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(54) **USE OF TRI-SUBSTITUTED GLYCEROL COMPOUNDS FOR THE TREATMENT OF RADIATION INJURIES**

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(57) **ABSTRACT**

The present invention relates to the use of a tri-substituted glycerol compound or a pharmaceutically acceptable salt thereof for the manufacture of a medicament for the prevention and/or treatment of radiation injuries. Furthermore, the invention relates to in vitro corresponding methods for preventing or treating of radiation damage or injury in one or more cells comprising contacting said cells with a medicament as defined in the invention.

FIG. 1

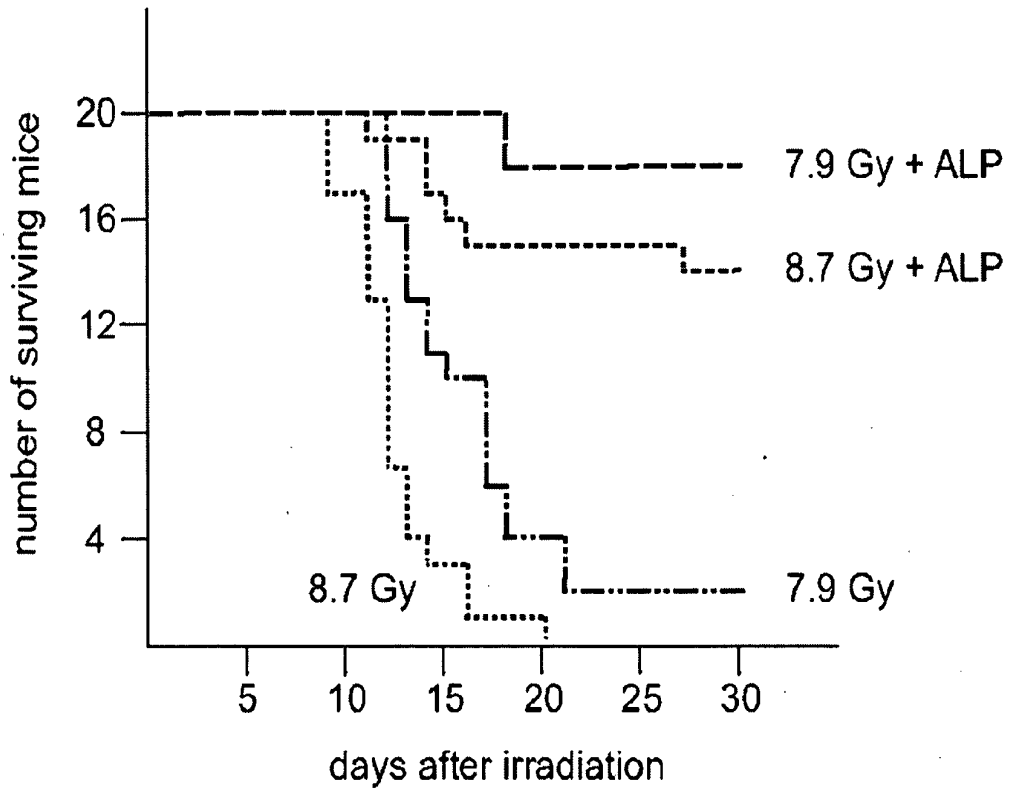

number of surviving mice
20
16
12
8
4
7.9 Gy + ALP
8.7 Gy + ALP
8.7 Gy
7.9 Gy
5
10
15
20
25
30
days after irradiation

FIG. 2

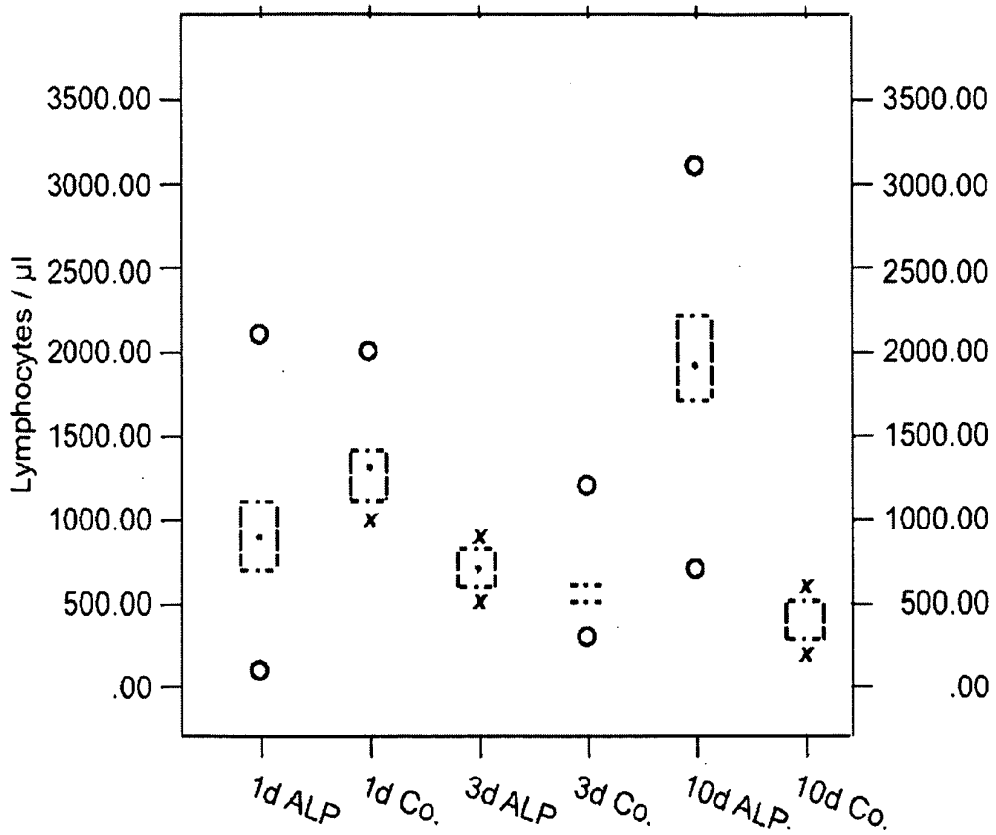
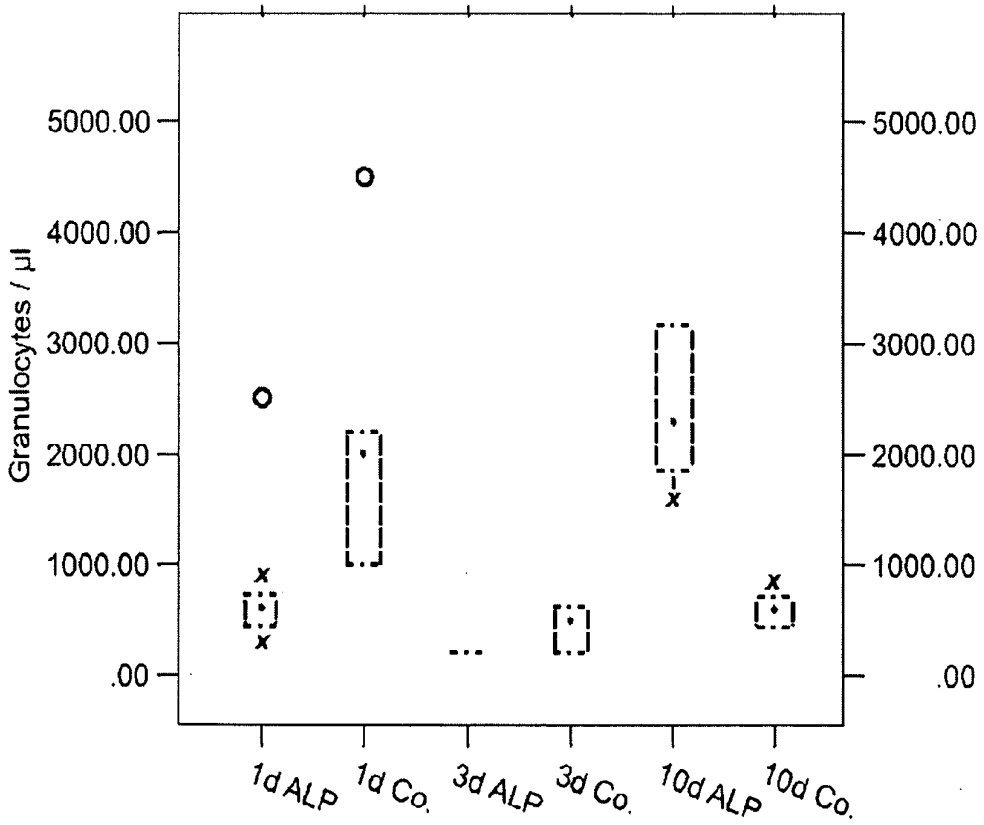

