(19) DANMARK

(10) DK/EP 3724336 T3

(12) Oversættelse af europæisk patentskrift

Patent- og Varemærkestyrelsen

(51) Int.Cl.: *C 12 N 15/113 (2010.01)* *A 61 K 31/712 (2006.01)* *A 61 P 9/00 (2006.01)*

(45) Oversættelsen bekendtgjort den: **2022-03-21**

(80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2022-02-09**

(86) Europæisk ansøgning nr.: **18833849.5**

(86) Europæisk indleveringsdag: **2018-12-14**

(87) Den europæiske ansøgnings publiceringsdag: **2020-10-21**

(86) International ansøgning nr.: **EP2018085008**

(87) Internationalt publikationsnr.: **WO2019115788**

(30) Prioritet: **2017-12-15 EP 17207738** **2017-12-15 US 201762599050 P**

(84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**

(73) Patenthaver: **Medizinische Hochschule Hannover, Carl-Neuberg-Straße 1, 30625 Hannover, Tyskland**

(72) Opfinder: **THUM, Thomas, Lange Rade 23, 30627 Hannover, Tyskland**
BATKAI, Sandor, Lindenallee 49, 30657 Hannover, Tyskland
FOINQUINOS, Ariana, Van Baerlestraat 99-2, 1071 AV Amsterdam, Holland

(74) Fuldmægtig i Danmark: **Zacco Denmark A/S, Arne Jacobsens Allé 15, 2300 København S, Danmark**

(54) Benævnelse: **Forbedret forbindelse til behandling af hjerteinsufficiens**

(56) Fremdragne publikationer:
EP-A1- 2 474 617
WO-A1-2013/034653
WO-A2-2010/105096
WO-A2-2016/042561
GEULA HANIN ET AL: "miRNA-132 induces hepatic steatosis and hyperlipidaemia by synergistic multitarget suppression", GUT, 5 April 2017 (2017-04-05), XP055417785, UK ISSN: 0017-5749, DOI: 10.1136/gutjnl-2016-312869 -& Geula Hanin ET AL: "Supplementary material "miRNA-132 induces hepatic steatosis and hyperlipidaemia by synergistic multitarget suppression"", GUT, 5 April 2017 (2017-04-05), XP055471789, Retrieved from the Internet: URL:gut.bmj.com/content/gutjnl/early/2017/ 04/05/gutjnl-2016-312869/DC1/embed/inline- supplementary-material-1.pdf?download=true [retrieved on 2018-05-02]
B. HOU ET AL: "Positive feedback regulation between microRNA-132 and CREB in spinal cord contributes to bone cancer pain in mice", EUROPEAN JOURNAL OF PAIN, vol. 20, no. 8, 26 February 2016 (2016-02-26), pages 1299-1308, XP055471626, GB ISSN: 1090-3801, DOI: 10.1002/ejp.854
M. LEINDERS ET AL: "Increased miR-132-3p expression is associated with chronic neuropathic pain", EXPERIMENTAL NEUROLOGY, vol. 283, 24 June 2016 (2016-06-24), pages 276-286, XP055471784, AMSTERDAM, NL ISSN: 0014-4886, DOI: 10.1016/j.expneurol.2016.06.025
IFTACH SHAKED ET AL: "MicroRNA-132 Potentiates Cholinergic Anti-Inflammatory Signaling by Targeting

Fortsættes ...

Acetylcholinesterase", IMMUNITY., vol. 31, no. 6, 10 December 2009 (2009-12-10), pages 965-973, XP055471625, US ISSN: 1074-7613, DOI: 10.1016/j.immuni.2009.09.019
S. D. FIEDLER ET AL: "Hormonal Regulation of MicroRNA Expression in Periovulatory Mouse Mural Granulosa Cells", BIOLOGY OF REPRODUCTION, vol. 79, no. 6, 20 August 2008 (2008-08-20), pages 1030-1037, XP055034057, ISSN: 0006-3363, DOI: 10.1095/biolreprod.108.069690
EVA M. JIMENEZ-MATEOS ET AL: "miRNA Expression Profile after Status Epilepticus and Hippocampal Neuroprotection by Targeting miR-132", THE AMERICAN JOURNAL OF PATHOLOGY, vol. 179, no. 5, 23 September 2011 (2011-09-23), pages 2519-2532, XP055113107, ISSN: 0002-9440, DOI: 10.1016/j.ajpath.2011.07.036
AHMET UCAR ET AL: "The miRNA-212/132 family regulates both cardiac hypertrophy and cardiomyocyte autophagy", NATURE COMMUNICATIONS, vol. 3, no. 1, 25 September 2012 (2012-09-25), XP055471921, DOI: 10.1038/ncomms2090
ALZAHRANI ABDULLAH M ET AL: "Enhancing miR-132 expression by aryl hydrocarbon receptor attenuates tumorigenesis associated with chronic colitis", INTERNATIONAL IMMUNOPHARMACOLOGY, ELSEVIER, AMSTERDAM, NL, vol. 52, 7 October 2017 (2017-10-07), pages 342-351, XP085214584, ISSN: 1567-5769, DOI: 10.1016/J.INTIMP.2017.09.015
R. HINKEL ET AL: "P5384 LNA-based miR132 inhibition is cardioprotective in a pig model of percutaneous transverse aortic constriction (pTAC)", EUROPEAN HEART JOURNAL, vol. 38, no. suppl_1, 29 August 2017 (2017-08-29), XP055556356, GB ISSN: 0195-668X, DOI: 10.1093/eurheartj/ehx493.P5384

DESCRIPTION

[0001] The present invention refers to an oligonucleotide which is an effective inhibitor of the microRNA miR-132, and its use in medicine, particularly in the prevention or treatment of cardiac disorders and/or fibrotic disorders.

[0002] Heart failure is one of the leading pathological causes of mortality in the world. Myocardial infarction (MI) is the most important cause of heart failure as MI leads to subsequent progressive remodeling of the heart resulting in heart failure with poor prognosis. The currently used therapeutic pharmacologic options for heart failure include angiotensin-modulating agents, β-blockers, diuretics, aldosterone antagonists, combined neprilysin-inhibitor with angiotensin-II-receptor blocker, vasodilators, or inotropic agents. Although several clinical studies have shown significant decreases in heart failure-induced mortality rates for all these agents, the 5-year mortality rate remains unacceptably at almost 50%. Thus, there is a great need to develop novel and more efficient therapeutic approaches for heart failure.

[0003] Pathological hypertrophic growth of cardiomyocytes can lead to the development of cardiac remodeling, heart failure and sudden cardiac death. Hypertrophic growth of cardiomyocytes is a response to increased cardiac wall stress caused by cardiac volume and/or pressure overload. Initially, cardiac hypertrophy is a compensatory mechanism aiming to decrease wall stress and to increase cardiac output. However, prolonged cardiac hypertrophy progresses to contractile dysfunction, cardiac decompensation and finally heart failure (Hill and Olson, 2008; Barry and Townsend, 2010). The transition from physiological to pathological hypertrophy can occur depending on many factors including myocyte loss through apoptosis or necrosis, alterations in autophagy, defects in contractile response, dysregulated calcium homeostasis, desensitization of adrenergic receptors, or cardiac fibrosis (Hill and Olson, 2008; Barry and Townsend, 2010). Hypertrophic signaling is largely mediated by the insulin signaling pathway (DeBosch and Muslin, 2008; Barry and Townsend, 2010). Both insulin and insulin-like growth factor-1 (IGF-1) activate pro-hypertrophic pathways in cardiomyocytes via the IGF-1 receptor, which activates the phosphoinositine-3-kinase (PI3K) (McMullen et al., 2004). PI3K activity leads to the activation of the serine/threonine kinase Akt via its phosphorylation and active Akt phosphorylates anti-hypertrophic FoxO transcription factors leading to their de-stabilization and prevention of nuclear localization (Datta et al., 1999; Skurk et al., 2005; Ronnebaum and Patterson, 2010). In contrast, acetylation of FoxO factors by sirtuin-1 (Sirt-1) leads to their stabilization and nuclear translocation (Frescas et al., 2005). Stabilized FoxO transcription factors are localized in the nucleus in order to regulate the expression of anti-hypertrophic genes. The anti-hypertrophic functions of FoxO proteins are largely mediated through suppression of the pro-hypertrophic calcineurin signaling pathway via the expression of anti-hypertrophic gene targets of FoxO factors, such as atrogin-1 (Ni et al., 2006; Ronnebaum and Patterson, 2010; Glas, 2010). Moreover, FoxO transcription factors also induce apoptosis and regulate autophagy in cardiomyocytes (Ronnebaum and Patterson, 2010).

[0004] MicroRNAs have been shown to have a key role in adverse cardiac remodeling. WO 2013/034653 describes that miR-132 and/or miR-212 may induce cardiac hypertrophy and thus constitute potential therapeutic targets for heart failure treatment.

[0005] WO 2016/042561 describes a method of treating a lipid-related disorder by administering to the subject a therapeutically effective amount of a polynucleotide agent which is substantially complementary to a nucleotide sequence of a human miR-132.

[0006] The present inventors have identified a novel oligonucleotide analogue which is an effective inhibitor of miR-132 expression in cardiomyocytes. The oligonucleotide analogue, in the following designated CDR132L, is a mixmer consisting of DNA and LNA building blocks, having internucleosidic phosphorothioate linkages. It lacks significant toxicity in a human liver cell line and isolated neonatal rat cardiomyocytes. Further, it was shown that CDR132L exhibits superior effects compared to other oligonucleotide analogues having the same nucleotide sequence but a different distribution of LNA building blocks.

[0007] The efficacy of CDR132L was tested in several animal models. In a transgenic mouse model of cardiac hypertrophy, CDR132L led to reverse cardiac remodeling associated with reduced expression of miR-132. In a mouse model of post-MI heart failure it was found that CDR132L treatment reduces post-MI left ventricular dysfunction and load independent parameters of systolic contractile function. Further, administration of CDR132L resulted in an improvement of cardiac function, and reduces miR-132 expression, cardiac stress signaling and post-MI hypertrophy. In a pig model of post-MI heart failure CDR132L treatment was found to avert maladaptive remodeling and to improve left ventricular function. Further, CDR132L normalizes the tissue expression of pathologic heart failure markers such as BNP, ANP and provides a shift in myosine heavy change isoforms (MYH7/6 ratio).

[0008] In an additional study, the present inventors have identified antifibrotic therapeutic effects for the oligonucleotide analogue CDR132L in an *in vivo* mouse model of myocardial infarction and *in vitro* models of liver fibrosis and lung fibrosis.

[0009] Thus, the oligonucleotide CDR132L is useful as an active agent in medicine, particularly in the prevention or treatment of cardiac disorders and/or fibrotic disorders.

[0010] Accordingly, a first aspect of the present invention provides an oligonucleotide, comprising or having the sequence of formula II:
5'-A+TG+GC+TG+TA+GACTG+T+T-3'

wherein A, T, G and C are deoxyribonucleotide building blocks and

wherein +G and +T are bridged nucleotide building blocks.

[0011] The oligonucleotide analogue of formula II may comprise at least one modified

internucleosidic linkage, e.g. an internucleosidic linkage which is stabilized against nuclease digestion, e.g. a phosphorothioate or a phosphorodiamidate linkage. In specific embodiments, all internucleosidic linkages are modified linkages, particularly phosphorothioate linkages.

[0012] In a more specific embodiment, the invention relates to the oligonucleotide CDR132L as described herein.

[0013] The oligonucleotide CDR132L has a sequence of formula III:
5'-dA*+T*dG*+G*dC*+T*dG*+T*dA*+G*dA*dC*dT*dG*+T*+T-3'

wherein dA is 2'deoxyadenosine, dG is 2'deoxyguanosine, dC is 2'deoxycytidine and T is thymidine,

wherein +T is an LNA-T building block and +G is an LNA-G building block and wherein * is a phosphorothioate linkage.

[0014] A further aspect of the present invention relates to a pharmaceutical composition comprising as an active agent an oligonucleotide analogue comprising a sequence of formula II or III and a pharmaceutically acceptable carrier.

[0015] Still a further aspect of the present invention relates to the medical use of an oligonucleotide analogue comprising a sequence of formula II or III. In certain embodiments, the medical use relates to a use for the treatment or prevention of a disorder associated with, accompanied by and/or caused by pathological expression of miR-132. In certain embodiments, the medical use relates to the treatment or prevention of cardiac disorders, particularly cardiac hypertrophy-associated disorders. In certain embodiments, the medical use relates to the treatment of fibrotic disorders, e.g. disorders associated with, accompanied by and/or caused by pathological fibrosis, particularly cardiac fibrotic disorders, pulmonary fibrotic disorders or hepatic fibrotic disorders.

