tumor associated antigens. According to one embodiment the malignant glioma exhibits epidermal growth factor receptor (EGFR) overexpression. According to one embodiment the malignant glioma exhibits platelet-derived growth factor receptor (PDFR) overexpression. According to another embodiment the malignant glioma exhibits both platelet-derived growth factor receptor (PDFR) overexpression and epidermal growth factor receptor (EGFR) overexpression.

Examples of malignant gliomas include, but are not limited to glioblastoma, astrocytoma, oligodendroglioma, ependymoma, and juvenile onset neoplasms such as juvenile pilocystic astrocytoma.

Contemplated subjects to be treated include mammals – e.g. humans. According to one embodiment the subject has received a prior treatment for the malignant glioma

(e.g. radiotherapy and/or chemotherapy) and the malignant glioma has relapsed. According to another embodiment, the subject has not received a prior treatment for the malignant glioma.

The phrase "viral vector" refers to a replication competent or replication-deficient viral particle which are capable of transferring nucleic acid molecules into a host.

The present inventors contemplate use of Replication Defective Vectors and Replication Defective Vector-Producing Packaging Cells. Examples of such vectors are adenoviral vectors, AAV vectors and retroviral vectors and others described in Shir et al, Cellular and Molecular Neurobiology, Vol. 21, No. 6, December 2001, the contents of which are incorporated herein by reference.

The term "virus" refers to any of the obligate intracellular parasites having no protein-synthesizing or energy-generating mechanism. The viral genome may be RNA or DNA contained with a coated structure of protein of a lipid membrane. Examples of viruses useful in the practice of the present invention include baculoviridiae, parvoviridiae, picornoviridiae, herepesviridiae, poxviridiae, adenoviridiae, picotrnaviridiae. The term recombinant virus includes chimeric (or even multimeric) viruses, i.e. vectors constructed using complementary coding sequences from more than one viral subtype. (See, e.g. Feng, et al. Nature Biotechnology 15:866-870) The term "adenovirus" is synonymous with the term "adenoviral vector" and refers to viruses of the genus adenoviridiae. The term adenoviridiae refers collectively to animal adenoviruses of the genus mastadenovirus including but no limited to human, bovine, ovine, equine, canine, porcine, murine and simian adenovirus subgenera. In particular, human adenoviruses includes the A-F subgenera as well as the individual serotypes thereof the individual serotypes and A-F subgenera including but not limited to human adenovirus types 1, 2, 3, 4, 4a, 5, 6, 7, 8, 9, 10, 11 (Ad11A and Ad 11P), 12, 13, 14, 15, 16, 17, 18, 19, 19a, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 34a, 35, 35p, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, and 91. The term bovine adenoviruses includes but is not limited to bovine adenovirus types 1, 2, 3, 4, 7, and 10. The term canine adenoviruses includes but is not limited to canine types 1 (strains CLL, Glaxo, RI261, Utrect, Toronto 26-61) and 2. The term equine adenoviruses includes but is not limited to equine types 1 and 2. The term porcine adenoviruses includes but is not

limited to porcine types 3 and 4. In one embodiment of the invention, the adenovirus is derived from the human adenovirus serotypes 2 or 5. For purposes of this invention, adenovirus vectors can be replication-competent or replication deficient in a target cell. In some embodiments, the adenovirus vectors are conditionally or selectively replicating adenoviruses, wherein a gene[s] required for viral replication is [are] operatively linked to a cell and/or context-specific promoter. Examples of selectively replicating or conditionally replicating viral vectors are known in the art (see, for example, US 7,691,370). In one embodiment, the adenovirus vector is a conditionally replicating adenovirus wherein the E1 gene is under transcriptional control of the pre-proendothelin promoter PPE-1 (PPE-1, SEQ ID NO: 13). In another embodiment, the adenovirus vector is a conditionally replicating or selectively replicating adenovirus wherein the E1 gene is under transcriptional control of the modified pre-proendothelin promoter PPE-1-3X (PPE-1-3X, SEQ ID NO: 12). In some embodiments, adenovirus vectors suitable for use with the present invention include all adenovirus serotypes having hexon protein structure. Viral vectors suitable for therapeutic use include adenoviral vectors, retrovirusal vectors, AAV, herpesvirus vectors and the like. Engineering and production of viral vectors is well known in the art, as described in detail in, for example, US Patent No: 7,732,129 or 6,649,158, which are incorporated herein by reference, in their entirety. In specific embodiments, the adenovirus is a C-type adenovirus (Ad5, Ad2), a B-type adenovirus (Ad3, Ad16, Ad21, Ad35, Ad50), an E-type adenovirus (Ad4) or an F-type adenovirus (Ad41).

As used herein, the phrase adenoviral vector refers to a vector in which, among the nucleic acid molecules in the viral particle, sequences necessary to function as a viral vector are based on the adenoviral genome.

According to one embodiment the adenoviral vector is a non-replicating serotype 5 (Ad5) adenoviral vector.

According to another embodiment, the adenoviral vector comprises a sequence as set forth in SEQ ID NO: 1 or SEQ ID NO: 11.

It will be appreciated that the present invention also contemplates use of oncolytic viruses which reproduce themselves in cancer cells and subsequently kill the initially infected cells by lysis. Such viruses proceed to infect adjacent cells thus

repeating the cycle. Contemplated example of oncolytic viruses include, but are not limited to Herpes Simplex Virus, conditionally replicative Ads (CRAds) and reoviruses.

Two major strategies for development of CRAd vectors have been developed, mainly focusing on the genetic engineering of the early 1 (E1) genes to restrict virus replication to target cells and to spare normal tissue. Genetic complementation-type (type 1) CRAds, such as Ad524, have a mutation in the immediately early (E1A) or early (E1B) adenoviral region, which is complemented in tumor cells but not in normal cells. In trans complementation-type (type 2) CRAds, virus replication is controlled via a tumor/tissue-specific promoter.

Reovirus is a naturally occurring oncolytic virus that requires activated Ras signaling pathways of tumor cells for its replication. Ras pathways are activated in most malignant gliomas via upstream signaling by receptor tyrosine kinases.

As mentioned the viral vectors of this aspect of the present invention comprise:

(i) a first polynucleotide sequence encoding a Fas-chimera (Fas-c); and

(ii) a second polynucleotide sequence encoding an endothelial cell-specific promoter or a periendothelial cell-specific promoter, thereby treating the malignant glioma.

Typically, such viral vectors are constructed using genetic recombination technology – i.e. recombinant viral vectors.

The Fas-chimera (Fas-c), is a previously described fusion of two "death receptors", constructed from the extracellular region of TNFR1 (SEQ ID NO: 2) and the trans-membrane and intracellular regions of Fas (SEQ ID NO: 3) [Boldin MP et al. J Biol Chem (1995) 270(14):7795-8].

According to one embodiment the Fas-c is encoded by a polynucleotide as set forth in SEQ ID NO: 4.

It will be appreciated that the present invention also contemplates use of a viral construct (e.g. an adenoviral construct) comprising an endothelial/periendothelial cell-specific promoter operatively linked to other cytotoxic polypeptides for the treatment of malignant glioma.

Such polypeptides, include but are not limited to suicide polypeptides such as p53 and egr-1-TNF-alpha, cytotoxic pro-drug/enzymes for drug susceptibility therapy

such as ganciclovir/thymidine kinase and 5-fluorocytosine/cytosine deaminase, and antimetastatic polypeptides such as 5 E1A.

The term "promoter" as used herein refers to a DNA sequence which directs transcription of a polynucleotide sequence operatively linked thereto in the cell in a constitutive or inducible manner. The promoter may also comprise enhancer elements which stimulate transcription from the linked promoter.

As used herein, the phrase endothelial cell-specific promoter refers to a promoter which directs expression of a gene operatively linked thereto in endothelial cells, wherein the level of expression in endothelial cells is at least 2 times higher than in non-endothelial cells. According to a particular embodiment, the level of expression in endothelial cells is at least 5 times higher than in non-endothelial cells.

As used herein, the phrase periendothelial cell-specific promoter refers to a promoter which directs expression of a gene operatively linked thereto in periendothelial cells (i.e., pericytes in small vessels or smooth muscle cells in larger vessels), wherein the level of expression in endothelial cells is at least 2 times higher than in non-periendothelial cells. According to a particular embodiment, the level of expression in periendothelial cells is at least 5 times higher than in non-periendothelial cells.

Exemplary endothelial cell-specific promoters or periendothelial cell-specific promoters include, but are not limited to the preproendothelin-1 (PPE-1) promoter, and modifications thereof such as described herein below, the TIE-1 promoter, the TIE-2 promoter, the Endoglin promoter, the von Willerband promoter, the KDR/flk-1 promoter, The FLT-1 promoter, the Egr-1 promoter, the ICAM-1 promoter, the VCAM-1 promoter, the PECAM-1 promoter and the aortic carboxypeptidase-like protein (ACLP) promoter.

The preproendothelial promoter refers to the preproendothelin-1 promoter, of mammalian origin. In one embodiment, the preproendothelin 1 promoter is a murine preproendothelin 1 promoter as set forth in SEQ ID NO: 13.

According to one embodiment the promoter comprises at least one copy of an enhancer element that confers endothelial cell specific transcriptional activity. According to one embodiment the enhancer element is naturally found positioned between the –364 bp and –320 bp of the murine PPE-1 promoter (as set forth in SEQ ID

NO: 6). Preferably, the promoter comprises at least two and more preferably three of the above described enhancer elements. According to a specific embodiment, the promoter comprises two of the above described enhancer elements on one strand of the promoter DNA and one of the above described enhancer element on the complementary strand of the promoter DNA (as set forth in SEQ ID NO:7).

According to another embodiment, the promoter further comprises at least one hypoxia response element – e.g. comprising a sequence as set forth in SEQ ID NO: 5.

An exemplary promoter which can be used in the context of the present invention comprises a sequence as set forth in SEQ ID NO: 12. This promoter is also referred to herein as the PPE-1-3x promoter. This sequence comprises SEQ ID NO: 5 and SEQ ID NO: 7 (which itself comprises two copies of SEQ ID NO: 6 either side of one copy of SEQ ID NO: 8).

According to a particular embodiment of this aspect of the present invention, the viral vector consists of a sequence as set forth in SEQ ID NOs: 9 or 10. This viral vector is also referred to herein as VB111 and AD5PPE-1-3X-fas-chimera.

This sequence comprises SEQ ID NO: 12 in the antisense orientation at position 460-1437.

