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(54) Titre : PROCEDE POUR ATTENUER UNE MALADIE CARDIAQUE
(54) Title: METHOD FOR MITIGATING HEART DISEASE

(57) Abrégé/Abstract:
A method for preventing and/or treating myocardial injury and its related diseases of a subject, comprising administering an effective amount of plasminogen for preventing and/or treating to a subject who is in risk of suffering from myocardial injury, is suspected to suffer from myocardial injury, or suffers from myocardial injury. A drug, a pharmaceutical composition, a product, and a kit comprising plasminogen and used for preventing and/or treating myocardial injury and its related diseases of a subject.

Abstract

The present invention relates to a method for preventing and/or treating hyperlipemia and its related conditions in a subject, comprising administering a prophylactically and/or therapeutically effective amount of plasminogen to the subject susceptible to hyperlipemia, suffers from hyperlipemia or other diseases accompanied by hyperlipemia. The present invention further relates to a medicament, a pharmaceutical composition, an article of manufacture, and a kit comprising plasminogen which are useful for preventing and/or treating hyperlipemia and its related conditions in a subject.

Method for Mitigating Heart Disease

The present invention relates to treatment of cardiac lesions, especially myocardial injury and cardiac dysfunction caused by various causes.

Background Art

Cardiac lesion is a common type of disease, comprising coronary atherosclerosis, coronary heart disease, angina pectoris, myocardial infarction, arrhythmia, heart failure, pericarditis, etc. There are many factors contributing to cardiac lesions and they affect each other. For instance, diabetes mellitus can lead to hyperlipemia and atherosclerosis due to a fat metabolism disorder, and in turn hyperlipemia and atherosclerosis aggravate diabetes mellitus. In the interactive relationship, atherosclerosis is the common pathological basis of various cardiovascular and cerebrovascular diseases, and also the most common disease of cardiovascular system diseases, which seriously endangers human health. The development and progression of atherosclerosis comprises lipid invasion, platelet activation, thrombosis, intimal injury, inflammatory response, oxidative stress, vascular smooth muscle cell (VSMC) activation, selective matrix metabolism, vascular remodeling, etc. In the case of atherosclerosis alone, people do not feel any symptoms. The disease is only discovered when an artery connected to a vital organ in the body is blocked. Symptoms are more pronounced when arteries in the organ are blocked. For instance, people may feel angina pectoris if the cardiac feeding artery is partially blocked; however, if it is completely blocked, it may lead to a heart disease (the death of heart tissue fed by the blocked artery).

Diabetes mellitus is also a potential cause of cardiac lesions. Advanced glycation end products (AGEs) can promote the development and progression of atherosclerosis in diabetic patients. AGEs, as non-enzymatic glycosylation products of glucose with proteins and lipoproteins in the arterial walls, can bind to the corresponding receptors to accelerate atherosclerosis through the following mechanisms: long-term hyperglycemia can increase the production of AGEs. AGEs can modify proteins, nucleic acids and lipids, increase the production of reactive oxygen species and enhance oxidative stress. AGEs can increase

NADPH oxidase activity of neutrophils while increasing the production of oxygen free radicals in neutrophils, and can thus promote vascular oxidative stress, thereby increasing the incidence of cardiovascular disease in diabetic patients. Long-term hyperglycemia caused by diabetes mellitus can lead to severe diabetic complications, comprising diabetic cardiomyopathy, etc.

In another aspect, since the lipid metabolism disorder is often complicated with diabetes mellitus, diabetes mellitus is also known as “diabetes mellipitus”. The pathogenesis of diabetes mellitus is related to B cell dysfunction and insulin resistance, presenting as chronic hyperglycemia, and a disorder of glucose metabolism is often associated with a disorder of lipid metabolism. The lipid metabolism disorder with diabetes mellitus has become an independent risk factor for a cardiovascular disease, which is substantially manifested by hypertriglyceridemia, a low HDL level, and an increased LDL concentration. Studies have shown that the morbidity and mortality of cardiovascular diseases in diabetic patients are significantly higher than those in non-diabetic patients, and that diabetes mellitus has become an independent risk factor for cardiovascular diseases.

Studies have shown that the morbidity and mortality of cardiovascular diseases in diabetic patients are significantly higher than those in non-diabetic patients, and that diabetes mellitus has become an independent risk factor for cardiovascular diseases [3]. In the cardiovascular diseases, atherosclerosis has a high incidence and is often complicated with diabetes mellitus.

The occurrence of atherosclerosis in diabetic patients is related to various factors, but an abnormality in plasma lipid level is the most important factor. In recent years, the relationship between nephropathy and lipid metabolism disorders has attracted more and more attention. A chronic progressive renal injury is often accompanied by abnormal lipid metabolism, and in turn hyperlipemia can promote and aggravate the renal injury, and besides mediating glomerular injury, it also plays a role in a tubulointerstitial injury.

Clinical studies have confirmed that there is also a certain correlation between lipid metabolism disorders and diabetic nephropathy. In a diabetic

patient with a lipid metabolism disorder, an elevated lipid deposition on a glomerular basement membrane stimulates basement membrane cell proliferation and extracellular matrix formation. As early as in 1936, Kimmelstiel and Wilson found massive lipid depositions in renal arterioles, glomeruli and renal tubules of patients with diabetic nephropathy [7]. Abnormal lipid metabolism leading to glomerular and tubulointerstitial fibrosis is one of the most important causes of progressive renal impairment [8]. Lipid metabolism disorders themselves increase the chance of cardiac lesions in human bodies. For instance, one of the hazards of fatty liver is to induce or aggravate hypertension and coronary heart disease, which easily leads to myocardial infarction and thus sudden death.

The studies of the present invention found that plasminogen can be used for targeted treatment of cardiac lesions, which opens up a new idea for the treatment of heart diseases.

Summary of the Invention

The present invention relates to the following items:

In one aspect, the present invention relates to: Item 1. A method for preventing or treating myocardial injury in a subject, comprising administering an effective amount of plasminogen to the subject, wherein the subject has a risk of the myocardial injury, is suspected of having the myocardial injury, or suffers from the myocardial injury.

Item 2. The method of item 1, wherein the myocardial injury comprises myocardial injury caused by ischemia, an inflammation, an allergic reaction, autoimmunity, a thrombus, microcirculation disturbance, a trauma, a radiation injury, a glucose metabolism disorder, and a fat metabolism disorder.

Item 3. The method of item 1 or 2, wherein the myocardial injury is myocardial injury caused by a disease selected from a group consisting of: myocarditis, pericarditis, hypertension, atherosclerosis, coronary heart disease, angina pectoris, myocardial infarction, arrhythmia, heart failure, shock, diffuse intravascular coagulation, microcirculation disturbance, diabetes mellitus, hyperlipemia, arterial and venous thrombosis, fat embolism, ischemic reperfusion,

systemic sclerosis, systemic lupus erythematosus, coronary artery stenosis, rheumatic heart disease, mitral stenosis/insufficiency, and aortic valve stenosis/insufficiency.

Item 4. The method of item 1 or 2, wherein the myocardial injury is myocardial injury caused by ischemic heart disease.

Item 5. The method of item 4, wherein the ischemic heart disease is atherosclerosis, coronary heart disease, angina pectoris, myocardial infarction, arrhythmia, heart failure, shock, diffuse intravascular coagulation, microcirculation disturbance, ischemic reperfusion, coronary artery stenosis, mitral stenosis/insufficiency, and aortic valve stenosis/insufficiency.

Item 6. The method of item 1 or 2, wherein the myocardial injury is myocardial injury caused by arterial and venous thrombosis, or fat embolism.

Item 7. The method of item 6, wherein the thrombosis or embolism is caused by atherosclerosis.

In another aspect, the present invention relates to: Item 8. A method for preventing or treating myocardial injury in a subject, comprising administering an effective amount of plasminogen to the subject to protect a myocardial tissue.

Item 9. The method of item 8, wherein the plasminogen alleviates myocardial apoptosis caused by myocardial cell injury.

Item 10. The method of item 8 or 9, wherein the plasminogen promotes repair of an injured myocardium.

Item 11. The method of any one of items 8 to 10, wherein the plasminogen alleviates fibrosis of the injured myocardium.

Item 12. The method of any one of items 8 to 11, wherein the plasminogen promotes recovery of myocardial function.

Item 13. The method of any one of items 8 to 12, wherein the plasminogen alleviates dilation and compensatory cardiac hypertrophy after myocardial injury.

In another aspect, the present invention relates to: Item 14. A method for preventing or treating a lipid-induced myocardial injury in a subject, comprising administering an effective amount of plasminogen to the subject to protect a myocardium.

Item 15. The method of item 14, wherein the plasminogen alleviates lipid deposition in a cardiac tissue.

Item 16. The method of item 14 or 15, wherein the plasminogen promotes repair of an injured myocardium.

Item 17. The method of any one of items 14 to 16, wherein the plasminogen alleviates fibrosis of an injured myocardial tissue.

Item 18. The method of any one of items 14 to 17, wherein the plasminogen alleviates apoptosis of injured myocardial cells.

Item 19. The method of any one of items 14 to 18, wherein the plasminogen promotes recovery of myocardial function.

Item 20. The method of any one of items 14 to 19, wherein the plasminogen alleviates dilation and compensatory cardiac hypertrophy after myocardial injury.

Item 21. The method of any one of items 14 to 20, wherein the plasminogen alleviates blood lipid in one or more ways of: lowering serum triglyceride, low-density lipoprotein, very low-density lipoprotein, and serum cholesterol, and elevating serum high-density lipoprotein.

In another aspect, the present invention relates to: Item 22. A method for preventing or treating an inflammation-induced myocardial injury in a subject, comprising administering an effective amount of plasminogen to the subject to protect a myocardium.

Item 23. The method of item 22, wherein the inflammation is an inflammation caused by autoimmune in the subject.

Item 24. The method of item 23, wherein the inflammation is systemic lupus erythematosus, systemic sclerosis, myocarditis, and pericarditis.

Item 25. The method of any one of items 22 to 24, wherein the plasminogen promotes repair of an injured myocardium.

Item 26. The method of any one of items 22 to 25, wherein the plasminogen alleviates fibrosis of an injured myocardial tissue.

Item 27. The method of any one of items 22 to 26, wherein the plasminogen alleviates apoptosis of injured myocardial cells.

Item 28. The method of any one of items 22 to 27, wherein the plasminogen promotes recovery of myocardial function.

Item 29. The method of any one of items 22 to 28, wherein the plasminogen alleviates dilation and compensatory cardiac hypertrophy after myocardial injury.

In another aspect, the present invention relates to: Item 30. A method for preventing or treating a coronary arteriosclerotic myocardial injury in a subject, comprising administering an effective amount of plasminogen to the subject to protect a myocardium.

Item 31. The method of item 30, wherein the myocardial injury is caused by coronary heart disease in the subject.

Item 32. The method of item 31, wherein the plasminogen promotes repair of an injured myocardium.

Item 33. The method of any one of items 30 to 32, wherein the plasminogen alleviates fibrosis of an injured myocardial tissue.

Item 34. The method of any one of items 30 to 33, wherein the plasminogen alleviates apoptosis of injured myocardial cells.

Item 35. The method of any one of items 30 to 34, wherein the plasminogen promotes recovery of myocardial function.

Item 36. The method of any one of items 30 to 35, wherein the plasminogen alleviates dilation and compensatory cardiac hypertrophy after myocardial injury.

In another aspect, the present invention relates to: Item 37. A method for preventing or treating myocardial injury caused or complicated by diabetes mellitus in a subject, comprising administering an effective amount of plasminogen to the subject to protect a myocardium.

Item 38. The method of item 37, wherein the plasminogen promotes repair of an injured myocardium.

Item 39. The method of item 37 or 38, wherein the plasminogen alleviates fibrosis of an injured myocardial tissue.

Item 40. The method of any one of items 37 to 39, wherein the plasminogen alleviates apoptosis of injured myocardial cells.

Item 41. The method of any one of items 37 to 40, wherein the plasminogen promotes recovery of myocardial function.

Item 42. The method of any one of items 37 to 41, wherein the plasminogen alleviates dilation and compensatory cardiac hypertrophy after myocardial injury.

In another aspect, the present invention relates to: Item 43. A method for preventing or treating myocardial injury caused by lipid deposition in a subject, comprising administering an effective amount of plasminogen to the subject.

Item 44. The method of item 43, wherein the lipid deposition is induced by hyperlipemia caused by abnormal fat or glucose metabolism in the subject.

In another aspect, the present invention relates to: Item 45. A method for preventing or treating a renal tissue injury caused or accompanied by hyperlipemia in a subject, comprising administering an effective amount of plasminogen to the subject.

In another aspect, the present invention relates to: Item 46. A method for preventing or treating an ischemic reperfusion-induced myocardial tissue injury in a subject, comprising administering an effective amount of plasminogen to the subject.

Item 47. The method of any one of items 1 to 46, wherein the plasminogen is administered in combination with one or more other drugs or therapeutic means.

Item 48. The method of item 47, wherein the one or more other drugs comprises a drug for treating hypertension, a drug for treating diabetes mellitus, a drug for treating atherosclerosis, a drug for treating chronic glomerulonephritis, a drug for treating chronic pyelonephritis, a drug for treating nephrotic syndrome, a drug for treating renal insufficiency, a drug for treating uremia, a drug for treating kidney transplantation, a drug for treating fatty liver, a drug for treating hepatic cirrhosis, and a drug for treating obesity.

Item 49. The method of item 48, wherein the other drugs comprise: a hypolipidemic drug, an anti-platelet drug, an antihypertensive drug, a vasodilator, a hypoglycemic drug, an anticoagulant drug, a thrombolytic drug, a hepatoprotective drug, an anti-arrhythmia drug, a cardiotonic drug, a diuretic

drug, an anti-infective drug, an antiviral drug, an immunomodulatory drug, an inflammatory regulatory drug, an anti-tumor drug, a hormone drug, and thyroxine.

