METHOD OF USING MITOTICALLY INACTIVATED STEM CELLS FOR DAMAGED TISSUE REPAIR

[0001] This application claims the benefit under 35 USC 119(e) of U.S. provisional application number 60/807,861, filed July 20, 2006, which is incorporated herein by reference.

[0002] The present invention is directed to the use of mitotically and/or lethally inactivated stem cells for the repair of damaged organs and/or tissues. Any form of ex vivo inactivation of stem cells may be used such that the stem cells cannot undergo unwanted mitosis or cell division before or after in vivo application. Mitotically and/or lethally inactivated stem may be used to ameliorate numerous disease, injury, and/or degenerative conditions in different types of organs and/or tissues.

BACKGROUND OF THE INVENTION

[0003] Stem cells, especially ESC due to pleuripotency, are being investigated to repair or rejuvenate tissue. However ESC, due to their pleuripotential (also spelled pluripotent) behavior, when injected in vivo form teratomas, a dysregulated, cancerous tumor growth. Teratomas are composed of cells from all three embryonic germ layers: mesoderm, endoderm, and ectoderm.

[0004] To circumvent generation of teratomas, ESC presently used in transplantation must be differentiated ex vivo into lineage committed adult stem cell phenotypes and or fully differentiated cells. This process is time consuming, requires maintenance of Good Manufacturing Procedures (GMP) over an extended period of time, and a method to purify the final product to ensure there is no contamination from residual pleuripotent ESC, and a method to ensure desired cell identity and lot to lot equivalency. ESC-derived cells must be grown ex vivo and maintained in feeder free and defined-media conditions to meet GMP guidelines.

[0005] Recent advances in cell culture technology have met GMP requirements for maintenance and expansion of undifferentiated ESC. However, in order to avoid teratoma formation, ESC must undergo costly and labor intensive differentiation into a mature somatic cell prior to in vivo application. In addition, these somatic cells must undergo purification or selection to avoid contamination with residual teratoma forming ESC or other undifferentiated or differentiated contaminating cells.

[0006] Further advances in ESC technologies have been restrained due to governmental restrictions and ethical issues surrounding the use of human ESC. Of concern to many is the use of human ESC in medical procedures.

[0007] Notwithstanding the ethical issues surrounding ESC, patients who have received transplanted ESC produced by current methods may require lifetime immune suppression to prevent ESC derived somatic cell rejection. Immune suppression may be accomplished by the use of immunosuppressants. Immunosuppressants are a class of drugs capable of inhibiting the body's immune system. Many of the agents included in this category are also cytotoxic (cell poisons) and are used in the treatment of cancer. Cytotoxic agents used as immunosuppressants include antimetabolites (azathioprine), alkylating agents (cyclophosphamide), and folic-acid antagonists (methotrexate or 6-MP). Other immunosuppressants include mycophenolate (CellCept) and cyclosporin. These drugs may be used in ESC transplant patients to decrease the body's own natural defense to foreign bodies (such as the transplanted ESC) and thereby, attempt to prevent the ESC rejection by the body.

[0008] Suppression of the immune system may create a number of undesirable side effects in a patient such as stomach upset, nausea, vomiting, abdominal pain, mouth ulcers, darkened urine, pale stools, jaundice (yellowing of the skin or white portion of the eyes), unusual bleeding or bruising. A serious (and life threatening) side effect is reduced activity of bone marrow, which is monitored with regular blood tests. Occasionally, patients taking immunosuppressants will develop pancreatitis (inflammation of the pancreas) some months after starting these drugs.

[0009] Additionally, patients undergoing immunosuppression therapy are at a greater risk for various infections including bacterial infections, herpes infections (such as cold sores and shingles), cytomegalovirus, fungal infections, and *Pneumocystis carinii* (a lung infection). Because patients are at an increased risk for infection, they may be required to have routine assessments to check for any signs or symptoms of infection. To prevent illness, patients may be required to take anti-viral medications such as acyclovir, cytovene, and valacyclovir; anti-fungal medications such as fluconazole and voriconzaole; and antibiotics such as Bactrim.

[00010] Patients receiving immunosuppressant therapy will likely experience substantial changes in daily routine. Patients must be vigilant in avoiding persons and activities posing a risk of infection.