Lymphocytes / µl
3500.00
3000.00
2500.00
2000.00
1500.00
1000.00
500.00
.00
1d ALP
1d Co.
3d ALP
3d Co.
10d ALP
10d Co.

FIG. 3


Granulocytes / µl
5000.00
4000.00
3000.00
2000.00
1000.00
.00
1d ALP
1d Co.
3d ALP
3d Co.
10d ALP
10d Co.

USE OF TRI-SUBSTITUTED GLYCEROL COMPOUNDS FOR THE TREATMENT OF RADIATION INJURIES

[0001] The present invention relates to the use of a tri-substituted glycerol compound or a pharmaceutically acceptable salt thereof for the manufacture of a medicament for the prevention and/or treatment of radiation injuries. Furthermore, the invention relates to in vitro corresponding methods for preventing or treating of radiation damage or injury in one or more cells comprising contacting said cells with a medicament as defined in the invention.

[0002] Exposure to radiation (such as X-rays, gamma rays, and alpha-or beta-radiation) can cause damage to cells. This damage can result in cell death (e.g., through apoptosis), or can cause genetic changes in the cell, resulting in uncontrolled cell proliferation and as a consequence to the development and progression of tumors.

[0003] While, in general, exposure to such radiation is undesirable, the administration of carefully monitored doses of radiation is an accepted treatment for certain cancers such as leukemia, breast cancer, prostate cancer or colon cancer. By targeting the radiation to a tumor, cancer cells can be destroyed.

[0004] A frequent complication of radiotherapy is the irradiation of normal tissues surrounding the cancerous tissues. Such normal tissues are often damaged by the radiation, resulting in an undesired radiation injury to normal cells and tissues, which can have severe consequences for the affected patient.

[0005] Exposure to radiation can occur in several other ways, including exposure to normal background levels of radiation (such as cosmic rays or radiation due to naturally occurring isotopes present in the earth) or elevated environmental radiation (including occupational exposure of persons in medical facilities or nuclear power plants as well as exposure to X-rays during medical diagnosis). Another potential source of exposure to certain types of radiation is the accidental or intentional release of radioactive materials, for example, as the result of an accident or as a result of terrorist activity, e.g., as the result of a radiologic weapon such as a so-called "dirty bomb" (an explosive device intended to spread radioactive materials to contaminate an area).

[0006] The primary form of protection against radiation injury is avoidance of exposure to radiation. Shielding materials capable of preventing penetration of radiation into the body can be used when a source of radiation is known. For example, lead aprons can be used to block x-rays. Protective clothing can be used to prevent contamination of the body with radioactive materials, and decontamination procedures can be used to remove radioactive materials.

[0007] Treatment with radioprotective chemical compounds is an approach for preventing certain types of radiation damage, such as DNA damage due to free radicals (or other reactive species) produced by the radiation.

[0008] A widely used radioprotective agent is amifostine, an organic thiophosphate prodrug (2-[(3-aminopropyl) amino]ethanethiol dihydrogen phosphate) that is dephosphorylated in vivo by alkaline phosphatase to the active thiol metabolite (cf., for example, the U.S. Pat. No. 7,073,072 as well as the International patent Applications WO 02/092103 and WO 02/062350). The selective protection of non-malignant tissues is believed to be due to higher alkaline phosphatase activity, higher pH, and vascular permeation of normal tissues. Amifostine is used therapeutically inter alia to reduce the incidence of neutropenia-related fever, to decrease the cumulative nephrotoxicity associated with platinum-containing agents, and to reduce the incidence of xerostomia in patients undergoing radiotherapy for head and neck cancer. However, it has been shown that amifostine is only effective as radioprotectant when administered shortly prior to an exposure to radiation. An administration after exposure to radiation is without any therapeutic effect. Furthermore, the administration of amifostine or related thiol compounds is associated with pronounced adverse side effects such as systemic cytotoxicity as well as gastrointestinal incompatibilities like nausea and vomiting.