This sequence also comprises SEQ ID NO: 7 in the antisense orientation at position 894-1036; a single copy of SEQ ID NO: 8 in the antisense orientation at position 951-997; a first copy of SEQ ID NO: 6 in the antisense orientation at position 907-950; a second copy of SEQ ID NO: 6 in the antisense orientation at position 993-1036; and a third copy of SEQ ID NO: 6 at position 823-866 in the sense orientation.

In some embodiments of the invention, the viral vector comprises additional polynucleotide sequences capable of enhancing or inhibiting transcriptional activity of an endothelial specific promoter. According to an aspect of some embodiments of the invention, the additional polynucleotide sequence includes an isolated polynucleotide comprising at least 6 nucleotides of element X of a pre-proendothelin (PPE-1) promoter, the element X having a wild type sequence as set forth by SEQ ID NO:6, wherein the at least 6 nucleotides comprise at least 2 consecutive sequences derived from SEQ ID NO:6, each of the at least 2 consecutive sequences comprises at least 3 nucleotides, at least one of the at least 3 nucleotide being positioned next to at least one nucleotide

position in SEQ ID NO:6, the at least one nucleotide position in SEQ ID NO:6 is selected from the group consisting of:

(i) at least one nucleotide of wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC);

(ii) at least one nucleotide of wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG);

(iii) at least one nucleotide of wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC);

(iv) at least one nucleotide of wild type M6 sequence set forth by SEQ ID NO: 17 (GGGTG);

(v) at least one nucleotide of wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT);

(vi) at least one nucleotide of wild type M1 sequence set forth by SEQ ID NO: 20 (GTACT); and

(v) at least one nucleotide of wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT);

wherein the at least one nucleotide position is mutated as compared to SEQ ID NO:6 by at least one nucleotide substitution, at least one nucleotide deletion and/or at least one nucleotide insertion, with the proviso that a mutation of the at least one nucleotide position does not result in nucleotides GGTA at position 21-24 of SEQ ID NO:6 and/or in nucleotides CATG at position 29-32 of SEQ ID NO:6, such that when the isolated polynucleotide is integrated into the PPE-1 promoter and placed upstream of a reporter gene (e.g., luciferase coding sequence) the expression level of the reporter gene is upregulated or downregulated as compared to when SEQ ID NO:6 is similarly integrated into the PPE-1 promoter and placed upstream of the reporter gene coding sequence.

According to some embodiments of the invention, the isolated polynucleotide is not naturally occurring in a genome or a whole chromosome sequence of an organism.

As used herein the phrase "naturally occurring" refers to as found in nature, without any man-made modifications.

As described above, the at least 6 nucleotides of element X comprise at least 2 consecutive sequences derived from SEQ ID NO:6.

As used herein the phrase "consecutive sequence derived from SEQ ID NO:6 " refers to a nucleic acid sequence (a polynucleotide) in which the nucleotides appear in the same order as in the nucleic acid sequence of SEQ ID NO:6 from which they are derived. It should be noted that the order of nucleotides is determined by the chemical bond (phosphodiester bond) formed between a 3'-OH of a preceding nucleotide and the 5'-phosphate of the following nucleotide.

According to some embodiments of the invention, each of the at least 2 consecutive sequences comprises at least 3 nucleotides, e.g., 3 nucleotides, 4 nucleotides, 5 nucleotides, 6 nucleotides, 7 nucleotides, 8 nucleotides, 9 nucleotides, 10 nucleotides, 11 nucleotides, 12 nucleotides, 13 nucleotides, 14 nucleotides, 15 nucleotides, 16 nucleotides, 17 nucleotides, 18 nucleotides, 19 nucleotides, 20 nucleotides, 21 nucleotides, 22 nucleotides, 23 nucleotides, 24 nucleotides, 25 nucleotides, 26 nucleotides, 27 nucleotides, 28 nucleotides, 29 nucleotides, 30 nucleotide, 31 nucleotides, 32 nucleotides, 33 nucleotides, 34 nucleotides, 35 nucleotides, 36 nucleotides, 37 nucleotides, 38 nucleotides, 39 nucleotides, 40 nucleotides, 41 nucleotides of SEQ ID NO:6.

As described, the isolated polynucleotide comprises at least 2 consecutive sequences derived from SEQ ID NO:6. According to some embodiments of the invention, the isolated polynucleotide comprises 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 or 14 consecutive sequences derived from SEQ ID NO:6.

As used herein the phrase "wild type" with respect to a nucleotide sequence refers to the nucleic acid sequence as appears in SEQ ID NO:6. Examples include, but are not limited to wild type M4 sequence (SEQ ID NO: 15), wild type M5 sequence (SEQ ID NO: 16), wild type M8 (SEQ ID NO:19), wild type M6 sequence (SEQ ID NO:17), wild type M7 sequence (SEQ ID NO:18), wild type M1 (SEQ ID NO:20) and wild type M3 sequence (SEQ ID NO:21).

According to some embodiments of the invention, the mutation is an insertion of at least one nucleotide in a nucleotide position with respect to SEQ ID NO:6. According to some embodiments of the invention, the insertion includes at least 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 nucleotides, e.g., at least about 15, at least about 20, at least about 25, at least about 30, at least about 35, at least about 40, at least about 45, at least about 50, at least about 55, at least about 60, at least about 65, at least about 70, at least about 75, at least about

80, at least about 85, at least about 90, at least about 95, at least about 100, at least about 200, at least about 300, or more nucleotides.

It should be noted that the sequence which is inserted by the mutation can be derived from any source (e.g., species, tissue or cell type), and is not limited to the source of the sequence of element X.

According to some embodiments of the invention, the mutation is a combination of any of the mutation types described above, *i.e.*, substitution, insertion and deletion. For example, while one nucleotide position in SEQ ID NO:6 can be subject to a substitution mutation, another nucleotide position in SEQ ID NO:6 can be subject to a deletion or insertion. Additionally or alternatively, while one nucleotide position in SEQ ID NO:6 can be subject to a deletion mutation, another nucleotide position in SEQ ID NO:6 can be subject to a substitution or insertion. Additionally or alternatively, while one nucleotide position in SEQ ID NO:6 can be subject to an insertion mutation, another nucleotide position in SEQ ID NO:6 can be subject to a substitution or deletion. It should be noted that various other combinations are possible.

According to specific embodiments of the invention, the mutation in the isolated polynucleotide of the invention does not result in nucleotides GGTA at position 21-24 of SEQ ID NO:6 and/or in nucleotides CATG at position 29-32 of SEQ ID NO:6.

As used herein the phrase "integrated into the PPE-1 promoter" refers to a nucleotide sequence (the isolated polynucleotide) which is covalently conjugated within the PPE-1 promoter sequence.

According to some embodiments of the invention, the isolated polynucleotide further comprises at least one copy of a nucleic acid sequence selected from the group consisting of:

(i) wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC),

(ii) wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG),

(iii) wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC),

(iv) wild type M6 sequence set forth by SEQ ID NO: 17 (GGGTG),

(v) wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT);

(vi) wild type M1 sequence set forth by SEQ ID NO: 20 (GTACT), and

(vii) wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT).

According to some embodiments of the invention, the isolated polynucleotide is integrated into (within), downstream of, or upstream of any known (or unknown) promoter sequence to thereby regulate (e.g., increase, decrease, modulate tissue-specificity, modulate inductive or constitutive expression) the transcriptional promoting activity of the promoter.

According to some embodiments of the invention, the isolated polynucleotide is for increasing expression of a heterologous polynucleotide operably linked thereto in endothelial cells. Such a polynucleotide can include wild type sequences of M4 and/or M5 in the presence or absence of additional sequences from element X, and/or in the presence of other mutated sequences from element X.

According to some embodiments of the invention, the isolated polynucleotide comprises at least one copy of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC).

According to some embodiments of the invention, the isolated polynucleotide comprises at least one copy of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG).

According to some embodiments of the invention, the isolated polynucleotide comprises at least one copy of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC) and at least one copy of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG).

According to some embodiments of the invention, the at least one nucleotide position which is mutated as compared to SEQ ID NO:6 is at least one nucleotide of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC). It should be noted that such an isolated polynucleotide may further include a wild type M6 sequence (SEQ ID NO:17) and/or a wild type M7 sequence (SEQ ID NO:18)

Non-limiting examples of isolated polynucleotides which include at least one copy of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC) and a mutation in at least one nucleotide of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs:55-62.

Non-limiting examples of isolated polynucleotides which include at least one copy of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG) and a

mutation in at least one nucleotide of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs: 63-66.

Non-limiting examples of isolated polynucleotides which include at least one copy of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), at least one copy of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG) and a mutation in at least one nucleotide of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs: 67-70.

According to some embodiments of the invention, the isolated polynucleotide further comprising at least one copy of wild type M1 sequence set forth by SEQ ID NO: 20 (GTACT).

Non-limiting examples of isolated polynucleotides which include at least one copy of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), at least one copy of the wild type M1 sequence set forth by SEQ ID NO: 20 (GTACT), and a mutation in at least one nucleotide of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs: 71-105.

Non-limiting examples of isolated polynucleotides which include at least one copy of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M1 sequence set forth by SEQ ID NO: 20 (GTACT) and a mutation in at least one nucleotide of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs: 106-136.

Non-limiting examples of isolated polynucleotides which include at least one copy of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), at least one copy of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M1 sequence set forth by SEQ ID NO: 20 (GTACT) and a mutation in at least one nucleotide of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs:137-152.

According to some embodiments of the invention, the isolated polynucleotide reduces expression of a heterologous polynucleotide operably linked thereto in endothelial cells. Such a polynucleotide can include mutations in M4 and/or M5 in the presence or absence of additional sequences from element X, and/or in the presence of other mutated sequences from element X.

According to some embodiments of the invention, the at least one nucleotide position which is mutated as compared to SEQ ID NO:6 is at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC).

Non-limiting examples of isolated polynucleotides which includes a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO:46 (CATTC) are provided in SEQ ID NOs:153-162.

According to some embodiments of the invention, the at least one nucleotide position which is mutated as compared to SEQ ID NO:6 is at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG).

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG) are provided in SEQ ID NOs:163-171.

According to some embodiments of the invention, the at least one nucleotide position which is mutated as compared to SEQ ID NO:6 is at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC) and at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG).

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC) and a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG) are provided in SEQ ID NOs:172-180.

