Reovirus Clearance of Ras-mediated Neoplastic Cells From Mixed Cellular Compositions

FIELD OF THE INVENTION

The present invention relates to a method for removing ras-mediated neoplastic cells from mixed cellular compositions by infecting the mixed cellular compositions with reovirus which selectively lyse the ras-mediated neoplastic cells in the compositions.

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All of the above publications, patents and patent applications are herein incorporated by reference in their entirety to the same extent as if the disclosure of each

individual publication, patent application or patent was specifically and individually indicated to be incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

Normally, cell proliferation is regulated by both growth-promoting signals and growth-constraining signals. These two kinds of signals for each cell would normally strike a balance in a manner which reflects the need of the body for the particular cell. If a cell fails to respond to the growth-constraining signals or over-responds to the growth-promoting signals, it will proliferate abnormally fast (referred to as neoplastic cells) and may eventually develop into cancer, a malignant neoplasm.

Chemotherapy, a current method of treating cancer, is generally based on the fast-proliferating property of cancer cells. Since cancer cells proliferate rapidly, they are more sensitive to drugs which inhibit cellular proliferation. In theory, by carefully choosing the dosage of chemotherapeutic drugs, one can inhibit cancer cell proliferation without seriously damaging normal cells. However, some normal cells, such as hematopoietic stem cells, also proliferate rapidly. Therefore, any dosage which is harmful to cancer cells is often also harmful to the hematopoietic stem cells. On the other hand, if the dosage is not high enough to kill the cancer cells, there is the risk that the cancer would reappear shortly after chemotherapy is terminated.

Because it is hard to find a dosage which selectively kills cancer cells, high-dose chemotherapy followed by autologous hematopoietic progenitor stem cell transplantation has gained extensive application as a therapeutic approach in many cancers (see, for example, Winter, 1999; Nieto and Shpall, 1999). In this approach, a portion of the hematopoietic stem cells is removed from a cancer patient, and the patient is then treated with high-dose chemotherapy which is lethal to rapid-proliferating cells, such as cancer cells and hematopoietic stem cells. Subsequently, the patient receives transplantation of autologous hematopoietic stem cells which have been previously removed from the same patient to regenerate the hematopoietic system.

A serious drawback of this therapy is that when the hematopoietic progenitor stem cells are removed from the patients, they are often contaminated with cancer cells. This is especially a problem when the patient has a cancer of the hematopoietic origin, but patients with a solid tumor may also suffer from contamination of the hematopoietic stem cells, particularly if the solid tumor has metastasized. As a result, when the removed cells are transplanted back to reestablish the hematopoietic system, some cancer cells may also be placed back to the cancer patient where they may proliferate again and contribute to cancer recurrence. It is therefore desirable to purge the autografts before transplantation..

Several methods have been employed to purge autographs (Spyridonidis et al, 1998; Bensinger 1998). The autograph can be treated with chemotherapy to kill the contaminating neoplastic cells *in vitro*. However, as discussed above, it is hard to find a dosage for the chemotherapeutic drug which selectively kills neoplastic cells or cancer cells but leaves normal hematopoietic stem cells intact. Autographs can also be treated with a toxin conjugated to antibodies which recognize an antigen that is specific to the neoplastic cells, but such a tumor specific antigen does not always exist.

It is also possible to separate stem cells from the other cells based on a stem cell specific surface marker (CD34) by using flow cytometry, affinity columns or magnetic beads. However, by selecting only certain hematopoietic cells, e.g., the $CD34^+$ cells, other hematopoietic cells such as T cells, B cells, monocytes and natural killer cells are also eliminated, and immune recovery may be delayed (Bensinger, 1998). This method also results in the loss of about half the $CD34^+$ cells and retention of some contaminating cancer cells (Spyridonidis et al., 1998). Therefore, there remains a need for a highly selective method with a reasonable yield to purge autografts which may contain neoplastic cells.

SUMMARY OF THE INVENTION

The present invention is directed to a method for removing ras-mediated neoplastic cells from mixed cellular compositions by infecting the mixed cellular compositions with reovirus which selectively lyses ras-mediated neoplastic cells. Since many neoplastic cells are associated with an activated ras pathway, the present invention can be used to remove the contaminating or spontaneous neoplastic cells from a wide variety of mixed cellular compositions.

Accordingly, a first aspect of the present invention provides a method to remove ras-mediated neoplastic cells from a cellular composition suspected of containing such neoplastic cells, which method comprises contacting the cellular composition *in vitro* with reovirus under conditions which result in oncolysis of the ras-mediated neoplastic cells, wherein the cellular composition comprises hematopoietic stem cells.