[0009] Another compound, 5-androstenediol, has been tested as a radiation protectant in preclinical animal studies. This compound is reported to improve survival in mice exposed to radiation, possibly by stimulating production of neutrophils and other immune-system cells and thus preventing infection, a significant cause of death in radiation-injured subjects. However, this compound is a salvaging measure and it does not counteract the pathogenic mechanism of radiation nor protect organs other than the hematopoietic system. It has not yet been approved for human use.

[0010] As promising these prophylactic radiation protection effects may appear, as modest are the results of efforts to find a therapy with chemical substances given after irradiation. There are attempts to treat the irradiation-damaged nucleic acids by substituting the DNA or RNA. The initial results of these investigations, however, are not encouraging to further develop a therapeutic concept. Thus, the only option remaining is to treat the indirect consequences of the cellular damages, for example the impact on bone marrow insufficiency that governs the clinical outcome after a high dose whole body irradiation. Secondary effects of bone marrow damages are infections that are caused by leukopenia and accompanied by fever, agranulocytosis, petechiae and profuse bleeding as a consequence of thrombocytopenia. These symptoms may cause death in severe cases. A therapy of these secondary effects of the bone marrow damages includes antibiotic treatment as well as a substitution therapy with the blood cells that are missing such as granulocytes and thrombocytes. The ultima ratio in cases of very high radiation burden would be bone marrow transplantation.

[0011] While level of intensive care for lethally irradiated victims might be very high, such therapy will be available only in few specialized hospitals for a limited number of patients. In case of a real nuclear catastrophe with probably hundreds of highly irradiated patients such demanding specialized treatment is not feasible. An intensive care therapy using bone marrow transplantation may rescue people with a whole body irradiation of 10 Gy (Gray). However, in case of untreated or insufficiently treated victims the lethal dose is reduced to 3-4 Gy. Thus, an appropriate therapeutic approach in such scenario would be a chemotherapy that is effective to lead to an increased prognosis of those mid-level lethally irradiated people.

[0012] Tri-substituted glycerol compounds belonging to the class of synthetic ether-linked alkyl-lysophospholipids might be candidate compounds for such radioprotective therapy. In preliminary analyses, certain alkyl-lysophospholipid analogs have been shown to have a beneficial effect to cells upon an exposure to low X-ray radiation in mice (Berdel, W. et al. (1983) *Radiation Res.* 94, 166-170). However, this

study is silent with regard to a generalization to other types of radiation as well as concerning the radiation doses that can be treated. Furthermore, it has still to be unraveled whether such alkyl-lysophospholipid analogs are capable of both to prevent radiation damage or injury and to treat them.

[0013] Synthetic ether-linked alkyl-lysophospholipids are known to have an anti-cancerogenic activity (reviewed, e.g., by Arthur, G., and Bittman, R. (1998) *Biochim. Biophys. Acta* 1390, 85-102; Jendrossek, V., and Handrick, R. (2003) *Curr. Med. Chem. Anti-Canc. Agents* 3, 343-353; Mollinedo, F. et al. (2004) *Curr. Med. Chem.* 11, 3163-3184). 1-O-octadecyl-2-O-methyl-glycero-3-phosphocholine (also referred to as ET-18-OCH3, AP-121 or edelfosine) is considered to be the prototype of these lipids. 1-O-octadecyl-2-O-methyl-glycero-3-phosphocholine represents a synthetic analogue of the platelet activating factor (PAF; 1-O-alkyl-2-acetyl-sn-glycero-3-phosphocholine), a potent phospholipid activator and mediator of many leukocyte functions, including platelet aggregation, inflammation, and anaphylaxis. Unlike most conventional chemotherapeutic drugs, these synthetic ether lipids do not directly target cellular DNA but rather affect the plasma membrane lipid composition and/or interfere with various signal transduction pathways. Thus, their mode of action does not depend on the presence of particular cellular receptors or is it cell cycle-dependent.

[0014] Cancer chemotherapy generally aims to slow the growth of, or destroy, cancer cells while avoiding collateral damage to surrounding cells and tissues. Consequently, the most effective anticancer agents are those that are able to selectively target cancer cells while leaving normal cells relatively unaffected. Synthetic ether-lipids have been shown to exert such an effect (cf., for example, Magistrelli, A. et al. (1995) *Drug. Metab. Dispos.* 23, 113-118). Several mechanisms of action have been proposed for the toxicity of ether-lipids towards cancer cells, including the cells' lack of alkyl cleavage enzymes. The resultant inability to hydrolyze the ether-lipids leads to their intracellular accumulation and to consequent damage to cell membrane lipid organization. Other potential mechanisms of ether-lipid action include effects on levels of intracellular protein phosphorylation, and disruption of cellular lipid metabolism. Normal cells typically possess the means to avoid or overcome the potentially toxic effects of ether-lipids, while cancer cells do not.

[0015] Thus far, synthetic ether lipids have been used for the treatment of different types of tumors such as brain tumors or mamma carcinomas (cf., for example, the German Patent DE 2619686 as well as the International Patent Applications WO 99/59599 and WO 00/01392, respectively).

[0016] Although the anti-tumor activity of these synthetic ether lipids has been experimentally proven in several animal tumor models, their clinical use is often hampered by systemic cytotoxic effects including hemolysis, particularly in the gastrointestinal tract but also inter alia in lung, liver or kidney. In 10-20% of the patients treated with such water- and/or milk-based vehicles containing ether lipids severe gastrointestinal incompatibilities corresponding to WHO toxicity grades III or IV have been observed that are associated with nausea, vomiting, diarrhea or constipation (see, e.g., Drings, P. et al. (1992) *Onkologie* 15, 375-382).