[0016] The oligonucleotide of formula II or III may consist of deoxyribonucleotide DNA building blocks and bridged nucleotide building blocks . A "*bridged nucleotide*" refers to a modified ribonucleotide wherein the ribose moiety comprises a two-or-three atom bridge connecting the 2'- and the 4'-carbon atom. For example, the bridge may comprise the structure 2'-O-CH_2-4', 2'-O-CH_2-CH_2-4', 2'-O-CH(CH_3)-4' or a corresponding structure where O is replaced by S or NH. In a particular embodiment, the at least one bridged nucleotide building block is a locked nucleic acid (LNA) building block having a 2'-O-CH_2-4'-bridge.

[0017] The oligonucleotide of formula II or III has a length of at least 16 building blocks, e.g. a length of 16 to 20 building blocks. In a particular embodiment, the oligonucleotide of formula II or III has a length of 16 building blocks.

[0018] In some embodiments, the oligonucleotide of formula II or III comprises 5 to 10, e.g. 6

to 8, particularly, 7 bridged nucleotide building blocks, e.g. LNA building blocks.

[0019] In some embodiments, the oligonucleotide of formula II or III is a naked oligonucleotide. In some embodiments, the oligonucleotide may be conjugated to at least one heterologous moiety, e.g. a moiety which does not contribute to the binding of the oligonucleotide to miR-132. The heterologous moiety may be a moiety which improves targeting and/or cellular uptake, e.g. a lipid moiety such as cholesterol or a fatty acid, a saccharide or amino saccharide moiety such as a N-galactosamine containing moiety, a peptide or polypeptide moiety or a nucleosidic or nucleotidic moiety such as an aptamer. A heterologous moiety may be conjugated with the 5'- and/or 3'-terminus of the oligonucleotide analogue by means of covalent bond or a spacer.

[0020] The oligonucleotide of the present invention is suitable for use in medicine including human and veterinary medicine. In certain embodiments, the compound is useful in the prevention or treatment of a disorder associated with, accompanied by and/or caused by pathological expression, e.g. overexpression of miR-132. Administration of the compound was found to significantly reduce miR-132 expression *in vitro* and *in vivo.*

[0021] In some embodiments, the compound may be administered to patients showing an overexpression of miR-132 compared to healthy subjects. In some embodiments, the compound may be administered to patients not showing an overexpression of miR-132 compared to healthy subjects but still in need of a reduction of the level of miR-132.

[0022] The term "prevention" in the context of the present invention relates to the administration of the compound to a patient who is known to have an increased risk of developing a certain disorder. The term "treatment" in the context of the present invention relates to the administration of the compound to a patient which has already developed signs and/or symptoms of a certain disorder. The term "patient" relates to a subject in need of administration of the compound of the invention in the field of human or veterinary medicine. In specific embodiments the patient is a human patient.

[0023] In certain embodiments, the compound of the present invention is useful in the prevention or treatment of cardiac disorders, particularly of cardiac hypertrophy-associated disorders. For example, the compound is useful in the prevention or treatment of contractile dysfunction, cardiac decompensation, heart failure or for the prevention or treatment of cardiac remodeling after myocardial infarction, myocarditis, valvular heart diseases such as aortic stenosis or mitral valve insufficiency, genetic cardiac disorders with cardiac hypertrophy, e.g. hypertrophic non-obstructive and obstructive cardiomyopathy or Fabry disease.

[0024] The compound is useful for administration to patients selected from

1. (i) patients having an increased risk for developing heart failure,
2. (ii) patients suffering from (congestive) heart failure, e.g. patients having an increased risk of heart failure progression,

3. (iii) post-myocardial infarction patients and/or
4. (iv) patients with congenital heart diseases associated with cardiac hypertrophy, such as pulmonal vein stenosis, atrial or ventricular septum defects.

[0025] In certain embodiments, the compound of the present invention is useful in the prevention or treatment of fibroctic disorders, particularly disorders associated with, accompanied by and/or caused by pathological fibrosis.

[0026] Pathological fibrosis is the formation of excess fibrous connective tissue in an organ or tissue, particularly associated with, accompanied by and/or caused by a pathological state. Pathological fibrosis can occur in many different organs and tissues within the body, typically as a result of inflammation or damage.

[0027] In a certain embodiment, the fibrosis is a cardiac fibrosis, e.g. a condition involving pathological fibrosis in the heart. Exemplary types of cardiac fibrosis include atrial fibrosis, endomyocardial fibrosis or fibrosis resulting from a previous myocardial infarction.

[0028] In a further embodiment, the fibrosis is a pulmonary fibrosis, e.g. a condition involving pathological fibrosis in the lung. Exemplary types of pulmonary fibrosis include fibrotic disorders caused by occupational or environmental factors, for example by exposure to toxins and pollutants such as silica dust, asbestos fibers, metal dust, coal dust, grain dust, bird and animal droppings. Other types of pulmonary fibrotic disorders are caused by radiation treatment and/or treatment with medicaments such as chemotherapeutic drugs, cardiac drugs, antibiotics or anti-inflammatory drugs. Still other types of pulmonary fibrotic disorders are caused by disorders including idiopathic pulmonary fibrosis, dermatitis, polymyositis, mixed connective tissue disease, an autoimmune disease such as rheumatoid arthritis, scleroderma, Sjogren's syndrome or systemic lupus erythematosus, sarcoidosis, pneumonia, a viral infection or gastroesophageal reflux disease (GERD).

[0029] In a further embodiment, the fibrosis may be hepatic fibrosis, e.g. a conditions involving pathological fibrosis in the liver. Exemplary types of hepatic fibrosis are caused by a viral infection, e.g. by hepatitis B and/or C virus, hereditary metabolic disorders, autoimmune hepatitis, biliary obstruction, iron overload, non-alcoholic fatty liver disease, including non-alcoholic fatty liver (NAFL) and non-alcoholic steatohepatitis (NASH) and alcohol liver disease.

[0030] In still further embodiments, the fibrosis may also be a vascular fibrosis, e.g. arterial stiffness, a cutaneous fibrosis, e.g. keloid formation or nephrogenic systemic fibrosis, an arthrofibrosis, some forms of adhesive capsulitis, soft tissue fibrosis such as mediastinal fibrosis or retroperitoneal fibrosis or bone marrow fibrosis such as myelofibrosis.

[0031] In certain embodiments, the invention encompasses determining the amount and/or activity of certain physiological parameters in the subject to be treated before, during and/or

after administration of the compound of the invention. This concomitant diagnostic procedure may provide assistance for the medical use as described above. For example, the diagnostic procedure may provide assistance in risk assessment, patient stratification, monitoring of treatment course and/or post-treatment control.

[0032] In certain embodiments, the invention encompasses determining the amount and/or activity of miR-132 in the subject to be treated before, during and/or after administration of the compounds of the invention. In further embodiments, the invention encompasses determining the amount and/or activity of cardiac markers such as BNP, ANP or myosine heavy change isoforms, e.g. the MYH7/6 ratio, and/or the levels of FoxO3 and/or SERCA2. In still further embodiments, the invention encompasses determining the amount and/or activity of fibrotic markers such as collagen, e.g. collagen deposition and/or expression of fibrotic marker genes such as collagen 1A1, collagen 1A2, collagen 3A1 and/or a matrix metallopeptidase such as matrix metallopeptidase 2.

[0033] The determination of the above parameters may be carried out in body fluid samples such as blood, plasma or serum or in tissue samples according to known methods at the nucleic acid and/or protein level and may provide useful diagnostic information, e.g. on the course and/or success of the treatment.

[0034] The compound of the invention may be administered as a pharmaceutical composition comprising a pharmacologically acceptable carrier. Administration may be carried out by known methods, wherein the compound is introduced into the desired target cell or organ of the subject to be treated.

[0035] The compound may be administered as such or as a conjugate with a heterologous moiety as described above.

[0036] For pharmaceutical applications, the composition may be in the form of a solution, e.g. an injectable solution, emulsion, inhalation, suspension or the like.

[0037] The composition may be administered in any suitable way, e.g. parenterally, in particular by injection such as subcutaneous, intransmuscular, intravenous or intraarterial injection, or, infusion, by oral or inhalative intake and/or by dermal application. The carrier may be any suitable pharmaceutical carrier. Preferably, a carrier is used which is capable of increasing the efficacy of oligonucleotide molecules to enter the target cells. Suitable examples of such carriers are liposomes, e.g. cationic liposomes, or predesigned exosomes.

[0038] The compound is administered in a pharmaceutically effective dosage depending on the route of administration and the type or severity of the disease.

[0039] The compound may be administered as a monotherapy or in combination with a further different medicament, particularly a medicament suitable for the prevention or treatment of cardiac disorders or fibrotic disorders as described above.

[0040] Examples of further medicaments suitable for the prevention or treatment of cardiac disorders are angiotensin-modulating agents, β-blockers, diuretics, aldosterone antagonists, vasodilators, ionotrophic agents, statins, or neprilysin-inhibitors or combinations thereof, e.g. a combination of a neprilysin-inhibitor, e.g. sacubitril, with an angiotensin-II-receptor blocker, e.g. valsartan.

[0041] Examples of further medicaments suitable for the prevention of treatment of fibrotic disorders are medicaments for the prevention or treatment of cardiac fibrosis such as ACE inhibitors, e.g. lisinopril, Angiotensin II receptor blockers, e.g. candesartan, losartan or olmesartan, aldosteron antagonists, e.g. spironolactone and/or TGF β inhibitors, e.g. pirfenidone or tranilast, medicaments for the prevention or treatment of pulmonary fibrosis such as anti-fibrotic agents, e.g. nintedanib or pirfenidone, anti-inflammatory agents, e.g. corticosteroids, azathioprine, cyclophosphamide and mycophenolate mofetil, anti-reflux agents, e.g. protein pump inhibitors or H_2 blockers and/or anti-coughing agents and medicaments for the prevention and/or treatment of hepatic fibrosis such as ACE inhibitors, e.g. benazepril, lisinopril or ramipril, antiviral agents or PPAR α-agonists

[0042] Still further, the invention relates to the use of a compound of the invention as described herein above for the manufacture of a medicament for the prevention or treatment of a cardiac disorder.

[0043] Still further, the invention relates to the use of a compound of the invention as described herein above for the manufacture of a medicament for the prevention or treatment of a fibrotic disorder.

[0044] Further, the present invention shall be described in more detail by the following Figures and Examples.

Example 1 - Silencing of miR-132 expression in cardiomyocytes

[0045] A quantitative *in vitro* assay for miRNA inhibitory activity of numerous structure analogue compounds derived form an anti-miR-132 library was carried out. Silencing of miRNA expression was quantified by a TaqMan® assays and quantitative real-time PCR.

[0046] The study was conducted in isolated rat cardiomyocytes after hypertrophic stimulation by phenylephrine/isoproterenol treatment in concentrations of 10 µM. Cells were incubated for 48 hours in standard cell culture medium. Test compounds were administered individually in a concentration of 100 nM. Tests were carried out in triplicates.

[0047] The compound CDR132L, an LNA-DNA mixmer having a phosphorothioate backbone, was identified as most potent compound from the anti-miR-132 structure analogue library.

[0048] The structure of CDR132L is as follows:
5'-dA*+T*dG*+G*dC*+T*dG*+T*dA*+G*dA*dC*dT*dG*+T*+T-3'

wherein dA is 2'deoxyadenosine, dG is 2'deoxyguanosine, dC is 2'deoxycytidine and T is thymidine,

wherein +T is an LNA-T building block and +G is an LNA-G building block and wherein * is a phosphorothioate linkage.

Example 2 - Toxicology profiling

2.1 Study aim: Toxicity profiling of CDR132L

2.2 Study outline:

[0049] An *in vitro* cytotoxicity assay was carried out in human liver cell cells (HepG2) and isolated neonatal cardiomyocytes (NRCM). A colorimetric commercial MTT assay was used to assess cytotoxicity. After addition of individual compounds, cells were incubated in DMEM medium for 48h. The effect of CDR132L (red) was compared to a scrambled LNA oligonucleotide, used as control (blue) in a dose range of 0.01-100 µM. The therapeutic dose range is marked in grey.

[0050] **2.3 Results:** No significant toxicity of CDR132L in HepG2 cells and NRCM was found over the therapeutic dose range (cf. Figures 1A and 1B).