In one embodiment, a cellular composition comprising hematopoietic stem cells is treated to remove ras-mediated neoplastic cells which exist in the cellular composition as contaminating or spontaneously occurring neoplastic cells. Since reovirus is highly selective and lytically infects ras-mediated cells only, this method does not affect the ability of hematopoietic stem cells to differentiate and reconstitute the hematopoietic system. The method may be used to purge hematopoietic stem cells from bone marrow or blood. The hematopoietic stem cells may be autologous, allogeneic or xenogeneic.

In another embodiment, reovirus may be used to remove ras-mediated neoplastic cells from a tissue or organ transplant prior to transplantation. Because this method can be applied without regard to the type or age of the transplant or of the ras-mediated cell, and because the reovirus is essentially harmless to normal cells and tissues, this method may be used as a routine practice to "clean up" any transplant before transplantation.

In another embodiment, reovirus may be used to treat cultured cell lines to remove cells which are spontaneously transformed due to activation of the ras

pathway. This method may also be used to treat semen or donor eggs before artificial insemination or other reproduction-related procedures.

The reovirus useful in this invention may be any reovirus. Preferably the reovirus may be a mammalian reovirus, more preferably a human reovirus. Still more preferably the reovirus may be a serotype 3 reovirus, most preferably the Dearing Strain reovirus.

In another embodiment, the method further comprises the step of freezing and storing the reovirus-treated cellular composition in a solution containing DMSO. DMSO is routinely used to freeze and store animal cells but it denatures the reovirus. Therefore this treatment removes infectious reovirus from the cellular composition while preserving the activity of the composition in the frozen state for a prolonged period of time.

In another embodiment, reovirus may be removed from the reovirus-treated cellular composition by subjecting the mixture to anti-reovirus antibodies or a combination of anti-reovirus antibodies and complement in order to lyse the reovirus. Alternatively or additionally, anti-reovirus antibodies which recognize a molecule on the surface of the reovirus particle may be used to remove the reovirus particles by immobilizing the antibodies, applying the cellular composition to the immobilzed antibodies, and collecting the part of the composition which does not bind to the antibodies.

Similarly, anti-reovirus antibodies may be administered to the transplant recipient to eliminate reovirus *in vivo*, or the recipient can be given an immune system stimulant to achieve this purpose.

In another embodiment, reovirus may be removed from the reovirus-treated cellular composition by using a gradient which can separate reovirus from cells.

Also provided are cellular compositions which have been treated with reovirus to remove ras-mediated neoplastic cells. Such compositions may be used for *in vitro*

research, or in transplantation, insemination, or other *in vivo* procedures. The transplantation may be autologous, allogeneic, or even xenogeneic. Preferably the transplantation is autologous. More preferably, the composition comprises hematopoietic stem cells.

Therefore, a second aspect of the present invention provides a method of preparing a cellular composition for transplantation into a recipient, comprising the steps of:

(a) selecting a cellular composition for transplantation;

(b) contacting the composition with a reovirus under conditions which result in oncolysis of ras-mediated neoplastic cells; and

(c) collecting the reovirus-treated composition for transplantation.

A third aspect of the present invention provides a cellular composition prepared according to any of the methods disclosed in the first or second aspects of the present invention or embodiments of said methods.

In one embodiment said cellular composition may be useful in transplantation. In another embodiment, said transplantation may be autologous.

A fourth aspect of the present invention provides a pharmaceutical composition comprising the cellular composition disclosed in the third aspect of the present invention or embodiments thereof.

A fifth aspect of the present invention provides a use of an effective amount of the pharmaceutical composition of the fourth aspect of the present invention for the manufacture of a pharmaceutical preparation for transplantation into a transplantation recipient.

A sixth aspect of the present invention provides a use of an effective amount of a composition for the manufacture of a pharmaceutical preparation for reducing the risk of recurrence of tumor due to transplantation of autologous hematopoietic stem cell suspected of containing ras-mediated neoplastic cells, wherein the composition is prepared *in vitro* by contacting a cellular composition comprising autologous hematopoietic stem cells with a reovirus under conditions which result in oncolysis of ras-mediated neoplastic cells, and collecting the reovirus-treated composition for the purpose of transplantation.

A seventh aspect of the present invention provides a use of an effective amount of a pharmaceutical composition for the manufacture of a pharmaceutical preparation for reducing the risk of recurrence of tumor due to transplantation of autologous hematopoietic stem cell suspected of containing ras-mediated neoplastic cells, said pharmaceutical composition comprising autologous hematopoietic stem cells that have been treated *in vitro* with a reovirus under conditions which result in oncolysis of ras-mediated neoplastic cells.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1

Figures 1A-1C show the number of viable cells in MCF7 (Figure 1A), SKBR3 (Figure 1B) or MDA MB 468 (ATCC No. HTB132; Figure 1C) which were infected with live reovirus, dead virus or no virus as indicated. Figure 1D shows the percentage of MCF7 cells which were viable at various time points after reovirus infection.