According to some embodiments of the invention, the isolated polynucleotide is for increasing expression of a heterologous polynucleotide operably linked thereto in cells other than endothelial cells. Such a polynucleotide can include mutations in M4 and/or M5 and wild type sequences of M6 and/or M7, in the presence or absence of additional sequences from element X, and/or in the presence of other mutated sequences from element X.

According to some embodiments of the invention, the isolated polynucleotide comprises a mutation in M4 (SEQ ID NO: 15) and/or in M5 (SEQ ID NO: 16) and at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) and/or at least one copy of wild type M7 set forth by SEQ ID NO:18.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15

(CATTC) and at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) are provided in SEQ ID NOs:181-182.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG) and at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) are provided in SEQ ID NOs:183-189.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG) and at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) are provided in SEQ ID NOs:190-191.

According to some embodiments of the invention, the isolated polynucleotide further comprises at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT).

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC) and at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT) are provided in SEQ ID NOs:192-195.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG) and at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT) are provided in SEQ ID NOs:196-198.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG) and at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT) are provided in SEQ ID NOs:199-202.

According to some embodiments of the invention, the isolated polynucleotide further comprises at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) and at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT).

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) and at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT) are provided in SEQ ID NOs:203-205.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) and at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT) are provided in SEQ ID NOs:206-207.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) and at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT) are provided in SEQ ID NOs:208-209.

According to some embodiments of the invention, the isolated polynucleotide reduces expression in cells of a heterologous polynucleotide operably linked thereto. Such a polynucleotide can include mutations in M4, M5, M6 and/or M7, in the presence or absence of additional sequences from element X, and/or in the presence of other mutated sequences from element X.

According to some embodiments of the invention, the isolated polynucleotide comprises at least one mutation in wild type M4 (SEQ ID NO: 15) and/or in wild type M5 (SEQ ID NO:47) and in wild type M6 set forth by SEQ ID NO: 17 (GGGTG).

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC) and a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) are provided in SEQ ID NOs:210-213.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG) and a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) are provided in SEQ ID NOs:214-222.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), and a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) are provided in SEQ ID NOs:223-231.

According to some embodiments of the invention, the isolated polynucleotide further comprises at least one mutation in wild type M7 set forth by SEQ ID NO: 18 (ACTTT).

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC) and a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT) are provided in SEQ ID NOs:232-236.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG) and a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT) are provided in SEQ ID NOs:237-240.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), and a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT) are provided in SEQ ID NOs:241-248.

According to some embodiments of the invention, the isolated polynucleotide further comprises at least one mutation in wild type M6 set forth by SEQ ID NO: 17 (GGGTG) and at least one mutation in wild type M7 set forth by SEQ ID NO: 18 (ACTTT).

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) and a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT) are provided in SEQ ID NOs:249-258.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) and a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT) are provided in SEQ ID NOs:259-264.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) and a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT) are provided in SEQ ID NOs:265-270.

According to some embodiments of the invention, the isolated polynucleotide comprises at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) with additional wild type or mutated sequences derived from element X (SEQ ID NO:6).

Non-limiting examples of isolated polynucleotides which includes a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC) and at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs:271-279.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG) and at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs:280-287.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG) and at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs:288-291.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG)

and at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs:294-298.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) and at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs:299-301.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) and at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs:302-303.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs:304-308.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs:309-311.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs:312-315.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG),

at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NO:316.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NO:317.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NO:318.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) and at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs:319-327.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) and at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs:328-333.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) and at least one copy of the wild type

M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs:334-337.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs:338-344.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs:345-348.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs:349-354.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs:355-361.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type

M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs:362-365.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) are provided in SEQ ID NOs:366-369.

According to some embodiments of the invention, the isolated polynucleotide comprises at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) with additional wild type or mutated sequences derived from element X (SEQ ID NO:6).

Non-limiting examples of isolated polynucleotides which includes a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:378-384.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:628-634.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:370-377.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:385-390.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:391-396.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:397-401.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:402-409.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:410-417.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:418-423.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT)

and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:424-425.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:538-540.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NO:426.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:427-435.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:436-444.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:445-451.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:452-458.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:459-465.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NO:466.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:467-471.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:472-477.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15

(CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:478-483.

According to some embodiments of the invention, the isolated polynucleotide further comprises at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) with additional wild type or mutated sequences derived from element X (SEQ ID NO:6).

Non-limiting examples of isolated polynucleotides which includes a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:484-495.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:496-507.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:508-515.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC)

and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:516-519.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:520-523.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:524-525.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT), at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:526-529.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT), at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:530-533.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT), at least one copy of the wild type M8 sequence set forth

by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:534-535.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT), at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT)are provided in SEQ ID NOs:536-537.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT) at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:538-539.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), at least one copy of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), at least one copy of the wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT), at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NO:540.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:541-547.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16

(CAATG), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:548-554.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:555-559.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT), at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:560-566.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT), at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:567-573.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT), at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:574-578.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT), at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:579-583.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT), at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:584-588.

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of the wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC), a mutation in at least one nucleotide of the wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG), a mutation in at least one nucleotide position of the wild type M6 set forth by SEQ ID NO: 17 (GGGTG), a mutation in at least one nucleotide position of the wild type M7 set forth by SEQ ID NO: 18 (ACTTT), at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) are provided in SEQ ID NOs:589-592.

According to some embodiments of the invention, the isolated polynucleotide comprises at least one copy of wild type M3 sequence (SEQ ID NO: 21) and at least one copy of wild type M8 sequence (SEQ ID NO: 19) , with at least one mutation in wild type M6 (SEQ ID NO: 17) and/or in wild type M7 (SEQ ID NO:50).

Non-limiting examples of isolated polynucleotides which include at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT), with a

mutation in at least one nucleotide of the wild type M6 sequence (SEQ ID NO: 17) , and/or a mutation in at least one nucleotide of the wild type M7 (SEQ ID NO: 18) are provided in SEQ ID NOs:593-600.

The present inventors have envisaged that an isolated polynucleotide which includes the wild type M8 sequence (SEQ ID NO: 19) and/or the wild type M3 (SEQ ID NO: 21) sequence in addition to tissue specific enhancers (e.g., wild type M4 and/or wild type M5), and/or induced enhancers (e.g., developmentally related- or stress related-enhancers) is expected to exert a more specific regulatory effect by suppressing expression in non-target cells or under non-induced conditions.

According to some embodiments of the invention, the isolated polynucleotide comprises at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and an endothelial specific enhancer sequence.

According to some embodiments of the invention, the isolated polynucleotide comprises at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of wild type M4 sequence set forth by SEQ ID NO: 15.

According to some embodiments of the invention, the isolated polynucleotide comprises at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of wild type M5 sequence set forth by SEQ ID NO:16.

According to some embodiments of the invention, the isolated polynucleotide comprises at least one copy of the wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC), at least one copy of wild type M4 sequence set forth by SEQ ID NO: 15 and at least one copy of wild type M5 sequence set forth by SEQ ID NO:16.

According to some embodiments of the invention, the isolated polynucleotide comprises at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) and an endothelial specific enhancer sequence.

According to some embodiments of the invention, the isolated polynucleotide comprises at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) and at least one copy of wild type M4 sequence set forth by SEQ ID NO: 15.

According to some embodiments of the invention, the isolated polynucleotide comprises at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT) and at least one copy of wild type M5 sequence set forth by SEQ ID NO:16.

According to some embodiments of the invention, the isolated polynucleotide comprises at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT), at least one copy of wild type M4 sequence set forth by SEQ ID NO: 15 and at least one copy of wild type M5 sequence set forth by SEQ ID NO:16.

According to some embodiments of the invention, the isolated polynucleotide comprises at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT), at least one copy of wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and an endothelial specific enhancer sequence.

According to some embodiments of the invention, the isolated polynucleotide comprises at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT), at least one copy of wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of wild type M4 sequence set forth by SEQ ID NO: 15.

According to some embodiments of the invention, the isolated polynucleotide comprises at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT), at least one copy of wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one copy of wild type M5 sequence set forth by SEQ ID NO: 16.

According to some embodiments of the invention, the isolated polynucleotide comprises at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT), at least one copy of wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC), at least one copy of wild type M4 sequence set forth by SEQ ID NO: 15 and at least one copy of wild type M5 sequence set forth by SEQ ID NO: 16.

According to some embodiments of the invention, the isolated polynucleotide comprises at least one copy of the wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT), at least one copy of wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC) and at least one enhancer element such as wild type M6 (SEQ ID NO: 17) and/or wild type M7 sequence (SEQ ID NO:18).

According to some embodiments of the invention, the isolated polynucleotide includes at least one copy of wild type M8 with additional flanking sequences such as at least one copy of a wild type M8 sequence (SEQ ID NO:19), at least one copy of wild type M7 (SEQ ID NO: 18) and/or wild type M9 sequence (SEQ ID NO: 14, CTGGA); and/or the isolated polynucleotide includes at least one copy of wild type M8 and at least

one mutation in M7, with or without M9 (SEQ ID NO: 22). Such polynucleotides can be used as a non-specific repressor.

According to some embodiments of the invention, the isolated polynucleotide is for increasing expression of a heterologous polynucleotide operably linked thereto in cells/tissues.

According to some embodiments of the invention, the isolated polynucleotide comprises at least one copy of wild type M6 sequence set forth by SEQ ID NO: 17 (GGGTG) and/or at least one copy of wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT).

According to some embodiments of the invention, the isolated polynucleotide includes at least one copy of wild type M6 (SEQ ID NO: 17) and a mutation in at least one nucleotide of wild type M8 (SEQ ID NO: 19) .

Non-limiting examples of isolated polynucleotide which include at least one copy of wild type M6 (SEQ ID NO: 17) and a mutation in at least one nucleotide of the wild type M8 (SEQ ID NO: 19) are provided in SEQ ID NOs:23-26.

According to some embodiments of the invention, the isolated polynucleotide includes at least one copy of wild type M7 (SEQ ID NO: 18) and a mutation in at least one nucleotide of wild type M8 (SEQ ID NO: 19) .

Non-limiting examples of isolated polynucleotide which include at least one copy of wild type M7 (SEQ ID NO: 18) and a mutation in at least one nucleotide of the wild type M8 (SEQ ID NO: 19) are provided in SEQ ID NOs:27-28.

According to some embodiments of the invention, the isolated polynucleotide includes at least one copy of wild type M6 (SEQ ID NO: 17) , at least one copy of wild type M7 (SEQ ID NO: 18) and a mutation in at least one nucleotide of wild type M8 (SEQ ID NO: 19) .