[00011] Patients may need to restrict the number of individuals with whom they come in contact with on any given day and avoid crowded, enclosed areas. Patients must avoid contact with friends and family who have been sick including school-aged children. If a member of the patient's immediate family is ill, the patient may be required to stay in another room or stay in a hotel until the family member is no longer sick. Patients must also avoid contact with babies and children who have been recently vaccinated with the live-virus oral polio vaccine for at least eight weeks. Recipients of the vaccine can shed the virus in body excretions such as saliva and stool and infect an immunosuppressed individual. Patients may be required to avoid crowed places such as restaurants, churches or temples, retail stores, and public transportation.

[00012] Patients may also be restricted from performing or engaging in certain activities which have a high risk for infection. These activities may include changing a baby's diaper, interacting with pets, and gardening.

SUMMARY

[00013] The present invention is directed to a method for repairing damaged tissue by mitotically inactivating and/or lethally inactivating stems cells and transplanting the mitotically and/or lethally inactivated stem cells into the damaged tissue. The

transplanted mitotically and/or lethally inactivated stem cells are effective for regeneration of damaged cells. Transplantation of the mitotically and/or lethally inactivated stem cells into the damaged tissue is not dependent on a permanent presence of the foreign stem cells in the recipient and the immune system of the recipient does not need to be suppressed to allow life-long engraftment. Furthermore for pleuripotent stem cells, mitotic inactivation prevents formation of teratomas. Every organ and or tissue in the body may be repaired using mitotically and/or lethally inactivated stem cells including but not limited to cardiac tissue, nerve tissue, muscle tissue, pancreatic tissue, and liver tissue. The method is effective for repairing these tissues in animals, including mammals, primates and humans.

[00014] Stem cells which may be utilized include pluripotent stem cells. Pluripotent stem cells include any stem cell independent of its in vivo source of origin such as but not limited to embryos (ESC), placenta, amniotic fluid, bone marrow, or pleuripotent stem cells derived ex vivo from adult stem cell. A pluripotent stem cell is capable of differentiating into more than one germ line or tissue specific cell lineages.

[00015] Stem cells are mitotically and/or lethally inactivated by treating the stem cells with a method effective for inhibiting or preventing unlimited proliferation of stem cells. In this aspect, the embryonic stem cells are inactivated with irradiation, mitomycin C, phototherapy, or any agent that inhibits cell proliferation including but not limited to inhibitors of cellular components necessary for mitosis such as but not limited to protein synthesis, microtubule function, spindle check point unit, cell cycle specific kinases, cyclins, and or apoptotic inducing agents, as well as any means of genetic, protein, and or cell manipulation that will allow termination or prevention of unregulated or unlimited cell proliferation.

A first specific expression of the invention is a method of mitotically and/or lethally inactivating stem cells comprising: providing pluripotent stem cells; and inactivating the pluripotent stem cells with a method effective for inhibiting unlimited proliferation of the pluripotent stem cells and effective for inactivating adult stem cells such as umbilical cord blood stem cells to prevent their growth or persistence in a recipient.

A second specific expression of the invention is mitotically inactivated stem cell produced by a method comprising: providing pluripotent stem cells; and inactivating the pluripotent stem cells with a method effective for inhibiting unlimited proliferation of the pluripotent stem cells.

BRIEF DESCRIPTION OF THE DRAWINGS

[00016] FIG. 1a is a graphical representation of the results of Example 1 (discussed herein below) where median blood pressure (mmHg) in mice having ESC treated

ischemic hearts is compared to median blood pressure (mmHg) in mice having ischemic hearts receiving no treatment.

[00017] FIG. 1b is a graphical representation of the results of Example 1 (discussed herein below) where median contractility (mmHg/s) in mice having ESC treated ischemic hearts is compared to median contractility (mmHg/s) in mice having ischemic hearts receiving no treatment.

[00018] FIG. 1c is a graphical representation of the results of Example 1 (discussed herein below) where median relaxation (mmHg) in mice having ESC treated ischemic hearts is compared to median relaxation (mmHg) in mice having ischemic hearts receiving no treatment.

[00019] FIG. 2 demonstrates the effect of mitotically inactivated ESC treatment on diabetes.

[00020] FIG. 3 shows % survival following different does of total body irradiation.

[00021] FIG. 4 shows a survival curve for total body irradiation (TBI) experiments in controls (exposed to TBI) compared to mammals exposed to TBI and then injected with mitotically inactivated ESC.

DETAILED DESCRIPTION

[00022] The above and other problems addressed above are solved by the preferred embodiments discussed below. The following description is of the best mode presently contemplated for practicing the invention. This description is not to be taken in a limiting sense, but is made merely for the purpose of describing the general principles of the invention.