Figure 2

Figure 2 shows that apoptosis was induced by reovirus infection in MCF7, SKBR3 or MDA MB 468 cells. Figures 2A-2C demonstrate the percentage DNA which were fragmented after reovirus infection. Figure 2D shows the percentage of the apoptotic marker Annexin V staining after reovirus infection. Figures 2E-2G show the percentage of $APO2.7^+$ cells in each cell type as indicated.

Figure 3

Figure 3A shows the number of viable cells at various time points after $CD34^+$ stem cells had been infected with reovirus. Figure 3B shows the effect of reovirus on long-term stem cell culture. Stem cells were infected with reovirus and incubated for 2, 24, 48 or 72 hours, respectively, then the cells were diluted and cultured for 14 days to allow individual colonies to form. The number of each kind of colony, granulocytes (G), erythroids (E) or granulocyte erythroid macrophage megakaryocyte (GEMM), was then determined for cells infected with no virus (NV) or live virus (LV), respectively. For example, NV-G stands for the granulocyte colonies derived from cells which were treated with no virus, and LV-G stands for those derived from cells which were treated with live reovirus.

Figure 4

Figures 4A-4C show the purging effects of reovirus on mixtures of apheresis product with MCF7, MDA MB 468 or SKBR3 cells, respectively.

DETAILED DESCRIPTION OF THE INVENTION

The invention is directed to methods of removing ras-mediated neoplastic cells from a cellular composition by using reovirus, and to compositions which have been treated according to these methods.

Prior to describing the invention in further detail, the terms used in this description are defined as follows unless otherwise indicated.

Definitions

As used herein, "neoplastic cells", also known as "cells with a proliferative disorder", refer to cells which proliferate without the normal growth inhibition properties. A new growth comprising neoplastic cells is a neoplasm or tumor. A neoplasm is an abnormal tissue growth, generally forming a distinct mass, that grows by cellular proliferation more rapidly than normal tissue growth. Neoplasms may show partial or total lack of structural organization and functional coordination with normal tissue. As used herein, a neoplasm is intended to encompass hematopoietic neoplasms as well as solid neoplasms.

A neoplasm may be benign (benign tumor) or malignant (malignant tumor or cancer). Malignant tumors can be broadly classified into three major types. Malignant neoplasms arising from epithelial structures are called carcinomas, malignant neoplasms that originate from connective tissues such as muscle, cartilage, fat or bone are called sarcomas and malignant tumors affecting hematopoietic structures (structures pertaining to the formation of blood cells) including components of the immune system, are called leukemias and lymphomas. Other neoplasms include, but are not limited to neurofibromatosis.

As used herein, "ras-activated neoplastic cells" or "ras-mediated neoplastic cells" refer to cells which proliferate at an abnormally high rate due to, at least in part, activation of the ras pathway. The ras pathway may be activated by way of ras gene structural mutation, elevated level of ras gene expression, elevated stability of the ras gene message, or any mutation or other mechanism which leads to the activation of ras or a factor or factors downstream or upstream from ras in the ras pathway, thereby increasing the ras pathway activity. For example, activation of EGF receptor, PDGF receptor or Sos results in activation of the ras pathway. Ras-mediated neoplastic cells include, but are not limited to, ras-mediated cancer cells, which are cells proliferating in a malignant manner due to activation of the ras pathway.

As used herein, "cellular composition" means a composition comprising cells. The composition may contain non-cellular matter. For example, whole blood is a cellular composition which contains plasma, platelets, hormones and other non-cellular matter in addition to cells such as erythrocytes and leukocytes. A cellular composition may contain cells of various types, origin or organization. For example, tissues and organs which contain different cell types arranged in defined structures are considered cellular compositions.

As used herein, "reovirus" refers to any virus classified in the reovirus genus. The name reovirus (*R*espiratory and *e*nteric *o*rphan virus) is a descriptive acronym suggesting that these viruses, although not associated with any known disease state in humans, can be isolated from both the respiratory and enteric tracts (Sabin, 1959). The term "reovirus" refers to all viruses classified in the reovirus genus.

The human reovirus consists of three serotypes: type 1 (strain Lang or T1L), type 2 (strain Jones, T2J) and type 3 (strain Dearing or strain Abney, T3D). The three serotypes are easily identifiable on the basis of neutralization and hemagglutinin-inhibition assays (See, for example, Fields *et al.*, 1996).

The reovirus may be naturally occurring or modified. The reovirus is "naturally-occurring" when it can be isolated from a source in nature and has not been intentionally

modified by humans in the laboratory. For example, the reovirus can be from a "field source", that is, from a human who has been infected with the reovirus.

The reovirus may be modified but still capable of lytically infecting a mammalian cell having an active ras pathway. The reovirus may be chemically or biochemically pretreated (e.g., by treatment with a protease, such as chymotrypsin or trypsin) prior to administration to the proliferating cells. Pretreatment with a protease removes the outer coat or capsid of the virus and may increase the infectivity of the virus. The reovirus may be coated in a liposome or micelle (Chandron and Nibert, 1998) to reduce or prevent an immune response from a mammal which has developed immunity to the reovirus. For example, the virion may be treated with chymotrypsin in the presence of micelle forming concentrations of alkyl sulfate detergents to generate a new infectious subvirion particle.