Item 50. The method of item 49, wherein the drugs comprise hypolipidemic drugs: statins; fibrates; niacin; cholestyramine; clofibrate; unsaturated fatty acids such as Yishouning, Xuezhiping, and Xinmaile; and alginic sodium diester; anti-platelet drugs: aspirin; dipyridamole; clopidogrel; and cilostazol; vasodilators: hydralazine; nitroglycerin, and isosorbide dinitrate; sodium nitroprusside; α1-receptor blockers such as prazosin; α-receptor blockers such as phentolamine; β2-receptor stimulants such as salbutamol; captopril, enalapril; nifedipine, diltiazem; and salbutamol, loniten, prostaglandin, and atrial natriuretic peptide; thrombolytic drugs: urokinase, and streptokinase; tissue-type plasminogen activators; single chain urokinase-type plasminogen activators; and a TNK tissue-type plasminogen activator; and anticoagulant drugs: heparin; enoxaparin; nadroparin; and bivalirudin.

Item 51. The method of any one of items 1 to 50, wherein the plasminogen has at least 75%, 80%, 85%, 90%, 95%, 96%, 97%, 98% or 99% sequence identity with SEQ ID No. 2, 6, 8, 10 or 12, and still has the plasminogen activity.

Item 52. The method of any one of items 1 to 51, wherein the plasminogen is a protein that has 1-100, 1-90, 1-80, 1-70, 1-60, 1-50, 1-45, 1-40, 1-35, 1-30, 1-25, 1-20, 1-15, 1-10, 1-5, 1-4, 1-3, 1-2 or 1 amino acid added, deleted and/or substituted in SEQ ID No. 2, 6, 8, 10 or 12, and still has the plasminogen activity.

Item 53. The method of any one of items 1 to 52, wherein the plasminogen is a protein that comprises a plasminogen active fragment and still has the plasminogen activity.

Item 54. The method of any one of items 1 to 53, wherein the plasminogen is selected from Glu-plasminogen, Lys-plasminogen, mini-plasminogen, micro-plasminogen, delta-plasminogen or their variants that retain the plasminogen activity.

Item 55. The method of any one of items 1 to 54, wherein the plasminogen is a natural or synthetic human plasminogen, or a variant or fragment thereof that still retains the plasminogen activity.

Item 56. The method of any one of items 1 to 54, wherein the plasminogen is an ortholog of human plasminogen from a primate or a rodent, or a variant or fragment thereof that still retains the plasminogen activity.

Item 57. The method of any one of items 1 to 56, wherein the amino acids of the plasminogen are as shown in SEQ ID No. 2, 6, 8, 10 or 12.

Item 58. The method of any one of items 1 to 57, wherein the plasminogen is a natural human plasminogen.

Item 59. The method of any one of items 1 to 58, wherein the subject is a human.

Item 60. The method of any one of items 1 to 59, wherein the subject has a lack or deficiency of plasminogen.

Item 61. The method of item 60, wherein the lack or deficiency is congenital, secondary and/or local.

In another aspect, the present invention relates to: Item 62. A plasminogen for use in the method of any one of items 1 to 61.

In another aspect, the present invention relates to: Item 63. A pharmaceutical composition, comprising a pharmaceutically acceptable carrier and the plasminogen for use in the method of any one of items 1 to 61.

In another aspect, the present invention relates to: Item 64. A preventive or therapeutic kit comprising: (i) the plasminogen for use in the method of any one of items 1 to 61, and (ii) a means for delivering the plasminogen to the subject.

Item 65. The kit of item 64, wherein the means is a syringe or a vial.

Item 66. The kit of item 64 or 65, further comprising a label or an instruction for use indicating the administration of the plasminogen to the subject to implement the method of any one of items 1 to 46.

In another aspect, the present invention relates to: Item 67. An article of manufacture, comprising:

a container comprising a label; and

(i) the plasminogen for use in the method of any one of items 1 to 61 or a pharmaceutical composition comprising the plasminogen, wherein the label

indicates the administration of the plasminogen or the composition to the subject to implement the method of any one of items 1 to 61.

Item 68. The kit of any one of items 64 to 66 or the article of manufacture of item 67, further comprising one or more additional means or containers containing other drugs.

Item 69. The kit or the article of manufacture of item 68, wherein the other drugs are selected from a group of: a hypolipidemic drug, an anti-platelet drug, an antihypertensive drug, a vasodilator, a hypoglycemic drug, an anticoagulant drug, a thrombolytic drug, a hepatoprotective drug, an anti-arrhythmia drug, a cardiotonic drug, a diuretic drug, an anti-infective drug, an antiviral drug, an immunomodulatory drug, an inflammatory regulatory drug, an anti-tumor drug, a hormone drug, and thyroxine.

The present invention further relates to the use of plasminogen for implementing the method of any one of items 1 to 61.

The present invention further relates to the use of plasminogen in the preparation of a medicament, a pharmaceutical composition, an article of manufacture, and a kit for the method of any one of items 1 to 61.

In some embodiments, the kit or the article of manufacture further comprises one or more additional means or containers containing other drugs. In some embodiments, the other drugs are selected from a group of: a hypolipidemic drug, an anti-platelet drug, an antihypertensive drug, a vasodilator, a hypoglycemic drug, an anticoagulant drug, a thrombolytic drug, a hepatoprotective drug, an anti-arrhythmia drug, a cardiotonic drug, a diuretic drug, an anti-infective drug, an antiviral drug, an immunomodulatory drug, an inflammatory regulatory drug, an anti-tumor drug, a hormone drug, and thyroxine.

In some embodiments of the above-mentioned method, the plasminogen is administered by systemic or topical route, preferably by the following routes: intravenous, intramuscular, and subcutaneous administration of plasminogen for treatment. In some embodiments of the above-mentioned method, the plasminogen is administered in combination with a suitable polypeptide carrier or stabilizer. In some embodiments of the above-mentioned method, the

plasminogen is administered at a dosage of 0.0001-2000 mg/kg, 0.001-800 mg/kg, 0.01-600 mg/kg, 0.1-400 mg/kg, 1-200 mg/kg, 1-100 mg/kg or 10-100 mg/kg (by per kg of body weight) or 0.0001-2000 mg/cm^2, 0.001-800 mg/cm^2, 0.01-600 mg/cm^2, 0.1-400 mg/cm^2, 1-200 mg/cm^2, 1-100 mg/cm^2 or 10-100 mg/cm^2 (by per square centimeter of body surface area) daily, preferably the dosage is repeated at least once, preferably the dosage is administered at least daily.

The present invention explicitly encompasses all the combinations of technical features belonging to the embodiments of the present invention, and these combined technical solutions have been explicitly disclosed in the present application, as if the above-mentioned technical solutions were individually and explicitly disclosed. In addition, the present invention also explicitly encompasses all the combinations between various embodiments and elements thereof, and the combined technical solutions are explicitly disclosed herein.

Detailed Description of Embodiments

Plasmin is a key component of the plasminogen activation system (PA system). It is a broad-spectrum protease that can hydrolyze several components of the extracellular matrix (ECM), including fibrin, gelatin, fibronectin, laminin, and proteoglycan. In addition, plasmin can activate some pro-matrix metalloproteinases (pro-MMPs) to form active matrix metalloproteinases (MMPs). Therefore, plasmin is considered to be an important upstream regulator of extracellular proteolysis. Plasmin is formed by the proteolysis of plasminogen by two physiological PAs: tissue plasminogen activator (tPA) or urokinase-type plasminogen activator (uPA). Due to the relatively high level of plasminogen in plasma and other body fluids, it is traditionally believed that the regulation of the PA system is primarily achieved through the levels of PA synthesis and activity. The synthesis of PA system components is strictly regulated by different factors, such as hormones, growth factors and cytokines. In addition, there are also specific physiological inhibitors of plasmin and PAs. The main inhibitor of plasmin is α2-antiplasmin. The activity of PAs is simultaneously inhibited by the plasminogen activator inhibitor-1 (PAI-1) of uPA and tPA and regulated by the

plasminogen activator inhibitor-2 (PAI-2) that primarily inhibits uPA. There are uPA-specific cell surface receptors (uPARs) that have direct hydrolytic activity on certain cell surfaces.

Plasminogen is a single-stranded glycoprotein composed of 791 amino acids and has a molecular weight of about 92 kDa. Plasminogen is mainly synthesized in the liver and is abundantly present in the extracellular fluid. The content of plasminogen in plasma is about 2 μM. Therefore, plasminogen is a huge potential source of proteolytic activity in tissues and body fluids. Plasminogen exists in two molecular forms: glutamic acid-plasminogen (Glu-plasminogen) and lysine-plasminogen (Lys-plasminogen). The naturally secreted and uncleaved forms of plasminogen have an amino-terminal (N-terminal) glutamic acid and are therefore referred to as glutamic acid-plasminogen. However, in the presence of plasmin, glutamic acid-plasminogen is hydrolyzed to lysine-plasminogen at Lys76-Lys77. Compared with glutamic acid-plasminogen, lysine-plasminogen has a higher affinity for fibrin and can be activated by PAs at a higher rate. The Arg560-Val561 peptide bond between these two forms of plasminogen can be cleaved by uPA or tPA, resulting in the formation of plasmin as a disulfide-linked double-strand protease. The amino-terminal portion of plasminogen contains five homotrimeric rings, i.e., the so-called kringles, and the carboxy-terminal portion contains a protease domain. Some kringles contain lysine-binding sites that mediate the specific interaction of plasminogen with fibrin and its inhibitor α2-AP. A newly discovered plasminogen is a 38 kDa fragment, comprising kringles 1-4, is a potent inhibitor of angiogenesis. This fragment is named as angiostatin and can be produced by proteolysis of plasminogen by several proteases.

The main substrate of plasmin is fibrin, and the dissolution of fibrin is the key to prevent pathological thrombosis. Plasmin also has substrate specificity for several components of ECM, including laminin, fibronectin, proteoglycan and gelatin, indicating that plasmin also plays an important role in ECM remodeling. Indirectly, plasmin can also degrade other components of ECM by converting certain protease precursors into active proteases, including MMP-1, MMP-2, MMP-3 and MMP-9. Therefore, it has been proposed that plasmin may be an

important upstream regulator of extracellular proteolysis. In addition, plasmin has the ability to activate certain potential forms of growth factors. *In vitro*, plasmin can also hydrolyze components of the complement system and release chemotactic complement fragments.

"Plasmin" is a very important enzyme that exists in the blood and can hydrolyze fibrin clots into fibrin degradation products and D-dimers.

"Plasminogen" is the zymogenic form of plasmin, and based on the sequence in the swiss prot and calculated from the amino acid sequence (SEQ ID No. 4) of the natural human plasminogen containing a signal peptide, is a glycoprotein composed of 810 amino acids, which has a molecular weight of about 90 kD and is synthesized mainly in the liver and capable of circulating in the blood; and the cDNA sequence encoding this amino acid sequence is as shown in SEQ ID No. 3. Full-length plasminogen contains seven domains: a C-terminal serine protease domain, an N-terminal Pan Apple (PAp) domain and five Kringle domains (Kringles 1-5). Referring to the sequence in the swiss prot, the signal peptide comprises residues Met1-Gly19, PAp comprises residues Glu20-Val98, Kringle 1 comprises residues Cys103-Cys181, Kringle 2 comprises residues Glu184-Cys262, Kringle 3 comprises residues Cys275-Cys352, Kringle 4 comprises residues Cys377-Cys454, and Kringle 5 comprises residues Cys481-Cys560. According to the NCBI data, the serine protease domain comprises residues Val581-Arg804.

Glu-plasminogen is a natural full-length plasminogen and is composed of 791 amino acids (without a signal peptide of 19 amino acids); the cDNA sequence encoding this sequence is as shown in SEQ ID No. 1; and the amino acid sequence is as shown in SEQ ID No. 2. *In vivo*, Lys-plasminogen, which is formed by hydrolysis of amino acids at positions 76-77 of Glu-plasminogen, is also present, as shown in SEQ ID No.6; and the cDNA sequence encoding this amino acid sequence is as shown in SEQ ID No.5. δ-plasminogen is a fragment of full-length plasminogen that lacks the structure of Kringle 2-Kringle 5 and contains only Kringle 1 and the serine protease domain. The amino acid sequence (SEQ ID No. 8) of δ-plasminogen has been reported in the literature, and the

cDNA sequence encoding this amino acid sequence is as shown in SEQ ID No. 7. Mini-plasminogen is composed of Kringle 5 and the serine protease domain, and has been reported in the literature to comprise residues Val443-Asn791 (with the Glu residue of the Glu-plasminogen sequence that does not contain a signal peptide as the starting amino acid); the amino acid sequence is as shown in SEQ ID No. 10; and the cDNA sequence encoding this amino acid sequence is as shown in SEQ ID No. 9. Micro-plasminogen comprises only the serine protease domain, the amino acid sequence of which has been reported in the literature to comprise residues Ala543-Asn791 (with the Glu residue of the Glu-plasminogen sequence that does not contain a signal peptide as the starting amino acid), and the sequence of which has been also reported in patent document CN 102154253 A to comprise residues Lys531-Asn791 (with the Glu residue of the Glu-plasminogen sequence that does not contain a signal peptide as the starting amino acid) (the sequence in this patent application refers to the patent document CN 102154253 A); the amino acid sequence is as shown in SEQ ID No. 12; and the cDNA sequence encoding this amino acid sequence is as shown in SEQ ID No. 11.

In the present invention, "plasmin" is used interchangeably with "fibrinolysin" and "fibrinoclase", and the terms have the same meaning; and "plasminogen" is used interchangeably with "plasminogen" and "fibrinoclase zymogen", and the terms have the same meaning.