According to some embodiments of the invention, the isolated polynucleotide includes at least one copy of wild type M1 (SEQ ID NO: 20) and a mutation in at least one nucleotide of wild type M8 (SEQ ID NO: 19) .

Non-limiting examples of isolated polynucleotide which include at least one copy of wild type M1 (SEQ ID NO: 20) and a mutation in at least one nucleotide of the wild type M8 (SEQ ID NO: 19) are provided in SEQ ID NOs:43-54 and 601-632.

According to some embodiments of the invention, the isolated polynucleotide includes at least one copy of wild type M1 (SEQ ID NO: 20) , at least one copy of wild type M6 (SEQ ID NO: 17) and/or at least one copy of wild type M7 (SEQ ID NO: 18) and a mutation in at least one nucleotide of wild type M8 (SEQ ID NO: 19) .

Non-limiting examples of isolated polynucleotides which include a mutation in at least one nucleotide of wild type M8 (SEQ ID NO: 19) and at least one copy of wild type M1 (SEQ ID NO: 20) , wild type M6 (SEQ ID NO: 17) and/or wild type M7 (SEQ ID NO: 18) are provided in SEQ ID NOs:29-42.

Additional examples of regulatory isolated polynucleotides which can be used according to some embodiments of the invention are provided (; SEQ ID NOs: 633-644) in the Examples section which follows.

According to an aspect of some embodiments of the invention, there is provided an isolated polynucleotide comprising a nucleic acid sequence which comprises a first polynucleotide comprising the pre-proendothelin (PPE-1) promoter set forth by SEQ ID NO:13 and a second polynucleotide comprising at least one copy of a nucleic acid sequence selected from the group consisting of:

(i) wild type M4 sequence set forth by SEQ ID NO: 15 (CATTC),

(ii) wild type M5 sequence set forth by SEQ ID NO: 16 (CAATG),

(iii) wild type M8 sequence set forth by SEQ ID NO: 19 (GCTTC),

(iv) wild type M6 sequence set forth by SEQ ID NO: 17 (GGGTG),

(v) wild type M7 sequence set forth by SEQ ID NO: 18 (ACTTT);

(vi) wild type M1 sequence set forth by SEQ ID NO: 20 (GTACT), and

(vii) wild type M3 sequence set forth by SEQ ID NO: 21 (CTTTT);

with the proviso that the second polynucleotide is not SEQ ID NO:6 (element X), and wherein the isolated polynucleotide is not SEQ ID NO:12 (PPE-1-3X).

According to some embodiments of the invention, each of the wild type M4, M5, M8, M6, M7 and/or M1 sequences is placed in a head to tail (5'→3') orientation with respect to the PPE-1 promoter set forth by SEQ ID NO:13.

According to some embodiments of the invention, each of the wild type M4, M5, M8, M6, M7 and/or M1 sequences is placed in a tail to head (3'→5') orientation with respect to the PPE-1 promoter set forth by SEQ ID NO:13.

According to some embodiments of the invention, the wild type M4, M5, M8, M6, M7 and/or M1 sequences are placed in various orientations (head to tail or tail to head) and/or sequential order with respect the other wild type M4, M5, M8, M6, M7 and/or M1 sequences, and/or with respect to the orientation of SEQ ID NO:13.

Construction of such viral vectors may be effected using known molecular biology techniques such as those described in Sambrook et al., Molecular Cloning: A Laboratory Manual, Cold Springs Harbor Laboratory, New York (1989, 1992), in Ausubel et al., Current Protocols in Molecular Biology, John Wiley and Sons, Baltimore, Md. (1989), Chang et al., Somatic Gene Therapy, CRC Press, Ann Arbor, Mich. (1995), Vega et al., Gene Targeting, CRC Press, Ann Arbor Mich. (1995), Vectors: A Survey of Molecular Cloning Vectors and Their Uses, Butterworths, Boston Mass. (1988) and Gilboa et at. [Biotechniques 4 (6): 504-512, 1986].

Construction of the viral vector of SEQ ID NO: 9 is described in International Application WO/2008/132729, the contents of which are incorporated herein by reference.

The viral vector of this aspect of the present invention may be administered per se or as part of a pharmaceutical composition which also includes a physiologically acceptable carrier. The purpose of a pharmaceutical composition is to facilitate administration of the active ingredient to an organism.

As used herein a "pharmaceutical composition" refers to a preparation of one or more of the active ingredients described herein with other chemical components such as physiologically suitable carriers and excipients. The purpose of a pharmaceutical composition is to facilitate administration of a compound to an organism.

Herein the term "active ingredient" refers to the viral vector of the present invention accountable for the biological effect.

Hereinafter, the phrases "physiologically acceptable carrier" and "pharmaceutically acceptable carrier" which may be interchangeably used refer to a carrier or a diluent that does not cause significant irritation to an organism and does not abrogate the biological activity and properties of the administered compound. An adjuvant is included under these phrases.

Herein the term "excipient" refers to an inert substance added to a pharmaceutical composition to further facilitate administration of an active ingredient.

Examples, without limitation, of excipients include calcium carbonate, calcium phosphate, various sugars and types of starch, cellulose derivatives, gelatin, vegetable oils and polyethylene glycols.

Techniques for formulation and administration of drugs may be found in "Remington's Pharmaceutical Sciences," Mack Publishing Co., Easton, PA, latest edition, which is incorporated herein by reference.

Suitable routes of administration may, for example, include oral, rectal, transmucosal, especially transnasal, intestinal or parenteral delivery, including intramuscular, subcutaneous and intramedullary injections as well as intrathecal, direct intraventricular, intracardiac, e.g., into the right or left ventricular cavity, into the common coronary artery, intravenous, inrtaperitoneal, intranasal, or intraocular injections. Injection of the viral vectors into a spinal fluid can also be used as a mode of administration.

In order to enhance delivery of the virus to the central nervous system (CNS) various approaches may be taken. These include: neurosurgical strategies (e.g., intracerebral injection or intracerebroventricular infusion) and molecular manipulation of the virus. Thus for example, Tang et al., Gene Therapy (2007) 14, 523–532 teaches re-directing Ad5 vectors to the MTf transcytosis pathway in order to cross the BBB by manipulating the virus to express a full-length melanotransferrin (sCAR-MTf) polypeptide.

Other approaches for enhancing the delivery of the virus to the CNS include pharmacological strategies designed to increase the lipid solubility of an agent (e.g., conjugation of water-soluble agents to lipid or cholesterol carriers); and the transitory disruption of the integrity of the BBB by hyperosmotic disruption (resulting from the infusion of a mannitol solution into the carotid artery or the use of a biologically active agent such as an angiotensin peptide).

The present invention also contemplates engineering of the viral vectors in order to avoid, suppress or manipulate the immune response, ideally resulting in sustained expression and immune tolerance to the transgene product – such methods are described for example in Nayak et al., *Gene Therapy* (12 November 2009), incoporated herein by reference.

Alternately, one may administer the pharmaceutical composition in a local rather than systemic manner, for example, via injection of the pharmaceutical composition directly into the brain of a patient and even more directly into the tumor cells themselves.

Pharmaceutical compositions of the present invention may be manufactured by processes well known in the art, e.g., by means of conventional mixing, dissolving, granulating, dragee-making, levigating, emulsifying, encapsulating, entrapping or lyophilizing processes.

Pharmaceutical compositions for use in accordance with the present invention thus may be formulated in conventional manner using one or more physiologically acceptable carriers comprising excipients and auxiliaries, which facilitate processing of the active ingredients into preparations which, can be used pharmaceutically. Proper formulation is dependent upon the route of administration chosen.

For injection, the active ingredients of the pharmaceutical composition may be formulated in aqueous solutions, preferably in physiologically compatible buffers such as Hank's solution, Ringer's solution, or physiological salt buffer. For transmucosal administration, penetrants appropriate to the barrier to be permeated are used in the formulation. Such penetrants are generally known in the art.

For buccal administration, the compositions may take the form of tablets or lozenges formulated in conventional manner.

For administration by nasal inhalation, the active ingredients for use according to the present invention are conveniently delivered in the form of an aerosol spray presentation from a pressurized pack or a nebulizer with the use of a suitable propellant, e.g., dichlorodifluoromethane, trichlorofluoromethane, dichloro-tetrafluoroethane or carbon dioxide. In the case of a pressurized aerosol, the dosage unit may be determined by providing a valve to deliver a metered amount. Capsules and cartridges of, e.g., gelatin for use in a dispenser may be formulated containing a powder mix of the compound and a suitable powder base such as lactose or starch.

The pharmaceutical composition described herein may be formulated for parenteral administration, e.g., by bolus injection or continuous infusion. Formulations for injection may be presented in unit dosage form, e.g., in ampoules or in multidose containers with optionally, an added preservative. The compositions may be

suspensions, solutions or emulsions in oily or aqueous vehicles, and may contain formulatory agents such as suspending, stabilizing and/or dispersing agents.

Pharmaceutical compositions for parenteral administration include aqueous solutions of the active preparation in water-soluble form. Additionally, suspensions of the active ingredients may be prepared as appropriate oily or water based injection suspensions. Suitable lipophilic solvents or vehicles include fatty oils such as sesame oil, or synthetic fatty acids esters such as ethyl oleate, triglycerides or liposomes. Aqueous injection suspensions may contain substances, which increase the viscosity of the suspension, such as sodium carboxymethyl cellulose, sorbitol or dextran. Optionally, the suspension may also contain suitable stabilizers or agents which increase the solubility of the active ingredients to allow for the preparation of highly concentrated solutions.

Alternatively, the active ingredient may be in powder form for constitution with a suitable vehicle, e.g., sterile, pyrogen-free water based solution, before use.

The pharmaceutical composition of the present invention may also be formulated in rectal compositions such as suppositories or retention enemas, using, e.g., conventional suppository bases such as cocoa butter or other glycerides.

Pharmaceutical compositions suitable for use in context of the present invention include compositions wherein the active ingredients are contained in an amount effective to achieve the intended purpose. More specifically, a therapeutically effective amount means an amount of active ingredients (i.e. viral particles) effective to prevent, alleviate or ameliorate symptoms of a disorder (e.g., glioblastoma) or prolong the survival of the subject being treated.

Determination of a therapeutically effective amount is well within the capability of those skilled in the art, especially in light of the detailed disclosure provided herein.