[00023] The invention advantageously eliminates the costly steps of stem differentiation and somatic cell purification because mitotically and/or lethally inactivated stem cells either allogeneic (from another person) tissue specific adult stem cells or plueripotent stem cells i.e. ESC (also allogenic) or allogeneic amniotic fluid derived pleuripotent stem cells (or pleuripotent stem cells from any source) can provide a transient in vivo chaperone assist to endogenous tissue without need of immune

suppression or undesirable teratoma formation (ESC that are not mitotically inactivated form teratomas). As used herein, not forming teratomas means prevention of uncontrolled proliferation and its subsequent complications. Inactivated stem cells are not capable of undergoing unchecked cellular division and therefore do not form teratomas. Furthermore, because the stem cells chaperone effect is effective even if only present transiently, long-term (i.e life-long) immunosuppression in a patient is not necessarily a requirement of treatment with mitotically and/or lethally inactivated stem cells. Avoiding immunosuppression therapy drastically improves the patient's comfort and quality of life.

[00024] In another aspect of the invention, as demonstrated for the first time herein for embryonic stem cells, ESC produce a pronounced chaperone effect or in vivo cell-help-cell effect which mediates endogenous tissue regeneration. This chaperone or cell-help-cell effect is provided in vivo. ESC mediated chaperone effect is transient and rejection of the allogeneic ESC by host immune system does not diminish the effectiveness of the ESC.

[00025] In one embodiment, this chaperone effect can occur across xenogenic barriers allowing the substitution of animal ESC for human ESC for tissue regeneration which would mitigate ethical concerns and restraints on ESC therapies. In another embodiment, this chaperone effect could be obtained from pleuripotent stem cells derived from adult stem cells or from amniotic fluid or placenta or other sources that would mitigate ethical concerns.

Stem Cells

[00026] Stem cells are undifferentiated cells that through replication have the capability of both self-renewal and differentiation into mature specialized cells. In broad terms, there are two types of stem cells, embryonic stem cells (ESC) and adult stem cells (ASC). Human ESC are traditionally isolated from a 50- to 150-cell, 4- to 5-day-old post-fertilization blastocyst. ESC generate every specialized cell in the human body; and while capable of indefinite ex vivo proliferation, exist only transiently in vivo – during

embryogenesis. ASC are located in tissues throughout the body and function as a reservoir to replace damaged or aging cells. ASC are restricted in their differentiation to cell lineages of the organ system in which they are located. Stem cells are also referred to as toti-, pluri-, multi-, or unipotent . Totipotent stem cells arise from the morula and are capable of forming all cells essential for the body, including placental trophoblasts. In the next stage of embryonic development the morula becomes a blastocyst. Pluripotent stem cells traditionally arise from the blastocyst stage of development and give rise to every cell in the body, but not placental trophoblasts. Pleuripotent stem cells have also been recovered from amniotic fluid and may be found or generated from other sources such as placenta or from manipulation of ASC. ASC are multipotent stem cells in that their differentiation is limited to the tissue lineage or compartment in which they are located. Unipotent stem cells, also termed transient amplifying cells, are restricted in differentiation into a single specialized cell.

[00027] ESC have great promise and versatility but, compared to ASC, are currently difficult to tame due to their tendency to form all types of tissue within the body, i.e. a teratoma. In contrast, ASC normally behave well without formation of tumors, and follow traditional lineage-specific differentiation patterns, fulfilling their physiologic homologous function of replacing normal turnover, aging or damaged tissues,

[00028] Herein we demonstrate that ESC that are mitotically inactivated have a potent chaperone effect on endogenous tissue repair and do not form teratomas. While we demonstrate this effect for mitotically inactivated ESC, we maintain that mitotic inactivation of other pleuripotent stem cells and even mitotically inactivated adult stem cells such as umbilical cord blood may convey, albeit with lesser efficacy, a similar effect without concern of uncheck proliferation of allogeneic cells in a genetically different recipient.

[00029] Pluripotent stem cells may be obtained originally from a number of sources including embryos, placenta, amniotic fluid, from manipulation of adult stem cells, and from various commercial sources that expanded the cells in culture.

Mitotic and/or Lethal Inactivation

[00030] Stem cells may be mitotically inactivated with any method effective for inhibiting unlimited proliferation of stem cells. Inhibiting unlimited proliferation means that stem cells do not present complications in vivo from uncontrolled proliferation.