The reovirus may be a recombinant reovirus from two or more types of reoviruses with differing pathogenic phenotypes such that it contains different antigenic determinants, thereby reducing or preventing an immune response by a mammal previously exposed to a reovirus subtype. Such recombinant virions can be generated by co-infection of mammalian cells with different subtypes of reovirus with the resulting resorting and incorporation of different subtype coat proteins into the resulting virion capsids.

"Resistance" of cells to reovirus infection indicates that infection of the cells with the virus did not result in significant viral production or yield. Cells that are "susceptible" are those that demonstrate induction of cytopathic effects, viral protein synthesis, and/or virus production. Resistance to reovirus infection was found to be at the level of gene translation, rather than at early transcription: while viral transcripts were produced, virus proteins were not expressed. Without being limited to a theory, it is thought that viral gene transcription in resistant cells correlated with phosphorylation of an approximately 65 kDa cell protein, determined to be double-stranded RNA-activated protein kinase (PKR), that was not observed in transformed cells. Phosphorylation of PKR lead to inhibition of translation. When phosphorylation was suppressed by 2-aminopurine, a known inhibitor of PKR, drastic enhancement of reovirus protein synthesis occurred in the untransformed cells.

As used herein, "oncolysis" or "decrease of viability of neoplastic cells" refers to a decrease of at least about 20% in viability of the target neoplastic cells. The viability can be determined by a viable cell count of the treated cells, and the extent of decrease can be determined by comparing the number of viable cells in the treated cells to that in the untreated cells, or by comparing the viable cell count before and after reovirus treatment. The decrease in viability is preferably at least about 50%, more preferably at least about 70%, still more preferably at least about 80%, and most preferably at least about 90%.

As used herein, a "transplant recipient" is a mammal which receives a transplantation of cellular compositions. Preferably the recipient is a human, and more preferably a recipient is a human who is receiving transplantation in the treatment of cancer.

As used herein, "CPE" as an apoptotic marker refers to the cytopathic effects typically associated with apoptosis which are observable under the microscope, such as cell membrane blebbing, nuclear condensation and chromatin condensation.

Methods

The present invention relates to the use of reovirus to remove ras-mediated neoplastic cells from cellular compositions which are suspected of containing such neoplastic cells. Since the activated ras pathway is associated with many tumors, this invention can be applied to cellular compositions suspected of having any of a large variety of neoplastic cells.

For mammalian reoviruses, the cell surface recognition signal is sialic acid (Armstrong, 1984; Gentsch and Pacitti, 1985; Paul *et al.*, 1989). Due to the ubiquitous nature of sialic acid, reovirus binds efficiently to a multitude of cell lines and as such can potentially target many different tissues; however, there are significant differences in susceptibility to reovirus infection between cell lines. One reason for this discrepancy in susceptibility may be the activity of the ras pathway in each cell type.

We recently discovered that reovirus selectively lyses ras activated neoplastic cells *in vitro*, *in vivo* and *ex vivo* (Coffey et al., 1998; WO 99/08692). Normally, cells are not

susceptible to reovirus infection. However, when the ras pathway is activated, reovirus can successfully replicate in the cells and eventually results in lysis of the host cells. For example, when reovirus-resistant NIH 3T3 cells were transformed with activated Ras or Sos, a protein which activates Ras, reovirus infection was enhanced (Strong et al., 1998). Similarly, mouse fibroblasts that are resistant to reovirus infection became susceptible after transfection with the EGF receptor gene or the v-erbB oncogene (Strong et al., 1993; Strong et al., 1996).

Without being limited to a theory, it seems that reovirus replication is regulated at the translational level (Strong et al., 1998; Norman et al., 2000). In untransformed NIH 3T3 cells, early viral transcripts activate the double-stranded RNA-activated protein kinase (PKR), which inhibits translation, thereby inhibiting viral replication. Activated Ras (or an activated element of the ras pathway) presumably inhibits or reverses PKR activation. Therefore, viral protein synthesis proceeds, viral particles are made, and the cells are eventually lysed.

The ras oncogene accounts for a large number of tumors. Activating mutations of the ras gene itself occur in about 30% of all human tumors (Bos, J.L.,1989), primarily in pancreatic (90%), sporadic colorectal (50%) and lung (40%) carcinomas, and myeloid leukemia (30%). Activation of the factors upstream or downstream of ras in the ras pathway is also associated with tumors. For example, overexpression of HER2/Neu/ErbB2 or the epidermal growth factor (EGF) receptor is common in breast cancer (25-30%), and overexpression of platelet-derived growth factor (PDGF) receptor or EGF receptor is prevalent in gliomas and glioblastomas (40-50%). EGF receptor and PDGF receptor are both known to activate ras upon binding to their respective ligand, and v-erbB encodes a constitutively activated receptor lacking the extracellular domain.