In the present application, the meaning of "lack" in plasminogen is that the content or activity of plasminogen in the body of a subject is lower than that of a normal person, which is low enough to affect the normal physiological function of the subject; and the meaning of "deficiency" in plasminogen is that the content or activity of plasminogen in the body of a subject is significantly lower than that of a normal person, or even the activity or expression is extremely small, and only through exogenous supply can the normal physiological function be maintained.

Those skilled in the art can understand that all the technical solutions of the plasminogen of the present invention are suitable for plasmin. Therefore, the

technical solutions described in the present invention cover plasminogen and plasmin.

In the course of circulation, plasminogen is in a closed, inactive conformation, but when bound to thrombi or cell surfaces, it is converted into an active plasmin in an open conformation under the mediation of a plasminogen activator (PA). The active plasmin can further hydrolyze the fibrin clots to fibrin degradation products and D-dimers, thereby dissolving the thrombi. The PAp domain of plasminogen comprises an important determinant that maintains plasminogen in an inactive, closed conformation, and the KR domain is capable of binding to lysine residues present on receptors and substrates. A variety of enzymes that can serve as plasminogen activators are known, including: tissue plasminogen activator (tPA), urokinase plasminogen activator (uPA), kallikrein, coagulation factor XII (Hagmann factor), and the like.

"Plasminogen active fragment" refers to an active fragment in the plasminogen protein that is capable of binding to a target sequence in a substrate and exerting the proteolytic function. The technical solutions of the present invention involving plasminogen encompass technical solutions in which plasminogen is replaced with a plasminogen active fragment. The plasminogen active fragment of the present invention is a protein comprising a serine protease domain of plasminogen. Preferably, the plasminogen active fragment of the present invention comprises SEQ ID No.14, or an amino acid sequence having an amino acid sequence identity of at least 80%, 90%, 95%, 96%, 97%, 98% or 99% with SEQ ID No.14. Therefore, plasminogen of the present invention comprises a protein containing the plasminogen active fragment and still having the plasminogen activity.

At present, methods for determining plasminogen and its activity in blood include: detection of tissue plasminogen activator activity (t-PAA), detection of tissue plasminogen activator antigen (t-PAAg) in plasma, detection of tissue plasminogen activity (plgA) in plasma, detection of tissue plasminogen antigen (plgAg) in plasma, detection of activity of the inhibitor of tissue plasminogen activators in plasma, detection of inhibitor antigens of tissue plasminogen

activators in plasma and detection of plasmin-anti-plasmin (PAP) complex in plasma. The most commonly used detection method is the chromogenic substrate method: streptokinase (SK) and a chromogenic substrate are added to a test plasma, the PLG in the test plasma is converted into PLM by the action of SK, PLM acts on the chromogenic substrate, and then it is determined that the increase in absorbance is directly proportional to plasminogen activity using a spectrophotometer. In addition, plasminogen activity in blood can also be determined by immunochemistry, gel electrophoresis, immunonephelometry, radioimmuno-diffusion and the like.

"Orthologues or orthologs" refer to homologs between different species, including both protein homologs and DNA homologs, and are also known as orthologous homologs and vertical homologs. The term specifically refers to proteins or genes that have evolved from the same ancestral gene in different species. The plasminogen of the present invention includes human natural plasminogen, and also includes orthologues or orthologs of plasminogens derived from different species and having plasminogen activity.

"Conservatively substituted variant" refers to one in which a given amino acid residue is changed without altering the overall conformation and function of the protein or enzyme, including, but not limited to, replacing an amino acid in the amino acid sequence of the parent protein by an amino acid with similar properties (such as acidity, alkalinity, hydrophobicity, etc.). Amino acids with similar properties are well known. For example, arginine, histidine and lysine are hydrophilic basic amino acids and are interchangeable. Similarly, isoleucine is a hydrophobic amino acid that can be replaced by leucine, methionine or valine. Therefore, the similarity of two proteins or amino acid sequences with similar functions may be different. For example, the similarity (identity) is 70%-99% based on the MEGALIGN algorithm. "Conservatively substituted variant" also includes a polypeptide or enzyme having amino acid identity of 60% or more, preferably 75% or more, more preferably 85% or more, even more preferably 90% or more as determined by the BLAST or FASTA algorithm, and having the same

or substantially similar properties or functions as the natural or parent protein or enzyme.

"Isolated" plasminogen refers to the plasminogen protein that is isolated and/or recovered from its natural environment. In some embodiments, the plasminogen will be purified (1) to a purity of greater than 90%, greater than 95% or greater than 98% (by weight), as determined by the Lowry method, such as more than 99% (by weight); (2) to a degree sufficiently to obtain at least 15 residues of the N-terminal or internal amino acid sequence using a spinning cup sequenator; or (3) to homogeneity, which is determined by sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) under reducing or non-reducing conditions using Coomassie blue or silver staining. Isolated plasminogen also includes plasminogen prepared from recombinant cells by bioengineering techniques and separated by at least one purification step.

The terms "polypeptide", "peptide" and "protein" are used interchangeably herein and refer to polymeric forms of amino acids of any length, which may include genetically encoded and non-genetically encoded amino acids, chemically or biochemically modified or derivatized amino acids, and polypeptides having modified peptide backbones. The term includes fusion proteins, including, but not limited to, fusion proteins having heterologous amino acid sequences, fusions having heterologous and homologous leader sequences (with or without N-terminal methionine residues); and the like.

The "percent amino acid sequence identity (%)" with respect to the reference polypeptide sequence is defined as the percentage of amino acid residues in the candidate sequence identical to the amino acid residues in the reference polypeptide sequence when a gap is introduced as necessary to achieve maximal percent sequence identity and no conservative substitutions are considered as part of sequence identity. The comparison for purposes of determining percent amino acid sequence identity can be achieved in a variety of ways within the skill in the art, for example using publicly available computer softwares, such as BLAST, BLAST-2, ALIGN or Megalign (DNASTAR) software. Those skilled in the art can determine appropriate parameters for

aligning sequences, including any algorithm needed to achieve the maximum comparison over the full length of the sequences being compared. However, for purposes of the present invention, the percent amino acid sequence identity value is generated using the sequence comparison computer program ALIGN-2.

In the case of comparing amino acid sequences using ALIGN-2, the % amino acid sequence identity of a given amino acid sequence A relative to a given amino acid sequence B (or may be expressed as a given amino acid sequence A having or containing a certain % amino acid sequence identity relative to, with or for a given amino acid sequence B) is calculated as follows:

fraction X/Y × 100

wherein X is the number of identically matched amino acid residues scored by the sequence alignment program ALIGN-2 in the alignment of A and B using the program, and wherein Y is the total number of amino acid residues in B. It will be appreciated that where the length of amino acid sequence A is not equal to the length of amino acid sequence B, the % amino acid sequence identity of A relative to B will not be equal to the % amino acid sequence identity of B relative to A. Unless specifically stated otherwise, all the % amino acid sequence identity values used herein are obtained using the ALIGN-2 computer program as described in the previous paragraph.

As used herein, the terms "treatment" and "treating" refer to obtaining a desired pharmacological and/or physiologic effect. The effect may be complete or partial prevention of a disease or its symptoms and/or partial or complete cure of the disease and/or its symptoms, and includes: (a) prevention of the disease from developing in a subject that may have a predisposition to the disease but has not been diagnosed as having the disease; (b) suppression of the disease, i.e., blocking its formation; and (c) alleviation of the disease and/or its symptoms, i.e., eliminating the disease and/or its symptoms.

The terms "individual", "subject" and "patient" are used interchangeably herein and refer to mammals, including, but not limited to, murine (rats and mice), non-human primates, humans, dogs, cats, hoofed animals (e.g., horses, cattle, sheep, pigs, goats) and so on.

"Therapeutically effective amount" or "effective amount" refers to an amount of plasminogen sufficient to achieve the prevention and/or treatment of a disease when administered to a mammal or another subject to treat the disease. The "therapeutically effective amount" will vary depending on the plasminogen used, the severity of the disease and/or its symptoms, as well as the age, body weight of the subject to be treated, and the like.

Preparation of the plasminogen of the present invention

Plasminogen can be isolated and purified from nature for further therapeutic uses, and can also be synthesized by standard chemical peptide synthesis techniques. When chemically synthesized, a polypeptide can be subjected to liquid or solid phase synthesis. Solid phase polypeptide synthesis (SPPS) is a method suitable for chemical synthesis of plasminogen, in which the C-terminal amino acid of a sequence is attached to an insoluble support, followed by the sequential addition of the remaining amino acids in the sequence. Various forms of SPPS, such as Fmoc and Boc, can be used to synthesize plasminogen. Techniques for solid phase synthesis are described in Barany and Solid-Phase Peptide Synthesis; pp. 3-284 in The Peptides: Analysis, Synthesis, Biology. Vol. 2: Special Methods in Peptide Synthesis, Part A., Merrifield, et al. J. Am. Chem. Soc., 85: 2149-2156 (1963); Stewart et al. Solid Phase Peptide Synthesis, 2nd ed. Pierce Chem. Co., Rockford, Ill. (1984); and Ganesan A. 2006 Mini Rev. Med Chem. 6:3-10 and Camarero JA et al. 2005 Protein Pept Lett. 12:723-8. Briefly, small insoluble porous beads are treated with a functional unit on which a peptide chain is constructed. After repeated cycles of coupling/deprotection, the attached solid phase free N-terminal amine is coupled to a single N-protected amino acid unit. This unit is then deprotected to expose a new N-terminal amine that can be attached to another amino acid. The peptide remains immobilized on the solid phase before it is cut off.

Standard recombinant methods can be used to produce the plasminogen of the present invention. For example, a nucleic acid encoding plasminogen is inserted into an expression vector, so that it is operably linked to a regulatory

sequence in the expression vector. Expression regulatory sequence includes, but is not limited to, promoters (e.g., naturally associated or heterologous promoters), signal sequences, enhancer elements and transcription termination sequences. Expression regulation can be a eukaryotic promoter system in a vector that is capable of transforming or transfecting eukaryotic host cells (e.g., COS or CHO cells). Once the vector is incorporated into a suitable host, the host is maintained under conditions suitable for high-level expression of the nucleotide sequence and collection and purification of plasminogen.

A suitable expression vector is usually replicated in a host organism as an episome or as an integral part of the host chromosomal DNA. In general, an expression vector contains a selective marker (e.g., ampicillin resistance, hygromycin resistance, tetracycline resistance, kanamycin resistance or neomycin resistance) to facilitate detection of those exogenous cells transformed with a desired DNA sequence.

Escherichia coli is an example of prokaryotic host cells that can be used to clone a polynucleotide encoding the subject antibody. Other microbial hosts suitable for use include *Bacillus*, for example, *Bacillus subtilis* and other species of enterobacteriaceae (such as *Salmonella* spp. and *Serratia* spp.), and various *Pseudomonas* spp. In these prokaryotic hosts, expression vectors can also be generated which will typically contain an expression control sequence (e.g., origin of replication) that is compatible with the host cell. In addition, there will be many well-known promoters, such as the lactose promoter system, the tryptophan (trp) promoter system, the beta-lactamase promoter system or the promoter system from phage lambda. Optionally in the case of manipulation of a gene sequence, a promoter will usually control expression, and has a ribosome binding site sequence and the like to initiate and complete transcription and translation.

Other microorganisms, such as yeast, can also be used for expression. *Saccharomyces* (e.g., *S. cerevisiae*) and *Pichia* are examples of suitable yeast host cells, in which a suitable vector has an expression control sequence (e.g., promoter), an origin of replication, a termination sequence and the like, as

required. A typical promoter comprises 3-phosphoglycerate kinase and other glycolytic enzymes. Inducible yeast promoters specifically include promoters derived from alcohol dehydrogenase, isocytochrome C, and enzymes responsible for maltose and galactose utilization.

In addition to microorganisms, mammalian cells (e.g., mammalian cells cultured in cell culture *in vitro*) can also be used to express and generate the anti-Tau antibody of the present invention (e.g., a polynucleotide encoding a subject anti-Tau antibody). See Winnacker, From Genes to Clones, VCH Publishers, N.Y., N.Y. (1987). Suitable mammalian host cells include CHO cell lines, various Cos cell lines, HeLa cells, myeloma cell lines and transformed B cells or hybridomas. Expression vectors for these cells may comprise an expression control sequence, such as an origin of replication, promoter and enhancer (Queen et al. Immunol. Rev. 89:49 (1986)), as well as necessary processing information sites, such as a ribosome binding site, RNA splice site, polyadenylation site and transcription terminator sequence. Examples of suitable expression control sequences are promoters derived from white immunoglobulin gene, SV40, adenovirus, bovine papilloma virus, cytomegalovirus and the like. See Co et al. J. Immunol. 148:1149 (1992).

Once synthesized (chemically or recombinantly), the plasminogen of the present invention can be purified according to standard procedures in the art, including ammonium sulfate precipitation, affinity column, column chromatography, high performance liquid chromatography (HPLC), gel electrophoresis and the like. The plasminogen is substantially pure, e.g., at least about 80% to 85% pure, at least about 85% to 90% pure, at least about 90% to 95% pure, or 98% to 99% pure or purer, for example free of contaminants such as cell debris, macromolecules other than the subject antibody and the like.