Example 3 - Left ventricular reverse remodeling of the failing heart by administration of CDR132L in a transgenic mouse model

3.1 Study aim: Test efficacy of CDR132L in reversing heart failure in a mouse model of heart failure.

3.2 Study outline:

[0051] Model of cardiac hypertrophy: Transgenic (TG) mice with cardiac miR-132 overexpression (Ucar *et al.* 2012).

[0052] Treatment: weekly 20 mg/kg ip. CDR132L or placebo (cf. Figure 2A) Groups: wild type (WT) littermate +placebo, WT+CDR132L, TG+placebo, TG+CDR132L. n=6/group.

[0053] Expression levels of miR-132 were detected via qPCR. Statistical test: unpaired t-test. (Figure 2B).

[0054] **p<0.01, n=6/group.

3.3 Results:

[0055] Representative echocardiography images of the heart (Figure 3A).

[0056] CDR132L reverses hypertrophy as measured by cardiac mass and enddiastolic volume (LVEDV) (Figure 3B).

[0057] CDR132L improves regional contractile function in most segments of the left ventricle (AB, anterior basal; AM, mid anterior; AA, anterior apex; PA posterior apex; PM, mid posterior and PB,posterior basal) (Figure 3C).

Example 4 - Administration of CDR132L in a mouse model of post-MI heart failure

4.1 Study aim: Test efficacy of CDR132L in a mouse model of post-MI heart failure

4.2 Study outline

[0058] Mouse model of myocardial infarction (MI): permanent ligation of coronary artery (LAD) in C57BL/6N mice (Kolk *et al.*, 2009).

Groups: MI or sham, treated with CDR132L or placebo

Treatment: 20 mg/kg ip, on day 7 and 14 post-MI

Endpoint: LV function at day 28 post-MI. n=6-7/group. (Figure 4),

4.3 Results:

[0059] CDR132L treatment improves post-MI left ventricular dysfunction (Figure 5A). Load independent parameters of systolic contractile function were also improved (Figure 5B) (*p<0.05).

[0060] CDR132L treatment also improves longitudinal strain rate (LSR) and thus reverses the post-MI contractile dysfunction in individual cardiac segments in the remote area of the heart. (*p<0.05) (Figure 6).

[0061] CDR123L treatment effectively silences miR-132 expression in cardiac tissues, in e.g. remote (non-infarct) area and peri-infarct zone (Figure 7A).

[0062] At histological level, CDR132L reduces cardiomyocyte size in remote area of the post-MI heart (Figure 7B).

[0063] At tissue level, CDR132L reduces the expression of the cardiac stress signal ANP in the post-MI heart (Figure 7C).

Example 5 - Test of CDR132L in a pig model of post-MI heart failure

5.1 Study aim: Proof of *in vivo* efficacy of CDR132L in a clinically relevant model of post-myocardial infarction.

5.2 Study setup:

[0064]

- Pig model of myocardial infarction elicited by 90 min ischemia (LAD occlusion) and subsequent reperfusion.
- Groups: Placebo or CDR132L, n=6 per group.
- Treatment: twice, on day 3 and day 28 post-MI, 0.3 mg/kg intracoronary and 0.5 mg/kg intravenously, respectively (Figure 8).
- Endpoint: 8 weeks post-MI. Primary outcome measures: EF and LV remodeling.

5.3 Results:

[0065]

- CDR132L treatment averts maladaptive remodeling and improves function, as

determined by measurement of enddiastolic volume, endsystolic volume, ejection fraction and left ventricular function (Figures 9A-D).

- CDR132L treatment improves segmental contractility in segments corresponding to surviving/remote myocardium; cardiac MRI at endpoint: n=6/group, red area: $p<0.05$ (Figure 9E).
- CDR132L treatment averts maladaptive remodeling and improves LV viability in the apical area as determined by NOGA, electro-anatomical mapping at endpoint: n=6/group, placebo vs CDR132L: $p<0.05$ (Figure 10).
- CDR132L normalizes the tissue expression of pathologic heart failure markers in ANP and BNP and provides a shift in myosin heavy change isoforms, i.e. MYH7/6 ratio (Figure 11).
- At histological level, CDR132L treatment effectively reduces cardiomyocyte hypertrophy in remote LV areas representative photomicrography images of LV area (WGA/DAPI Staining 20x) (Figure 12A) and graphic depiction (Figure 12B), n=6/group, placebo vs CDR132L: $p<0.05$.

Example 6 - PD profile/target engagement of CDR132L in pigs

6.1 Study set up:

[0066] Treatment: 1x, day 0, 0.5 mg/kg or 5 mg/kg intracoronary perfusion, n=3 pigs/group, placebo vs CDR132L: $p<0.05$.

- qPCR tissue miRNA assay at endpoint (24h post-treatment).

6.2 Results:

[0067]

- A single dose of CDR132L treatment dose-dependently silences cardiac miR-132 levels (Figure 13).

Example 7 - Organ toxicology profiling

7.1 Study set up:

[0068]

- Treatment: twice, on day 3 and day 28 post-MI, 0.3 mg/kg intracoronary and 0.5 mg/kg intravenously, respectively.
- Serial blood sampling, endpoint: 72h-post treatment, n=6 pigs/group, placebo vs CDR132L: $p<0.05$.

7.2 Results:

[0069]

- CDR132L treatment in vivo does not elicit any organ toxicity in pigs (Figure 14).

Example 8 - Cardiac levels of FoxO3 and SERCA2 mRNA in a mouse model of heart failure

[0070] Cardiac FoxO3 and Serca2 mRNA levels were measured in control and miR-132 TG mice treated with intraperitoneal injection of either control scrambled oligonucleotide or CDR132L, weekly, 4 times. All values represent mean ± SEM. $*P < 0.05$ (Figures 15A and 15B)

Example 9 - Comparison of different oligonucleotides

[0071] The purpose of this study was to evaluate therapeutic effect of the novel miR-132-3p inhibitor CDR132L according to the prevent invention with two comparative oligonucleotides The two comparative oligonucleotides exhibit the same oligonucleotide sequence and a phosphorothioate backbone as CDR132L but differ in the distribution of LNA building blocks within the molecule. CDR2u1 harbors two LNA building blocks at the 5' and the 3' end, while for CDR301 each nucleotide carries an LNA building block.

[0072] To test the efficiency, the different oligonucleotides were administered to neonatal rat cardiomyocytes (NRCMs). Effects of this treatment were monitored by quantitative real-time PCR (qRT-PCR) following alterations in expression of miR-132-3p and its known target gene FoxO3 (Forkhead box O3).

[0073] The experimental design and the results are shown in Fig. 16: (A) Overview of the

experimental setup. Neonatal rat cardiomyocytes were seeded on day 0 and treated with the oligonucleotides CDR132L, CDR2u1 or CDR301 (100 nM each) on day 1. At the endpoint, cells are harvested for gene expression analysis. (B) Expression levels of miR-132-3p after treatment with CDR132L, CDR2u1 or CDR301. (C) Expression levels of the miR-132-3p target gene Forkhead box O3 (FoxO3) after treatment with CDR132L, CDR2u1 or CDR301. Data are mean ± SD. *P* values oligonucleotides versus placebo were determined by two-tailed Student's *t* test.

[0074] Treatment of NRCMs with CDR132L and CDR301 led to a significant reduction of miR-132-3p levels by 96%, while CDR2u1 reduced the miRNA expression by 30% (Fig. 16A-B). Further, treatment with CDR132L led to a significant depression of the miR-132-3p target gene Foxo3, which was not achieved with CDR2u1 and CDR301 (Fig. 16C).

[0075] In summary, our data demonstrate a superior inhibitory effect of CDR132L compared to CDR2u1 and CDR301 indicated by significantly lowered expression levels or miR-132-3p and significant repression of its target gene FoxO3.

Example 10 - Effects of CDR132L in cardiac fibrosis

[0076] The purpose of this study was to evaluate antifibrotic therapeutic effects of CDR132L in an *in vivo* model of fibrosis.

[0077] For *in vivo* proof of antifibrotic activity, the mouse model of myocardial infarction (MI) by permanent left anterior descending coronary artery (LAD) ligation in C57BL/6N mice was used. CDR132L treatment was applied at day 7 and 14 placebo (scrambled oligo analogue to CDR132L, 20 mg/kg) and CDR132L (20 mg/kg). Groups included the control operated group (sham operated mice) and LAD-ligated mice (MI, myocardial infarction), receiving either placebo or CDR132L: Sham+placebo, Sham+CDR132L, MI+placebo, MI+CDR132L. n=6-7/group. The experimental design is described in Fig. 17.

[0078] The assessment of the antifibrotic effect of CDR132L *in vivo* in post MI heart failure is shown in Fig. 18. Fibrosis (shown as % of collagen deposition detected by Picro-sirius red (PSR) staining and Collagen Type III Alpha 1 Chain (Col3a1) gene expression relative to β-Actin) was attenuated after MI by treatment with CDR132L. Groups included the control operation group (sham operated mice) and LAD ligated mice (MI), receiving either placebo (black column) or CDR132L (white column): Sham+placebo, Sham+CDR132L, MI+placebo, MI+CDR132L. Statistical test (unpaired t-test) was done between MI mice treated with placebo or CDR132L. **p<0.01, n=6-7/group.

[0079] According to the histological results, fibrosis was attenuated after CDR132L treatment (Fig. 18A). This was confirmed at molecular level, with reduced gene expression for fibrosis markers like Collagen Type III Alpha 1 Chain (Col3a1) (Fig. 18B).

Example 11 - Effects of CDR132L in pulmonary and hepatic fibrosis

[0080] The antifibrotic effect of CDR132L was tested in *in vitro* models for pulmonary and hepatic fibrosis. For that, human primary fibroblasts derived from liver (human primary liver fibroblasts, HPLF, PeloBiotech) and lung (normal human primary lung fibroblasts, NHLF, Lonza) were stimulated with pro-fibrotic agents and treated with CDR132L. Therapeutic effects of CDRL132L were monitored by following key processes within the fibrotic pathway including proliferation rate and alterations in expression of fibrotic marker genes at endpoint. In addition, expression of miR-132-3p was assessed to prove effective CDR132L treatment.

[0081] To determine cell proliferation, a Cell Proliferation ELISA (Enzyme-linked Immunosorbent Assay) Kit (provided by Roche) was used. This colorimetric assay allows to quantitate cell proliferation based on the measurement of BrdU (Bromdesoxyuridin) incorporated in newly synthesized DNA of proliferating cells. The amount of incorporated BrdU has been detected and quantified. Absorbance values directly correlate to the amount of DNA synthesis and hereby to the number of proliferating cells in the respective microcultures. Gene expression has been assessed using quantitative real-time PCR (qRT-PCR) measuring expression levels of miR-132-3p and fibrotic markers including Collagen 1A1 (COL1A1), Collagen 1A2 (COL1A2), and Matrix Metallopeptidase 2 (MMP2).

[0082] Fig. 19 refers to the *in vitro* model of liver fibrosis: (A) Overview of the experimental setup. Human primary liver fibroblasts (provided by PeloBiotech) were seeded on day 0 and treated with fibrotic stimulus (10 ng/ml TGF-β in normal growth medium (complete fibroblast medium supplemented with 10% FBS)) and CDR132L (100 nM) on day 1. At endpoint, cell proliferation and gene expression of fibrotic markers have been assessed. (B) Expression levels of miR-132-3p after treatment with CDR132L. (C) Proliferation assessed by monitoring of BrdU (Bromdesoxyuridin) incorporation during DNA synthesis. The BrdU reagent has been added to the medium 20 h before endpoint. (D) Expression levels of fibrotic marker genes (Collagen 1A1 (COL1A1), Collagen 1A2 (COL1A2), and Matrix Metallopeptidase 2 (MMP2)). In (B) and (D) dashed line indicates expression level of unstimulated control cells. Data are mean ± SD. P values CDR132L versus control were determined by two-tailed Student's *t* test.

[0083] Stimulation of HPLFs with transforming growth factor beta (TGF-β) (Fig. 19A) led to slight induction of miR-132-3p that was significantly reduced by CDR132L treatment (Fig. 19B). Further, this compound reduced fibroblast proliferation (Fig. 19C) and fibrotic gene expression including COL1A1, COL1A2, and MMP2 (Fig. 19D).