We demonstrate in this invention that reovirus efficiently caused oncolysis of three breast cancer model systems, MCF7, SKBR3 and MDA MB 468, by inducing apoptosis in the infected cells (Example 1). Thus, reovirus treatment resulted in a marked decrease in viability of MCF7, SKBR3 and MDA MB 468 cells, while controls treated with no virus or dead virus grew normally (Figures 1A-1D). The decrease in viability was accompanied by characteristics which are associated with apoptosis, such as DNA fragmentation,

annexin V or APO 2.7 staining positivity (Figures 2A-2G) and cytopathic effects, such as cell membrane blebbing, nuclear condensation and chromatin condensation observed under the microscope.

Since reovirus infection is usually blocked at the translational level in normal cells but not in ras-mediated neoplastic cells, we examined the extent of protein synthesis in reovirus treated MCF7 cells and $CD34^+$ stem cels (Example 2). Indeed, viral proteins were synthesized in the reovirus infected cancer cell line, but not in $CD34^+$ stem cells which were also treated with reovirus (data not shown). This result suggests that it will be safe to treat hematopoietic stem cells with reovirus, since reoviral proteins were not synthesized in reovirus treated stem cells and cellular protein synthesis proceeded normally. To confirm this point, viability of the reovirus treated $CD34^+$ cells was determined at various time points after reovirus treatment (Example 3). Cell numbers in populations treated with live reovirus or no virus were similar after each time point (Figure 3A), indicating that $CD34^+$ cells are not susceptible to reovirus infection.

In order for reovirus to be useful in purging hematopoietic stem cell in high dose chemotherapy treatments, it is essential that the reovirus treatment does not alter the ability of stem cells to differentiate into each and every hematopoietic lineage to reconstitute the whole hematopoietic system. Therefore, long term effect of reovirus treatment was assessed (Example 3). $CD34^+$ cells treated with either no virus or live virus showed essentially no difference in their ability to differentiate into granulocytes, erythroids, or granulocyte erythroid macrophage megakaryocytes even after 72 hours of reovirus treatment (Figure 3B). The ratio between these three lineages also remained the same after this prolonged treatment. Accordingly, reovirus treatment neither killed $CD34^+$ cells nor changed the potential of them to reconstitute the hematopoietic system.

Furthermore, reovirus is capable of purging a mixed cellular composition, as demonstrated by the selective killing of MCF7, SKBR3 or MDA MB 468 cells in a mixture of cancer cells and apheresis product which contained $CD34^+$ stem cells (Example 4). By measuring CD34 and cytokeratin, a marker specific for epithelial cells such as MCF7, SKBR3 or MDA MB 468, it was shown that reovirus essentially eliminated the cancer cells from the mixed cellular composition (Figures 4A-4C) while leaving the stem

cells intact. Therefore, reovirus treatment is an efficient method to purge neoplastic cells from hematopoietic stem cell compositions.

Accordingly, in the preferred embodiment of this invention, stem cell- containing autographs are treated with reovirus prior to transplantation to remove the contaminating or spontaneous ras-mediated neoplastic cells. This increases the efficacy of the high dose chemotherapy/autologous hematopoietic stem cell transplantation treatment. Of particular interest will be the treatment of Hodgkin's disease, multiple myeloma, non-Hodgkin's lymphoma, acute myelogenous leukemia, germ cell (testicular) cancers, brain tumors, and breast tumors, since high dose chemotherapy and autologous stem cell transplantation have been performed efficiently in patients with these tumors. However, it is contemplated that the present method will be useful in other cancers as well to remove any ras-mediated neoplastic cells, since activation of the ras pathway may occur in any cell or tissue type.

Hematopoietic progenitor stem cells can be removed from bone marrow of the patient in advance of treatment. Alternatively, in a cancer patient who has been receiving traditional, non-high dose chemotherapy, many stem cells typically appear in the peripheral blood. Therefore, hematopoietic progenitor stem cell can be removed from the blood as apheresis product, which can be stored for a long time before being transplanted. The present invention can be applied to stem cell-containing autographs which are harvested from any tissue source, including bone marrow and blood.

Although reovirus normally is not associated with any known disease, it may be more infectious to cancer patients whose immune systems are weakened due to chemotherapy. Accordingly, in another embodiment of this invention, the stem cell compositions which have been treated with reovirus are frozen in a solution containing DMSO and thawed prior to transplantation. While DMSO is routinely used to freeze and store animal cells, it denatures reovirus, thereby removing infectious reovirus from the stem cell preparation. This reduces the risk that reovirus may cause undesired infections when it is introduced into the transplant recipient via stem cell transplantation.