Pharmaceutical formulations

A therapeutic formulation can be prepared by mixing plasminogen of a desired purity with an optional pharmaceutical carrier, excipient or stabilizer (Remington's Pharmaceutical Sciences, 16th edition, Osol, A. ed. (1980)) to form

a lyophilized preparation or an aqueous solution. Acceptable carriers, excipients and stabilizers are non-toxic to the recipient at the dosages and concentrations employed, and include buffers, such as phosphates, citrates and other organic acids; antioxidants, including ascorbic acid and methionine; preservatives (e.g., octadecyl dimethyl benzyl ammonium chloride; hexane chloride diamine; benzalkonium chloride and benzethonium chloride; phenol, butanol or benzyl alcohol; alkyl p-hydroxybenzoates, such as methyl or propyl p-hydroxybenzoate; catechol; resorcinol; cyclohexanol; 3-pentanol; and m-cresol); low molecular weight polypeptides (less than about 10 residues); proteins, such as serum albumin, gelatin or immunoglobulins; hydrophilic polymers, such as polyvinylpyrrolidone; amino acids, such as glycine, glutamine, asparagine, histidine, arginine or lysine; monosaccharides, disaccharides and other carbohydrates, including glucose, mannose or dextrins; chelating agents, such as EDTA; sugars, such as sucrose, mannitol, fucose or sorbitol; salt-forming counterions, such as sodium; metal complexes (e.g., zinc-protein complexes); and/or non-ionic surfactants, such as TWEENTM, PLURONICSTM or polyethylene glycol (PEG). Preferred lyophilized anti-VEGF antibody formulations are described in WO 97/04801, which is incorporated herein by reference.

The formulations of the invention may also comprise one or more active compounds required for the particular condition to be treated, preferably those that are complementary in activity and have no side effects with one another, for example anti-hypertensive drugs, anti-arrhythmic drugs, drugs for treating diabetes mellitus, and the like.

The plasminogen of the present invention may be encapsulated in microcapsules prepared by techniques such as coacervation or interfacial polymerization, for example, it may be incorporated in a colloid drug delivery system (e.g., liposomes, albumin microspheres, microemulsions, nanoparticles and nanocapsules), or incorporated in hydroxymethylcellulose or gel-microcapsules and poly-(methyl methacrylate) microcapsules in macroemulsions.

These techniques are disclosed in Remington's Pharmaceutical Sciences, 16th edition, Osol, A. Ed. (1980).

The plasminogen of the present invention for *in vivo* administration must be sterile. This can be easily achieved by filtration through a sterile filtration membrane before or after freeze drying and reconstitution.

The plasminogen of the present invention can be prepared into a sustained-release preparation. Suitable examples of sustained-release preparations include solid hydrophobic polymer semi-permeable matrices having a shape and containing glycoproteins, such as films or microcapsules. Examples of sustained-release matrices include polyesters, hydrogels (e.g., poly(2-hydroxyethyl-methacrylate)) (Langer et al. J. Biomed. Mater. Res., 15: 167-277 (1981); and Langer, Chem. Tech., 12:98-105 (1982)), or poly(vinyl alcohol), polylactides (US Patent 3773919, and EP 58,481), copolymer of L-glutamic acid and □ ethyl-L-glutamic acid (Sidman et al. Biopolymers 22:547(1983)), nondegradable ethylene-vinyl acetate (Langer et al. *supra*), or degradable lactic acid-glycolic acid copolymers such as Lupron DepotTM (injectable microspheres composed of lactic acid-glycolic acid copolymer and leuprolide acetate), and poly D-(-)-3-hydroxybutyric acid. Polymers, such as ethylene-vinyl acetate and lactic acid-glycolic acid, are able to persistently release molecules for 100 days or longer, while some hydrogels release proteins for a shorter period of time. A rational strategy for protein stabilization can be designed based on relevant mechanisms. For example, if the aggregation mechanism is discovered to be formation of an intermolecular S-S bond through thio-disulfide interchange, stability is achieved by modifying sulfhydryl residues, lyophilizing from acidic solutions, controlling moisture content, using appropriate additives, and developing specific polymer matrix compositions.

Administration and dosage

The pharmaceutical composition of the present invention is administered in different ways, for example by intravenous, intraperitoneal, subcutaneous,

intracranial, intrathecal, intraarterial (e.g., via carotid), and intramuscular administration.

Preparations for parenteral administration include sterile aqueous or non-aqueous solutions, suspensions and emulsions. Examples of non-aqueous solvents are propylene glycol, polyethylene glycol, vegetable oils such as olive oil, and injectable organic esters such as ethyl oleate. Aqueous carriers include water, and alcoholic/aqueous solutions, emulsions or suspensions, including saline and buffered media. Parenteral vehicles include sodium chloride solution, Ringer's dextrose, dextrose and sodium chloride, or fixed oils. Intravenous vehicles include liquid and nutrient supplements, electrolyte supplements and the like. Preservatives and other additives may also be present, for example, such as antimicrobial agents, antioxidants, chelating agents and inert gases.

The medical staff will determine the dosage regimen based on various clinical factors. As is well known in the medical field, the dosage of any patient depends on a variety of factors, including the patient's size, body surface area, age, the specific compound to be administered, sex, frequency and route of administration, overall health and other drugs administered simultaneously. The dosage range of the pharmaceutical composition comprising plasminogen of the present invention may be, for example, such as about 0.0001 to 2000 mg/kg, or about 0.001 to 500 mg/kg (such as 0.02 mg/kg, 0.25 mg/kg, 0.5 mg/kg, 0.75 mg/kg, 10 mg/kg and 50 mg/kg) of the subject's body weight daily. For example, the dosage may be 1 mg/kg body weight or 50 mg/kg body weight, or in the range of 1 mg/kg-50 mg/kg, or at least 1 mg/kg. Dosages above or below this exemplary range are also contemplated, especially considering the above factors. The intermediate dosages in the above range are also included in the scope of the present invention. A subject may be administered with such dosages daily, every other day, weekly or based on any other schedule determined by empirical analysis. An exemplary dosage schedule includes 1-10 mg/kg for consecutive days. During administration of the drug of the present invention, the therapeutic effect and safety are required to be assessed real-timely.

Articles of manufacture or kits

One embodiment of the present invention relates to an article of manufacture or a kit comprising plasminogen of the present invention or plasmin useful in the treatment of angiocardiopathy and its related conditions caused by diabetes mellitus. The article preferably includes a container, label or package insert. Suitable containers include bottles, vials, syringes and the like. The container can be made of various materials, such as glass or plastic. The container contains a composition that is effective to treat the disease or condition of the present invention and has a sterile access (for example, the container may be an intravenous solution bag or vial containing a plug that can be pierced by a hypodermic injection needle). At least one active agent in the composition is plasminogen/plasmin. The label on or attached to the container indicates that the composition is used to treat the angiocardiopathy and its related conditions caused by diabetes mellitus according to the present invention. The article may further comprise a second container containing a pharmaceutically acceptable buffer, such as phosphate buffered saline, Ringer's solution and glucose solution. It may further comprise other substances required from a commercial and user perspective, including other buffers, diluents, filters, needles and syringes. In addition, the article comprises a package insert with instructions for use, including, for example, instructions to direct a user of the composition to administer to a patient the plasminogen composition and other drugs for treating an accompanying disease.

Brief Description of the Drawings

Figure 1 shows detection results of the content of troponin in serum after administration of plasminogen to 24- to 25-week-old diabetic mice for 31 days. The results showed that the concentration of cardiac troponin I in the group administered with plasminogen was remarkably lower than that in the control group administered with vehicle PBS, and the statistical difference was extremely significant (** indicates $P<0.01$). It indicates that plasminogen can remarkably promote the repair of myocardial injury in mice with late-stage diabetes mellitus.

Figure 2 shows statistical results of cardiac organ coefficient after administration of plasminogen to ApoE atherosclerosis model mice for 30 days. The results showed that the cardiac organ coefficient of mice in the group administered with plasminogen was remarkably lower than that in the control group administered with vehicle PBS. It indicates that plasminogen can ameliorate the compensatory cardiac hypertrophy caused by cardiac injury in ApoE atherosclerosis model mice.

Figure 3 shows a representative image of oil red O staining of aortic sinus after administration of plasminogen to ApoE atherosclerosis model mice for 30 days. A represents the control group administered with vehicle PBS, and B represents the group administered with plasminogen. The results showed that the fat deposition (indicated by arrow) in aortic sinus of mice in the group administered with plasminogen was remarkably less than that in the control group administered with vehicle PBS. It indicates that plasminogen can ameliorate fat deposition in aortic sinus.

Figure 4 shows a representative image of HE staining of aortic valve after administration of plasminogen to ApoE atherosclerosis model mice for 30 days. A and C refer to the control group administered with vehicle PBS, and B and D refer to the group administered with plasminogen. The results showed that the plaque deposition (indicated by arrow) in aortic valve of mice in the group administered with plasminogen was remarkably less than that in the control group administered with vehicle PBS, and the degree of aortic valve fusion in the former group was less than that in the latter group. It indicates that plasminogen can ameliorate aortic valve injury in atherosclerosis model mice.

Figure 5 shows a representative image of IgM immunostaining of heart after administration of plasminogen to ApoE atherosclerosis model mice for 30 days. A represents the control group administered with vehicle PBS, and B represents the group administered with plasminogen. The results showed that the positive expression of IgM (indicated by arrow) in the heart of mice in the group administered with plasminogen was remarkably less than that in the control group

administered with vehicle PBS, indicating that plasminogen can promote the repair of cardiac injury caused by atherosclerosis.

Figure 6 shows a representative image of Sirius red staining of aortic sinus after administration of plasminogen to ApoE atherosclerosis model mice for 30 days. A and C refer to the control group administered with vehicle PBS, and B and D refer to the group administered with plasminogen. The results showed that the area of collagen deposition (indicated by arrow) on the inner walls of blood vessels of aortic sinus in the group administered with plasminogen was remarkably less than that in the control group administered with vehicle PBS, indicating that plasminogen can alleviate the fibrosis level of aortic sinus of arteriosclerosis model mice.

Figure 7 shows calculation results of cardiac risk index after administration of plasminogen to 3% cholesterol hyperlipemia model mice for 20 days. The results showed that CRI in the group administered with plasminogen was remarkably lower than that in the control group administered with vehicle PBS, and the statistical difference was extremely significant. It indicates that plasminogen can effectively lower the risk of heart disease in hyperlipemia model mice.

Figure 8 shows observed results of oil red O staining of aortic sinus after administration of plasminogen to 16-week hyperlipemia model mice for 30 days. A and C represent the control group administered with vehicle PBS, B and D represent the group administered with plasminogen, and E represents the quantitative analysis results. The results showed that the fat deposition in aortic sinus of mice in the group administered with plasminogen was remarkably lower than that in the control group administered with vehicle PBS, and the statistical difference was significant (* indicates $P<0.05$). It indicates that plasminogen can ameliorate fat deposition in aortic sinus of hyperlipemia model mice.

Figure 9 shows a representative image of HE staining of aortic sinus after administration of plasminogen to 16-week hyperlipemia model mice for 30 days. A and C refer to the control group administered with vehicle PBS, and B and D refer to the group administered with plasminogen. The results showed that the

foam cell deposition (indicated by arrow) and the plaque deposition on the aortic wall in the control group administered with vehicle PBS were severe; while in the group administered with plasminogen, only a mild foam cell deposition was observed on the aortic wall, no obvious atherosclerotic plaque deposition was observed under the intima, and the aortic injury in the group administered with plasminogen was relatively minor. It indicates that plasminogen can ameliorate the wall injury caused by lipid deposition on the arterial sinus wall of hyperlipemia model mice.

Figure 10 shows an image of immunohistochemical staining of cardiac fibrin after administration of plasminogen to 16-week hyperlipemia model mice for 30 days. A represents the control group administered with vehicle PBS, B represents the group administered with plasminogen, and C represents the quantitative analysis results. The results showed that the positive expression of cardiac fibrin in mice in the group administered with plasminogen was remarkably lower than that in the control group administered with vehicle PBS, and the statistical difference was significant (* indicates $P<0.05$). It indicates that plasminogen can reduce the cardiac injury caused by hyperlipemia.

Figure 11 shows a representative image of IgM immunostaining of heart after administration of plasminogen to 16-week hyperlipemia model mice for 30 days. A represents the control group administered with vehicle PBS, and B represents the group administered with plasminogen. The results showed that the positive expression of IgM in the heart of mice in the group administered with plasminogen was remarkably less than that in the control group administered with vehicle PBS, indicating that plasminogen can alleviate the cardiac injury caused by hyperlipemia.

Figure 12 shows a representative image of Sirius red staining of heart after administration of plasminogen to 16-week hyperlipemia model mice for 30 days. A represents the control group administered with vehicle PBS, and B represents the group administered with plasminogen. The results showed that the collagen deposition in the group administered with plasminogen was remarkably less than

that in the control group administered with vehicle PBS, indicating that plasminogen can alleviate the cardiac fibrosis in hyperlipemia model mice.

Figure 13 shows detection results of serum troponin after administration of plasminogen to 16-week hyperlipemia model mice for 30 days. The results showed that the concentration of cardiac troponin in serum in the control group administered with vehicle PBS was remarkably higher than that in the group administered with plasminogen, and the statistical difference was significant (* indicates $P<0.05$). It indicates that plasminogen can repair the damage to hyperlipidemic heart.

Figure 14 shows a representative image of oil red O staining of ventricle after administration of plasminogen to 26-week-old diabetic mice for 35 days. A represents the control group administered with vehicle PBS, and B represents the group administered with plasminogen. The results showed that the lipid deposition in ventricle (indicated by arrow) of mice in the group administered with plasminogen was remarkably less than that in the control group administered with vehicle PBS. It indicates that plasminogen can reduce lipid deposition in ventricle of diabetic mice, and promote the repair of ventricular injury.

Figure 15 shows a representative image of Sirius red staining of aortic sinus after administration of plasminogen to 16-week-old hyperlipemia model mice for 30 days. A and C refer to the control group administered with vehicle PBS, and B and D refer to the group administered with plasminogen. The results showed that the area of collagen deposition (indicated by arrow) on the inner walls of blood vessels of aortic sinus in the group administered with plasminogen was remarkably less than that in the control group administered with vehicle PBS, indicating that plasminogen can alleviate the level of aortic sinus fibrosis in hyperlipemia model mice.