[0017] Thus, aside from exerting the desired pharmaceutical efficacy there is a need for a medicament, which allows for an easy and convenient administration. In particular, there remains a need for a medicament that is simultaneously suitable for preventing radiation damage or injury prior to exposure to radiation and for ameliorating or treating radiation damage or injury once the exposure to radiation has occurred.

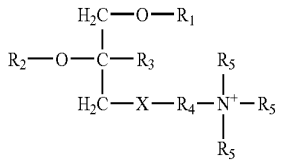
[0018] Accordingly, it is an object of the present invention to provide a medicament for the prevention and/or treatment of radiation damage or injury having such properties.

[0019] This object is achieved by the use of a tri-substituted glycerol compound having the features of independent claim **1** for the manufacture of a corresponding medicament. Some of the preferred embodiments of the present invention are defined by the subject matter of the dependent claims.

[0020] Surprisingly, it has been found that tri-substituted glycerol compounds such as 1-O-octadecyl-2-O-methyl-glycero-3-phosphocholine that are known as anti-cancerogenic agents are also exerting a radioprotective effect on cells and tissues, which allows for an efficient prevention and/or treatment of radiation damage or injury in response to different types of radiation. The inventive medicament provides the desired efficacy, can be conveniently administered to a patient, and does not show adverse side effects.

[0021] In the context of the present invention any numerical value indicated is typically associated with an interval of accuracy that the person skilled in the art will understand to still ensure the technical effect of the feature in question. As used herein, the deviation from the indicated numerical value is in the range of ±10%, and preferably of ±5%.

[0022] In a first aspect, the present invention relates to the use of a tri-substituted glycerol compound according to formula (I)



or an enantiomer or diastereomer or a pharmaceutically acceptable salt thereof and at least one pharmaceutically acceptable excipient for the manufacture of a medicament for the prevention and/or treatment of radiation damage or injury, wherein

[0023] X is selected from the group consisting of phosphate and sulfate;

[0024] R_1 is selected from the group consisting of C_{16}-C_{20} alkyl;

[0025] R_2 is selected from the group consisting of C_1-C_3 alkyl and C_1-C_3 hydroxyalkyl;

[0026] R_3 is selected from the group consisting of hydrogen and C_1-C_3 alkyl;

[0027] R_4 is selected from the group consisting of C_1-C_3 alkyl and C_3-C_6 cycloalkyl; and

[0028] R_5 is selected from the group consisting of hydrogen and methyl.

[0029] The tri-substituted glycerol compound may be present in amorphous or in crystalline form. The term "amorphous", as used herein, refers to a solid in which there is no long-range order of the positions of the atoms, i.e. a non-crystalline material. In preferred embodiments of the invention, the tri-substituted glycerol compound is present in crystalline form.

[0030] The terms "C_n alkyl", "C_n hydroxyalkyl", and "C_n cycloalkyl", as used herein, denote an alkyl group, a hydroxyalkyl group or a cycloalkyl group having n carbon atoms,

respectively. For example, the term "C_{18} alkyl" refers to an alkyl group having 18 carbon atoms. The alkyl groups or hydroxyalkyl groups according to the invention may be straight or branched.

[0031] The tri-substituted glycerol compounds of formula (I) have one or more asymmetric centers and thus they can exist as enantiomers or diastereomers. Thus, the medicament as defined in the present invention may comprise either one or more separate individual isomers (such as the L form and the D form) or mixtures of isomers, preferably racemic mixtures.

[0032] In some embodiments of the invention, the tri-substituted glycerol compounds of formula (I) are present in the medicament as pharmaceutically acceptable salts. Such salts may comprise any pharmaceutically acceptable anion "neutralizing" the positive charge of the nitrogen (e.g. chloride, bromide or iodide) or any pharmaceutically acceptable cation "neutralizing" the negative charge of the phosphate or sulfate moiety (e.g. sodium or potassium cations).

[0033] In a particular preferred embodiment of the present invention, the pharmaceutical solid dosage form comprises a tri-substituted glycerol compound according to formula (I), wherein X is phosphate, R_1 is $—(CH_2)_{17}—CH_3$, R_2 is CH_3, R_3 is H, R_4 is $—(CH_2)_2—$, and R_5 is CH_3.

[0034] The medicament according to the present invention may be any pharmaceutical dosage form that is therapeutically effective. Examples of such pharmaceutical dosage forms include inter alia tablets, pills, capsules, suspensions, emulsions, injection or infusion solutions, tinctures, powders and the like.

[0035] The medicaments used in the present invention comprise at least one pharmaceutically acceptable excipient. The term "pharmaceutically acceptable excipient", as used herein denotes any substance used for the preparation of pharmaceutical dosage forms such as coating materials, film-forming materials, fillers, disintegrating agents, release-modifying materials, carrier materials, diluents, binding agents and other adjuvants, all of them well known in the art (cf. the references cited below). Preferably, the excipient used in the invention comprises at least one filler, at least one binder, at least one disintegrating agent, at least one flowability-controlling agent, and at least one lubricant.

[0036] The medicament may be administered via any parenteral or non-parenteral route. Parenteral application methods comprise, for example, intracutaneous, subcutaneous, intramuscular or intravenous injection and infusion techniques. Non-parenteral delivery modes include, for instance, oral or topical administration. Furthermore, the medicament may be administered locally or systemically.

[0037] Preferably, the medicament employed in the present invention is a pharmaceutical dosage form suitable for oral application. Particularly preferably, the dosage form is a solid dosage form. Examples of such dosage forms include inter alia tablets, pills, capsules, granulates, pellets, powders, multi-particulate formulations (e.g., beads, granules or crystals), and dragees. The unit doses of multi-particulates may be incorporated into a pharmaceutical solid dosage form, e.g. via compression or shaping into tablets or by placing a requisite amount inside a gelatin capsule.