In another embodiment, the reovirus-treated cell compositions are treated with anti-reovirus antibodies or a combination of anti-reovirus antibodies and complements in order

to inactivate or lyse the reovirus. Alternatively or additionally, anti-reovirus antibodies which recognize a molecule on the surface of the reovirus particle may be used to remove the reovirus particles from the reovirus-treated cellular composition. Thus, the antibodies are immobilized to a column, beads or any other material or device known in the art, the cellular composition is applied to the immobilized antibodies, and the part of the composition which does not bind to the antibodies is collected according to a procedure suitable for the particular method of immobilization.

Another method which may be used to remove reovirus from the reovirus-treated mixture is to subject the mixture to a gradient which separates cells from the virus, and collect the layer that contains only the cells.

In another embodiment, the transplant recipient is given treatments to stimulate the immune system in order to reduce the risk of reovirus infection. This treatment may be performed prior to, contemporaneously with, or after the transplantation, but is preferably performed prior to the transplantation. As an alternative treatment or in conjunction with the immune system stimulant, the recipient can be given anti-reovirus antibodies in order to reduce the risk of reovirus infection.

In addition to hematopoietic stem cells, the present invention can be broadly applied to remove ras-mediated neoplastic cells from many other cellular compositions. For example, reovirus can be used as a routine practice to "clean up" (remove ras-mediated neoplastic cells from) any tissue or organ transplant. Application of the present invention is not limited by cell or tissue type because as discussed above, the receptor for reovirus is ubiquitous, and the mechanism in normal cells to inhibit reovirus replication, PKR, is also ubiquitous. Therefore, any cell may become a ras-mediated neoplastic cell and become susceptible to reovirus infection. Of particular interest will be the use of the claimed methods to clean up whole blood or any portion thereof for a subsequent transfusion. Similarly, tissue or organ transplantation has become increasingly common, and it will be beneficial if the transplant can be treated to remove ras-mediated neoplastic cells before transplantation. Liver, kidney, heart, cornea, skin graft, pancreatic islet cells, bone marrow or any portions thereof are just a few examples of the tissues or organs to which this invention can be applied.

The tissue or organ can be autologous, allogeneic or xenogeneic. The tissue or organ may also be derived from a transgenic animal, be a tissue/organ which is developed *in vitro* from stem cells, or be expanded *ex vivo*. The tissue or organ to be treated with reovirus can be from an embryonic or adult origin. For example, embryonic neuronal cells can be treated before being transplanted into an Alzheimer's patient. Similarly, the invention can be used to treat semen or donor eggs *ex vivo*.

Application of the present invention is not limited to transplants. Rather, any cellular compositions can be "cleaned up" with reovirus for any purpose. Thus, all the examples described above are applicable even if the tissue or organ is not meant for transplantation.

Cell lines may also be treated routinely to safeguard against spontaneous or contaminating ras-mediated neoplastic cells. Again, any cell line will be a good candidate for this method except, of course, a cell line transformed by means of activation of the ras pathway.

Recently, many laboratories have been attempting to establish serially transplantable xenografts of human prostate cancer tissue inoculated into immune-compromised mice. However, contamination with mouse cancer cells often occurs during the serial passage of the xenografts and these calls can eventually outgrow the human prostate cancer cells (Gao et al., 1999). The present invention will be a simple solution to this problem if the contaminating cancer is ras-mediated and the xenograft is not.

The following examples are offered to illustrate this invention and are not to be construed in any way as limiting the scope of the present invention.

EXAMPLES

In the examples below, the following abbreviations have the following meanings. Abbreviations not defined have their generally accepted meanings.

μM = micromolar

	mM	=	millimolar
	M	=	molar
	ml	=	milliliter
	µl	=	microliter
	mg	=	milligram
	µg	=	microgram
	PAGE	=	polyacrylamide gel electrophoresis
	rpm	=	revolutions per minute
	FBS	=	fetal bovine serum
	DTT	=	dithiothrietol
	SDS	=	sodium dodecyl sulfate
	PBS	=	phosphate buffered saline
	DMEM	=	Dulbecco's modified Eagle's medium
	α-MEM	=	α-modified Eagle's medium
	β-ME	=	β-mercaptoethanol
	MOI	=	multiplicity of infection
	PFU	=	plaque forming units
	PKR	=	double-stranded RNA activated protein kinase
	EGF	=	epidermal growth factor
	PDGF	=	platelet derived growth factor
	DMSO	=	dimethylsulfoxide
	CPE	=	cytopathic effect

Example 1 Reovirus induced oncolysis and apoptosis in breast cancer cells

To determine the effect of reovirus on the viability of neoplastic cells, we first used three breast cancer model systems, MCF7 (ATCC number HTB-22), SKBR3 (ATCC number HTB-30) and MDA MB 468 (ATCC number HTB 132). Cells of each cell line were grown to 50-60% confluency and infected with reovirus serotype 3, strain Dearing, at a multiplicity of infection of 40. Reovirus was obtained and maintained as described in U.S. Patent No. 6,136,307. Reovirus infected and non-infected cells were harvested at 0, 24, 48 and 72 hours after infection and the viability was determined.