[0084] Fig. 20 refers to the *in vitro* model of lung fibrosis: (A) Overview of the experimental setup. Normal human lung fibroblasts (provided by Lonza) were seeded on day 0 and treated with fibrotic stimulus (High FBS (5%) in fibroblast growth medium and CDR132L (100 nM) on day 1. At endpoint, cell proliferation and gene expression have been assessed. (B) Expression levels of miR-132-3p after treatment with CDR132L. (C) Proliferation assessed by monitoring

of BrdU (Bromdesoxyuridin) incorporation during DNA synthesis.

[0085] The BrdU reagent has been added to the medium 20 h before endpoint. In (B) dashed line indicates expression level of unstimulated control cells. Data are mean ± SD. P values CDR132L versus control were determined by two-tailed Student's *t* test.

[0086] In NHLF cells, after fibrotic stimulation with high FBS (5% compared to normal growth conditions of 2% FBS) (Fig. 20A) no elevation of miR-132-3p was observed (Fig. 20B). Nevertheless, treatment with CDR132L led to a significant reduction of the targeted microRNA (Fig. 20B) and fibroblast proliferation (Fig. 20C).

[0087] In summary, our data demonstrate a significant anti-fibrotic effect of the oligonucleotide analogue CDR132L in liver- or lung-derived fibroblasts as well as in cardiac tissue. We assume this effect may be based on the drug's anti-proliferative capacity, and/or on its effect on the extracellular matrix protein expression.

References

[0088]

1. 1. Barry, S.P.; Townsend, P.A. (2010). What causes a broken heart-Molecular insights into heart failure. Int Rev Cell Mol Biol 284, 113-179.
2. 2. Datta, S.R.; Brunet, A.; Greenberg, M.E. (1999). Cellular survival: a play in three Akts. Genes Dev. 13, 2905-2927.
3. 3. DeBosch, B.J.; Muslin, A.J. (2008). Insulin signaling pathways and cardiac growth. J Mol Cell Cardiol. 44, 855-864.
4. 4. Frescas, D.; Valenti, L.; Accili, D. (2005). Nuclear trapping of the forkhead transcription factor FoxO1 via Sirt1-dependent deacetylation promotes expression of glucogenetic genes. J Biol Chem. 280, 20589-20595.
5. 5. Glas, D.J. (2010). PI3 kinase regulation of skeletal muscle hypertrophy and atrophy. Curr Top Microbiol Immunol. 346, 267-278.
6. 6. Gottlieb, R.A.; Gustafsson, A.B. (2011). Mitochondrial turnover in the heart. Biochim Biophys Acta. 1813, 1295-1301.
7. 7. Kolk, M.V.; Meyberg, D.; DenseT.; Tang-Quam, K. R.; Robbins R.C.; Reichenspurner, H.; Schrepfer. S (2009), J. Vis Exp. 32, pii: 1438. doi: 103791/1438
8. 8. McMullen, J.R.; Shioi, T.; Huang, W.Y.; Zhang, L.; Tarnavski, O.; Bisping, E.; Schinke, M.; Kong, S.; Sherwood, M.C.; Brown, J. et al. (2004). The insulin-like growth factor 1 receptor induces physiological heart growth via the phosphoinositide 3-kinase (p110alpha) pathway. J Biol Chem. 279, 4782-4793.
9. 9. Ni, Y.G.; Berenji, K.; Wang, N.; Oh, M.; Sachan, N.; Dey, A.; Cheng, J.; Lu, G.; Morris, D.J.; Castrillon, D.H. et al. (2006). Foxo transcription factors blunt cardiac hypertrophy by inhibiting calcineurin signaling. Circulation. 114, 1159-1168.
10. 10. Ronnebaum, S.M.; Patterson, C. (2010). The foxO family in cardiac function and

dysfunction. Annu Rev Physiol. 72, 81-94.
11. 11. Skurk, C.; Izumiya, Y.; Maatz, H.; Razeghi, P.; Shiojima, I.; Sandri, M.; Sato, K.; Zeng, L.; Schiekofer, S.; Pimentel, D. et al. (2005). The FOXO3a transcription factor regulates cardiac myocyte size downstream of AKT signaling. J Biol Chem. 280, 20814-23.
12. 12. Ucar, A. et al. (2012), Nat. Commun. 3: 1078. doi: 10.1038/ncomms2009.

SEQUENCE LISTING

[0089]

<110> Medizinische Hochschule Hannover

<120> Improved compound for treatment of heart failure

<130> 65069PWO

<140> EP17207738
<141> 2017-12-15

<160> 3

<170> PatentIn version 3.5

<210> 1
<211> 16
<212> DNA
<213> Artificial Sequence

<220>
<223> inhibitor

<220>
<221> misc_feature
<222> (1)..(16)
<223> at least one G or T is a bridged and/or a morpholino building block

<400> 1
atggctgtag actgtt 16

<210> 2
<211> 16
<212> DNA
<213> Artificial Sequence

<220>

<223> inhibitor

<220>
<221> misc_feature
<222> (2)..(2)
<223> bridged or morpholino building block

<220>
<221> misc_feature
<222> (4)..(4)
<223> bridged or morpholino building block

<220>
<221> misc_feature
<222> (6)..(6)
<223> bridged or morpholino building block

<220>
<221> misc_feature
<222> (8)..(8)
<223> bridged or morpholino building block

<220>
<221> misc_feature
<222> (10)..(10)
<223> bridged or morpholino building block

<220>
<221> misc_feature
<222> (15)..(15)
<223> bridged or morpholino building block

<220>
<221> misc_feature
<222> (16)..(16)
<223> bridged or morpholino building block

<400> 2
atggctgtag actgtt 16

<210> 3
<211> 16
<212> DNA
<213> Artificial Sequence

<220>
<223> CDR132L

<220>
<221> misc_feature
<222> (1)..(1)
<223> 2'deoxyadenosine

<220>
<221> misc_feature
<222> (1)..(15)
<223> phosphorothioate linkage

<220>
<221> misc_feature
<222> (2)..(2)
<223> LNA building block

<220>
<221> misc_feature
<222> (3)..(3)
<223> 2'deoxyguanosine

<220>
<221> misc_feature
<222> (4)..(4)
<223> LNA building block

<220>
<221> misc_feature
<222> (5)..(5)
<223> 2'deoxycytidine

<220>
<221> misc_feature
<222> (6)..(6)
<223> LNA building block

<220>
<221> misc_feature
<222> (7)..(7)
<223> 2'deoxyguanosine

<220>
<221> misc_feature
<222> (8)..(8)
<223> LNA building block

<220>
<221> misc_feature

<222> (9)..(9)
<223> 2'deoxyadenosine

<220>
<221> misc_feature
<222> (10)..(10)
<223> LNA building block

<220>
<221> misc_feature
<222> (11)..(11)
<223> 2'deoxyadenosine

<220>
<221> misc_feature
<222> (12)..(12)
<223> 2'deoxycytidine

<220>
<221> misc_feature
<222> (13)..(13)
<223> thymidine

<220>
<221> misc_feature
<222> (14)..(14)
<223> 2'deoxyguanosine

<220>
<221> misc_feature
<222> (15)..(16)
<223> LNA building block

<400> 3
atggctgtag actgtt 16

REFERENCES CITED IN THE DESCRIPTION

Cited references

This list of references cited by the applicant is for the reader's convenience only. It does not

form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO2013034653A [0004]
- WO2016042561A [0005]
- EP17207738A [0089]

Non-patent literature cited in the description

- **BARRY, S.P.TOWNSEND, P.A.**What causes a broken heart-Molecular insights into heart failureInt Rev Cell Mol Biol, 2010, vol. 284, 113-179 [0088]
- **DATTA, S.R.BRUNET, A.GREENBERG, M.E.**Cellular survival: a play in three AktsGenes Dev, 1999, vol. 13, 2905-2927 [0088]
- **DEBOSCH, B.J.MUSLIN, A.J.**Insulin signaling pathways and cardiac growthJ Mol Cell Cardiol, 2008, vol. 44, 855-864 [0088]
- **FRESCAS, D.VALENTI, L.ACCILI, D.**Nuclear trapping of the forkhead transcription factor FoxO1 via Sirt1-dependent deacetylation promotes expression of glucogenetic genesJ Biol Chem., 2005, vol. 280, 20589-20595 [0088]
- **GLAS, D.J.**PI3 kinase regulation of skeletal muscle hypertrophy and atrophyCurr Top Microbiol Immunol, 2010, vol. 346, 267-278 [0088]
- **GOTTLIEB, R.A.GUSTAFSSON, A.B.**Mitochondrial turnover in the heartBiochim Biophys Acta, 2011, vol. 1813, 1295-1301 [0088]
- **KOLK, M.V.MEYBERG, D.DENSET.TANG-QUAM, K. R.ROBBINS R.C.REICHENSPURNER, H.SCHREPFER. S**J. Vis Exp., 2009, vol. 32, 1438- [0088]
- **MCMULLEN, J.R.SHIOI, T.HUANG, W.Y.ZHANG, L.TARNAVSKI, O.BISPING, E.SCHINKE, M.KONG, S.SHERWOOD, M.C.BROWN, J. et al.**The insulin-like growth factor 1 receptor induces physiological heart growth via the phosphoinositide 3-kinase (p110alpha) pathwayJ Biol Chem., 2004, vol. 279, 4782-4793 [0088]
- **NI, Y.G.BERENJI, K.WANG, N.OH, M.SACHAN, N.DEY, A.CHENG, J.LU, G.MORRIS, D.J.CASTRILLON, D.H. et al.**Foxo transcription factors blunt cardiac hypertrophy by inhibiting calcineurin signalingCirculation, 2006, vol. 114, 1159-1168 [0088]
- **RONNEBAUM, S.M.PATTERSON, C.**The foxO family in cardiac function and dysfunctionAnnu Rev Physiol, 2010, vol. 72, 81-94 [0088]
- **SKURK, C.IZUMIYA, Y.MAATZ, H.RAZEGHI, P.SHIOJIMA, I.SANDRI, M.SATO, K.ZENG, L.SCHIEKOFER, S.PIMENTEL, D. et al.**The FOXO3a transcription factor

regulates cardiac myocyte size downstream of AKT signalingJ Biol Chem., 2005, vol. 280, 20814-23 [0088]

- **UCAR, A. et al.**Nat. Commun., 2012, vol. 3, 1078- [0088]

PATENTKRAV

1. Fremgangsmåde til genetisk manipulation af en C1-fikserende bakterie, hvilken fremgangsmåde omfatter indføring i en C1-fikserende bakterie, der indeholder et DNA-molekyle omfattende en målsekvens af et manipuleret, ikke-naturligt forekommende Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR)/CRISPR-associeret (Cas) (CRISPR/Cas)-system omfattende én eller flere vektorer, der omfatter:

(a) en nukleotidsekvens, der koder for et guide-RNA, der hybridiserer med målsekvensen; og

(b) en nukleotidsekvens, der koder for et type-II Cas9-protein under styring af en inducerbar promotor;

hvor den C1-fikserende bakterie er *Clostridium autoethanogenum.*

2. Fremgangsmåde ifølge krav 1, hvor CRISPR/Cas-systemet endvidere omfatter på den ene eller flere vektorer:

(c) en nukleotidsekvens, der omfatter en 5'-homologiarm, der hybridiserer opstrøms for målsekvensen og en 3'-homologiarm, der hybridiserer nedstrøms for målsekvensen,

hvorved 5'-homologiarmen og 3'-homologiarmen hybridiserer med DNA-molekylet, og der opstår homolog rekombination, hvilket resulterer i udskiftning af målsekvensen med DNA placeret mellem 5'-homologiarmen og 3'-homologiarmen.

3. Fremgangsmåde ifølge krav 1 eller 2, hvor Cas9;

(i) er katalytisk aktiv; eller

(ii) er nickase Cas9.

4. Fremgangsmåde ifølge krav 1, hvor Cas9 er katalytisk inaktiv.

5. Fremgangsmåde ifølge krav 1, hvor Cas9 blokerer DNA-molekylet i et område, der koder for et gen, hvorved ekspression af genet reduceres.

6. Fremgangsmåde ifølge krav 1 eller 2, hvor Cas9 spalter DNA-molekylet i et område, der koder for et gen, hvorved ekspression af genet reduceres.

7. Fremgangsmåde ifølge krav 2, hvor DNA'et placeret mellem 5'-homologiarmen og 3'-homologiarmen bryder DNA-molekylet i et område, der koder for et område, som koder for et gen, hvorved ekspression af genet reduceres.