For any preparation used in the methods of the invention, the therapeutically effective amount or dose can be estimated initially from in vitro and cell culture assays. For example, a dose can be formulated in animal models to achieve a desired concentration or titer. Such information can be used to more accurately determine useful doses in humans.

Toxicity and therapeutic efficacy of the active ingredients described herein can be determined by standard pharmaceutical procedures in vitro, in cell cultures or

experimental animals. The data obtained from these in vitro and cell culture assays and animal studies can be used in formulating a range of dosage for use in human. The dosage may vary depending upon the dosage form employed and the route of administration utilized. The exact formulation, route of administration and dosage can be chosen by the individual physician in view of the patient's condition. (See e.g., Fingl, et al., 1975, in "The Pharmacological Basis of Therapeutics", Ch. 1 p.1).

Dosage amount and interval may be adjusted individually to provide brain levels of the active ingredient are sufficient to induce or suppress the biological effect (minimal effective concentration, MEC). The MEC will vary for each preparation, but can be estimated from in vitro data. Dosages necessary to achieve the MEC will depend on individual characteristics and route of administration. Detection assays can be used to determine plasma concentrations.

Depending on the severity and responsiveness of the condition to be treated, dosing can be of a single or a plurality of administrations, with course of treatment lasting from several days to several weeks or until cure is effected or diminution of the disease state is achieved.

The amount of a composition to be administered will, of course, be dependent on the subject being treated, the severity of the affliction, the manner of administration, the judgment of the prescribing physician, etc.

The therapeutically effective amount of the active ingredient can be formulated in a unit dose. As used herein "unit dose" refers to a physically discrete unit containing a predetermined quantity of an active material calculated to individually or collectively produce a desired effect such as an anti-cancer effect. A single unit dose or a plurality of unit doses can be used to provide the desired effect, such as an anti-cancer therapeutic effect.

According to one embodiment, about 10^3 to about 10^{16} virus particles are administered to the subject.

According to another embodiment, about 10^5 to about 10^{13} virus particles are administered to the subject.

According to one embodiment, about 10^7 to about 10^{12} virus particles are administered to the subject.

According to one embodiment, about $1x10^{12}$ to about $5x10^{12}$ virus particles are administered to the subject.

According to one embodiment, about $1x10^{13}$ to about $5 x10^{13}$ virus particles are administered to the subject.

According to yet another embodiment the subject is administered intravenously with $1x10^{12}$ - $1x10^{13}$ viral particles of SEQ ID NO: 9. or SEQ ID NO: 10.

According to yet another embodiment the subject is administered intravenously with at least two doses of $1x10^{12}$ - $1x10^{13}$ viral particles of SEQ ID NO: 9. or SEQ ID NO: 10. According to yet another embodiment the subject is administered intravenously with at least three or more doses of $1x10^{12}$ - $1x10^{13}$ viral particles of SEQ ID NO: 9. or SEQ ID NO: 10. In a particular embodiment, the at least two doses are administered at least about 1day, at least about 3 days, at least about 5 days, at least about 7 days, at least about 2 weeks, at least about 3 weeks, at least about 4 weeks, at least about 2 months, at least about 6 months, at least about 9 months, at least about 1 year, at least about 1.25 years, at least about 1.5 years, at least about 1.75 years, at least about 2 years, at least about 2.5 years, at least about 3 years or more apart.

Compositions of the present invention may, if desired, be presented in a pack or dispenser device, such as an FDA approved kit, which may contain one or more unit dosage forms containing the active ingredient. The pack may, for example, comprise metal or plastic foil, such as a blister pack. The pack or dispenser device may be accompanied by instructions for administration. The pack or dispenser may also be accommodated by a notice associated with the container in a form prescribed by a governmental agency regulating the manufacture, use or sale of pharmaceuticals, which notice is reflective of approval by the agency of the form of the compositions or human or veterinary administration. Such notice, for example, may be of labeling approved by the U.S. Food and Drug Administration for prescription drugs or of an approved product insert. Compositions comprising a preparation of the invention formulated in a compatible pharmaceutical carrier may also be prepared, placed in an appropriate container, and labeled for treatment of an indicated condition, as is further detailed above.

The vectors of the present invention may be administered with additional ingredients which may improve the uptake of the nucleic acid construct by the cells,

expression of the chimeric polypeptide by the nucleic acid construct in the cells, or the activity of the expressed chimeric polypeptide.

For example, the uptake of adenoviral vectors into EC cells can be enhanced by treating the vectors with engineered antibodies or small peptides. Such "adenobody" treatment, was shown effective in directing adenovirus constructs to EGF receptors on cells (Watkins et al 1997, Gene Therapy 4:1004-1012). In addition, Nicklin et al have shown that a small peptide, isolated via phage display, increased specificity and efficiency of vectors in endothelial cells and decreased the expression in liver cells in culture (Nicklin et al 2000, Circulation 102:231-237). In a recent study, an FGF retargeted adenoviral vector reduced the toxicity of tk in mice (Printz et al 2000, Human Gene Therapy 11:191-204).

Low dose radiation has been shown to cause breaks in DNA strands primarily in the G2/M phase, cell membrane damage enhancing the bystander effect, and thus may potentiate other cytotoxic and anti-neoplastic therapies, when administered in combination. Vascular endothelial cells may be particularly suitable to such combination, or adjunct, therapies, since it has been demonstrated that low dose radiation specifically targets the apoptotic system of the microvascular endothelial cells (Kolesnick et al., Oncogene 2003; 22:5897-906). Angiostatin has been shown to potentiate the therapeutic effects of low dose radiation (Gorski et al. Can Res 1998;58:5686-89). However, the effects of radiation are still poorly understood, since irradiation has also been shown to increase pro-angiogenic "tissue repair factors" (Itasaka et al., Am Assoc Canc Res, 2003; abstract 115). Similarly, certain chemotherapeutic agents have been shown to activate specific cytotoxic and apoptotic pathways [doxorubicin, cisplatin and mitomycin C induce accumulation of Fas receptor, FADD, and other proapoptotic signals in the FADD/MORT-1 pathway (Micheau et al., BBRC 1999 256:603-07)].

For example International Application WO/2008/132729 teaches combined doxorubicin and AdPPE-1 (3x)-Fas-c chimera construct administration in endothelial cells (BAEC). Thus, the viral vectors and the pharmaceutical compositions comprising same of the present invention can be used to treat malignant gliomas alone or in combination with one or more other established or experimental therapeutic regimen for such disorders. Therapeutic regimen for treatment of malignant gliomas suitable for

combination with the viral vectors of the present invention include, but are not limited to chemotherapy, radiotherapy, phototherapy and photodynamic therapy, surgery, nutritional therapy, ablative therapy, combined radiotherapy and chemotherapy, brachiotherapy, proton beam therapy, immunotherapy, cellular therapy and photon beam radiosurgical therapy.

Anti-cancer drugs that can be co-administered with the compounds of the invention include, but are not limited to Acivicin; Aclarubicin; Acodazole Hydrochloride; Acronine; Adriamycin; Adozelesin; Aldesleukin; Altretamine; Ambomycin; Ametantrone Acetate; Aminoglutethimide; Amsacrine; Anastrozole; Anthramycin; Asparaginase; Asperlin; Azacitidine; Azetepa; Azotomycin; Batimastat; Benzodepa; Bicalutamide; Bisantrene Hydrochloride; Bisnafide Dimesylate; Bizelesin; Bleomycin Sulfate; Brequinar Sodium; Bropirimine; Busulfan; Cactinomycin; Calusterone; Caracemide; Carbetimer; Carboplatin; Carmustine; Carubicin Hydrochloride; Carzelesin; Cedefingol; Chlorambucil; Cirolemycin; Cisplatin; Cladribine; Crisnatol Mesylate; Cyclophosphamide; Cytarabine; Dacarbazine; Dactinomycin; Daunorubicin Hydrochloride; Decitabine; Dexormaplatin; Dezaguanine; Dezaguanine Mesylate; Diaziquone; Docetaxel; Doxorubicin; Doxorubicin Hydrochloride; Droloxifene; Droloxifene Citrate; Dromostanolone Propionate; Duazomycin; Edatrexate; Eflornithine Hydrochloride; Elsamitrucin; Enloplatin; Enpromate; Epipropidine; Epirubicin Hydrochloride; Erbulozole; Esorubicin Hydrochloride; Estramustine; Estramustine Phosphate Sodium; Etanidazole; Etoposide; Etoposide Phosphate; Etoprine; Fadrozole Hydrochloride; Fazarabine; Fenretinide; Floxuridine; Fludarabine Phosphate; Fluorouracil; Flurocitabine; Fosquidone; Fostriecin Sodium; Gemcitabine; Gemcitabine Hydrochloride; Hydroxyurea; Idarubicin Hydrochloride; Ifosfamide; Ilmofosine; Interferon Alfa-2a; Interferon Alfa-2b; Interferon Alfa-n1; Interferon Alfa-n3; Interferon Beta- I a; Interferon Gamma- I b; Iproplatin; Irinotecan Hydrochloride; Lanreotide Acetate; Letrozole; Leuprolide Acetate; Liarozole Hydrochloride; Lometrexol Sodium; Lomustine; Losoxantrone Hydrochloride; Masoprocol; Maytansine; Mechlorethamine Hydrochloride; Megestrol Acetate; Melengestrol Acetate; Melphalan; Menogaril; Mercaptopurine; Methotrexate; Methotrexate Sodium; Metoprine; Meturedepa; Mitindomide; Mitocarcin; Mitocromin; Mitogillin; Mitomalcin; Mitomycin; Mitosper; Mitotane; Mitoxantrone Hydrochloride;

Mycophenolic Acid; Nocodazole; Nogalamycin; Ormaplatin; Oxisuran; Paclitaxel; Pegaspargase; Peliomycin; Pentamustine; Peplomycin Sulfate; Perfosfamide; Pipobroman; Piposulfan; Piroxantrone Hydrochloride; Plicamycin; Plomestane; Porfimer Sodium; Porfiromycin; Prednimustine; Procarbazine Hydrochloride; Puromycin; Puromycin Hydrochloride; Pyrazofurin; Riboprine; Rogletimide; Safingol; Safingol Hydrochloride; Semustine; Simtrazene; Sparfosate Sodium; Sparsomycin; Spirogermanium Hydrochloride; Spiromustine; Spiroplatin; Streptonigrin; Streptozocin; Sulofenur; Talisomycin; Taxol; Tecogalan Sodium; Tegafur; Teloxantrone Hydrochloride; Temoporfin; Teniposide; Teroxirone; Testolactone; Thiamiprine; Thioguanine; Thiotepa; Tiazofuirin; Tirapazamine; Topotecan Hydrochloride; Toremifene Citrate; Trestolone Acetate; Triciribine Phosphate; Trimetrexate; Temozolomide (Temodar™); Bevacizumab, Dorafinib, Sorafenib (Nexavar™), Sunitinib (Sutent™), Vandetanib (ZD6474; Zactima™), Pazopanib (GW786034), and Vatalanib (PTK787), Trimetrexate Glucuronate; Triptorelin; Tubulozole Hydrochloride; Uracil Mustard; Uredepa; Vapreotide; Verteporfin; Vinblastine Sulfate; Vincristine Sulfate; Vindesine; Vindesine Sulfate; Vinepidine Sulfate; Vinglycinate Sulfate; Vinleurosine Sulfate; Vinorelbine Tartrate; Vinrosidine Sulfate; Vinzolidine Sulfate; Vorozole; Zeniplatin; Zinostatin; Zorubicin Hydrochloride. Additional antineoplastic agents include those disclosed in Chapter 52, Antineoplastic Agents (Paul Calabresi and Bruce A. Chabner), and the introduction thereto, 1202-1263, of Goodman and Gilman's "The Pharmacological Basis of Therapeutics", Eighth Edition, 1990, McGraw-Hill, Inc. (Health Professions Division).