The results are shown in Figures 1A-1D. Viable cell count in reovirus-infected MCF7 (Figure 1A), SKBR3 (Figure 1B) or MDA MB 468 cells (Figure 1C) dropped significantly after the infection, while the cells infected with dead virus or no virus proliferated as expected. Reovirus treatment caused MCF7 (Figure 1D) and SKBR3 viability to drop from 93% to 16% by 72 hours after infection. In MDA MB 468 cells, virus treated intact cell numbers dropped to 12.7%, 8.8% and 3.6% of the original cell counts, respectively, at 24, 48 and 72 hours after infection. Thus, reovirus caused oncolysis efficiently in all three kinds of cancer cells.

The cells died by apoptosis. Typical apoptotic markers such as CPE, Annexin-V and DNA laddering could be observed in a time course parallel to the decrease of viability. Figures 2A-2G show the percentage of DNA fragmentation (2A-2C), Annexin V staining (2D) or APO2.7$^+$ cells (2E-2G) at various time points after reovirus infection. The reovirus treated cells exhibited all signs of apoptosis at a dramatic level compared to the no virus or dead virus controls, demonstrating that reovirus induced apoptosis in all of these three cell lines. Apoptosis in the controls seemed to increase slowly with time as well, probably because cells began to die when they had grown too densely.

Example 2 Reovirus selectively inhibited protein synthesis in cancer cells but not CD34$^+$ stem cells

For further proof of selective viral infection of cancer cells, ^{35}S labeling/SDS/PAGE of viral proteins was undertaken. Viral protein synthesis was evident after 1-2 days in MCF7 cells infected with reovirus, while cellular protein synthesis decreased at the same time, indicating that reovirus had taken over the cellular machinery. At 4 days after infection, no protein synthesis could be detected anymore, suggesting that all the cells had been killed. In the control experiments where cells were infected with dead reovirus or no virus, there was no viral protein synthesis, whereas cellular protein synthesis was at the normal level. In contrast, ^{35}S labeling of CD34$^+$ stem cells in the presence or absence of reovirus showed no viral protein synthesis up to 72 hours after the addition of virus. Therefore, reovirus selectively infect MCF7 cells but not CD34$^+$ stem cells.

Example 3 Reovirus treatment neither inhibited cell proliferation nor altered differentiation potential of $CD34^+$ cells

Consistent with the protein synthesis results, viable cell count indicated that reovirus treatment did not decrease the number of viable cells in $CD34^+$ cells (Figure 3A) as compared to the no virus control.

While the number of $CD34^+$ cells was unaffected by reovirus infection, there remained the question whether reovirus changed the potential of $CD34^+$ stem cells to differentiate into all the hematopoietic lineages in the appropriate proportion. If this was the case, reovirus treated stem cells would not be a good candidate for the reconstitution of the whole hematopoietic system. To investigate this possibility, $CD34^+$ cells were incubated with reovirus for 2, 24, 48 or 72 hours, respectively. The reovirus was then removed and the cells were diluted and cultured in fresh media for 14 days to allow colonies to form. Each colony was examined to determine if it belongs to the granulocyte, erythroid, or granulocyte erythroid macrophage megakaryocyte lineage. As shown in Figure 3B, stem cells treated with live virus (LV) yielded similar numbers of granulocutes (G), erythrocytes (E) or granulocyte erythroid macrophage megakaryocytes (GEMM) as the no virus (NV) control. Therefore, reovirus treatment did not change the differentiation potential of $CD34^+$ cells.

Example 4 Reovirus selectively removed cancer cells from a mixed cellular composition

Neoplastic cells were mixed with apheresis product and subjected to reovirus infection to investigate if reovirus can selectively remove neoplastic cells from the mixed cellular composition. Apheresis product was prepared according to a procedure previously described (Stewart et al., 1999; Duggan et al., 2000). When admixtures of apheresis product (90%) and MCF7 (10%) were treated with reovirus and tested daily for cell count and viability, there was a 100-fold depletion in the numbers of cytokeratin-positive MCF7 cells while the $CD34^+$ stem cells remained intact and viable (Figure 4A). Reovirus was similarly effective in selectively removing MDA MB 468 (Figure 4B) or SKBR3 cells (Figure 4C) from their mixture with apheresis product, respectively. These

results demonstrate that reovirus can selectively kill neoplastic cells in a cell mixture and leave the stem cells intact.

CLAIMS

1. A method to remove ras-mediated neoplastic cells from a cellular composition suspected of containing such neoplastic cells, which method comprises contacting the cellular composition *in vitro* with reovirus under conditions which results in oncolysis of the ras-mediated neoplastic cells, wherein the cellular composition comprises hematopoietic stem cells.