8. Fremgangsmåde ifølge krav 2, hvor DNA'et placeret mellem 5'-homologiarmen og 3'-homologiarmen koder for et eksogent gen, hvorved den homologe rekombination indsætter det eksogene gen i DNA-molekylet.

9. Fremgangsmåde ifølge krav 8, hvor den C1-fikserende bakterie udtrykker det eksogene gen.

10. Fremgangsmåde ifølge krav 1, hvor (a) og (b) placeres på de samme eller forskellige vektorer.

11. Fremgangsmåde ifølge krav 2, hvor (a), (b) og (c) placeres på de samme eller forskellige vektorer.

12. Fremgangsmåde ifølge krav 1, hvor CRISPR/Cas-systemet afledes af *Streptococcus pyogenes* eller *Streptococcus thermophilus.*

13. Fremgangsmåde ifølge krav 1, hvor den inducerbare promotor er en tetracyclin-inducerbar promotor eller en lactose-inducerbar promotor.

14. Fremgangsmåde ifølge krav 13, hvor den tetracyclin-inducerbare promotor er tet3no eller ipl12.

15. Fremgangsmåde ifølge krav 1, hvor den C1-fikserende bakterie er *Clostridium autoethanogenum* LZ1561, der er indleveret under DMSZ-accessionsnummer DSM23693.

DRAWINGS

Figure 1

Figure 1A

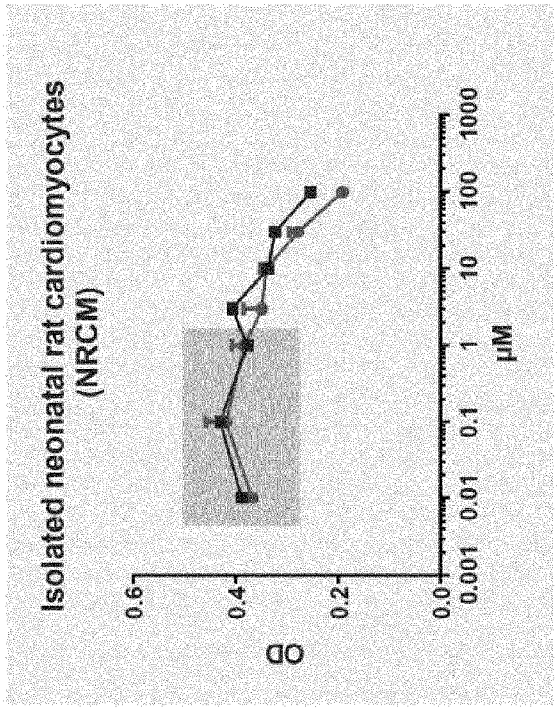


Figure 1B

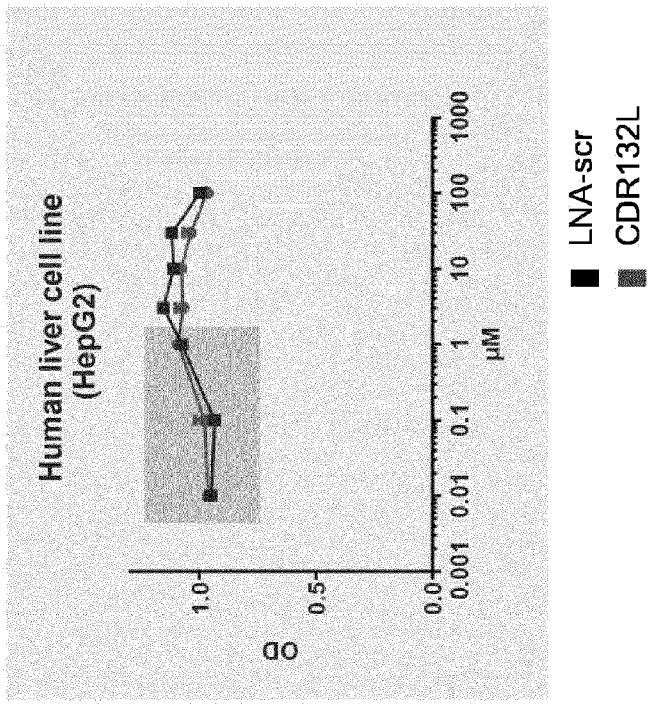


Figure 2

Figure 2A

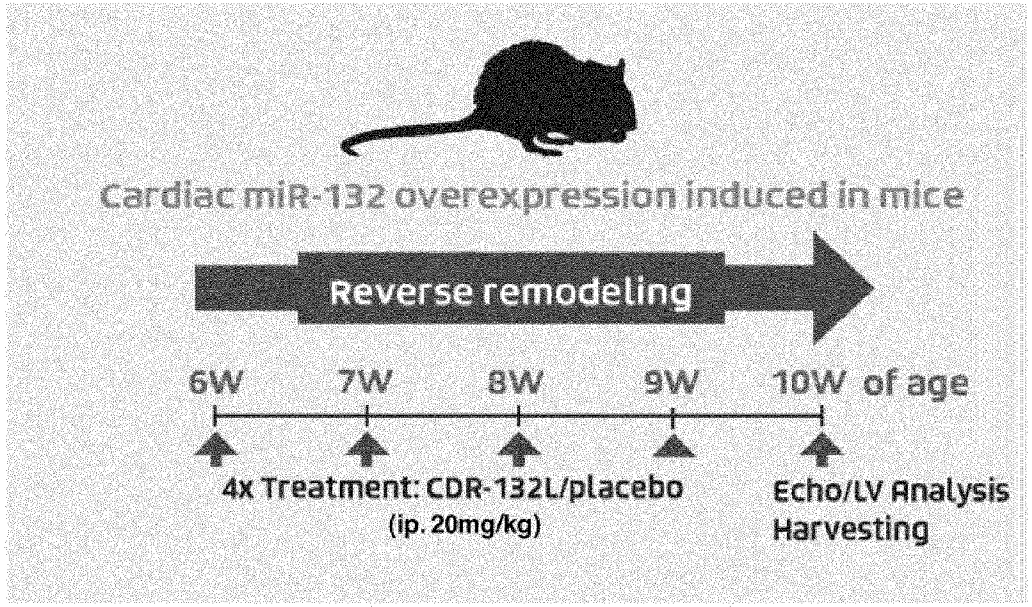


Figure 2B

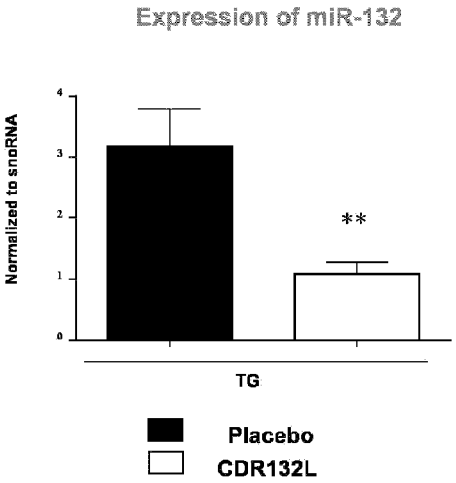


Figure 3

Figure 3A

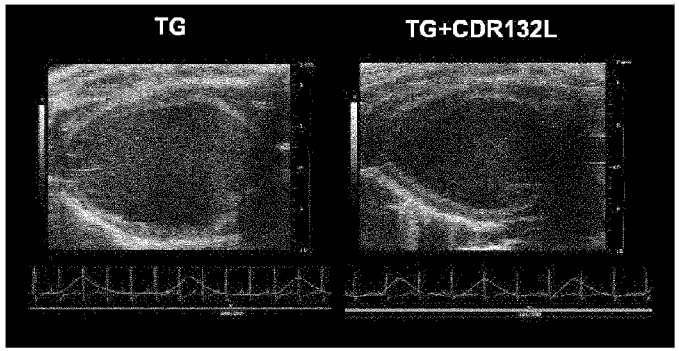


Figure 3B

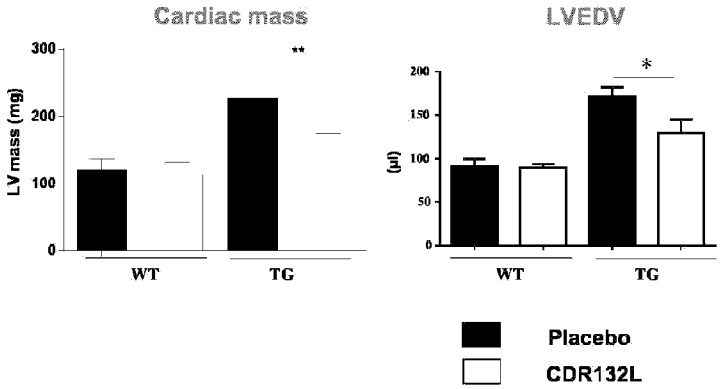


Figure 3C

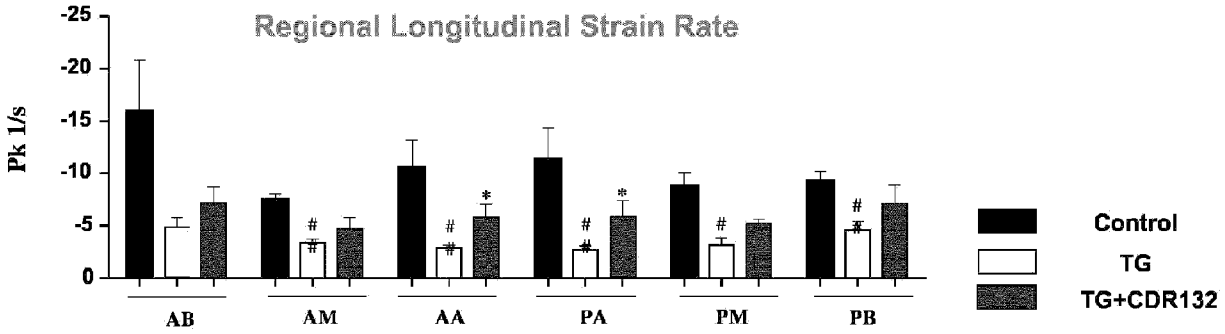


Figure 4

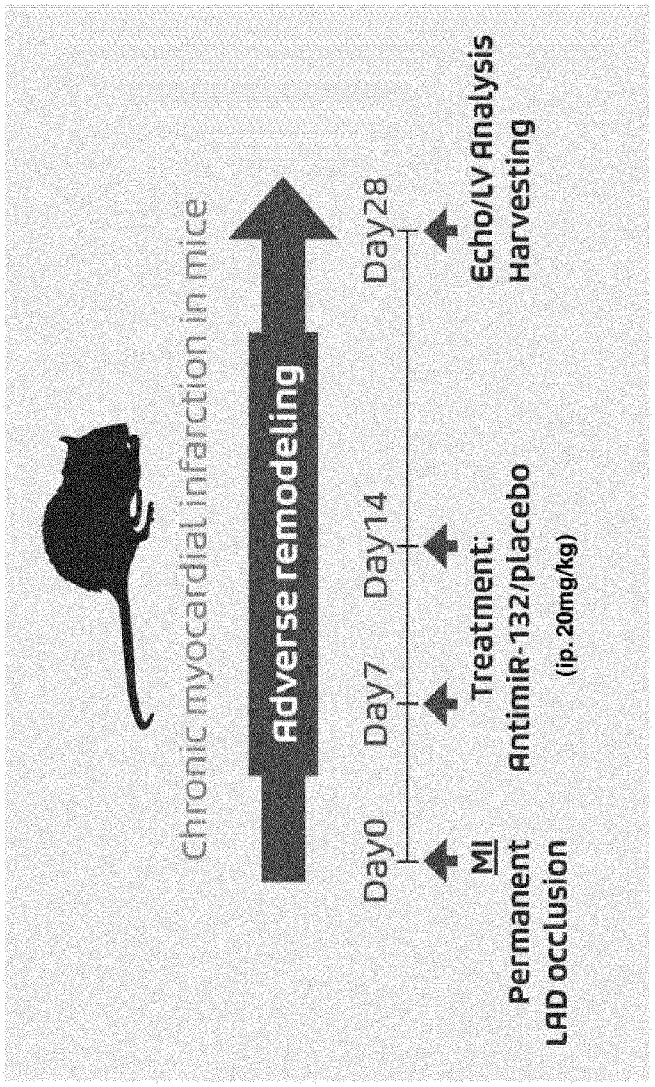

Chronic myocardial infarction in mice
Adverse remodeling
Day0
Day7
Day14
Day28
MI
Permanent
LAD occlusion
Treatment:
AntimiR-132/placebo
(ip. 20mg/kg)
Echo/LV Analysis
Harvesting