[00031] Stem cells, such as ESC may be mitotically inactivated with radiation, mitomycin phototherapy, or any agent that inhibits cell proliferation including but not limited to inhibitors of cellular components necessary for mitosis such as but not limited to protein synthesis, microtubule function, spindle check point unit, cell cycle specific kinases, cyclins, and or apoptotic inducing agents. Stem cells may also be mitotically inactivated by any means of protein or genetic or cellular manipulation that will terminate or prevent unwanted proliferation and or differentiation. This approach applies to any form of ex vivo inactivation of stem cells so that the stem cells cannot undergo mitosis or cell division in vivo. We have shown that ESC provide a tissue repair chaperone effect after exposure to wide ranges of radiation doses of 10 to 40 Gy.

[00032] In another aspect, the stem cells may be lethally inactivated. Lethally inactivated means that the dose of radiation or apoptotic inducing agent is such that the ESC will not only stop dividing but die within hours, days, or weeks of injection.

Transplantation of Stem Cells

[00033] The invention disclosed herein utilizes mitotically inactivated and/or lethally inactivated stem cells for the repair of damaged organs and/or tissues. According to one embodiment, mitotically and/or lethally inactivated stem cells such as ESC are transplanted or injected into a site of damaged tissue or intravenously or into surrounding fluid such as cerebrospinal fluid in a patient. This covers all routes of administration or delivering mitotically inactivated stem cells into the body in single or repeated intervals and in all doses.

Treatments

[00034] The methods described herein apply to all different types of organs and/or tissues for any type of injury, disease state, or natural degenerative state caused by aging. Virtually any organ can be repaired with mitotically and/or lethally inactivated stem cells such as ESC. For example, the types of organs and/or tissue that can be repaired by transplantation of mitotically inactivated stem cells include but are not limited to (1) heart or cardiac tissue after ischemic or traumatic injury, (2) brain or central nervous system (CNS) preservation after cerebral vascular accident or stroke, (3) oligodendrocyte repair in demyelinating CNS diseases such as multiple sclerosis, (4) aoxnal repair of degenerating CNS diseases such as Parkinsons, Huntingtons and Alzheimer's diseases, (5) rapid wound healing after trauma such as follows gun shot or explosive injuries, (6) repair of spinal cord injuries (SCI) for reinervation / remyelination, (7) prevention of tissue apoptosis and damage following radiation injury either from accidental exposure, following a terrorist attack, or for recovery from radiation induced injury used as medical therapy, (8) islet cell regeneration for type I and II diabetes, (9) lung tissue in patients with emphysema, (10) cartilage repair in degenerative or inflammatory joint diseases, (11) regeneration of ischemic renal epithelium after acute tubular injury (ATN), (12) regeneration of vascular supply to chronically or acutely ischemic tissue, and (13) repair of toxic and/or radiation induced tissue injury.

[00035] Although not wishing to be limited by theory, it is hypothesized that undifferentiated ESC provide a chaperone (cell-help-cell) effect by humoral or paracrine mediators and or cellular factors or factors mediated through cell contact that can mediate ASC or somatic cell proliferation, growth, and renewal which is required only transiently and can be provided by either lethally inactivated or mitotically inactivated ESC. This effect does not depend on immune acceptance of the ESC or on the establishment of a committed or differentiated cell progeny derived from the ESC.

[00036] The method is advantageously simple and practical. It avoids differentiation of ESC which involves gene therapy or cytokine / media directed ex vivo differentiation and extensive purification of the ESC-derived somatic cell. The undifferentiated ESC can be directly used to augment organ specific regeneration without unwanted side

effects of teratoma formation from non-mitotically inactivated ESC . This is a tremendous savings in time, effort, expense, and compliance with regulatory issues.

[00037] Furthermore, immune tolerance in patients is not required. ESC-derived or pluripotent stem cell-derived or adult allogeneic stem cell derived somatic cells are foreign and can be rejected by the recipient unless he/she receives life long immune suppression. The methods described herein do not require immune suppression. The paracrine or chaperone effect of the mitotically inactivated ESC is transient and immune mediated rejection or apoptosis of the ESC would be expected.

[00038] From an ethical standpoint, xenogeneic mitotically inactivated ESC in addition to human derived ESC are effective to treat disease and injury in mammals. Although human ESC may be superior for a given application, the use of mitotically inactivated ESC from another species avoids any ethical issue for a patient treatment arising from procurement and use of human ESC. Also from an ethical standpoint, mitotically inactivated pluripotent stem cells derived from non-embryonic sources such as but not limited to placenta or amniotic fluid or derived from adult stem cells may be used with the same or similar albeit perhaps lesser effect.