2. The method of claim 1 wherein the hematopoietic stem cells have been harvested from bone marrow.

3. The method of claim 1 wherein the hematopoietic stem cells have been harvested from blood.

4. The method of claim 1 wherein the reovirus is a recombinant reovirus.

5. The method of claim 1 wherein the reovirus is a mammalian reovirus.

6. The method of claim 1 wherein the reovirus is an avian reovirus.

7. The method of claim 5 wherein the mammalian reovirus is a human reovirus.

8. The method of claim 5 wherein the mammalian reovirus is serotype 3 virus.

9. The method of claim 8 wherein the serotype 3 virus is the Dearing strain.

10. The method of claim 1 further comprising the step of freezing and storing the reovirus-treated composition in a solution containing DMSO.

11. The method of claim 1 further comprising the step of treating the reovirus-treated composition with anti-reovirus antibodies and complements.

12. The method of claim 1 further comprising the steps of subjecting the treated cells to a gradient which separates the cells from the reovirus and collecting the layer which contains cells.

13. A method of preparing a cellular composition for transplantation into a recipient, comprising the steps of:

(a) selecting a cellular composition for transplantation;

(b) contacting the composition with a reovirus under conditions which result in oncolysis of ras-mediated neoplastic cells; and

(c) collecting the reovirus-treated composition for transplantation.

14. The method of claim 13 wherein said transplantation is autologous.

15. The method of claim 13 wherein the cellular composition comprises hematopoietic stem cells.

16. The method of claim 15 wherein the hematopoietic stem cells have been harvested from bone marrow.

17. The method of claim 15 wherein the hematopoietic stem cells have been harvested from blood.

18. The method of claim 13 wherein the cellular composition comprises a tissue, an organ or any portion of a tissue or an organ.

19. The method of claim 18 wherein the tissue or organ is selected from the group consisting of liver, kidney, heart, cornea, skin, lung, pancreatic islet cells, and whole blood.

20. The method of claim 18 wherein the tissue, organ or portion of the tissue or organ is useful for transplantation.

21. The method of claim 13 wherein the cellular composition comprises cultured cells, semen or eggs.

22. The method of claim 13 wherein the reovirus is a recombinant reovirus.

23. The method of claim 13 wherein the reovirus is a mammalian reovirus.

24. The method of claim 13 wherein the reovirus is an avian reovirus.

25. The method of claim 23 wherein the mammalian reovirus is a human reovirus.

26. The method of claim 23 wherein the mammalian reovirus is serotype 3 virus.

27. The method of claim 26 wherein the serotype 3 virus is the Dearing strain.

28. The method of claim 13 further comprising the step of freezing and storing the reovirus-treated composition in a solution containing DMSO.

29. The method of claim 13 further comprising the step of treating the reovirus-treated composition with anti-reovirus antibodies and complements.

30. The method of claim 13 further comprising the steps of subjecting the treated cells to a gradient which separates the cells from the reovirus and collecting the layer which contains cells.

31. A cellular composition prepared according to the method of any of claims 1, 2-3, 5-14, and 15-30.

32. The composition of claim 31 which is useful in transplantation.

33. The composition of claim 32 wherein said transplantation is autologous.

34. A pharmaceutical composition comprising any of the composition according to claim 31, 32 or 33.

35. A use of an effective amount of the pharmaceutical composition of claim 34 for the manufacture of a pharmaceutical preparation for transplantation into a transplantation recipient.

36. The use of claim 35 wherein the transplantation recipient further receives at least one substance selected from the group consisting of an anti-reovirus antibody and/or an immune system stimulating agent.

37. The use of claim 36 wherein the transplantation is performed for the treatment of a neoplasm.

38. The use of claim 37 wherein the neoplasm is selected from the group consisting of Hodgkin's disease, multiple myeloma, non-Hodgkin's lymphoma, acute myelogenous leukemia, germ cell (testicular) cancers, brain tumors, and breast tumors.

39. A use of an effective amount of a composition for the manufacture of a pharmaceutical preparation for reducing the risk of recurrence of tumor due to transplantation of autologous hematopoietic stem cell suspected of containing ras-mediated neoplastic cells, wherein the composition is prepared *in vitro* by contacting a cellular composition comprising autologous hematopoietic stem cells with a reovirus under conditions which result in oncolysis of ras-mediated neoplastic cells, and collecting the reovirus-treated composition for the purpose of transplantation.

40. A use of an effective amount of a pharmaceutical composition for the manufacture of a pharmaceutical preparation for reducing the risk of recurrence of tumor due to transplantation of autologous hematopoietic stem cell suspected of containing ras-mediated neoplastic cells, said pharmaceutical composition comprising autologous hematopoietic stem cells that have been treated *in vitro* with a reovirus under conditions which result in oncolysis of ras-mediated neoplastic cells.