Figure 16 shows a representative image of Sirius red staining of heart after administration of plasminogen to bleomycin-induced systemic sclerosis model mice for 21 days. A represents the control group administered with vehicle PBS, and B represents the group administered with plasminogen. Studies have found that in the bleomycin-induced systemic sclerosis mouse model, the degree of

collagen deposition (indicated by arrow) in heart in the control group administered with vehicle PBS was higher than that in the group administered with plasminogen. It indicates that plasminogen can effectively reduce bleomycin-induced cardiac fibrosis.

Figure 17 shows observed results of masson staining of heart after administration of plasminogen to 24- to 25-week-old diabetic mice for 31 days. A represents the control group administered with vehicle PBS, and B represents the group administered with plasminogen. The results showed that in the control group administered with vehicle PBS, blue hyperplastic collagen fibers (indicated by arrow) could be seen between myocardial fibers, showing mild myocardial fibrosis; while in the group administered with plasminogen, a few light blue hyperplastic collagen fibers could be seen between myocardial fibers, and the myocardial fibrosis was remarkably alleviated compared with the control group. It indicates that plasminogen can ameliorate cardiac fibrosis in diabetic mice.

Figure 18 shows a representative image of Sirius red staining of heart after administration of plasminogen to 17- to 18-week-old diabetic mice for 35 days. A represents the control group administered with vehicle PBS, and B represents the group administered with plasminogen. The results showed that the deposition of collagen fibers (indicated by arrow) in mice in the group administered with plasminogen was remarkably less than that in the control group administered with vehicle PBS. It indicates that plasminogen can reduce cardiac fibrosis in diabetic mice.

Figure 19 shows a representative image of Sirius red staining of heart after administration of plasminogen to 26- to 27-week-old diabetic mice for 35 days. A represents the control group administered with vehicle PBS, and B represents the group administered with plasminogen. The results showed that the collagen deposition (indicated by arrow) in mice in the group administered with plasminogen was remarkably less than that in the control group administered with vehicle PBS. It indicates that plasminogen can attenuate cardiac fibrosis in diabetic mice.

Figure 20 shows observed results of oil red O staining of ventricle after administration of plasminogen to ApoE atherosclerosis model mice for 30 days. A represents the control group administered with vehicle PBS, B represents the group administered with plasminogen, and C represents the quantitative analysis results. The results showed that the lipid deposition (indicated by arrow) in ventricle of mice in the group administered with plasminogen was remarkably less than that in the control group administered with vehicle PBS, and the statistical difference was significant (* indicates $P<0.05$). It indicates that plasminogen can reduce lipid deposition in ventricle of atherosclerosis model mice, and promote the repair of ventricular injury caused by lipid deposition.

Figure 21 shows a representative image of Sirius red staining of heart after administration of plasminogen to ApoE atherosclerosis model mice for 30 days. A represents the control group administered with vehicle PBS, and B represents the group administered with plasminogen. The results showed that the collagen deposition (indicated by arrow) in the group administered with plasminogen was remarkably less than that in the control group administered with vehicle PBS, indicating that plasminogen can alleviate cardiac fibrosis in ApoE atherosclerosis model mice.

Examples:

Example 1. Protective effect of plasminogen on the myocardial injury in diabetic mice

Diabetes mellitus is usually complicated with cardiovascular atherosclerosis [1,2]. Cardiovascular atherosclerosis can lead to ischemic injury of cardiac myocytes. Cardiac troponin I (CTNI) is an important marker of myocardial injury, and its serum concentration can reflect the extent of myocardial injury [3]. In this experiment, the repair effect of plasminogen on myocardial injury was observed by detecting cardiac troponin I.

Twenty-eight 24- to 25-week-old male db/db mice were randomly divided into two groups, 12 mice in the control group administered with vehicle PBS, and 16 mice in the group administered with plasminogen. The mice were weighed

and grouped on the day when the experiment began, i.e., Day 0. Plasminogen or PBS was administered from the next day after grouping, i.e., Day 1, for 31 consecutive days. Mice in the group administered with plasminogen were injected with plasminogen at a dose of 2 mg/0.2 mL/mouse/day via the tail vein, and an equal volume of PBS was administered to mice in the control group administered with vehicle PBS via the tail vein. On day 32, blood was taken from the removed eyeballs and centrifuged at 3500 r/min for 15-20 minutes, and the supernatant was used for detection for determining cardiac troponin I concentration. The results showed that the concentration of cardiac troponin I in the group administered with plasminogen was remarkably lower than that in the control group administered with vehicle PBS, and the statistical difference was extremely significant (Figure 1). It indicates that plasminogen can remarkably promote the repair of myocardial injury in diabetic mice.

Example 2. Plasminogen ameliorates compensatory cardiac hypertrophy in ApoE atherosclerosis mice

Thirteen 6-week-old male ApoE mice were fed with a high-fat and high-cholesterol diet (Nantong TROPHIC, TP2031) for 16 weeks to induce the atherosclerosis model [4,5]. 50 μL of blood was taken from each model mouse three days before administration, and the total cholesterol (T-CHO) content was detected. The mice were randomly divided into two groups based on the T-CHO content, 7 mice in the control group administered with vehicle PBS, and 6 mice in the group administered with plasminogen. The first day of administration was set as Day 1. Mice in the group administered with plasminogen were injected with human plasminogen at a dose of 1 mg/0.1 mL/mouse/day via the tail vein, and an equal volume of PBS was administered to mice in the control group administered with vehicle PBS via the tail vein. The administration lasted for 30 days. During the administration, mice continued to be fed with a high-fat and high-cholesterol diet. After weighed on Day 31 of administration, the mice were sacrificed, their hearts were weighed, and cardiac coefficients were calculated. Cardiac coefficient (%) = heart weight/body weight × 100.

The results showed that the cardiac coefficient of mice in the group administered with plasminogen was remarkably lower than that in the control group administered with vehicle PBS (Figure 2). It indicates that plasminogen can alleviate the compensatory cardiac hypertrophy caused by cardiac injury in ApoE atherosclerosis model mice.

Example 3. Plasminogen ameliorates lipid deposition in aortic sinus of ApoE atherosclerosis mice

Thirteen 6-week-old male ApoE mice were fed with a high-fat and high-cholesterol diet (Nantong TROPHIC, TP2031) for 16 weeks to induce the atherosclerosis model [4,5]. 50 μL of blood was taken from each model mouse three days before administration, and the total cholesterol (T-CHO) content was detected. The mice were randomly divided into two groups based on the T-CHO content, 7 mice in the control group administered with vehicle PBS, and 6 mice in the group administered with plasminogen. The first day of administration was set as Day 1. Mice in the group administered with plasminogen were injected with human plasminogen at a dose of 1 mg/0.1 mL/mouse/day via the tail vein, and an equal volume of PBS was administered to mice in the control group administered with vehicle PBS via the tail vein. The mice were administered for 30 days and sacrificed on Day 31. The hearts were fixed in 4% paraformaldehyde for 24 to 48 hours, then sedimented in 15% and 30% sucrose at 4°C overnight, respectively, and embedded in OCT. The frozen sections were 8 μm thick, stained with oil red O for 15 min, differentiated with 75% ethanol for 5 s, followed by nuclear staining with hematoxylin for 30 s, and sealing with glycerine and gelatin. The sections were observed under an optical microscope at 200×.

The results showed that the fat deposition (indicated by arrow) in aortic sinus of mice in the group administered with plasminogen (Figure 3B) was remarkably less than that in the control group administered with vehicle PBS (Figure 3A). It indicates that plasminogen can ameliorate fat deposition in aortic sinus in atherosclerosis.

Example 4. Plasminogen ameliorates aortic sinus injury in ApoE atherosclerosis mice

Thirteen 6-week-old male ApoE mice were fed with a high-fat and high-cholesterol diet (Nantong TROPHIC, TP2031) for 16 weeks to induce the atherosclerosis model [4,5]. 50 μL of blood was taken from each model mouse three days before administration, and the total cholesterol (T-CHO) content was detected. The mice were randomly divided into two groups based on the T-CHO content, 7 mice in the control group administered with vehicle PBS, and 6 mice in the group administered with plasminogen. The first day of administration was set as Day 1. Mice in the group administered with plasminogen were injected with human plasminogen at a dose of 1 mg/0.1 mL/mouse/day via the tail vein, and an equal volume of PBS was administered to mice in the control group administered with vehicle PBS via the tail vein. The administration lasted for 30 days. During the administration, mice continued to be fed with a high-fat and high-cholesterol diet. The mice were sacrificed on Day 31. The hearts were fixed in 4% paraformaldehyde for 24 to 48 hours. The fixed tissue samples were paraffin-embedded after dehydration with alcohol gradient and permeabilization with xylene. The aortic sinus tissue sections were 3 μm thick. The sections were dewaxed and rehydrated, stained with hematoxylin and eosin (HE staining), differentiated with 1% hydrochloric acid in alcohol, and returned to blue with ammonia water. The sections were sealed after dehydration with alcohol gradient, and observed under an optical microscope at 40× (Figures 4A and 4B) and 200× (Figures 4C and 4D), respectively.

The staining results showed that the lipid plaque deposition (indicated by arrow) in aortic sinus of mice in the group administered with plasminogen (Figures 4B and 4D) was remarkably less than that in the control group administered with vehicle PBS (Figures 4A and 4C), and the degree of aortic valve fusion in the former group was less than that in the latter group. It indicates that plasminogen can ameliorate aortic valve injury in atherosclerosis.

Example 5. Plasminogen ameliorates cardiac injury in ApoE atherosclerosis mice

Thirteen 6-week-old male ApoE mice were fed with a high-fat and high-cholesterol diet (Nantong TROPHIC, TP2031) for 16 weeks to induce the atherosclerosis model [4,5]. 50 μL of blood was taken from each model mouse three days before administration, and the total cholesterol (T-CHO) content was detected. The mice were randomly divided into two groups based on the T-CHO content, 7 mice in the control group administered with vehicle PBS, and 6 mice in the group administered with plasminogen. The first day of administration was set as Day 1. Mice in the group administered with plasminogen were injected with human plasminogen at a dose of 1 mg/0.1 mL/mouse/day via the tail vein, and an equal volume of PBS was administered to mice in the control group administered with vehicle PBS via the tail vein. The administration lasted for 30 days. During the administration, mice continued to be fed with a high-fat and high-cholesterol diet. The mice were sacrificed on Day 31. The hearts were fixed in 4% paraformaldehyde for 24 to 48 hours. The fixed tissues were paraffin-embedded after dehydration with alcohol gradient and permeabilization with xylene. The thickness of the tissue sections was 3 μm. The sections were dewaxed and rehydrated and washed with water once. The tissues were circled with a PAP pen, incubated with 3% hydrogen peroxide for 15 minutes, and washed with 0.01M PBS twice for 5 minutes each time. The sections were blocked with 5% normal goat serum (Vector laboratories, Inc., USA) for 30 minutes, and after the time was up, the goat serum liquid was discarded. Goat anti-mouse IgM (HRP) antibody (Abcam) was added to the sections dropwise, incubated for 1 hour at room temperature and washed with 0.01M PBS twice for 5 minutes each time. The sections were developed with a DAB kit (Vector laboratories, Inc., USA). After washed with water, the sections were counterstained with hematoxylin for 30 seconds and flushed with running water for 5 minutes. After dehydration with alcohol gradient, permeabilization with xylenehe, and sealing with a neutral gum, the sections were observed under an optical microscope at 200×. IgM antibodies play an important role during the clearance of apoptotic and necrotic cells, and the local level of IgM antibodies at the injury site in tissues and organs are positively correlated with the degree of

injury [6,7]. Therefore, detection of local level of IgM antibodies in tissues and organs can reflect the injury of the tissues and organs. The experiment showed that the positive expression of IgM in the heart of mice in the group administered with plasminogen (Figure 5B) was remarkably less than that in the control group administered with vehicle PBS (Figure 5A). It indicates that plasminogen can remarkably ameliorate myocardial injury in ApoE mice.

Example 6. Plasminogen lowers the level of cardiac fibrosis in ApoE atherosclerosis mice

Thirteen 6-week-old male ApoE mice were fed with a high-fat and high-cholesterol diet (Nantong TROPHIC, TP2031) for 16 weeks to induce the atherosclerosis model [4,5]. 50 μL of blood was taken from each model mouse three days before administration, and the total cholesterol (T-CHO) content was detected. The mice were randomly divided into two groups based on the T-CHO content, 7 mice in the control group administered with vehicle PBS, and 6 mice in the group administered with plasminogen. The first day of administration was set as Day 1. Mice in the group administered with plasminogen were injected with human plasminogen at a dose of 1 mg/0.1 mL/mouse/day via the tail vein, and an equal volume of PBS was administered to mice in the control group administered with vehicle PBS via the tail vein. The administration lasted for 30 days. During the administration, mice continued to be fed with a high-fat and high-cholesterol diet. The mice were sacrificed on Day 31. The hearts were fixed in 4% paraformaldehyde for 24 to 48 hours. The fixed tissues were paraffin-embedded after dehydration with alcohol gradient and permeabilization with xylene. The tissue sections was 3 μm thick. The sections were dewaxed and rehydrated and washed with water once. After stained with 0.1% Sirius red in saturated picric acid for 30 min, the sections were flushed with running water for 2 min. After stained with hematoxylin for 1 min, the sections were flushed with running water, differentiated with 1% hydrochloric acid in alcohol, returned to blue with ammonia water, flushed with running water, dried and sealed with a neutral gum. The sections were observed under an optical microscope at 200×.

Sirius red staining allows for long-lasting staining of collagen, and is a special staining method for collagen tissue in pathological sections to show collagen tissue specifically.

The staining results showed that the collagen deposition (indicated by arrow) in the atherosclerotic portion of the cardiac artery sinus in the group administered with plasminogen (Figure 6B) was remarkably less than that in the control group administered with vehicle PBS (Figure 6A), indicating that plasminogen can lower collagen deposition in cardiac tissue and reduce cardiac fibrosis in ApoE atherosclerosis model mice.