[0038] All these solid dosage forms for oral application as well as methods for their preparation are well established in the art (see, e.g., Gennaro, A. L. and Gennaro, A. R. (2000) *Remington: The Science and Practice of Pharmacy,* 20th Ed., Lippincott Williams & Wilkins, Philadelphia, Pa.; Ritschel, W. A. & Bauer-Brandl, A. (2002) *Die Tablette: Handbuch der Entwicklung, Herstellung and Qualitätssicherung.* Editio-Cantor Verlag, Aulendorf, Germany; Crowder, T. M. et al. (2003) *A Guide to Pharmaceutical Particulate Science.* Interpharm/CRC, Boca Raton, Fla.; Stricker, H. (2003) *Arzneiformenentwicklung,* Springer Verlag, Berlin, Germany; Niazi, S. K. (2004) *Handbook of Pharmaceutical Manufacturing Formulations,* CRC Press, Boca Raton, Fla.).

[0039] In preferred embodiments of the invention, the pharmaceutical solid dosage form is selected from the group consisting of tablets, pills, capsules, and granules, with tablets being particularly preferred.

[0040] Preferably, the solid dosage form is an enteric dosage form. That is, the dosage form remains stable in the stomach, i.e. in an acidic environment, with pH values in the range of $\leqq 2.5$. This may be achieved by providing a solid dosage form comprising a film coating. For example, the inventive dosage form may be in the form of a so-called film tablet.

[0041] Methods for the preparation of film coated dosage forms are also well established in the art (see, e.g., the references cited above). Furthermore, the skilled artisan also knows how to provide film coatings with specific properties, like enteric coatings, film coating which dissolve upon contact with body fluids, controlled release coatings, taste-masking coatings or disintegrating coatings. In a particularly preferred embodiment, the solid dosage form of the invention comprises an enteric coating.

[0042] According to the present invention, it is to be understood that the tri-substituted glycerol compound is present in the medicament in any amount being effective to achieve the desired pharmacological effect when administered to a patient. Effective amounts are generally chosen in accordance with a number of factors, e.g., the age, size and general condition of the patient and the medical condition being treated, and determined by a variety of means, for example, dose ranging trials, well known to, and readily practiced by persons of ordinary skill in art given the teachings of this invention.

[0043] Typically, in a medicament as defined in the present invention the amount of the tri-substituted glycerol compound according to formula (I) is less than 400 mg, preferably it is in the range of 30 to 250 mg, and most preferably it is in the range of 50 to 150 mg. In particularly preferred embodiments of the invention, the amount of the tri-substituted glycerol compound according to formula (I) is 75 mg and 100 mg, respectively.

[0044] The daily dosage of the tri-substituted glycerol compound administered to a patient is less than 1200 mg, typically less than 900 mg, preferably in the range of 30 to 600 mg, more preferably in the range of 40 to 400 mg, and most preferably in the range of 50 to 350 mg. In specific embodiments, the daily dosage is 75, 100, 150, 200, 225, and 300 mg. Preferably, the daily dosage of the tri-substituted glycerol compound is administered as a single dose such as in form of one up to four tablets or capsules. However, it may also be possible to administer the compound in multiple doses such as two or three individual doses administered during the day, e.g. in the morning, at noon, and at night.

[0045] The medicament according to the invention may be used for the prevention and/or treatment of radiation damage or injury individually or in combination with at least one other medicament comprising at least one additional active ingredient. That is, it is also within the scope of the present invention to use a medicament comprising a tri-substituted glycerol

compound defined in the claims together with at least one other medicament comprising one or more different active ingredients such as chemotherapeutics or monoclonal antibodies.

[0046] The term "radiation damage or injury", as used herein, refers to any negative or adverse effect an exposure to radiation—independent of the radiation dose applied and the time of exposure, respectively—may exert on cells, tissues, organs or organisms resulting in uncontrolled cell proliferation and/or differentiation and as a consequence to the development and progression of tumors. Examples of such radiation damages or injuries include inter alia genetic changes in the cell (e.g., DNA and/or RNA mutations, DNA and/or RNA decay, chromosomal aberrations) as well as cell death (e.g., programmed cell death/apoptosis).

[0047] In some embodiments of the invention the radiation damage or injury is caused by ionizing radiation. The term"ionizing radiation" as used herein, denotes either particle radiation or electromagnetic radiation in which an individual particle/photon carries enough energy to ionize an atom or molecule by completely removing an electron from its orbit. If the individual particles do not carry this amount of energy, it is essentially impossible for even a large flood of particles to cause ionization. These ionizations, if enough occur, can be very destructive to living tissue. Examples of particle radiation that are ionizing may be energetic electrons, neutrons, atomic ions or photons. Electromagnetic radiation can cause ionization if the energy per photon, or frequency, is high enough, and thus the wavelength is short enough. The amount of energy required vanes between molecules being ionized.

[0048] Preferably, the ionizing radiation is selected from the group consisting of neutron radiation, alpha radiation, beta radiation, gamma radiation, and X-rays.

[0049] Neutron radiation is often called indirectly ionizing radiation. It does not ionize atoms in the same way protons, photons, and electrons do because neutrons have no charge. However, neutron interactions are largely ionizing, for example when neutron absorption results in gamma emission and the gamma subsequently removes an electron from an atom, or a nucleus recoiling from a neutron interaction is ionized and causes more traditional subsequent ionization in other atoms. Because neutrons are uncharged, they are more penetrating than alpha radiation (helium nuclei) and beta radiation (electrons or positrons). In some cases they are more penetrating than gamma radiation (electromagnetic radiation), which is impeded in materials of high atomic number.

[0050] X-rays are a form of electromagnetic radiation with a wavelength in the range of 10 to 0.01 nm, corresponding to frequencies in the range 30 to 30 000 PHz (10^{15} Hz). X-rays are primarily used for diagnostic radiography and cristallography. X-rays are a form of ionizing radiation.

[0051] Within the scope of the present invention, the radiation damage or injury to be prevented and/or treated may be the result of an exposure to naturally occurring or to artificial radiation. Exposure to radiation, within the meaning of the invention, can occur in several other ways, including exposure to normal background levels of radiation (such as cosmic rays or radiation due to naturally-occurring isotopes present in the earth) or elevated environmental radiation (including occupational exposure of persons in medical facilities or nuclear power plants as well as exposure to X-rays during medical diagnosis, e.g. computer tomography). Another potential source of exposure to certain types of radiation is the accidental or intentional release of radioactive materials, for example, as the result of an accident or as a result of terrorist activity, e.g., as the result of a radiologic weapon such as a so-called "dirty bomb" (an explosive device intended to spread radioactive materials to contaminate an area).