[00039] Any type of mammal may be treated with mitotically and/or lethally inactivated stem cells. Examples of mammals that may be treated include, but are not limited to rodents, such as mice and rats, pigs, cats, dogs, and primates, including for example humans and chimpanzees. Since embryonic and pluripotent stem cells are a consistently conserved evolutionary theme, any type of mammal may likewise be a donor of stem cells, such as, for example, rodents such as mice and rats, pigs, cats, dogs, and primates, including, for example, humans and chimpanzees.

[00040] There are a wide range of applications for which the mitotically and/or lethally inactivated stem can be used. The applications are available for use in any organ system damaged by disease, trauma, ischemis, aging, degeneration, or exposure to noxious substances. Advantageously, many of the applications can be derived from a single off the shelf product. Since mitotically inactivated ESC are a universal product that can be used for any diseased or traumatized or ischemia organ independent of

immunologic differences between individuals, they are a readily available off the shelf commercial product.

EXAMPLES

[00041] A better understanding of the present embodiment and of its many advantages may be clarified with the following example, given by way of illustration.

EXAMPLE 1: CARIDAC ISCHEMIA

[00042] Mouse irradiated (20 Gy to 30 Gy) ESC were injected into ischemic murine myocardium using coronary artery clamping as an ischemic / reperfusion model. Mice receiving irradiated ESC were compared to mice receiving non-irradiated ESC and mice receiving no ESC.

[00043] Mice with infarct receiving non-irradiated ESC and mitotically inactivated ESC showed a marked improvement in terms of cardiac relaxation and contractility in comparison to mice receiving no ESC.

[00044] Untreated ESC gave rise to malignant rapidly growing teratomas in several of the subject heart while no residual ESC could be found in the hearts or any other organ of animals receiving mitotically inactivated ESC.

[00045] The materials, methods, and results follow herein below:

Mice

[00046] Female 129X1/SvJ mice were purchased from the Jackson Laboratories (Jackson Lab, Bar Harbor, Main) and housed in filtered-top cages under barrier conditions with easy access to water and food. All animal experiments were approved by the Institutional Animal Care and Use Committee of Northwestern University.

Embryonic stem cells

[00047] Various animal ESC lines such as the 129/SvJX129/SV-CP male F1 hybrid 3.5-day mouse (H-2^b) blastocyst-derived embryonic stem cell lines or human ESWC line WA09 may be utilized. Human ESC were obtained commercially (WiCell Research Madison, Wisconsin) as NIH approved cell line WA09. ESC culture in maintenance

culture may be performed in numerous published manners and are not unique for success of this approach. For mouse ESC, to maintain embryonic stem cells in an undifferentiated state, cells were cultured on gelatinized tissue culture dishes in high-glucose Dulbecco's modified Eagle's medium supplemented with 15% fetal bovine serum (FBS), 2mM L-glutamine, 0,1mM β-mercaptoethanol, 1 x nonessential amino acids, 1 x sodium pyruvate and 1000 U/ml leukemia inhibitory factor (LIF) (Specialty Media, Phillipsburg, NJ; StemCell Technologies, Vancouver, Canada). Mitomycin C-treated primary embryonic fibroblasts (StemCell Technologies) were used as a feeder layer for long-term culture of R1 ESC. Embryonic stem cells were cultured in gelatin-coated plastic dishes without PMEF for the two last passages before collection for the injection.

ESC mitotic inactivation and Analysis of cell proliferation

[00048] ESC were grown under culture conditions as above to 70% confluence, then collected and irradiated with 30 Gy using Gammacell 40 irradiator one day prior the injection. Irradiated (20 to 30 Gy) and non-irradiated ESC were analyzed for proliferation rate using bromodeoxyuridine (BrdU) uptake. The cells were cultured in a total volume of 2mL in MESC media in the presence of LIF and 10uL/mL of BrdU. 24 or 48 hours later, cells were harvested and processed with a BrdU Flow Kit (BD Pharmingen) according to the manufacturer's protocol. Cells were stained with FITC anti-BrdU and 7-amino-actinomycin (7-AAD). Flow cytometric data were acquired using an Epics XL flow cytometer and analyzed with CellQuest software.