Example 7. Plasminogen lowers risk of onset of heart disease in 3% cholesterol hyperlipemia model mice

Sixteen 9-week-old male C57 mice were fed with a 3% cholesterol high-fat diet (Nantong TROPHIC) for 4 weeks to induce hyperlipemia [8,9]. This model was designated as the 3% cholesterol hyperlipemia model. The model mice continued to be fed with a 3% cholesterol high-fat diet. 50 μL of blood was taken from each mouse three days before administration, and the total cholesterol (T-CHO) was detected. The mice were randomly divided into two groups based on the total cholesterol concentration, 8 mice in each group. The first day of administration was recorded as Day 1. Mice in the group administered with plasminogen were injected with human plasminogen at a dose of 1 mg/0.1 mL/mouse/day via the tail vein, and an equal volume of PBS was administered to mice in the control group administered with vehicle PBS via the tail vein. After administration on Day 20, the mice began to fast for 16 hours, and on Day 21, 50 μL of blood was collected from orbital venous plexus, and centrifuged to obtain a supernatant. The total cholesterol content was detected by using a total cholesterol detection kit (Nanjing Jiancheng Bioengineering Institute, Cat# A111-1); and the high-density lipoprotein cholesterol (HDL-C) content was detected using a high-density lipoprotein cholesterol detection kit (Nanjing Jiancheng Bioengineering Institute, Cat# A112-1).

Cardiac risk index (CRI) is used to assess the risk of heart disease induced by dyslipidemia[10].

Cardiac risk index = T-CHO/HDL-C.

The results showed that CRI in the group administered with plasminogen was remarkably lower than that in the control group administered with vehicle PBS, and the statistical difference was extremely significant (Figure 7). It indicates that plasminogen can effectively lower the risk of heart disease in hyperlipemia model mice.

Example 8. Plasminogen reduces lipid deposition in aortic sinus of 16-week hyperlipemia model mice

Eleven 6-week-old male C57 mice were fed with a high-fat and high-cholesterol diet (Nantong TROPHIC, TP2031) for 16 weeks to induce the hyperlipemia model [8,9]. This model was designated as the 16-week hyperlipemia model. The model mice continued to be fed with a high-cholesterol diet. 50 μL of blood was taken from each mouse three days before administration, and the total cholesterol (T-CHO) content was detected. The mice were randomly divided into two groups based on the T-CHO content, 6 mice in the control group administered with vehicle PBS, and 5 mice in the group administered with plasminogen. The first day of administration was recorded as Day 1. Mice in the group administered with plasminogen were injected with human plasminogen at a dose of 1 mg/0.1 mL/mouse/day via the tail vein, and an equal volume of PBS was administered to mice in the control group administered with vehicle PBS via the tail vein. The mice were administered for 30 days and sacrificed on Day 31. The heart tissues were fixed in 4% paraformaldehyde for 24 to 48 hours, then sedimented in 15% and 30% sucrose at 4°C overnight, respectively, and embedded in OCT. The frozen sections of aortic sinus were 8 μm thick, stained with oil red O for 15 min, differentiated with 75% ethanol for 5 s, followed by nuclear staining with hematoxylin for 30 s, and sealing with glycerine and gelatin. The sections were observed under an optical microscope at 40× (Figures 8A and 8B) and 200× (Figures 8C and 8D).

The results showed that the fat deposition in aortic sinus of mice in the group administered with plasminogen (Figures 8B and 8D) was remarkably lower than that in the control group administered with vehicle PBS (Figures 8A and 8C),

and the statistical difference was significant (Figure 8E). It indicates that plasminogen can reduce lipid deposition in aortic sinus of hyperlipemia model mice.

Example 9. Plasminogen improves aortic sinus injury in 16-week hyperlipemia model mice

Eleven 6-week-old male C57 mice were fed with a high-fat and high-cholesterol diet (Nantong TROPHIC, TP2031) for 16 weeks to induce the hyperlipemia model [8,9]. This model was designated as the 16-week hyperlipemia model. The model mice continued to be fed with a high-cholesterol diet. 50 μL of blood was taken from each mouse three days before administration, and the total cholesterol (T-CHO) content was detected. The mice were randomly divided into two groups based on the T-CHO content, 6 mice in the control group administered with vehicle PBS, and 5 mice in the group administered with plasminogen. The first day of administration was recorded as Day 1. Mice in the group administered with plasminogen were injected with human plasminogen at a dose of 1 mg/0.1 mL/mouse/day via the tail vein, and an equal volume of PBS was administered to mice in the control group administered with vehicle PBS via the tail vein. The mice were administered for 30 days and sacrificed on Day 31. The heart tissues were fixed in 4% paraformaldehyde for 24 to 48 hours. The fixed tissues were paraffin-embedded after dehydration with alcohol gradient and permeabilization with xylene. The fixed tissue samples were paraffin-embedded after dehydration with alcohol gradient and permeabilization with xylene. The aortic sinus tissue sections were 3 μm thick. The sections were dewaxed and rehydrated, stained with hematoxylin and eosin (HE staining), differentiated with 1% hydrochloric acid in alcohol, and returned to blue with ammonia water. The sections were sealed after dehydration with alcohol gradient, and observed under an optical microscope at 40× (Figures 9A and B) and 200× (Figures 9C and D).

The results showed that the foam cell deposition (indicated by arrow) and the plaque deposition on the inner wall of aortic sinus in the control group administered with vehicle PBS (Figures 9A and C) were severe; while in the group administered with plasminogen (Figures 9B and D), only a mild foam cell

deposition was observed on the inner wall of aortic sinus, no obvious atherosclerotic plaque deposition was observed under the intima, and the injury to the inner wall of aorta in the group administered with plasminogen was relatively minor. It indicates that plasminogen can ameliorate the damage to the inner wall of arterial sinus of hyperlipemia model mice.

Example 10. Plasminogen reduces expression of cardiac fibrin in 16-week hyperlipemia model mice

Eleven 6-week-old male C57 mice were fed with a high-fat and high-cholesterol diet (Nantong TROPHIC, TP2031) for 16 weeks to induce the hyperlipemia model [8,9]. This model was designated as the 16-week hyperlipemia model. The model mice continued to be fed with a high-cholesterol diet. 50 μL of blood was taken from each mouse three days before administration, and the total cholesterol (T-CHO) content was detected. The mice were randomly divided into two groups based on the T-CHO content, 6 mice in the control group administered with vehicle PBS, and 5 mice in the group administered with plasminogen. The first day of administration was recorded as Day 1. Mice in the group administered with plasminogen were injected with human plasminogen at a dose of 1 mg/0.1 mL/mouse/day via the tail vein, and an equal volume of PBS was administered to mice in the control group administered with vehicle PBS via the tail vein. The mice were administered for 30 days and sacrificed on Day 31. The heart tissues were fixed in 4% paraformaldehyde for 24 to 48 hours. The fixed tissues were paraffin-embedded after dehydration with alcohol gradient and permeabilization with xylene. The thickness of the tissue sections was 3 μm. The sections were dewaxed and rehydrated and washed with water once. The sections were incubated with 3% hydrogen peroxide for 15 minutes and washed with water twice for 5 minutes each time. The sections were blocked with 5% normal goat serum liquid (Vector laboratories, Inc., USA) for 30 minutes, and after the time was up, the goat serum liquid was discarded, and the tissues were circled with a PAP pen. The sections were incubated with 3% hydrogen peroxide for 15 minutes and washed with water twice for 5 minutes each time. The sections were incubated with rabbit anti-mouse fibrin antibody (Abcam) overnight at 4°C and

washed with 0.01M PBS twice for 5 minutes each time. The sections were incubated with a secondary antibody, goat anti-rabbit IgG (HRP) antibody (Abcam), for 1 hour at room temperature and washed with PBS twice for 5 minutes each time. The sections were developed with a DAB kit (Vector laboratories, Inc., USA). After washed with water three times, the sections were counterstained with hematoxylin for 30 seconds and flushed with running water for 5 minutes. After dehydration with alcohol gradient, permeabilization with xylenehe, and sealing with a neutral gum, the sections were observed under an optical microscope at 200×.

Fibrinogen is the precursor of fibrin, and in the presence of tissue injury, as a stress response to the body's injury, fibrinogen is hydrolyzed into fibrin and deposited at the injury site [11,12]. Therefore, the local fibrin level at the injury site can be used as a sign of the degree of injury.

The immunohistochemical staining results showed that the positive expression of cardiac fibrin in mice in the group administered with plasminogen (Figure 10B) was remarkably less than that in the control group administered with vehicle PBS (Figure 10A), and the statistical difference was significant (Figure 10C), indicating that plasminogen can reduce a myocardial injury caused by hyperlipemia.

Example 11. Plasminogen protects 16-week hyperlipemia model mice from myocardial injury effectively

Eleven 6-week-old male C57 mice were fed with a high-fat and high-cholesterol diet (Nantong TROPHIC, TP2031) for 16 weeks to induce the hyperlipemia model [8,9]. This model was designated as the 16-week hyperlipemia model. The model mice continued to be fed with a high-cholesterol diet. 50 μL of blood was taken from each mouse three days before administration, and the total cholesterol (T-CHO) content was detected. The mice were randomly divided into two groups based on the T-CHO content, 6 mice in the control group administered with vehicle PBS, and 5 mice in the group administered with plasminogen. The first day of administration was recorded as Day 1. Mice in the group administered with plasminogen were injected with human plasminogen at a

dose of 1 mg/0.1 mL/mouse/day via the tail vein, and an equal volume of PBS was administered to mice in the control group administered with vehicle PBS via the tail vein. The mice were administered for 30 days and sacrificed on Day 31. The heart tissues were fixed in 4% paraformaldehyde for 24 to 48 hours. The fixed tissues were paraffin-embedded after dehydration with alcohol gradient and permeabilization with xylene. The thickness of the tissue sections was 3 μm. The sections were dewaxed and rehydrated and washed with water once. The sections were incubated with 3% hydrogen peroxide for 15 minutes and washed with water twice for 5 minutes each time. The sections were blocked with 5% normal goat serum liquid (Vector laboratories, Inc., USA) for 30 minutes, and after the time was up, the goat serum liquid was discarded, and the tissues were circled with a PAP pen. The sections were incubated with 3% hydrogen peroxide for 15 minutes and washed with water twice for 5 minutes each time. The sections were incubated with goat anti-mouse IgM (HRP) antibody (Abcam) for 1 hour at room temperature and washed with PBS twice for 5 minutes each time. The sections were developed with a DAB kit (Vector laboratories, Inc., USA). After washed with water three times, the sections were subjected to nuclear staining with hematoxylin for 30 seconds and flushing with running water for 5 minutes. After dehydration with alcohol gradient, permeabilization with xylenehe, and sealing with a neutral gum, the sections were observed under an optical microscope at 200×.

IgM antibodies play an important role during the clearance of apoptotic and necrotic cells, and the local level of IgM antibodies in damaged tissues and organs is positively correlated with the degree of injury [6,7]. Therefore, detection of local level of IgM antibodies in tissues and organs can reflect the extent of injury of the tissues and organs.

The immunostaining results showed that the positive expression of IgM in the heart of mice in the group administered with plasminogen (Figure 11B) was remarkably less than that in the control group administered with vehicle PBS (Figure 11A), indicating that plasminogen can reduce the cardiac injury in hyperlipemia model animals.

Example 12. Plasminogen reduces cardiac fibrosis in 16-week hyperlipemia model mice

Eleven 6-week-old male C57 mice were fed with a high-fat and high-cholesterol diet (Nantong TROPHIC, TP2031) for 16 weeks to induce the hyperlipemia model [8,9]. This model was designated as the 16-week hyperlipemia model. The model mice continued to be fed with a high-cholesterol diet. 50 μL of blood was taken from each mouse three days before administration, and the total cholesterol (T-CHO) content was detected. The mice were randomly divided into two groups based on the T-CHO content, 6 mice in the control group administered with vehicle PBS, and 5 mice in the group administered with plasminogen. The first day of administration was recorded as Day 1. Mice in the group administered with plasminogen were injected with human plasminogen at a dose of 1 mg/0.1 mL/mouse/day via the tail vein, and an equal volume of PBS was administered to mice in the control group administered with vehicle PBS via the tail vein. The mice were administered for 30 days and sacrificed on Day 31. The heart tissues were fixed in 4% paraformaldehyde for 24 to 48 hours. The fixed tissues were paraffin-embedded after dehydration with alcohol gradient and permeabilization with xylene. The tissue sections was 3 μm thick. The sections were dewaxed and rehydrated and washed with water once. After stained with 0.1% Sirius red in saturated picric acid for 30 min, the sections were flushed with running water for 2 min. After stained with hematoxylin for 1 min, the sections were flushed with running water, differentiated with 1% hydrochloric acid in alcohol, returned to blue with ammonia water, flushed with running water, dried and sealed with a neutral gum. The sections were observed under an optical microscope at 200×.

Sirius red staining allows for long-lasting staining of collagen. As a special staining method for pathological sections, Sirius red staining can show the collagen tissue specifically.

The staining results showed that the deposition of collagen in the group administered with plasminogen (Figure 12B) was remarkably less than that in the control group administered with vehicle PBS (Figure 12A), indicating that

plasminogen can reduce the deposition of collagen in the heart tissues of hyperlipemia model mice and alleviate myocardial fibrosis.