[0052] In preferred embodiments of the invention, the radiation damage or injury is associated with cancer therapy, i.e. is the result of cancer radiotherapy. In a special embodiment of the invention, the radiation damage or injury is associated with bone marrow transplantation during cancer therapy.

[0053] In a second aspect, the present invention relates to a tri-substituted glycerol compound, as defined, herein for the prevention and/or treatment of radiation damage or injury. In preferred embodiments; the radiation damage or injury is associated with cancer therapy or with bone marrow transplantation during cancer therapy.

[0054] In a third aspect, the present invention relates to a corresponding method for the prevention and/or the treatment of radiation damage or injury, wherein the method comprises administering to a patient a medicament as defined in the invention.

[0055] As outlined above, the medicament according to the present invention may be administered via any parenteral or non-parenteral route. Preferably, the medicament is administered orally. Furthermore, Preferably, the medicament may be administered as a single dose such as in form of one tablet or capsule per day. However, it may also be possible to administer the medicament in multiple doses such as two or three individual doses administered during the day. For the prevention of radiation damage or injury the medicament is preferably administered prior to an exposure to radiation. However, it is also possible to administer the medicament during and/or after an exposure to radiation.

[0056] In a forth aspect, the invention relates to in vitro methods for preventing radiation damage or injury and for treating preventing radiation damage or injury in one or more cells, respectively, each of them comprising contacting the one or more cells to radiation with a medicament as defined in the invention. In the first method, the cells are contacted with the medicament prior to an exposure to radiation.

[0057] Preferably, the one or more cells are non-cancerous cells (i.e. non-tumorgenic control cells) such as bone marrow cells.

[0058] The invention is further described by the following figures and examples, which are solely for the purpose of illustrating specific embodiments of this invention, and are not to be construed as limiting the scope of the invention in any way.

[0059] Materials used in tests below are either commercially available or easily prepared from commercially available materials by those skilled in the art.

FIGURES

[0060] FIG. **1** depicts the radioprotective effect of ET18-OCH3 on the survival rate of mice. ET18-OCH3 was administered as a single dose of 50 mg/kg body weight to each of 40 mice (20 control mice, 20 test mice). 24 hours later, the 20 test mice were exposed to a gamma radiation dose of 7.9 Gy (Gray) and 8.7 Gy, respectively. The survival rates were monitored for 30 days.

[0061] FIG. **2** depicts the radioprotective effect of ET18-OCH3 (referred to as "ALP") on the lymphocyte numbers of mice. Mice were treated with a single dose 70 mg/kg ET18-OCH3 (administered subcutaneously) 24 hours before expo-

sure to neutron radiation (radiation dose 2.0 Gy). The number of lymphocytes per µl blood of untreated (irradiated) control mice and treated (test) mice was determined at days 1, 3, and 10 after irradiation.

[0062] FIG. **3** depicts the radioprotective effect of ET18-OCH3 (referred to as "ALP") on the granulocyte numbers of mice. The experiment was performed in an analogous manner as described in FIG. **2**.

EXAMPLES

[0063] The efficacy of 1-O-octadecyl-2-O-methyl-glycero-3-phosphocholine (in the following referred to as "ET18-OCH3") as a radioprotectant in the treatment of an acute radiation injury that is caused by (mid)lethal radiation doses was analyzed by determining its influence on the survival rate of mice and on the hematological syndrome of the radiation injury in response to different types of radiation.

Example 1

Efficacy of ET18-OCH3 in Response to X-Rays

[0064] A single dose of 25 mg/kg ET18-OCH3 was administered at a time intravenously to 25 mice 12 hours after exposure to an X-ray dose of 650 cGy (centiGray). Only one of the 25 treated mice died, as compared to 6 of the 25 mice in the control group.

[0065] After an intravenous administration of 25 mg/kg ET18-OCH3 6 hours and 12 hours after X-ray irradiation, respectively, the following results were obtained (Table 1). The chi-square distribution is given for all positive values. The chi-square test was used for comparing the results of the treated versus the control animals.

TABLE 1

Survival rates of X-ray irradiated mice after administration of 2 × 25 mg/kg ET18-OCH3 6 hours and 12 hours after irradiation, respectively.

X-ray Dose (cGy)	Death/Survival control	Death/Survival treated	Chi^2	p
650	4/26	2/28	0.74	0.402
700	19/11	3/25	17.03	<0.001
750	27/3	14/16	13.02	<0.001
800	30/0	22/8	9.23	0.002

[0066] The $LD_{50/30}$ X-ray dose was increased from 688.1±38.6 to 749±37.1 cGy for the treated versus the untreated controls animals. X-ray mediated lethality was delayed in the treated mice, as compared to the control mice.

[0067] After an oral administration of 25 mg/kg ET18-OCH3 6 hours and 24 hours after exposure to a X-ray dose of 700 cGy X-ray irradiation, respectively, 2 of 25 treated animals died, as compared to 7 of 25 of the control animals.

Example 2

Efficacy of ET18-OCH3 in Response to Neutron Radiation

[0068] Mice were irradiated using a van de Graaf generator with of 3-8 MeV neutrons. The radiation doses used in the following analyses were 400, 410, and 420 cGy for each third of the treated and the control mice, respectively. A single dose of 50 mg/kg ET18-OCH3 was administered to half of the mice by subcutaneous injection. The results obtained are shown in Table 2.

TABLE 2

Survival rates of mice after exposure to 400-420 cGy neutron radiation and subcutaneous administration of 50 mg/kg ET18-OCH3 at various time points. The chi-square test was used to compare the treated versus the control animals.

Number	Treatment	Survival/Death	Comp.	Chi^2	p
1	—	8 (38%)/13 (62%)			
2	ET18-OCH3, 6 h	12 (52%)/11 (48%)	1 vs. 2	0.88	0.382
3	—	8 (36%)/14 (64%)			
4	ET18-OCH3, 2 h	13 (54%)/11 (46%)	3 vs. 4	1.46	0.226
5		6 (29%)/15 (71%)			
6	ET18-OCH3, 30 min	18 (75%)/6 (25%)	5 vs. 6	9.79	0.002

[0069] From these results, it can be concluded that a treatment with a single dose of ET18-OCH3 should be carried out at the earliest possible time point after neutron irradiation. As the therapy experiments were carried out with an irradiation dose range, in which the hematological syndrome of the radiation injury predominates, the evaluation of the therapeutic effect of the drug on the blood forming (hematopoetic) system is important. From Table 3 it becomes apparent that ET18-OCH3 significantly increases the concentration of leukocytes and granulocytes in the peripheral blood during the time period when the irradiated mice died (day 10-15 after irradiation).