Figure 5

Figure 5A

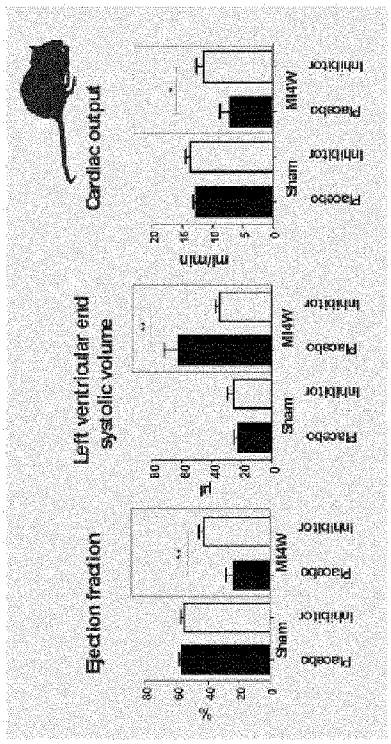
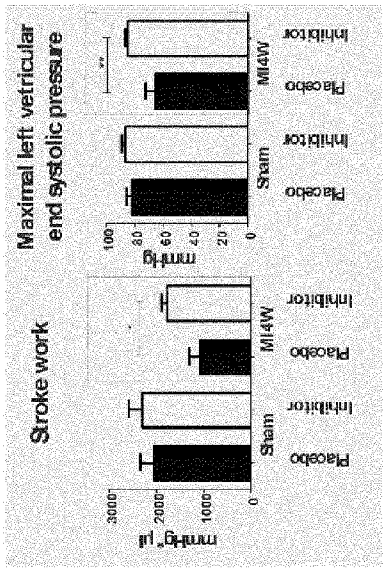


Figure 5B



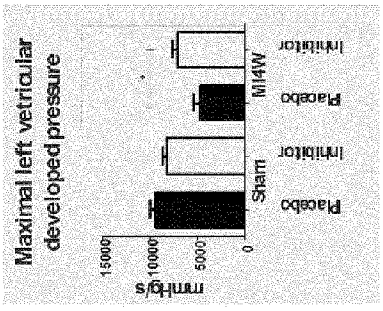
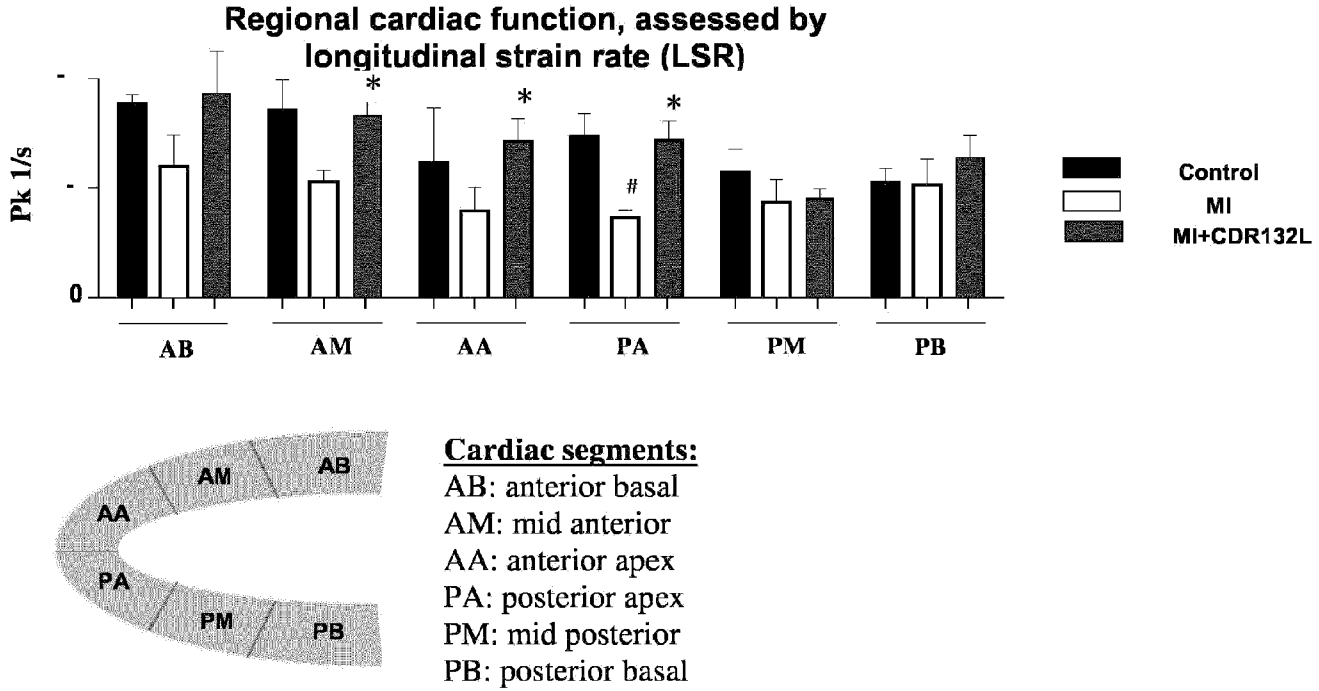


Figure 6



Cardiac segments:
AB: anterior basal
AM: mid anterior
AA: anterior apex
PA: posterior apex
PM: mid posterior
PB: posterior basal

Figure 7

Figure 7A

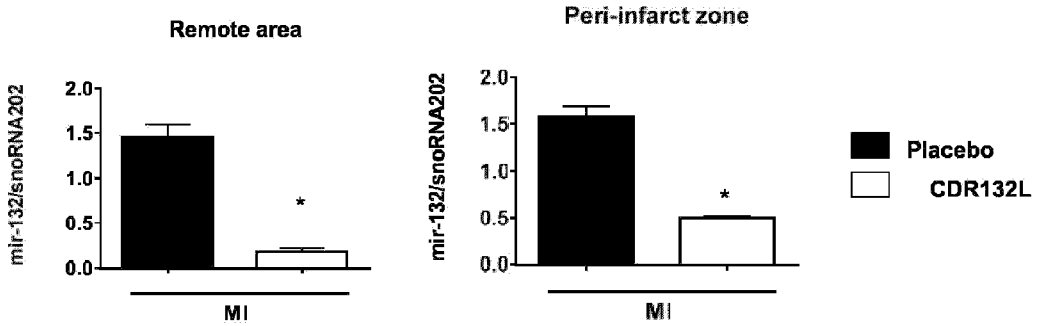


Figure 7B

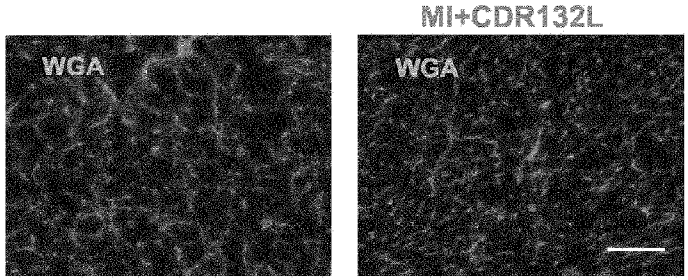


Figure 7C

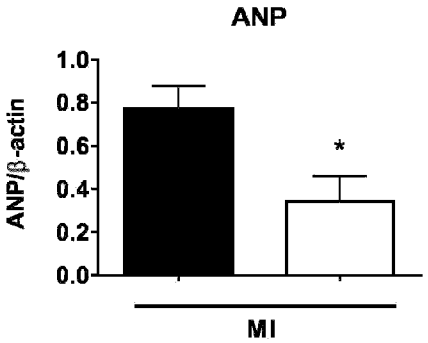


Figure 8

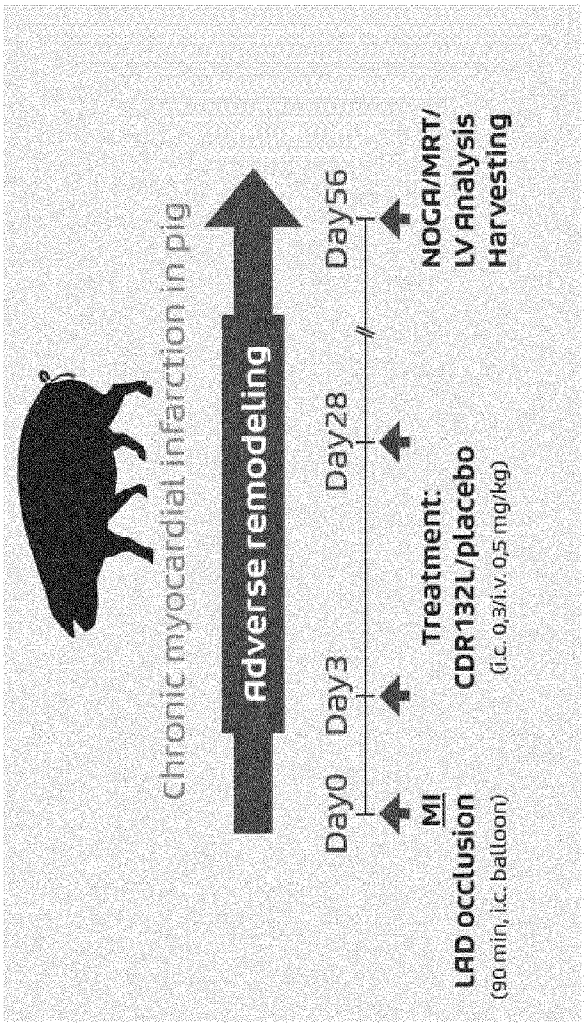

Chronic myocardial infarction in pig
Adverse remodeling
Day0
Day3
Day28
Day56
MI
LAD occlusion
(90 min, i.c. balloon)
Treatment:
CDR132L/placebo
(i.c. 0,3/i.v. 0,5 mg/kg)
NOGA/MRT/
LV Analysis
Harvesting

Figure 9

Figure 9A

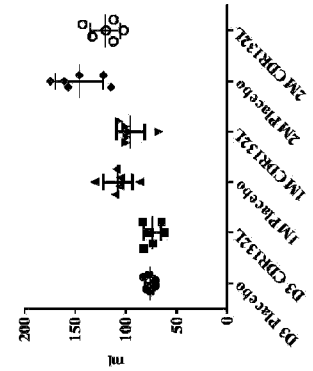


Figure 9B

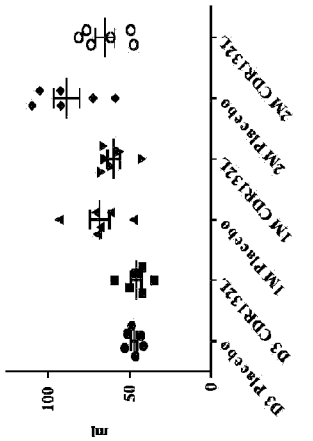


Figure 9C

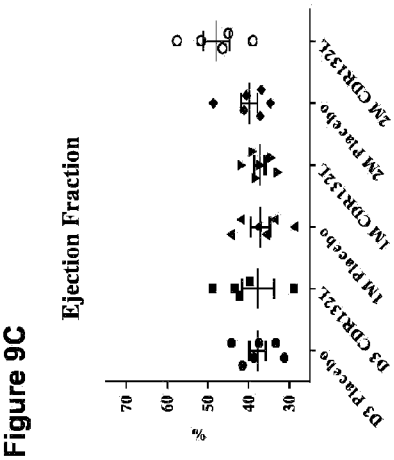


Figure 9D

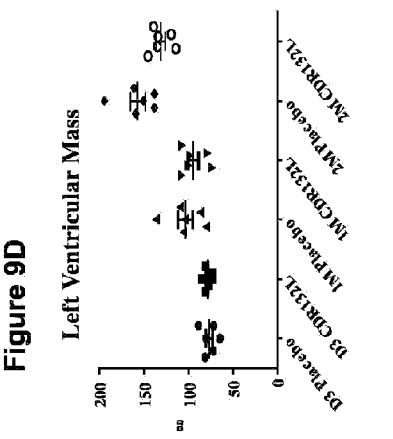


Figure 9E

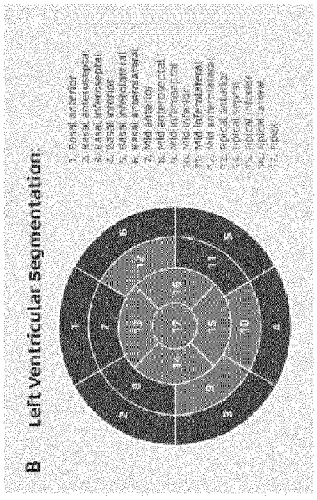
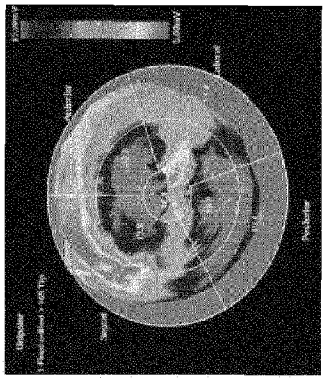
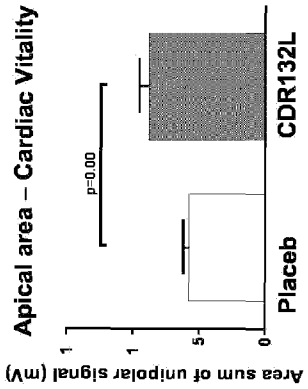