Coronary artery ligation

[00049] Anesthetized mouse was placed in a supine position with paws taped to the operating table. The tongue was slightly retracted. A150-W halogen light source (World Precision Instruments, Sarasota, FL) with two 24-in flexible fiber-optic arms allowed transillumination of the trachea just below the vocal cords to provide visualization of the trachea for endotracheal intubation. A catheter was inserted through the larynx and into the

trachea. Ventilation was provided by a rodent ventilator. The chest was opened along the left side of the sternum cutting through the ribs to approximately midsternum. The chest walls were retracted by the use of 5-0 or 6-0 silk or monofilament suture. The left auricle was slightly retracted exposing the entire left main coronary artery system. Ligation proceeded with a 7-0 silk suture passed with a tapered needle underneath the left anterior descending branch of the left coronary artery 1-3 mm from tip of the normally positioned left auricle. A 1-mm section of PE-10 tubing was placed on top of vessel, and knot was tied on the top of the tubing to occlude the coronary artery. After occlusion for 60 minutes, reperfusion occurred by cutting the knot on top of the PE-10 tubing. Cells were injected into the ischemic myocardium at the border of the infarct site immediately before removing artery occlusion. The chest wall was then closed. The mouse was removed from the respirator, the endotracheal tube was withdrawn, and the mouse was kept warm by a heat pad and allowed 100% oxygen via nasal cone under intensive care for up to 24 hours. Functional studies and immunohistochemistry were done 30 days after coronary artery ligation.

Hemodynamics measurement and determination of infarct size

[00050] Mice were anaesthetized. A high-fidelity transducer tipped pressure–volume catheter (SPR 839, Millar Instruments, Houston, TX, USA) was zeroed in 37°C saline. The right carotid artery was isolated, and two ties were gently pulled back, using hemostats, to block blood flow from the vessel. When pulsatile flow was no longer visible, a small cut was made just below the distal tie, and the catheter was placed inside the carotid artery, and secured in place. The transducer was advanced into the heart, where its position was confirmed by the rapid deflection of the diastolic pressure wave without any change in systolic pressure. Mice were allowed to stabilize for 30 min. After stabilization, 30s of data were collected. At the end of data collection, the catheter was removed from the heart for measurement of arterial pressure, in order to verify that the valves were not damaged. The catheter was then removed from the mouse. Signals were digitized by use of a data translation series analog digital converter and then stored and

analyzed on a Millar PVAN data acquisition and analysis system. Values derived from pressure traces were averaged no less than 20 bears. After ventricular function assessment, hearts were collected and fixed in 10% paraformaldheide. All hearts were cut into 4 blocks and were paraffin-embedded with flat side down. Serial sections of heart were cut at 5 μm thickness with a microtome.

Histology

[00051] Infarct size was assessed by H&E staining. Infarct area was determined by planimetry using image analyzing software (NIH image). All sections of the 4 blocks of each heart were assessed. The infarct size was expressed as the average percentage of the left ventricle on the 4 blocks of each heart. H&E stained slides were used as well to analyze morphology of cardiomyocytes, the presence or absence of infiltration, and/or tumor growth within myocardium.

FISH analysis

[00052] Single-label (whole Y-chromosome) FISH analysis was performed according to the manufacturer's protocol (Cambio Ltd, Cambridge, UK). Serial sections from paraffin-embedded whole heart block were cut (4 μm thickness) and prepared for procedure using tissue microarray (TMA). TMA permitted the combination of all tissue specimens including positive and negative controls on one slide. Tissue sections on coated slides were dewaxed, rehydrated, treated with sodium thiocyanate solution and pepsin, fixed and dehydrated. After air drying, 15-20 μl of denatured nucleotide probe was added to each slide, covered by coverslip and sealed. After overnight hybridization at 37 C, the coverslip was removed and serial washings were performed. Nuclei were counterstained with DAPI. Slides were examined by fluorescent microscope (Olympus BX-41) with an appropriate filter system.

Results

[00053] Actual values of contractility between mice with infarct receiving non-irradiated ESC (Non-irradiated ESC- N), mice that received mitotically inactivated ESC (Irradiated ESC -I), and mice getting infarct with no ESC injected (control-C) are shown in table 1.