The viral vectors of the present invention may also be administered with an agent that enhances expression of transgenes in adenoviral-mediated transient expression. For example International Application WO/2008/132729 teaches administration of a corticosteroid (e.g. dexamethasone and/or N-Acetyl Cysteine (NAC) prior to AdPPE-1 (3x)-Fas-c chimera construct administration.

In addition, the viral vectors of the present invention may also be administered with an agent that brings about transient immunosuppression, such as for example deoxyspergualin (DSG) or cyclophosphamide (see for example Smith et al., Gene Ther. 1996 Jun;3(6):496-502) in order to allow for repetitive dosing.

It is expected that during the life of a patent maturing from this application many relevant chemotherapeutic agents will be developed and the scope of the term chemotherapeutic agent is intended to include all such new technologies *a priori*.

As used herein the term "about" refers to ± 10 %.

The terms "comprises", "comprising", "includes", "including", "having" and their conjugates mean "including but not limited to".

The term "consisting of means "including and limited to".

The term "consisting essentially of" means that the composition, method or structure may include additional ingredients, steps and/or parts, but only if the additional ingredients, steps and/or parts do not materially alter the basic and novel characteristics of the claimed composition, method or structure.

As used herein, the singular form "a", "an" and "the" include plural references unless the context clearly dictates otherwise. For example, the term "a compound" or "at least one compound" may include a plurality of compounds, including mixtures thereof.

Throughout this application, various embodiments of this invention may be presented in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the invention. Accordingly, the description of a range should be considered to have specifically disclosed all the possible subranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed subranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

Whenever a numerical range is indicated herein, it is meant to include any cited numeral (fractional or integral) within the indicated range. The phrases "ranging/ranges between" a first indicate number and a second indicate number and "ranging/ranges from" a first indicate number "to" a second indicate number are used herein interchangeably and are meant to include the first and second indicated numbers and all the fractional and integral numerals therebetween.

As used herein the term "method" refers to manners, means, techniques and procedures for accomplishing a given task including, but not limited to, those manners, means, techniques and procedures either known to, or readily developed from known manners, means, techniques and procedures by practitioners of the chemical, pharmacological, biological, biochemical and medical arts.

As used herein, the term "treating" includes abrogating, substantially inhibiting, slowing or reversing the progression of a condition, substantially ameliorating clinical or aesthetical symptoms of a condition or substantially preventing the appearance of clinical or aesthetical symptoms of a condition.

It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable subcombination or as suitable in any other described embodiment of the invention. Certain features described in the context of various embodiments are not to be considered essential features of those embodiments, unless the embodiment is inoperative without those elements.

Various embodiments and aspects of the present invention as delineated hereinabove and as claimed in the claims section below find experimental support in the following examples.

EXAMPLES

Reference is now made to the following examples, which together with the above descriptions illustrate some embodiments of the invention in a non limiting fashion.

Generally, the nomenclature used herein and the laboratory procedures utilized in the present invention include molecular, biochemical, microbiological and recombinant DNA techniques. Such techniques are thoroughly explained in the literature. See, for example, "Molecular Cloning: A laboratory Manual" Sambrook et al., (1989); "Current Protocols in Molecular Biology" Volumes I-III Ausubel, R. M., ed. (1994); Ausubel et al., "Current Protocols in Molecular Biology", John Wiley and Sons, Baltimore, Maryland (1989); Perbal, "A Practical Guide to Molecular Cloning", John Wiley & Sons, New York (1988); Watson et al., "Recombinant DNA", Scientific

American Books, New York; Birren et al. (eds) "Genome Analysis: A Laboratory Manual Series", Vols. 1-4, Cold Spring Harbor Laboratory Press, New York (1998); methodologies as set forth in U.S. Pat. Nos. 4,666,828; 4,683,202; 4,801,531; 5,192,659 and 5,272,057; "Cell Biology: A Laboratory Handbook", Volumes I-III Cellis, J. E., ed. (1994); "Culture of Animal Cells - A Manual of Basic Technique" by Freshney, Wiley-Liss, N. Y. (1994), Third Edition; "Current Protocols in Immunology" Volumes I-III Coligan J. E., ed. (1994); Stites et al. (eds), "Basic and Clinical Immunology" (8th Edition), Appleton & Lange, Norwalk, CT (1994); Mishell and Shiigi (eds), "Selected Methods in Cellular Immunology", W. H. Freeman and Co., New York (1980); available immunoassays are extensively described in the patent and scientific literature, see, for example, U.S. Pat. Nos. 3,791,932; 3,839,153; 3,850,752; 3,850,578; 3,853,987; 3,867,517; 3,879,262; 3,901,654; 3,935,074; 3,984,533; 3,996,345; 4,034,074; 4,098,876; 4,879,219; 5,011,771 and 5,281,521; "Oligonucleotide Synthesis" Gait, M. J., ed. (1984); "Nucleic Acid Hybridization" Hames, B. D., and Higgins S. J., eds. (1985); "Transcription and Translation" Hames, B. D., and Higgins S. J., eds. (1984); "Animal Cell Culture" Freshney, R. I., ed. (1986); "Immobilized Cells and Enzymes" IRL Press, (1986); "A Practical Guide to Molecular Cloning" Perbal, B., (1984) and "Methods in Enzymology" Vol. 1-317, Academic Press; "PCR Protocols: A Guide To Methods And Applications", Academic Press, San Diego, CA (1990); Marshak et al., "Strategies for Protein Purification and Characterization - A Laboratory Course Manual" CSHL Press (1996); all of which are incorporated by reference as if fully set forth herein. Other general references are provided throughout this document. The procedures therein are believed to be well known in the art and are provided for the convenience of the reader. All the information contained therein is incorporated herein by reference.

EXAMPLE 1

Effect of VB-111 in an animal model of glioblastoma

MATERIALS AND METHODS

Construction and cloning of the viral vector: The vector was constructed using a backbone containing most of the genome of adenovirus type 5, as well as partial homology to an adaptor plasmid, which enables recombination.

The E1 early transcriptional unit was deleted from the backbone plasmid, and further modified by deleting the pWE25 and the Amp resistance selection marker site.

The adaptor plasmid, containing sequences of the Ad5, CMV promoter, MCS, and SV40 polyA was modified to delete deleting the CMV promoter, and the PPE-1 promoter and Fas-c fragment were inserted by restriction digestion.

The modified PPE-1 promoter (PPE-1-3X, SEQ ID NO: 12) and the Fas-chimera transgene (Fas-c, SEQ ID NO: 4) were utilized for construction of the adenoviral vector. The PPE-1- (3X)-Fas-c element (2115bp) was constructed from the PPE-1- (3X)-luc element. This element contains the 1.4kb of the murine preproendothelin PPE-1-(3X) promoter, the Luciferase gene, the SV40 polyA site and the first intron of the murine ET-1 gene, originated from the pEL8 plasmid (8848bp) used by Harats et al (Harats D. et al., JCI, 1995). The PPE-3-Luc cassette was extracted from the pEL8 plasmid using the BamHI restriction enzyme. The Luciferase gene was substituted by the Fas-c gene [composed of the extra cellular and intra membranal domains of the human TNF-R1 (Tumor Necrosis Factor Receptor 1, SEQ ID NO: 2) and of the Fas (p55) intracellular domain (SEQ ID NO: 3) (Boldin et al, JBC, 1995)] to obtain the PPE-1-3x-Fas-c cassette.

PPE-1(3x)-Fas-c Plasmid - The cassette was further introduced into the backbone plasmid by restriction digestion, resulting with the PPE-1(3x)-Fas-c plasmid.

Adaptor-PPE-1(3x)-Fas-c Plasmid - The PPE-1-3x-Fas-c element was extracted from the first generation construct PPE-1-3x-Fas-c plasmid, and was amplified with designated PCR primers introducing SnaB1 and EcoR1 restriction sites at the 5'-and-3'-end respectively. These sites were used to clone the PPE-Fas-c fragment into the adaptor plasmid digested with SnaB1 and EcoR1, resulting in the adaptor-PPE-1-3x-Fas-c used for transfection of the host cells (for example, PER.C6 cells).

Xenografts: 10^6 U87 human glioma tumor cells expressing a biofluorescent/bioluminescent protein (luciferase) were implanted intracranially in the striatum of athymic nude rats (NxGen BioSciences). Animals were anesthesized with isoflurane prior to implantation. Briefly, glioma tumor cells expressing luciferase were implanted intracranially in the striatum of athymic nude rats (NxGen BioSciences). Animals were anesthesized with isoflurane prior to implantation and placed secured on a Just for Mice Stereotaxic (Stoelting) apparatus. A 1cm incision was made in the scalp

and the bregma identified. A small burr hole was made in the cranium using a mounted Micromotor drill (Stoelting) at the identified position (1 mm forward and 4 mm lateral of the bregma). $1x10^6$ cells in a volume of 5ul were injected into the caudate over 5 minutes using a Quintessential Stereotaxic Injector (Stoelting) containing a 10ul Hamilton syringe mounted to the stereotaxic device to assure appropriate placement. Animals were imaged following isofluorane sedation using an IVIS chemiluminescence system. The fluorescence/bioluminescence of these tumors are typically detectable within 7-10 days due to rapid growth and high expression of the marker. An alternative imaging modality, i.e. MRI, was also utilized to assist with tumor visualization. Animals received chemical anesthesia for MRI imaging. Once tumor establishment and growth was detected (variable depending on the rate of growth for the respective line), rats were treated with VB-111. The total dose was 10^{11} vp in a volume of 100 ul. Control groups received vehicle only. Animals were monitored for tumor growth or response through non-invasive imaging of fluorescence/luminescence - see Figure 1 for a typical treatment and monitoring regimen.