Example 13. Plasminogen repairs myocardial injury in 16-week hyperlipemia model mice

Eleven 6-week-old male C57 mice were fed with a high-fat and high-cholesterol diet (Nantong TROPHIC, TP2031) for 16 weeks to induce the hyperlipemia model [8,9]. This model was designated as the 16-week hyperlipemia model. The model mice continued to be fed with a high-cholesterol diet. 50 μL of blood was taken from each mouse three days before administration, and the total cholesterol (T-CHO) content was detected. The mice were randomly divided into two groups based on the T-CHO content, 6 mice in the control group administered with vehicle PBS, and 5 mice in the group administered with plasminogen. The first day of administration was recorded as Day 1. Mice in the group administered with plasminogen were injected with human plasminogen at a dose of 1 mg/0.1 mL/mouse/day via the tail vein, and an equal volume of PBS was administered to mice in the control group administered with vehicle PBS via the tail vein. The administration lasted for 30 days. After administration on Day 30, the mice began to fast for 16 hours, and on Day 31, the blood was collected from removed eyeballs, and centrifuged to obtain a supernatant, which was detected for the concentration of troponin in serum using cardiac troponin (Cardiac troponin I, CTNI) detection kit (Nanjing Jiancheng).

Cardiac troponin I is an important marker of myocardial injury, and its serum concentration can reflect the extent of myocardial injury [3].

The detection results showed that the concentration of cardiac troponin in serum in the control group administered with vehicle PBS was remarkably higher than that in the group administered with plasminogen, and the statistical difference was significant (Figure 13). It indicates that plasminogen can significantly repair the cardiac injury in hyperlipemia model mice.

Example 14. Plasminogen lowers lipid deposition in ventricle of diabetic mice

Nine 26-week-old male db/db mice were randomly divided into groups, 4 mice in the group administered with plasminogen, and 5 mice in the control group administered with vehicle PBS. Mice in the group administered with plasminogen were injected with human plasminogen at a dose of 2 mg/0.2 mL/mouse/day via the tail vein, and an equal volume of PBS was administered to mice in the control group administered with vehicle PBS via the tail vein, both lasting for 35 days. The mice were sacrificed on Day 36. The hearts were fixed in 4% paraformaldehyde for 24 to 48 hours, then sedimented in 15% and 30% sucrose at 4°C overnight, respectively, and embedded in OCT. The frozen sections were 8 μm thick, stained with oil red O for 15 min, differentiated with 75% ethanol for 5 s, followed by nuclear staining with hematoxylin for 30 s, and sealing with glycerine and gelatin. The sections were observed under an optical microscope at 200×.

The results showed that the lipid deposition (indicated by arrow) in ventricle of mice in the group administered with plasminogen (Figure 14B) was remarkably less than that in the control group administered with vehicle PBS (Figure 14A). It indicates that plasminogen can reduce fat deposition in ventricle of diabetic mice, and promote the repair of ventricular injury.

Example 15. Plasminogen reduces aortic sinus fibrosis in 16-week hyperlipemia model mice

Eleven 6-week-old male C57 mice were fed with a high-fat and high-cholesterol diet (Nantong TROPHIC, TP2031) for 16 weeks to induce the hyperlipemia model [8,9]. This model was designated as the 16-week hyperlipemia model. The model mice continued to be fed with a high-cholesterol diet. 50 μL of blood was taken from each mouse three days before administration, and the total cholesterol (T-CHO) content was detected. The mice were randomly divided into two groups based on the T-CHO content, 6 mice in the control group administered with vehicle PBS, and 5 mice in the group administered with plasminogen. The first day of administration was recorded as Day 1. Mice in the group administered with plasminogen were injected with human plasminogen at a dose of 1 mg/0.1 mL/mouse/day via the tail vein, and an equal volume of PBS

was administered to mice in the control group administered with vehicle PBS via the tail vein. The mice were administered for 30 days and sacrificed on Day 31. The hearts were fixed in 4% paraformaldehyde for 24 to 48 hours. The fixed tissues were paraffin-embedded after dehydration with alcohol gradient and permeabilization with xylene. The aortic sinus sections was 3 μm thick. The sections were dewaxed and rehydrated and washed with water once. After stained with 0.1% Sirius red in saturated picric acid for 30 min, the sections were flushed with running water for 2 min. After stained with hematoxylin for 1 min, the sections were flushed with running water, differentiated with 1% hydrochloric acid in alcohol, returned to blue with ammonia water, flushed with running water, dried and sealed with a neutral gum. The sections were observed under an optical microscope at 40× (Figures 15A and 15B) and 200× (Figures 15C and 15D).

The results showed that the area of collagen deposition (indicated by arrow) on the inner walls of blood vessels of aortic sinus in the group administered with plasminogen (Figures 15B and 15D) was remarkably less than that in the control group administered with vehicle PBS (Figures 15A and 15C), indicating that plasminogen can alleviate the level of aortic sinus fibrosis in hyperlipemia model mice.

Example 16. Plasminogen lowers cardiac fibrosis in systemic sclerosis mice

Ten 12-week-old male C57 mice were randomly divided into two groups, 5 mice in each of the control group administered with vehicle PBS and the group administered with plasminogen. The mice were weighed and grouped on the day when the experiment began, i.e., Day 0. Model establishment and administration began from Day 1, wherein mice were injected with bleomycin subcutaneously at a dose of 0.1 mg/0.1 mL/mouse/day to induce systemic sclerosis [13], and plasminogen or PBS was administered for 21 consecutive days. Mice in the group administered with plasminogen were injected with plasminogen at a dose of 1 mg/0.1 mL/mouse/day via the tail vein, and an equal volume of PBS was administered to mice in the control group administered with vehicle PBS via the tail vein. The mice were sacrificed on Day 22. The hearts were fixed in 4%

paraformaldehyde fixative for 24 hours. The fixed hearts were paraffin-embedded after dehydration with alcohol gradient and permeabilization with xylene. The tissue sections was 3 μm thick. The sections were dewaxed and rehydrated and washed with water once. After stained with 0.1% Sirius red in saturated picric acid for 30 min, the sections were flushed with running water for 2 min. After stained with hematoxylin for 1 min, the sections were flushed with running water, differentiated with 1% hydrochloric acid in alcohol, returned to blue with ammonia water, flushed with running water, dried and sealed with a neutral gum. The sections were observed under an optical microscope at 200×.

Studies have found that in the bleomycin-induced systemic sclerosis mouse model, it was observed under a microscope that the collagen deposition in heart in the control group administered with vehicle PBS (Figure 16A) was higher than that in the group administered with plasminogen (Figure 16B). It indicates that plasminogen can effectively reduce bleomycin-induced cardiac fibrosis.

Example 17. Plasminogen ameliorates cardiac fibrosis in 24- to 25-week-old diabetic mice

Ten 24- to 25-week-old male db/db mice were randomly divided into two groups, five mice in each of a control group administered with vehicle PBS and a group administered with plasminogen. The mice were weighed and grouped on the day when the experiment began, i.e. Day 0. Plasminogen or PBS was administered from day 1 for 31 consecutive days. Mice in the group administered with plasminogen were injected with plasminogen at a dose of 2 mg/0.2 mL/mouse/day via the tail vein, and an equal volume of PBS was administered to mice in the control group administered with vehicle PBS. The mice were sacrificed after administration of plasminogen for 31 days. The heart tissues were fixed in 4% paraformaldehyde fixative for 24 hours. The fixed heart tissues were paraffin-embedded after dehydration with alcohol gradient and permeabilization with xylene. The thickness of the tissue sections was 4 μm. The sections were dewaxed and rehydrated and then put into a potassium dichromate solution overnight. The sections were stained with iron hematocylin for 3 to 5 minutes, and flushed slightly with running water. The sections were differentiated with 1%

hydrochloric acid in alcohol, treated with ammonia water for 1 second, and rinsed with water. The sections were stained in ponceau acid fuchsin fluid for 8 minutes, and rinsed rapidly in water. The sections were treated with 1% phosphomolybdic acid aqueous solution for about 2 minutes, and counterstained with aniline blue solution for 6 minutes. The sections were rinsed with 1% glacial acetic acid for about 1 minute. The sections were sealed after dehydration with absolute ethanol, and permeabilization with xylene, and were observed under an optical microscope at 200×.

The most common complication of diabetes mellitus is excessive accumulation of connective tissues (pathological fibrosis). Myocardial interstitial fibrosis may be the characteristic pathological change of diabetic cardiomyopathy [14,15].

Masson staining can reveal tissue fibrosis. The results showed that in the control group administered with vehicle PBS (Figure 17A), blue hyperplastic collagen fibers (indicated by arrow) could be seen between myocardial fibers, showing mild myocardial fibrosis; while in the group administered with plasminogen (Figure 17B), a few light blue hyperplastic collagen fibers could be seen between myocardial fibers, and the myocardial fibrosis was remarkably alleviated compared with the control group. It indicates that plasminogen can ameliorate cardiac fibrosis in diabetic mice.

Example 18. Plasminogen lowers collagen deposition in heart of 17- to 18-week-old diabetic mice

Eight 17- to 18-week-old male db/dbmicewere randomly divided into two groups, four mice in each of the control group administered with vehicle PBS and the group administered with plasminogen. The mice were weighed and grouped on the day when the experiment began, i.e. Day 0. Plasminogen or PBS was administered from day 1 for 35 consecutive days. Mice in the group administered with plasminogen were injected with plasminogen at a dose of 2 mg/0.2 mL/mouse/day via the tail vein, and an equal volume of PBS was administered to mice in the control group administered with vehicle PBS. The mice were sacrificed after administration of plasminogen for 35 days. The heart tissues were

fixed in 4% paraformaldehyde fixative for 24 hours. The fixed hearts were paraffin-embedded after dehydration with alcohol gradient and permeabilization with xylene. The tissue sections was 3 μm thick. The sections were dewaxed and rehydrated and washed with water once. After stained with 0.1% Sirius red in saturated picric acid for 30 min, the sections were flushed with running water for 2 min. After stained with hematoxylin for 1 min, the sections were flushed with running water, differentiated with 1% hydrochloric acid in alcohol, returned to blue with ammonia water, flushed with running water, dried and sealed with a neutral gum. The sections were observed under an optical microscope at 200×.

The results showed that the deposition of collagen fibers (indicated by arrow) in mice in the group administered with plasminogen (Figure 18B) was remarkably less than that in the control group administered with vehicle PBS (Figure 18A). It indicates that plasminogen can reduce collagen deposition in the heart tissue, and suggests that plasminogen is expected to alleviate heart tissue fibrosis in relatively young (17- to 18-week-old) diabetic mice by lowering collagen deposition in the heart tissue.

Example 19. Plasminogen lowers collagen deposition in heart of 26- to 27-week-old diabetic mice

Nine 26- to 27-week-old male db/db mice were randomly divided into two groups, 5 mice in the control group administered with vehicle PBS, and 4 mice in the group administered with plasminogen. The mice were weighed and grouped on the day when the experiment began, i.e. Day 0. Plasminogen or PBS was administered from day 1 for 35 consecutive days. Mice in the group administered with plasminogen were injected with plasminogen at a dose of 2 mg/0.2 mL/mouse/day via the tail vein, and an equal volume of PBS was administered to mice in the control group administered with vehicle PBS. The mice were sacrificed after administration of plasminogen for 35 days. The heart tissues were fixed in 4% paraformaldehyde fixative for 24 hours. The fixed hearts were paraffin-embedded after dehydration with alcohol gradient and permeabilization with xylene. The tissue sections was 3 μm thick. The sections were dewaxed and rehydrated and washed with water once. After stained with 0.1% Sirius red for 60

min, the sections were flushed with running water. After stained with hematoxylin for 1 min, the sections were flushed with running water, differentiated with 1% hydrochloric acid in alcohol and returned to blue with ammonia water, flushed with running water, dried and sealed. The sections were observed under an optical microscope at 200×.

The results showed that the deposition of collagen fibers (indicated by arrow) in mice in the group administered with plasminogen (Figure 19B) was remarkably less than that in the control group administered with vehicle PBS (Figure 19A). It indicates that plasminogen can reduce collagen deposition in the heart tissue, and suggests that plasminogen is expected to alleviate heart tissue fibrosis in relatively old (26- to 27-week-old) diabetic mice by lowering collagen deposition in the heart tissue.

Example 20. Plasminogen ameliorates lipid deposition in ventricle of ApoE atherosclerosis mice

Thirteen 6-week-old male ApoE mice were fed with a high-fat and high-cholesterol diet (Nantong TROPHIC, TP2031) for 16 weeks to induce the atherosclerosis model [4,5]. 50 μL of blood was taken from each model mouse three days before administration, and the total cholesterol (T-CHO) content was detected. The mice were randomly divided into two groups based on the T-CHO content, 7 mice in the control group administered with vehicle PBS, and 6 mice in the group administered with plasminogen. The first day of administration was set as Day 1. Mice in the group administered with plasminogen were injected with human plasminogen at a dose of 1 mg/0.1 mL/mouse/day via the tail vein, and an equal volume of PBS was administered to mice in the control group administered with vehicle PBS via the tail vein. The mice were administered for 30 days and sacrificed on Day 31. The hearts were fixed in 4% paraformaldehyde for 24 to 48 hours, then sedimented in 15% and 30% sucrose at 4°C overnight, respectively, and embedded in OCT. The frozen ventricle sections were 8 μm thick, stained with oil red O for 15 min, differentiated with 75% ethanol for 5 s, followed by nuclear staining with hematoxylin for 30 s, and sealing with

glycerine and gelatin. The sections were observed under an optical microscope at 200×.

The results showed that the lipid deposition (indicated by arrow) in ventricle of mice in the group administered with plasminogen (Figure 20B) was remarkably less than that in the control group administered with vehicle PBS (Figure 20A), and the statistical difference was significant (Figure 20C). It indicates that plasminogen can reduce lipid deposition in ventricle of atherosclerosis model mice, and promote the repair of ventricular injury caused by lipid deposition.