Figure 10




Apical area – Cardiac Vitality
Area sum of unipolar signal (mV)
p=0.00
Placeb
CDR132L

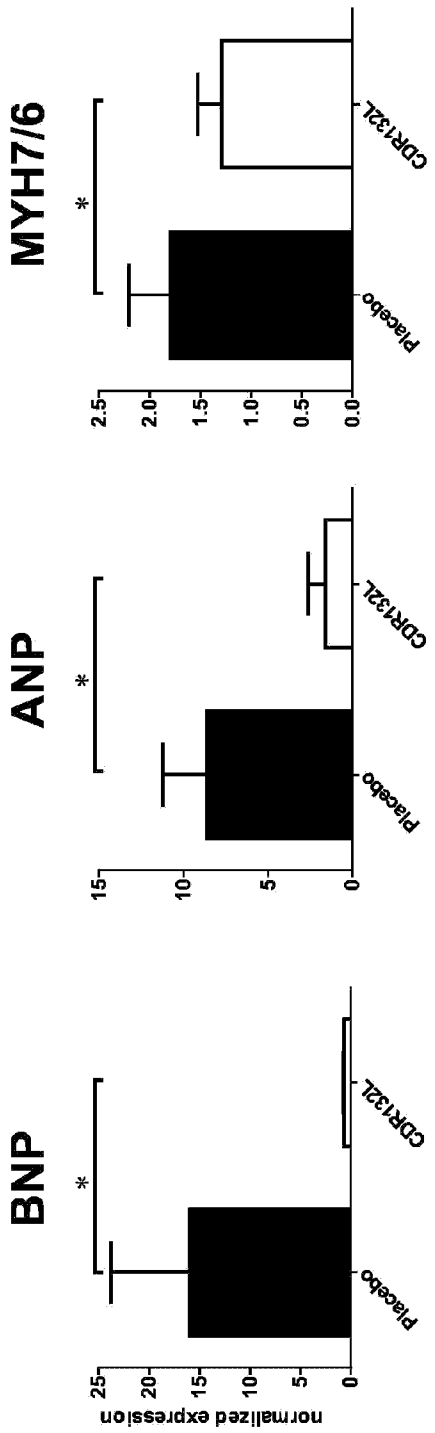

BNP
ANP
MYH7/6
normalized expression
25
20
15
10
5
0
2.5
2.0
1.5
1.0
0.5
0.0
*
Placebo
CDR132L

Figure 11

Figure 12

Figure 12A

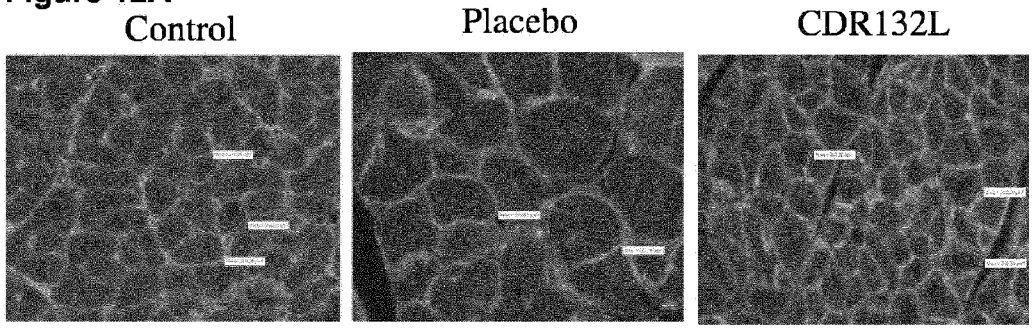
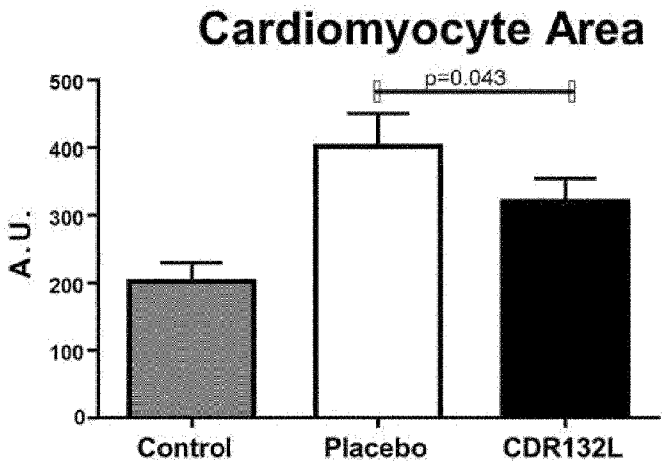


Figure 12B



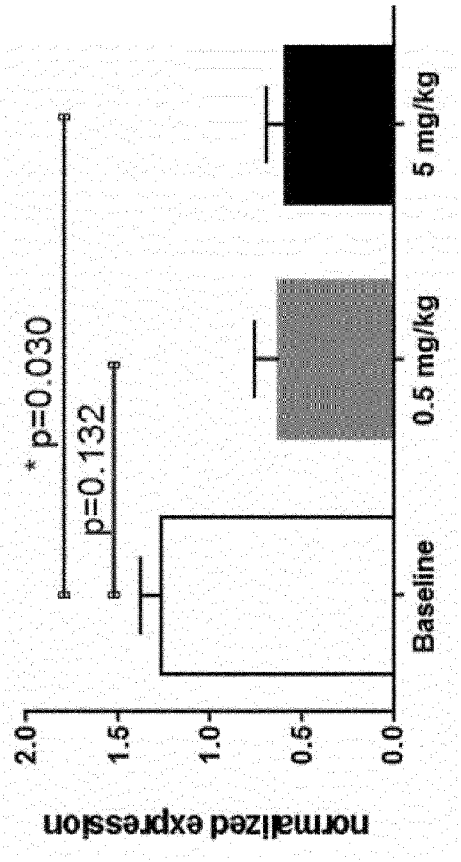

normalized expression
2.0
1.5
1.0
0.5
0.0
* p=0.030
p=0.132
Baseline
0.5 mg/kg
5 mg/kg