Experimental protocol: Two types of tumor growth experiments were performed, tumor growth inhibition (TGI) and tumor growth delay (TGD). The TGI experiment was terminated when the animals showed clinical signs of tumor development i.e. become dull, listless, or moribund, usually prior to 4 weeks post-implantation, as median survival of 28–29 days has been typically observed in prior studies. Upon termination, all rats were weighed, sacrificed, and their tumors excised. For a TGD experiment, animals were sacrificed on an individual basis and tumor-related parameters (e.g. size) were measured. The average day of sacrifice was determined for all groups, and the tumor growth delay (TGD) for each treatment group compared to the control group was calculated.

MRI: Magnetic resonance imaging has shown to be capable of demonstrating early changes within the tumor vasculature without any invasive measures. It is possible to generate maps of blood volume and blood flow, vascular permeability, white matter tracks, and apparent diffusion coefficient. These parameters offer clinically relevant physiological information that could help to characterize, stage tumor growth, and evaluate treatment efficacy. MRI was performed on a Bruker 7 Tesla scanner. Blood flow and blood volume was measured using dynamic contrast enhanced imaging

technique following a bolus of gadopentetate-dimeglumine (GdDTPA). White matter tracks and apparent diffusion coefficient was measured using diffusion tensor imaging. Vascular permeability was measured using T1-weighted MRI obtained prior to and following contrast (Gd-DTPA) injection. For dynamic contrast enhanced MRI, single-shot gradient echo planar imaging (EPI) was used, resolution at 0.27x0.27x0.5 mm, 5 slices (no gap), matrix = 96x96, field of view = 25.6x25.6 mm, repetition time TR = 0.5 s, echo time TE = 20 ms. For diffusion tensor imaging, single-shot spin-echo echo-planar imaging was used, resolution be 0.27x0.27x0.5 mm, 15 slices (no gap), matrix = 96x96, field of view = 25.6x25.6 mm, repetition time TR = 2 s, echo time TE = 40 ms, b value = 0 s/mm2, and 6 diffusion direction of b = 1100 s/mm2. For T1-weighted MRI, conventional acquisition was used, resolution 0.27x0.27x0.5 mm, 15 slices (no gap), matrix = 96x96, field of view = 25.6x25.6 mm, repetition time TR = 0.5 s, echo time TE = 20 ms. The number of slices analyzed adequately covered the entire tumor region and roughly cover the entire cerebrum.

The maps described above were calculated using standard software. For permeability maps, the maps were processed using codes in Matlab to obtain maps of Ktrans (corresponding roughly to wash-in rates of the contrastagent. Ktrans can be influenced by flow, or by permeability, or both. In high-flow organs such as the brain, flow limitations are not usually a concern, but the blood-brain barrier severely limits permeability unless it is disrupted by disease. Even in such a state, Ktrans does not fully correspond to permeability, but it is related rather to the permeability*surface area product of the capillary bed (in nonflow-limited situations).

Histopathology: To further characterize changes at the microscopic level, animals were sacrificed by cardiac puncture, followed by intracardiac saline and formalin irrigation. Necropsy was performed, and brains underwent standard H&E processing. The number of vessels per medium power field were counted.

RESULTS

As illustrated in Figure 2, animal death began at approximately day 32. The median survival for the control group was 39.25 (+/-3.8) days and for the treatment group was 45.8 days.

Luciferase activity: Luciferase activity was followed by ip injection of luciferin and optical imaging on a Xenogen system. The region of interest was generated

automatically without manipulation and total photons recorded. As illustrated in Figure 3, a clear separation in activity was observed at day 33 with a mean (SD) in the control group of 9.7 (2.9) x 10^6 versus 5.3 (6.2) x 10^5 in the treated group.

MRI: As illustrated in Figure 4, mean of the maximum diameters of tumors in the VB111 treated group was smaller than those for controls.

EXAMPLE 2

Effect of VB-111 in glioblastoma patients

Treatment plan: VB-111 will be administered as a single intravenous infusion of $1x10^{12}$ or $3x10^{12}$ Dose.

Study consists of 2 cohorts.

Cohort 1a: 3-6 subjects, safety ($1x10^{12}$ VPs);

Cohort 1b: 3-6 subjects, safety ($3x10^{12}$ VPs);

Cohort 2: 23-26 subjects, efficacy & safety ($3x10^{12}$ VPs)

Cohort 1a & Cohort 1b: Study subjects will be enrolled sequentially. The first subject of each cohort will be treated and observed for 14 days; if no dose-limiting toxicities (DLT) are observed, then another two subjects will be recruited to that cohort. All six subjects of cohort 1 need to be observed for a minimum of 14 days and show no DLT for the start of the next cohort. If a DLT is observed in one patient in a specific dosing cohort, three additional subjects will be accrued for the same dosing cohort, and safety will be reassessed. If DLT is confirmed, i.e. two out of six subjects experience a DLT, then the study will be discontinued. All subjects in cohorts 1a and 1b must be observed for a minimum of 28 days prior to commencing cohort 2.

The study will be conducted according to the Simon's 2 step method. A total of 29 subjects are anticipated to enroll at the 3x1012 VP dose level (3-6 from cohort 2 and 23-26 in cohort 3). Step one will include the first 10 patients at this dose level. A subject will be considered to have a response if s/he has either 6 months progression free survival or at least a partial tumor response according to Rano criteria. An interim analysis will be performed after 10 patients from cohorts 2 and 3 have completed the study. If 2 or more responses occur in the step 1 subjects, step 2 will commence, enrolling an additional 19 subjects.

The following study stopping rule for halting the study will be applied:

A) If 3 out of 6 (or 5 out of 9 or 6 out of 12) subjects in the cohort 1a & 1b experience drug related DLT.

B) If 2 out of the subjects in cohort 1a experience a DLT.

C) If ANY death occurs within two weeks after the product is given, except death due to disease progression or clearly unrelated to study drug. Enrollment will be temporarily suspended for an ad hoc, emergency IDMC meeting to review the case and make a recommendation if enrolment can be reinstated.

When safety end point is achieved for cohorts 1a and 1b (day 28), eligible subjects will be enrolled into the study and commence cohort 2. It is expected that 26 GBM subjects will be enrolled into cohort 2 for additional safety and efficacy endpoints (or 23 patients if 6 were enrolled in cohort 2).

One dose of VB 111 ($1x10^{12}$, $3x10^{12}$ or $1x10^{13}$ VPs) administered within 3 weeks after the screening visit. Subjects will return to the clinic for follow up visits at days 4, 7, 14 and 28 and on monthly schedule on days 56, 84, 112, 140 and 168 if no disease progression has occurred prior to the visit.

On days 7, 14, 28, 56, 112 and 168, subjects will be assessed for response using contrast and non-contrast brain magnetic resonance imaging (MRI) with assessment based on the RANO criteria.

The post study follow up period will include telephone contacts every two months after day 168 , early termination, or disease progression (whichever occurs earlier) to follow up on survival. Follow up will continue until patient expires. The study duration is 7 months (6 months post dose), thereafter the subjects will be followed by telephone for survival data every two months. Surveillance MRIs will be performed every 2 months until 1 year, and then every 3 months until 2 years post dosing (or until progression).

Population: Up to 35 eligible subjects (cohort 1 & cohort 2) with relapsed GBM.

Main inclusion criteria:

1. Ability to understand and the willingness to sign a written informed consent document.

2. Subjects ≥18 years of age

3. Subjects must have histologically confirmed diagnosis of primary malignant glioma (glioblastoma multiforme, gliosarcoma or anaplastic astrocytoma, or anaplastic oligodendroglioma). Subjects with recurrent disease whose diagnostic pathology confirmed malignant glioma (glioblastoma multiforme, gliosarcoma or anaplastic astrocytoma, or anaplastic oligodendroglioma) will not need re-biopsy.

4. Evidence of measurable recurrent or residual primary CNS neoplasm on contrast-enhanced MRI, unless medically contraindicated (CT scan will then be used).

5. Measurable disease by RANO criteria.

6. Avastin and anti-angiogenic (TKIs such as sunitinib or sorafenib) naive subjects.

7. Disease progression or recurrence following standard of care treatment with radiotherapy and temozolomide.

8. An interval of at least 4 weeks between prior surgical resection and study enrolment.

9. Completed radiotherapy ≥90 days before study starts.

10. An interval of at least 12 weeks between prior radiotherapy or at least 4 weeks from prior chemotherapy, and enrolment on this protocol.

11. Recovered to Grade 1 or less from the toxic effects of any earlier intervention.

12. Karnofsky performance status ≥ 60%.

13. Adequate renal, liver, and bone marrow function according to the following criteria:

- Absolute neutrophil count ≥1500/mcL
- Platelets ≥125 000/mcL
- Total bilirubin within upper limit of normal (ULN)
- Aspartate aminotransferase (AST) ≤ 2.5 X institutional ULN
- Creatinine within normal limits or creatinine clearance ≥ 50 mL/min for patients with creatinine levels above normal limits.
- PT, PTT greater than 80% of the lower normal limits.

13. Subjects must be treated with corticosteroids on day 0. Subjects will be on a stable dose for *1 week* prior to entry, and is not anticipated to require increase in steroid dose throughout the study.

14. No evidence of haemorrhage on the baseline MRI or CT scan.

15. Males and Females of childbearing potential must utilize, throughout the course of the trial a standard contraception method.

Cohort 1a and 1b additional eligibility criteria: Subjects without major mass effect of Tumor.

Main exclusion criteria:

1. Pregnant or breastfeeding subjects

2. Co-medication that may interfere with study results; e.g. immuno-suppressive agents other than corticosteroids

3. Active Infection.

4. Greater than 3 prior recurrences.

5. Evidence of CNS haemorrhage CTCAE on baseline MRI or CT scan.

6. Requires therapeutic anti-coagulation.

7. Prior anti-angiogenic therapy including VEGF-sequestering agents (e.g. bevicizumab, aflibercept) or VEGF inhibitors (e.g. cedirinib, pazopanib, sunitinib, sorafenib).