TABLE 3

Change in cell numbers in the peripheral blood of mice 7 and 14 days after exposure to a neutron irradiation of 300 cGy and subcutaneous administration of 50 mg/kg ET18-OCH3 2 hours and 30 min after irradiation, respectively. Given is the median/interquartile distance for various types of cells/µl; for thrombocytes the values are given in 1000 cells/µl. The Wilcoxon-Mann-Whitney U-test was used for comparison of controls versus treated animals (p-values).

Cell type	Time (days)	ET18-OCH3 2 h	Control 2 h	p	ET18-OCH3 30 min	Control 30 min	p
Leukocytes	7	675/413	550/200	0.07	975/450	750/450	0.38
	14	9975/5863	4400/9200	0.013	8675/11827	3350/1900	0.029
Lymphocytes	7	446/132	399/9200	>0.4	684/255	641/264	>0.4
	14	5101/3765	2801/3266	0.013	7439/6942	1915/1257	0.017

TABLE 3-continued

Change in cell numbers in the peripheral blood of mice 7 and 14 days after exposure to a neutron irradiation of 300 cGy and subcutaneous administration of 50 mg/kg ET18-OCH3 2 hours and 30 min after irradiation, respectively. Given is the median/interquartile distance for various types of cells/µl; for thrombocytes the values are given in 1000 cells/µl. The Wilcoxon-Mann-Whitney U-test was used for comparison of controls versus treated animals (p-values).

Cell type	Time (days)	ET18-OCH3 2 h	Control 2 h	p	ET18-OCH3 30 min	Control 30 min	p
Granulocytes	7	240/304	125/132	0.034	209/202	112/264	0.1
	14	4189/2282	1542/3300	0.007	3063/3121	854/1089	0.011
Thrombocytes	7	900/315	934/273	>0.4	698/427	660/50	>0.4
	14	987/464	979/290	>0.4	533/263	580/320	>0.4
Hematokrit	7	42.5/9.0	43.0/5.0	>0.4	40.0/5.5	37.0/8.8	>0.4
	14	37.0/8.5	31.0/4.0	0.008	32.5/5.0	28.0/14.0	0.128

Example 3

Efficacy of ET18-OCH3 Before Applying Gamma Radiation

[0070] The effect of a prophylactic treatment with ET18-OCH3 on the survival rate of gamma-radiated mice is summarized in Table 4.

TABLE 4

Survival rate of mice after gamma irradiation and administration of a single dose of ET18-OCH3 at various time points before exposure to irradiation or after radiation (a.r.), respectively. The chi-square test was used to compare the treated versus the control animals.

Dose (cGy)	Treatment ET18-OCH3	Survival	Death	Chi^2	p
750	—	11 (55%)	9 (45%)		
750	30 mg/kg; a.r.	17 (94%)	1 (6%)	7.60	0.006
775	—	0	20 (100%)		
775	40 mg/kg; a.r.	8 (40%)	12 (60%)	10.00	0.002
800	—	0	35 (100%)		
800	40 mg/kg; a.r.	25 (71%)	10 (29%)	3889	<0.001
775	50 mg/kg; 2 h	15 (75%)	5 (25%)		
800	50 mg/kg; 2 h	17 (85%)	3 (15%)		
750	—	10 (50%)	10 (50%)		
750	50 mg/kg; 1 d	20 (100%)	0	13.33	<0.001
775	50 mg/kg; 1 d	18 (90%)	2 (10%)		
790	—	2 (10%)	18 (90%)		
790	50 mg/kg; 1 d	18 (90%)	2 (10%)	25.60	<0.001
830	—	1 (5%)	19 (95%)		
830	50 mg/kg; 1 d	17 (85%)	3 (15%)	25.85	<0.001
870	—	0	20 (100%)		
870	50 mg/kg; 1 d	13 (65%)	7 (35%)	19.26	<0.001

[0071] Thus, a treatment of the mice with ET18-OCH3 resulted in a significant radioprotective effect that was similar when ET18-OCH3 was given either 24 hours or shortly before irradiation. This is in contrast to the effect of conventional radioprotectants that is only apparent when the radioprotectant is given shortly before administration. When administering ET18-OCH3 one day before irradiation, the $LD_{50/30}$ gamma radiation dose increased from 7.47 Gy (untreated irradiated controls) to 8.98 Gy (treated irradiated mice) (as determined by a probit analysis). The effect of ET18-OCH3 on the survival rate of mice at two different radiation doses in depicted in FIG. **1**

Example 4

Efficacy of ET18-OCH3 Before Applying Neutron Radiation

[0072] The effect of ET18-OCH3 before applying different doses of neutron radiation on the survival rates of mice are summarized in Table 5.

TABLE 5

Effect of ET18-OCH3 administered subcutaneously 1 day before neutron irradiation. The chi-square test was used to compare the treated versus the control animals.

Dosis (cGy)	Treatment	Survival	Death	Chi^2	p
425	—	0	15 (100%)		
425	50 mg/kg	4 (27%)	11 (73%)	4.61	0.032
450	—	8 (28%)	21 (72%)		
450	50 mg/kg	22 (73%)	8 (26%)	12.35	<0.001
475	—	0	20 (100%)		
475	50 mg/kg	6 (24%	19 (76%)	5.54	0.019
425	—	0	15 (100%)		
425	70 mg/kg	5 (33%)	10 (67%)	6.00	0.014
450	—	1 (7%)	14 (93%)		
450	70 mg/kg	3 (20%)	12 (80%)	1.15	0.283

Example 5

Effect of ET18-OCH3 on the White Blood Cell Count (Hemogram)

[0073] After administration of 50 mg/kg and 70 mg/kg ET-18-OCH3, respectively, and exposure to neutron irradiation, the reduction of leukocyte numbers (both of lymphocytes and granulocytes) was slightly increased, as compared to untreated controls (not statistically significant; 5 experiments, n=90).