Table 1

	Group	BP (mmHg)	Contractility (mmHg/s)	Relaxation (mmHg)
1	N	92	8502	6079
2	N	95	8934	6400
3	N	90	7875	6008
4	N	92	9593	6384
5	I	91	10079	6996
6	I	82	7076	6408
7	I	94	7388	6204
8	I	92	7906	7059
9	I	96	10753	7162
10	C	62	3780	3553
11	C	66	4270	3710
12	C	68	4367	4230

[00054] Analysis of mean and median contractility between mice with infarct receiving non-irradiated ESC (Non-irradiated ESC- N), mice that received mitotically inactivated ESC (Irradiated ESC -I), and mice getting infarct with no ESC injected (control-C) are shown in table 2. Of importance there is no difference between irradiated and non-irradiated ESC in terms cardiac relaxation and contractility but there is marked improvement in both when compared to mice receiving no ESC.

Table 2

Group	#	BP	BP	Contractility	Contractility	Relaxation	Relaxation
Group	#	Mean ± SD	Median (Min; Max)	Mean ± SD	Median (Min; Max)	Mean ± SD	Median (Min; Max)
N	4	92.3 ± 2.1	92 (90; 95)	8712.3 ± 701.5	8718 (7875; 9538)	6217.8 ± 203.4	6231.5 (6008; 6400)
I	5	91 ± 5.4	92 (82; 96)	8638.6 ± 1667.0	7906 (7067; 10753)	6765.8 ± 429.9	6996 (6204; 7162)
C	3	65.3 ± 3.1	66 (62; 68)	4139 ± 314.7	4270 (3780; 4367)	3831 ± 354.3	3710 (3553; 4230)

Table 3

Mann-Whitney U Test (Sheet1 in heart-ESC1) By variable group1 Marked tests are significant at p <.05000	Mann-Whitney U Test (Sheet1 in heart-ESC1) By variable group1 Marked tests are significant at p <.05000	Mann-Whitney U Test (Sheet1 in heart-ESC1) By variable group1 Marked tests are significant at p <.05000	Mann-Whitney U Test (Sheet1 in heart-ESC1) By variable group1 Marked tests are significant at p <.05000	Mann-Whitney U Test (Sheet1 in heart-ESC1) By variable group1 Marked tests are significant at p <.05000	Mann-Whitney U Test (Sheet1 in heart-ESC1) By variable group1 Marked tests are significant at p <.05000	Mann-Whitney U Test (Sheet1 in heart-ESC1) By variable group1 Marked tests are significant at p <.05000	Mann-Whitney U Test (Sheet1 in heart-ESC1) By variable group1 Marked tests are significant at p <.05000	Mann-Whitney U Test (Sheet1 in heart-ESC1) By variable group1 Marked tests are significant at p <.05000	Mann Whitney U Test (Sheet1 in heart-ESC1) By variable group1 Marked tests are significant at p <.05000
	Rank Sum	**Rank Sum**	**U**	**Z**	**p-level**	**Z**	**p-level**	**Valid N**	**Valid N**	**2*1sided**
Blood Pressure (mmHg)	72.00000	6.000000	0.00	2.496151	0.012555	2.513792	0.011945	9	3	0.009091
Contractility (mmHg/s)	72.00000	6.000000	0.00	2.496151	0.012555	2.496151	0.012555	9	3	0.009091
Relaxation (mmHg)	72.00000	6.000000	0.00	2.496151	0.012555	2.496151	0.012555	9	3	0.009091

Conclusion

[00055] Mice with infarct receiving non-irradiated ESC and mitotically inactivated ESC showed a marked improvement in terms of cardiac relaxation and contractility in comparison to mice receiving no ESC. Untreated ESC gave rise to malignant rapidly growing teratomas in several of the subjects heart while no residual ESC could be found in the hearts or any other organ of animals receiving mitotically inactivated ESC.

EXAMPLE 2: DIABETES

[00056] Both type I and Type II diabetes are due to insufficient insulin for body requirements. In type I diabetes, beta islet cell loss is relatively rapid and profound with loss of insulin production. Non-obese diabetic mice develop clinical diabetes about 90 to 100 days of age. This process is due to immune-mediated destruction of insulin producing islet cells. We had previously demonstrated that mitotically inactivated ESC could repair ischemic injury induced dysfunction of myocardium. We next determined whether mitotically inactivated ESC could repair or prevent diabetes in NOD mice. The materials methods and results follow herein below

Mice

[00057] Six week old NOD/Ltj mice were obtained from Jackson laboratory.