8. Prior stereotactic radiotherapy.

9. Known active secondary malignancy.

10. Expected to have surgery during study period.

11. Subjects, who suffered from an acute cardiac event within the last 12 months.

12. Subjects with active vascular disease, either myocardial or peripheral

13. Subjects with proliferative and/or vascular retinopathy

14. Subjects with known liver disease (alcoholic, drug/toxin induced, genetic, or autoimmune).

15. Subjects with known CNS metastatic disease (other than GBM).

16. Subjets with known active second malignancy.

17. Subjects testing positive to one of the following viruses: HIV, HBV and HCV

18. Subjects that have undergone major surgery within the last 4 weeks before enrolment.

19. Subjects may not have received any other investigational agent within 4 weeks before enrolment.

20. Uncontrolled intercurrent illness including, but not limited to ongoing or active infection, symptomatic congestive heart failure, unstable angina pectoris, cardiac arrhythmia, or psychiatric illness/social situations that would limit compliance with study requirements

Test drug and formulation: VB-111 (SEQ ID NO: 9 or 10) is formulated as a sterile vector solution. The solution is supplied frozen (below -65°C), in single use, plastic screw cap vials. Each vial contains 1.1 mL of vector solution at a viral titer of $1x10^{12}$ VP/ml. The vector solution should be thawed and maintained on ice during dilution and handling for a maximum of 3 hours.

Dosage and administration: Prior to infusion, the solution for injection should be brought to room temperature Maximum time for drug in saline is 1 hour at room temperature. The vials should be opened in a biological safety cabinet and injected into 4 mL of normal saline for infusion for each 1 ml of drug. ie; for the $1x10^{12}$ viral particle (VP) dose 1ml of drug+4ml of saline, for the $3x10^{12}$ VP dose 3ml of drug+12ml of saline. A single infusion of approximately 5 mL/15ml of diluted VB-111 should be administered 1 mL/minute.

Safety Evaluations: Adverse events will be recorded on an ongoing basis and up to 2 months following the administration of the test drug. Adverse events will be assessed for seriousness, relatedness to study drug, and severity (according to CTCAE 4.0). Vital signs will be recorded at screening, prior to dosing, 30, 60 minutes, 4 and 6 hours after dosing and at all patient visits. A physical examination will be conducted at screening, days 14, 28, 56, 84, 112, 140, 168 and at the end of the study. A 12 lead ECG will be obtained at screening, prior to dosing and on days 28 and 168 (or ET). Safety laboratory assessment (blood haematology and chemistry, urine analysis) will be conducted at screening, prior to dosing, and at all patient visits, starting from day 4±1 to 168 ±7.

Distribution: Blood and urine samples will be collected prior to dosing, at the end of the infusion, days 4, 7, 14, 28 and 56, for evaluation of levels of virus DNA (in whole blood and urine) and its transgene (in whole blood).

Tumor response: Tumor response will be assessed at screening, prior to dosing, days 14, 28, 56, 112, 140 and 168, and then every 2 months for 1 year and every 3 months for 2 years post dosing, using contrast and non-contrast brain magnetic resonance imaging (MRI) with assessment based on the RANO criteria, until progression of disease (local and central independent radiology review). For patients who do not progress or die, PFS will be censored at the time of initiation of alternative anticancer therapy, date of last radiologic assessment, or time of last contact.

Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims.

All publications, patents and patent applications mentioned in this specification are herein incorporated in their entirety by reference into the specification, to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated herein by reference. In addition, citation or identification of any reference in this application shall not be construed as an admission that such reference is available as prior art to the present invention. To the extent that section headings are used, they should not be construed as necessarily limiting.

WHAT IS CLAIMED IS:

1. Use of a viral vector for preparation of a medicament for the treatment of a malignant glioma in a subject in need thereof, said viral vector comprising:
(i) a first polynucleotide sequence encoding a Fas-chimera (Fas-c); and
(ii) a second polynucleotide sequence encoding an endothelial cell-specific promoter or a periendothelial cell-specific promoter,
wherein the second polynucleotide sequence is operably linked to the first polynucleotide sequence.

2. The use of claim 1, wherein said first polynucleotide comprises (i) the sequence set forth in SEQ ID NO: 2 and the sequence set forth in SEQ ID NO: 3 or
(ii) the sequence set forth in SEQ ID NO: 4.

3. The use of any one of claims 1 or 2, wherein said promoter comprises the sequence set forth in SEQ ID NO: 12.

4. The use of any one of claims 1 or 2, wherein said promoter comprises the sequence set forth in SEQ ID NO: 13.

5. The use of any one of claims 1-4, wherein the viral vector is an adenoviral vector.

6. The use of claim 5, wherein said adenoviral vector is a non-replicating adenoviral vector.

7. The use of claim 5, wherein said adenoviral vector is an adenovirus serotype 5 vector.

8. The use of any one of claims 1 or 2 and 5-7, wherein said promoter comprises at least one copy of the sequence set forth in SEQ ID NO: 6 or the complementary sequence thereof.

9. The use of claim 8, wherein said promoter comprises at least two copies of the sequence set forth in SEQ ID NO: 6 or the complementary sequence thereof.

10. The use of any one of claims 1 or 2 and 5-9, wherein said promoter comprises the sequence set forth in SEQ ID NO: 8 or the complementary sequence thereof.

11. The use of any one of claims 1 or 2 and 5-7, wherein said promoter comprises the sequence set forth in SEQ ID NO: 7 or the complementary sequence thereof.

12. The use of any one of claims 1 or 2 and 5-11, wherein said promoter comprises the hypoxia response element (HRE) set forth in SEQ ID NO: 5.

13. The use of any one of claims 1-12, wherein the viral vector consists of the sequence set forth in SEQ ID NO: 9 or SEQ ID NO: 10.

14. The use of any one of claims 1-13, wherein the malignant glioma is selected from the group consisting of glioblastoma, astrocytoma, oligodendroglioma, and ependymoma, and juvenile pilocystic astrocytoma.

15. The use of any one of claims 1-14, wherein said viral vector is for intravenous administration.

16. The use of the any one of claims 1-14, wherein said viral vector is for local administration.

17. The use of the any one of claims 1-14, wherein said viral vector is for systemic administration.

18. The use of any one of claims 1-17, wherein said viral vector is for administration in at least two doses.

19. The use of one of claims 1-17, wherein said viral vector is for administration in at least three doses.

20. The use of claim 1, wherein said first polynucleotide comprises the sequence set forth in SEQ ID NO: 4, said second polynucleotide comprises the sequence set forth in SEQ ID NO: 7, said viral vector is a non-replicating adenovirus serotype 5 vector, said malignant glioma is gliobastoma, and said viral vector is formulated for intravenous administration.

21. A viral vector for use in preparation of a medicament for the treatment of a malignant glioma in a subject in need thereof, said viral vector comprising:
(i) a first polynucleotide sequence encoding a Fas-chimera (Fas-c); and
(ii) a second polynucleotide sequence encoding an endothelial cell-specific promoter or a periendothelial cell-specific promoter,
wherein the second polynucleotide sequence is operably linked to the first polynucleotide sequence.

22. A viral vector for use in the treatment of a malignant glioma in a subject in need thereof, said viral vector comprising:
(i) a first polynucleotide sequence encoding a Fas-chimera (Fas-c); and (ii) a second polynucleotide sequence encoding an endothelial cell-specific promoter or a periendothelial cell-specific promoter, wherein the second polynucleotide sequence is operably linked to the first polynucleotide sequence.

23. The viral vector for use of claim 21 or 22, wherein said first polynucleotide comprises (i) the sequence set forth in SEQ ID NO: 2 and the sequence set forth in SEQ ID NO: 3 or (ii) the sequence set forth in SEQ ID NO: 4.

24. The viral vector for use of any one of claims 21-23, wherein said promoter comprises the sequence set forth in SEQ ID NO: 12.

25. The viral vector for use of any one of claims 21-23, wherein said promoter comprises the sequence set forth in SEQ ID NO: 13.

26. The viral vector for use of any one of claims 21-25, wherein the viral vector is an adenoviral vector.

27. The viral vector for use of claim 26, wherein said adenoviral vector is a non-replicating adenoviral vector.

28. The viral vector for use of claim 26, wherein said adenoviral vector is an adenovirus serotype 5 vector.

29. The viral vector for use of any one of claims 21-23 and 26-28, wherein said promoter comprises at least one copy of the sequence set forth in SEQ ID NO: 6 or the complementary sequence thereof.

30. The viral vector for use of claim 29, wherein said promoter comprises at least two copies of the sequence set forth in SEQ ID NO: 6 or the complementary sequence thereof.

31. The viral vector for use of any one of claims 21-23 and 26-30, wherein said promoter comprises the sequence set forth in SEQ ID NO: 8 or the complementary sequence thereof.

32. The viral vector for use of any one of claims 21-23 and 26-28, wherein said promoter comprises the sequence set forth in SEQ ID NO: 7 or the complementary sequence thereof.

33. The viral vector for use of any one of claims 21-23 and 26-32, wherein said promoter comprises the hypoxia response element (HRE) set forth in SEQ ID NO: 5.

34. The viral vector for use of any one of claims 21-33, wherein the viral vector consists of the sequence set forth in SEQ ID NO: 9 or SEQ ID NO: 10.

35. The viral vector for use of any one of claims 21-34, wherein the malignant glioma is selected from the group consisting of glioblastoma, astrocytoma, oligodendroglioma, and ependymoma, and juvenile pilocystic astrocytoma.

36. The viral vector for use of any one of claims 21-35, wherein said viral vector is for intravenous administration.

37. The viral vector for use of the any one of claims 21-35, wherein said viral vector is for local administration.

38. The viral vector for use of the any one of claims 21-35, wherein said viral vector is for systemic administration.

39. The viral vector for use of any one of claims 21-38, wherein said viral vector is for administration in at least two doses.

40. The viral vector for use of one of claims 21-38, wherein said viral vector is for administration in at least three doses.

41. The viral vector for use of claim 21 or claim 22, wherein said first polynucleotide comprises the sequence set forth in SEQ ID NO: 4, said second polynucleotide comprises the sequence set forth in SEQ ID NO: 7, said viral vector is a non-replicating adenovirus serotype 5 vector, said malignant glioma is gliobastoma, and said viral vector is formulated for intravenous administration.