[0074] However, starting at day 3 after irradiation, the ET-18-OCH3 treatment resulted in an increase in leukocyte numbers (both lymphocytes and granulocytes), which became significant at day 7 (4 experiments; n=30, $p<0.003$). No statistically significant difference could be observed between the administration of 50 mg/kg and 70 mg/kg ET18-OCH3. The radioprotective effect of ET18-OCH3 on lymphocyte and granulocyte numbers in mice is shown in FIG. **2** and FIG. **3**, respectively.

[0075] Despite a significant increase caused by the administration of ET18-OCH3, at mid-lethal irradiation doses the

number of lymphocyte remains at a low level, which is average about one tenth of the normal value, whereas the number of leukocyte of the treated animals shows a much higher variation than that of the controls. Thus, at day 7 to 10 after irradiation the treated animals can be classified into two groups, in one of which the number of leukocytes is almost unchanged, as compared to the control group. These mice normally die at day 10 to 14 after irradiation. The respective portions of leukocyte fractions was inconsistent, however, in general both the numbers leukocytes and granulocytes were significantly increased.

[0076] The present invention illustratively described herein may suitably be practiced in the absence of any element or elements, limitation or limitations, not specifically disclosed herein. Thus, for example, the terms "comprising", "including", "containing", etc. shall be read expansively and without limitation. Additionally, the terms and expressions employed herein have been used as terms of description and not of limitation, and there is no intention in the use of such terms and expressions of excluding any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the invention claimed. Thus, it should be understood that although the present invention has been specifically disclosed by preferred embodiments and optional features, modifications and variations of the inventions embodied therein herein disclosed may be resorted to by those skilled in the art, and that such modifications and variations are considered to be within the scope of this invention.

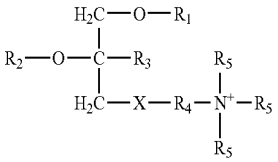
[0077] All documents cited or referenced herein including any manufacturer's instructions, descriptions, product specifications, and product sheets for any products mentioned herein or in any document referenced herein, are hereby incorporated by reference, and may be employed in the practice of the invention. Citation or identification of any document in this application is not an admission that such document is available as prior art to the present invention.

[0078] The invention has been described broadly and generically herein. Each of the narrower species and subgeneric groupings falling within the generic disclosure also form part of the invention. This includes the generic description of the invention with a proviso or negative limitation removing any subject matter from the genus, regardless of whether or not the excised material is specifically recited herein.

[0079] Other embodiments are within the following claims. In addition, where features or aspects of the invention are described in terms of Markush groups, those skilled in the art will recognize that the invention is also thereby described in terms of any individual member or subgroup of members of the Markush group.

1-21. (canceled)

22. Use of a tri-substituted glycerol compound according to formula (I)



or an enantiomer or diastereomer or a pharmaceutically acceptable salt thereof and at least one pharmaceutically acceptable excipient for the manufacture of a medicament for the prevention and/or treatment of radiation damage or injury, wherein

a) X is selected from the group consisting of phosphate and sulfate;

b) R_1 is selected from the group consisting of C_{16}-C_{20} alkyl;

c) R_2 is selected from the group consisting of C_1-C_3 alkyl and C_1-C_3 hydroxyalkyl;

d) R_3 is selected from the group consisting of hydrogen and C_1-C_3 alkyl;

e) R_4 is selected from the group consisting of C_1-C_3 alkyl and C_3-C_6 cycloalkyl; and

f) R_5 is selected from the group consisting of hydrogen and methyl.

23. The use according to claim **22**, wherein X is phosphate, R_1 is $—(CH_2)_{17}—CH_3$, R_2 is CH_3, R_3 is H, R_4 is $—(CH_2)_2—$, and R_5 is CH_3.

24. The use according to claim **22**, wherein the medicament is a dosage form for oral administration.

25. The use according to claim **24**, wherein the dosage form is a solid dosage form.

26. The use according to claim **25**, wherein the dosage form is selected from the group consisting of tablets, pills, capsules, and granules.

27. The use according to claim **22**, wherein the amount of the tri-substituted glycerol compound in the medicament is in the range of 30 to 250 mg.

28. The use according to claim **27**, wherein the amount of the tri-substituted glycerol compound in the medicament is in the range of 50 to 150 mg.

29. The use according to claim **22**, wherein the daily dosage of the tri-substituted glycerol compound is in the range of 50 to 350 mg.

30. The use according to claim **22**, wherein the radiation damage or injury is caused by ionizing radiation selected from the group consisting of neutron radiation, alpha radiation, beta radiation, gamma rays, and X-rays.

31. The use according to claim **22**, wherein the radiation damage or injury is associated with cancer therapy or with bone marrow transplantation during cancer therapy.

32. Tri-substituted glycerol compound as defined in any of claims **22** to **31** for the prevention and/or treatment of radiation damage or injury.

33. The tri-substituted glycerol compound according to claim **32**, wherein the radiation damage or injury is associated with cancer therapy or with bone marrow transplantation during cancer therapy.

34. Method for the prevention and/or treatment of radiation damage or injury, comprising: administering to a patient a medicament as defined in any of claims **22** to **31**.

35. The method according to claim **34**, wherein the medicament is administered prior to an exposure to radiation or during and/or after an exposure to radiation.

37. In vitro method for preventing radiation damage or injury in one or more cells, comprising: contacting the one or more cells prior to an exposure to radiation with a medicament as defined in any of claims **22** to **31**.

38. The in vitro method according to claim **37**, wherein the one or more cells are non-cancerous cells.

39. The in vitro method according to claim **38**, wherein the non-cancerous cells are bone marrow cells.

40. In vitro method for treating radiation damage or injury in one or more cells, comprising: contacting the one or more cells with a medicament as defined in any of claims **22** to **31**.

41. The in vitro method according to claim **40**, wherein the one or more cells are non-cancerous cells.

42. The in vitro method according to claim **41**, wherein the non-cancerous cells are bone marrow cells.

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