Embryonic stem cells

[00058] Various animal blastocyst-derived embryonic stem cell lines may be utilized., To maintain mouse embryonic stem cells in an undifferentiated state, cells were cultured on gelatinized tissue culture dishes in high-glucose Dulbecco's modified Eagle's medium supplemented with 15% fetal bovine serum (FBS), 2mM L-glutamine, 0,1mM β-mercaptoethanol, 1 x nonessential amino acids, 1 x sodium pyruvate and 1000 U/ml leukemia inhibitory factor (LIF) (Specialty Media, Phillipsburg, NJ; StemCell Technologies, Vancouver, Canada). Mitomycin C-treated primary embryonic fibroblasts

(StemCell Technologies) were used as a feeder layer for long-term culture of R1 ESC. Embryonic stem cells were cultured in gelatin-coated plastic dishes without PMEF for the two last passages before collection for the injection.

ESC mitotic inactivation and Analysis of cell proliferation

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ESC transplantation

[00060] Mice were divided into control and mitotically inactivated ESC treated groups. Control mice received no intervention. Treated mice received intravenous (tail vein) injection) of 5 million ESC that had been irradiated with 30 gray and washed with PBS three times. The irradiated ESC were injected in 200ul PBS on day 70 of the animals life.

Blood glucose monitoring

[00061] A drop of peripheral blood was obtained by puncturing one lateral tail vein with a 25G needle. Blood glucose was measured using OneTouch Strip and Accu-Check Advantage Kit. Measurements were performed twice a week since the first injection. Glycemia above 300 mg/ml was consider hyperglycemic.

Results

[00062] All NOD mice treated with irradiated ESC remained euglycemic without evidence of diabetes, while all control (untreated) mice developed diabetes, as demonstrated in Figure 2.

[00063] No NOD mice treated with irradiated ESC developed clinical or histological evidence for teratomas. The chaperone (cell-help-cell) effect of mitotically inactivated ESC may be due to paracrine, cell fusion, growth factor, angiogenic or antiapoptotic effects as well as beneficial immune mediated effects.

EXAMPLE 3: LETHAL RADIATION INJURY\

[00064] Lethal dose of total body irradiation—SJL/J mice survival was determined following different doses of total body irradiation (TBI) as shown in Figure 3.

[00065] At 8 grays single dose TBI all mice died with 12 days. Next we irradiated mice with 8 gray TBI and while control mice received no further therapy, treated mice either received one injection one day after TBI or 3 injections on days 0, 2, and 4 after TBI. Irradiated washed ESC were injected either intravenous (tail vein or retro-orbital) at 5 million ESC per injection. Results are shown in Figure 4.

[00066] All mice receiving 8 gray TBI alone died, only mice receiving mitotically inactivated ESC (treated with 30 Gy irradiation prior to injection) survived. Irradiated mice were female and injected mitotically inactivated ESC were male. There was no documentation of circulating y –chromosmes. The mitotically inactivated ESC provided a chaperone effect to endogenous hematopoiesis and there appeared to be a dose response effect with higher doses of mitotically inactivated cells injected over several days giving longer survival. No teratomas occurred, while injection of untreated ESC into irradiated mice resulted in teratoma formation at sites of injection in some mice.

CLAIMS

What is claimed is:

1. A method of mitotically and/or lethally inactivating stem cells comprising:

providing pluripotent stem cells; and

inactivating the pluripotent stem cells with a method effective for inhibiting unlimited proliferation of the pluripotent stem cells and effective for inactivating adult stem cells such as umbilical cord blood stem cells to prevent their growth or persistence in a recipient.

2. The method of claim 1 wherein the pluripotent stem cells are isolated from embryos, placenta, or amniotic fluid and adult stem cells are isolated from any adult organ, from umbilical cord blood or placenta, wherein adult stem cells may be utilized to generate pluripotent stem cells

3. The method of claim 2 wherein the stem cells are inactivated with irradiation or mitomycin C, or any agent or technique effective for inhibiting cell proliferation up to and including lethal damage to the cell.

4. Mitotically inactivated stem cell produced by a method comprising:

providing pluripotent stem cells; and

inactivating the pluripotent stem cells with a method effective for inhibiting unlimited proliferation of the pluripotent stem cells.

5. The stem cell of claim 4 wherein the pluripotent stem cells are isolated from embryos, placenta, or amniotic fluid or from adult stem cells.

6. The stem cell of claim 4 wherein the embryonic stem cells are inactivated with irradiation, mitomycin C, phototherapy, or any agent that inhibits cell proliferation including but not limited to inhibitors of cellular components necessary for mitosis such as but not limited to protein synthesis, microtubule function, spindle check point unit, cell cycle specific kinases, cyclins, and or apoptotic inducing agents.