Figure 13

Figure 14

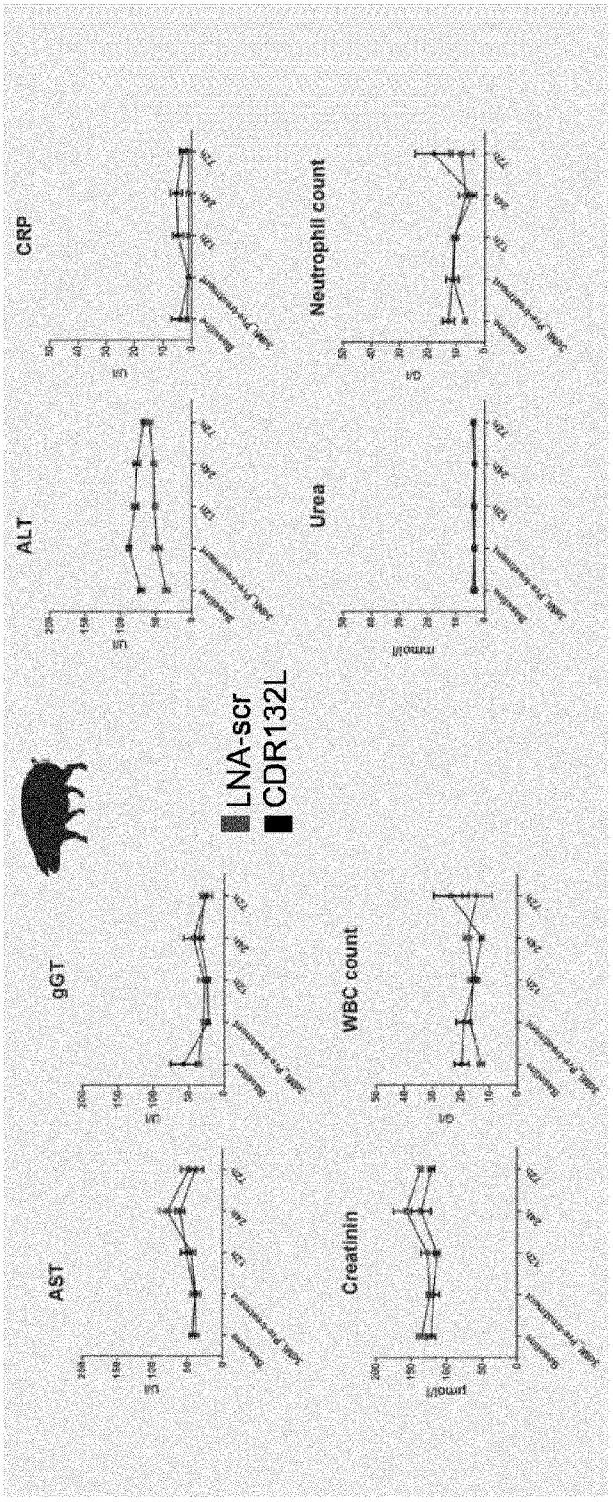

AST
gGT
ALT
CRP
Creatinin
WBC count
Urea
Neutrophil count
LNA-scr
CDR132L

Figure 15

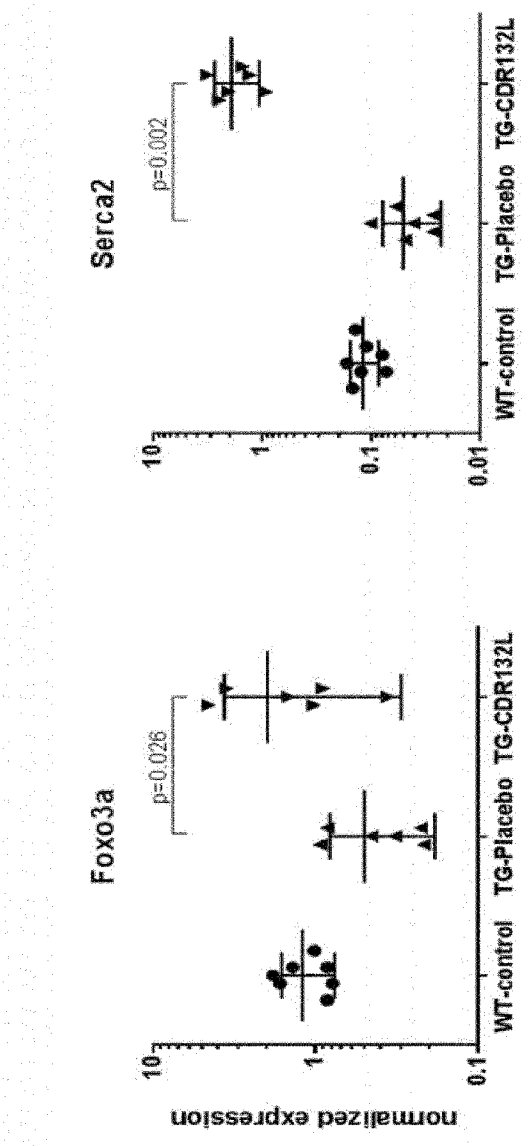
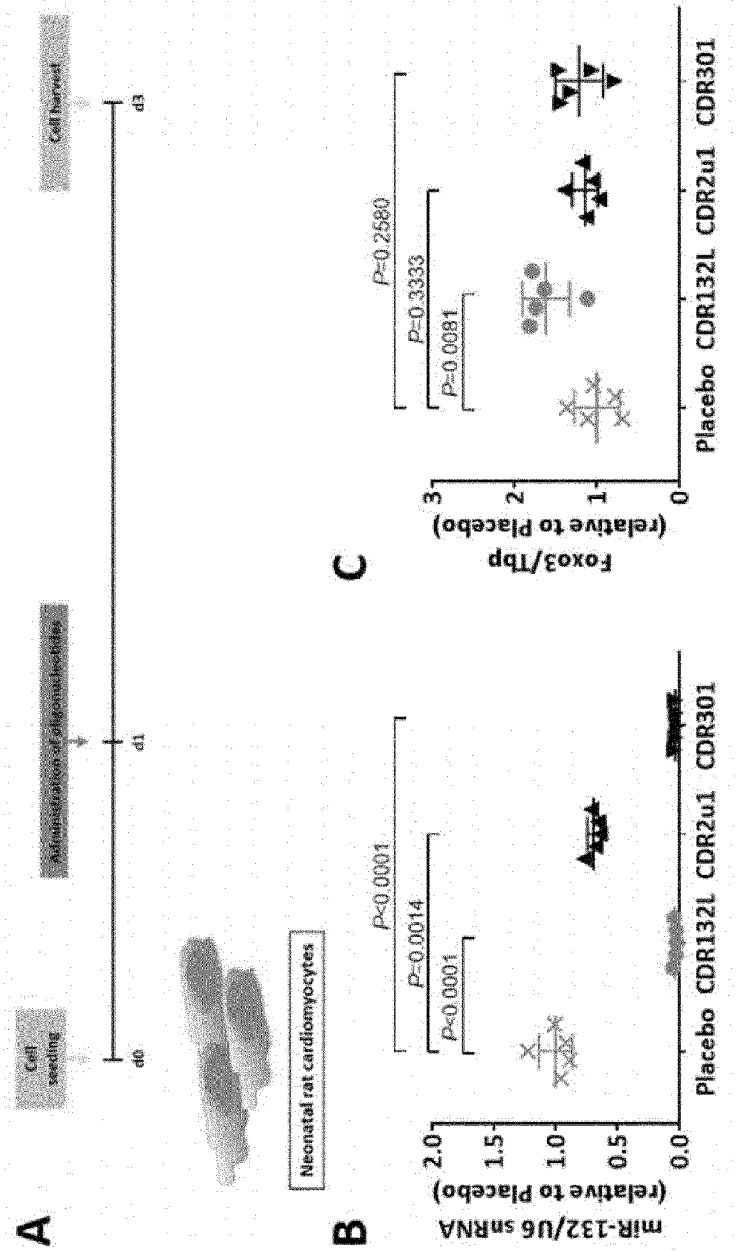

Foxo3a
p=0.026
Serca2
p=0.002
normalized expression
10
1
0.1
0.01
WT-control
TG-Placebo
TG-CDR132L

Figure 16


A
Cell seeding
Administration of oligonucleotides
Cell harvest
d0
d1
d3
Neonatal rat cardiomyocytes
B
miR-132/U6 snRNA
(relative to Placebo)
P<0.0001
P=0.0014
P<0.0001
Placebo
CDR132L
CDR2u1
CDR301
C
Foxo3/Tbp
(relative to Placebo)
P=0.2580
P=0.3333
P=0.0081
Placebo
CDR132L
CDR2u1
CDR301

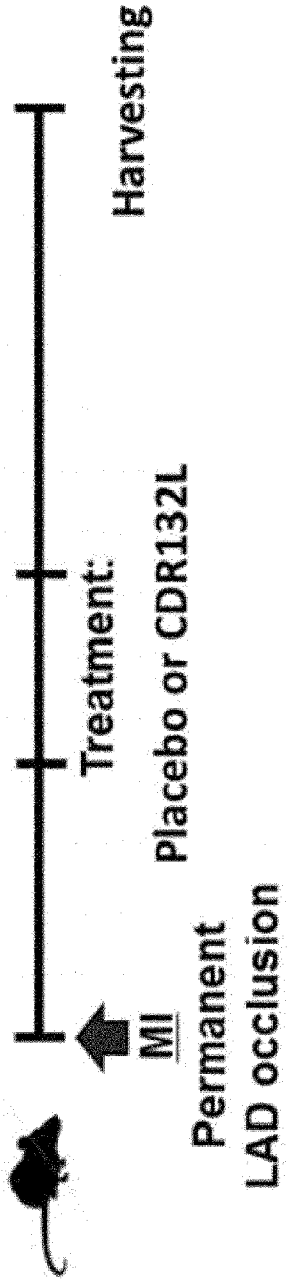

Day0
Day7
Day14
Day28
MI
Permanent
LAD occlusion
Treatment:
Placebo or CDR132L
Harvesting

Figure 17

Figure 18

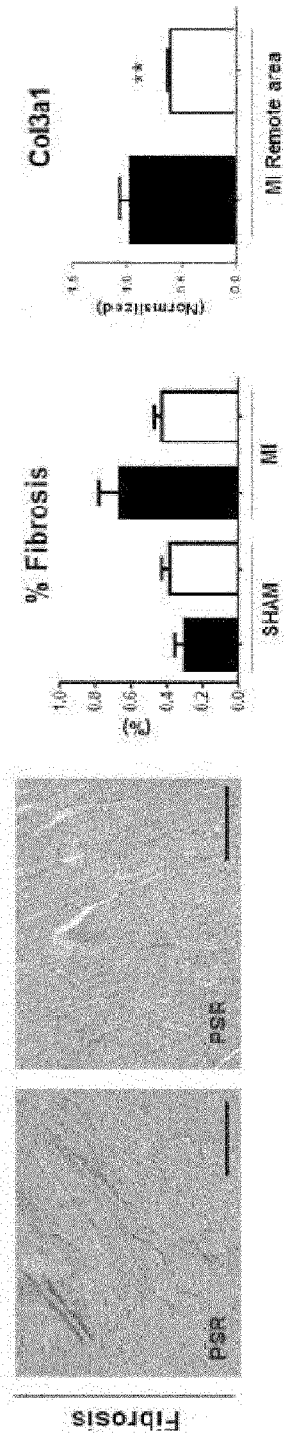

Placebo
CDR132L
PSR
PSR
Fibrosis
% Fibrosis
(%)
1.0
0.8
0.6
0.4
0.2
0.0
SHAM
MI
Col3a1
(Normalized)
1.5
1.0
0.5
0.0
**
MI Remote area

Figure 19

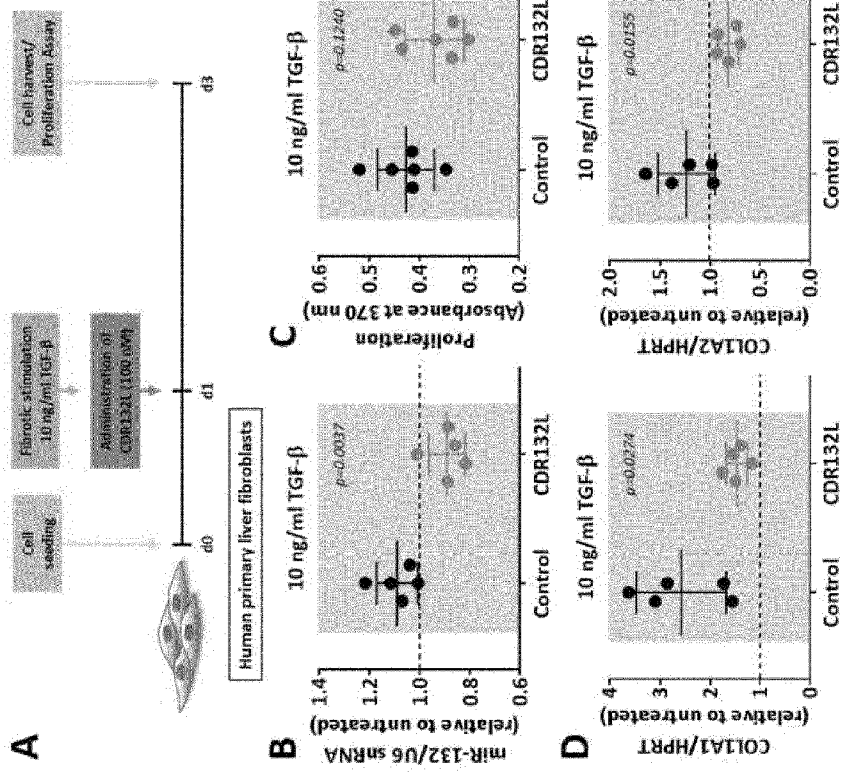
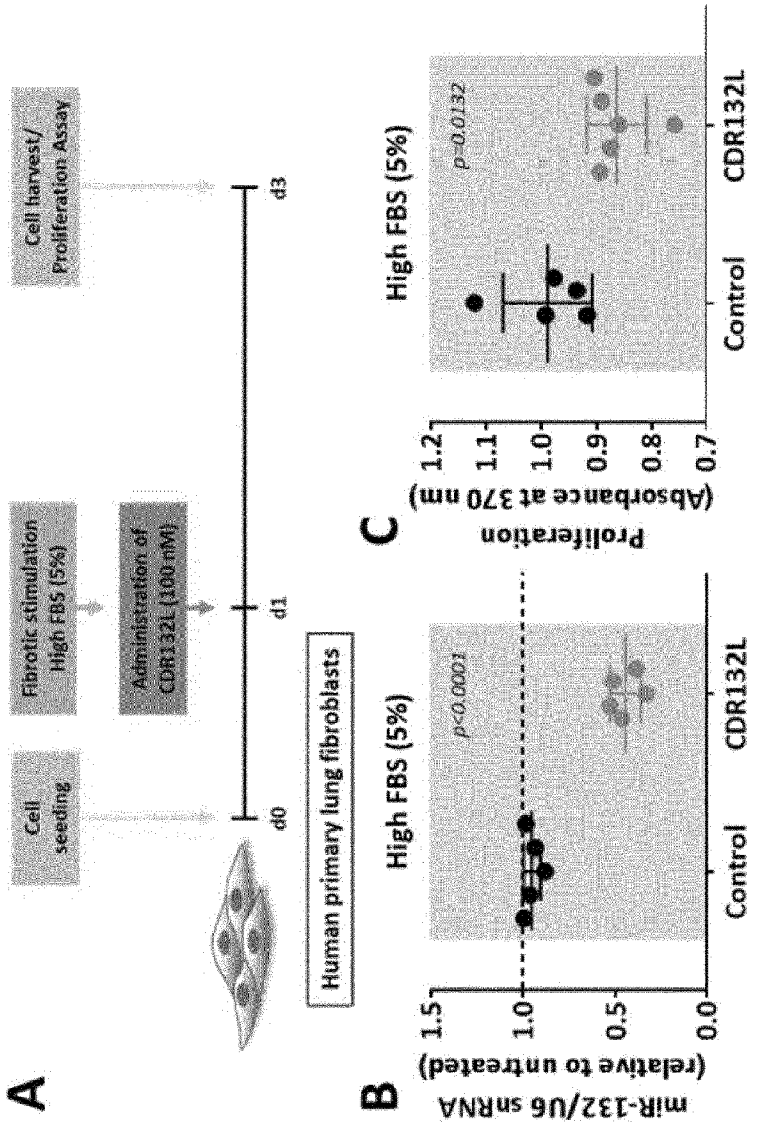

A
Cell seeding
Fibrotic stimulation 10 ng/ml TGF-β
Administration of CDR132L (100 nM)
Cell harvest/ Proliferation Assay
d0
d1
d3
Human primary liver fibroblasts
B
miR-132/U6 snRNA (relative to untreated)
10 ng/ml TGF-β
p=0.0037
Control
CDR132L
C
Proliferation (Absorbance at 370 nm)
10 ng/ml TGF-β
p=0.1240
Control
CDR132L
D
COL1A1/HPRT (relative to untreated)
10 ng/ml TGF-β
p=0.0274
Control
CDR132L
COL1A2/HPRT (relative to untreated)
10 ng/ml TGF-β
p=0.0155
Control
CDR132L
MMP2/HPRT (relative to untreated)
10 ng/ml TGF-β
p=0.0124
Control
CDR132L

Figure 20


A
Cell seeding
Fibrotic stimulation High FBS (5%)
Administration of CDR132L (100 nM)
Cell harvest/ Proliferation Assay
d0
d1
d3
Human primary lung fibroblasts
B
miR-132/U6 snRNA (relative to untreated)
High FBS (5%)
p<0.0001
Control
CDR132L
C
Proliferation (Absorbance at 370 nm)
High FBS (5%)
p=0.0132
Control
CDR132L