Example 21. Plasminogen lowers the level of cardiac fibrosis in ApoE atherosclerosis mice

Thirteen 6-week-old male ApoE mice were fed with a high-fat and high-cholesterol diet (Nantong TROPHIC, TP2031) for 16 weeks to induce the atherosclerosis model [4,5]. 50 μL of blood was taken from each model mouse three days before administration, and the total cholesterol (T-CHO) content was detected. The mice were randomly divided into two groups based on the T-CHO content, 7 mice in the control group administered with vehicle PBS, and 6 mice in the group administered with plasminogen. The first day of administration was set as Day 1. Mice in the group administered with plasminogen were injected with human plasminogen at a dose of 1 mg/0.1 mL/mouse/day via the tail vein, and an equal volume of PBS was administered to mice in the control group administered with vehicle PBS via the tail vein. The administration lasted for 30 days. During the administration, mice continued to be fed with a high-fat and high-cholesterol diet. The mice were sacrificed on Day 31. The hearts were fixed in 4% paraformaldehyde for 24 to 48 hours. The fixed tissues were paraffin-embedded after dehydration with alcohol gradient and permeabilization with xylene. The tissue sections was 3 μm thick. The sections were dewaxed and rehydrated and washed with water once. After stained with 0.1% Sirius red in saturated picric acid for 30 min, the sections were flushed with running water for 2 min. After stained with hematoxylin for 1 min, the sections were flushed with running water, differentiated with 1% hydrochloric acid in alcohol, returned to

blue with ammonia water, flushed with running water, dried and sealed with a neutral gum. The sections were observed under an optical microscope at 200×.

Sirius red staining allows for long-lasting staining of collagen, and is a special staining method for collagen tissue in pathological sections to show collagen tissue specifically.

The staining results showed that the collagen deposition (indicated by arrow) in the group administered with plasminogen (Figure 21B) was remarkably less than that in the control group administered with vehicle PBS (Figure 21A), indicating that plasminogen can lower collagen deposition in cardiac tissue and reduce cardiac fibrosis in ApoE atherosclerosis model mice.

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Claims

1. A method for preventing or treating myocardial injury in a subject, comprising administering an effective amount of plasminogen to the subject, wherein the subject has a risk of the myocardial injury, is suspected of having the myocardial injury, or suffers from the myocardial injury.

2. The method of claim 1, wherein the myocardial injury comprises myocardial injury caused by ischemia, an inflammation, an allergic reaction, autoimmunity, a thrombus, microcirculation disturbance, a trauma, a radiation injury, a glucose metabolism disorder, and a fat metabolism disorder.

3. The method of claim 1 or 2, wherein the myocardial injury is myocardial injury caused by a disease selected from a group consisting of: myocarditis, pericarditis, hypertension, atherosclerosis, coronary heart disease, angina pectoris, myocardial infarction, arrhythmia, heart failure, shock, diffuse intravascular coagulation, microcirculation disturbance, diabetes mellitus, hyperlipemia, arterial and venous thrombosis, fat embolism, ischemic reperfusion, systemic sclerosis, systemic lupus erythematosus, coronary artery stenosis, rheumatic heart disease, mitral stenosis/insufficiency, and aortic valve stenosis/insufficiency.

4. The method of claim 1 or 2, wherein the myocardial injury is myocardial injury caused by ischemic heart disease.

5. The method of claim 4, wherein the ischemic heart disease is atherosclerosis, coronary heart disease, angina pectoris, myocardial infarction, arrhythmia, heart failure, shock, diffuse intravascular coagulation, microcirculation disturbance, ischemic reperfusion, coronary artery stenosis, mitral stenosis/insufficiency, and aortic valve stenosis/insufficiency.

6. The method of claim 1 or 2, wherein the myocardial injury is myocardial injury caused by arterial and venous thrombosis, or fat embolism.

7. The method of claim 6, wherein the thrombosis or embolism is caused by atherosclerosis.

8. A method for preventing or treating myocardial injury in a subject, comprising administering an effective amount of plasminogen to the subject to protect a myocardial tissue.

9. The method of claim 8, wherein the plasminogen alleviates myocardial apoptosis caused by myocardial cell injury.

10. The method of claim 8 or 9, wherein the plasminogen promotes repair of an injured myocardium.

11. The method of any one of claims 8 to 10, wherein the plasminogen alleviates fibrosis of the injured myocardium.

12. The method of any one of claims 8 to 11, wherein the plasminogen promotes recovery of myocardial function.

13. The method of any one of claims 8 to 12, wherein the plasminogen alleviates dilation and compensatory cardiac hypertrophy after myocardial injury.

14. A method for preventing or treating a lipid-induced myocardial injury in a subject, comprising administering an effective amount of plasminogen to the subject to protect a myocardium.

15. The method of claim 14, wherein the plasminogen alleviates lipid deposition in a cardiac tissue.

16. The method of claim 14 or 15, wherein the plasminogen promotes repair of an injured myocardium.

17. The method of any one of claims 14 to 16, wherein the plasminogen alleviates fibrosis of an injured myocardial tissue.

18. The method of any one of claims 14 to 17, wherein the plasminogen alleviates apoptosis of injured myocardial cells.

19. The method of any one of claims 14 to 18, wherein the plasminogen promotes recovery of myocardial function.

20. The method of any one of claims 14 to 19, wherein the plasminogen alleviates dilation and compensatory cardiac hypertrophy after myocardial injury.

21. The method of any one of claims 14 to 20, wherein the plasminogen alleviates blood lipid in one or more ways of: lowering serum triglyceride, low-density lipoprotein, very low-density lipoprotein, and serum cholesterol, and elevating serum high-density lipoprotein.

22. A method for preventing or treating an inflammation-induced myocardial injury in a subject, comprising administering an effective amount of plasminogen to the subject to protect a myocardium.

23. The method of claim 22, wherein the inflammation is an inflammation caused by autoimmunity in the subject.

24. The method of claim 23, wherein the inflammation is systemic lupus erythematosus, systemic sclerosis, myocarditis, and pericarditis.

25. The method of any one of claims 22 to 24, wherein the plasminogen promotes repair of an injured myocardium.

26. The method of any one of claims 22 to 25, wherein the plasminogen alleviates fibrosis of an injured myocardial tissue.

27. The method of any one of claims 22 to 26, wherein the plasminogen alleviates apoptosis of injured myocardial cells.

28. The method of any one of claims 22 to 27, wherein the plasminogen promotes recovery of myocardial function.

29. The method of any one of claims 22 to 28, wherein the plasminogen alleviates dilation and compensatory cardiac hypertrophy after myocardial injury.

30. A method for preventing or treating a coronary arteriosclerotic myocardial injury in a subject, comprising administering an effective amount of plasminogen to the subject to protect a myocardium.

31. The method of claim 30, wherein the myocardial injury is caused by coronary heart disease in the subject.

32. The method of claim 31, wherein the plasminogen promotes repair of an injured myocardium.

33. The method of any one of claims 30 to 32, wherein the plasminogen alleviates fibrosis of an injured myocardial tissue.

34. The method of any one of claims 30 to 33, wherein the plasminogen alleviates apoptosis of injured myocardial cells.

35. The method of any one of claims 30 to 34, wherein the plasminogen promotes recovery of myocardial function.

36. The method of any one of claims 30 to 35, wherein the plasminogen alleviates dilation and compensatory cardiac hypertrophy after myocardial injury.

37. A method for preventing or treating myocardial injury caused or complicated by diabetes mellitus in a subject, comprising administering an effective amount of plasminogen to the subject to protect a myocardium.

38. The method of claim 37, wherein the plasminogen promotes repair of an injured myocardium.

39. The method of claim 37 or 38, wherein the plasminogen alleviates fibrosis of an injured myocardial tissue.

40. The method of any one of claims 37 to 39, wherein the plasminogen alleviates apoptosis of injured myocardial cells.

41. The method of any one of claims 37 to 40, wherein the plasminogen promotes recovery of myocardial function.

42. The method of any one of claims 37 to 41, wherein the plasminogen alleviates dilation and compensatory cardiac hypertrophy after myocardial injury.

43. A method for preventing or treating myocardial injury caused by lipid deposition in a subject, comprising administering an effective amount of plasminogen to the subject.

44. The method of claim 43, wherein the lipid deposition is induced by hyperlipemia caused by abnormal fat or glucose metabolism in the subject.

45. A method for preventing or treating a renal tissue injury caused or accompanied by hyperlipemia in a subject, comprising administering an effective amount of plasminogen to the subject.

46. A method for preventing or treating an ischemic reperfusion-induced myocardial tissue injury in a subject, comprising administering an effective amount of plasminogen to the subject.

47. The method of any one of claims 1 to 46, wherein the plasminogen is administered in combination with one or more other drugs or therapeutic means.

48. The method of claim 47, wherein the one or more other drugs comprises a drug for treating hypertension, a drug for treating diabetes mellitus, a drug for treating atherosclerosis, a drug for treating chronic glomerulonephritis, a drug for

treating chronic pyelonephritis, a drug for treating nephrotic syndrome, a drug for treating renal insufficiency, a drug for treating uremia, a drug for treating kidney transplantation, a drug for treating fatty liver, a drug for treating hepatic cirrhosis, and a drug for treating obesity.

49. The method of claim 48, wherein the other drugs comprise: a hypolipidemic drug, an anti-platelet drug, an antihypertensive drug, a vasodilator, a hypoglycemic drug, an anticoagulant drug, a thrombolytic drug, a hepatoprotective drug, an anti-arrhythmia drug, a cardiotonic drug, a diuretic drug, an anti-infective drug, an antiviral drug, an immunomodulatory drug, an inflammatory regulatory drug, an anti-tumor drug, a hormone drug, and thyroxine.

50. The method of claim 49, wherein the drugs comprise hypolipidemic drugs: statins; fibrates; niacin; cholestyramine; clofibrate; unsaturated fatty acids such as Yishouning, Xuezhiping, and Xinmaile; and alginic sodium diester; anti-platelet drugs: aspirin; dipyridamole; clopidogrel; and cilostazol; vasodilators: hydralazine; nitroglycerin, and isosorbide dinitrate; sodium nitroprusside; α1-receptor blockers such as prazosin; α-receptor blockers such as phentolamine; β2-receptor stimulants such as salbutamol; captopril, enalapril; nifedipine, diltiazem; and salbutamol, loniten, prostaglandin, and atrial natriuretic peptide; thrombolytic drugs: urokinase, and streptokinase; tissue-type plasminogen activators; single chain urokinase-type plasminogen activators; and a TNK tissue-type plasminogen activator; and anticoagulant drugs: heparin; enoxaparin; nadroparin; and bivalirudin.

51. The method of any one of claims 1 to 50, wherein the plasminogen has at least 75%, 80%, 85%, 90%, 95%, 96%, 97%, 98% or 99% sequence identity with SEQ ID No. 2, 6, 8, 10 or 12, and still has the plasminogen activity.

52. The method of any one of claims 1 to 51, wherein the plasminogen is a protein that has 1-100, 1-90, 1-80, 1-70, 1-60, 1-50, 1-45, 1-40, 1-35, 1-30, 1-25, 1-20, 1-15, 1-10, 1-5, 1-4, 1-3, 1-2 or 1 amino acid added, deleted and/or substituted in SEQ ID No. 2, 6, 8, 10 or 12, and still has the plasminogen activity.

53. The method of any one of claims 1 to 52, wherein the plasminogen is a protein that comprises a plasminogen active fragment and still has the

plasminogen activity.

54. The method of any one of claims 1 to 53, wherein the plasminogen is selected from Glu-plasminogen, Lys-plasminogen, mini-plasminogen, micro-plasminogen, delta-plasminogen or their variants that retain the plasminogen activity.

55. The method of any one of claims 1 to 54, wherein the plasminogen is a natural or synthetic human plasminogen, or a variant or fragment thereof that still retains the plasminogen activity.

56. The method of any one of claims 1 to 54, wherein the plasminogen is an ortholog of human plasminogen from a primate or a rodent, or a variant or fragment thereof that still retains the plasminogen activity.

57. The method of any one of claims 1 to 56, wherein the amino acids of the plasminogen are as shown in SEQ ID No. 2, 6, 8, 10 or 12.

58. The method of any one of claims 1 to 57, wherein the plasminogen is a natural human plasminogen.

59. The method of any one of claims 1 to 58, wherein the subject is a human.

60. The method of any one of claims 1 to 59, wherein the subject has a lack or deficiency of plasminogen.

61. The method of claim 60, wherein the lack or deficiency is congenital, secondary and/or local.

62. A plasminogen for use in the method of any one of claims 1 to 61.

63. A pharmaceutical composition, comprising a pharmaceutically acceptable carrier and the plasminogen for use in the method of any one of claims 1 to 61.

64. A preventive or therapeutic kit comprising: (i) the plasminogen for use in the method of any one of claims 1 to 61, and (ii) a means for delivering the plasminogen to the subject.

65. The kit of claim 64, wherein the means is a syringe or a vial.

66. The kit of claim 64 or 65, further comprising a label or an instruction for use indicating the administration of the plasminogen to the subject to implement the method of any one of claims 1 to 46.

67. An article of manufacture, comprising:

a container comprising a label; and

(i) the plasminogen for use in the method of any one of claims 1 to 61 or a pharmaceutical composition comprising the plasminogen, wherein the label indicates the administration of the plasminogen or the composition to the subject to implement the method of any one of claims 1 to 61.

68. The kit of any one of claims 64 to 66 or the article of manufacture of claim 67, further comprising one or more additional means or containers containing other drugs.

69. The kit or the article of manufacture of claim 68, wherein the other drugs are selected from a group of: a hypolipidemic drug, an anti-platelet drug, an antihypertensive drug, a vasodilator, a hypoglycemic drug, an anticoagulant drug, a thrombolytic drug, a hepatoprotective drug, an anti-arrhythmia drug, a cardiotonic drug, a diuretic drug, an anti-infective drug, an antiviral drug, an immunomodulatory drug, an inflammatory regulatory drug, an anti-tumor drug, a hormone drug, and thyroxine.

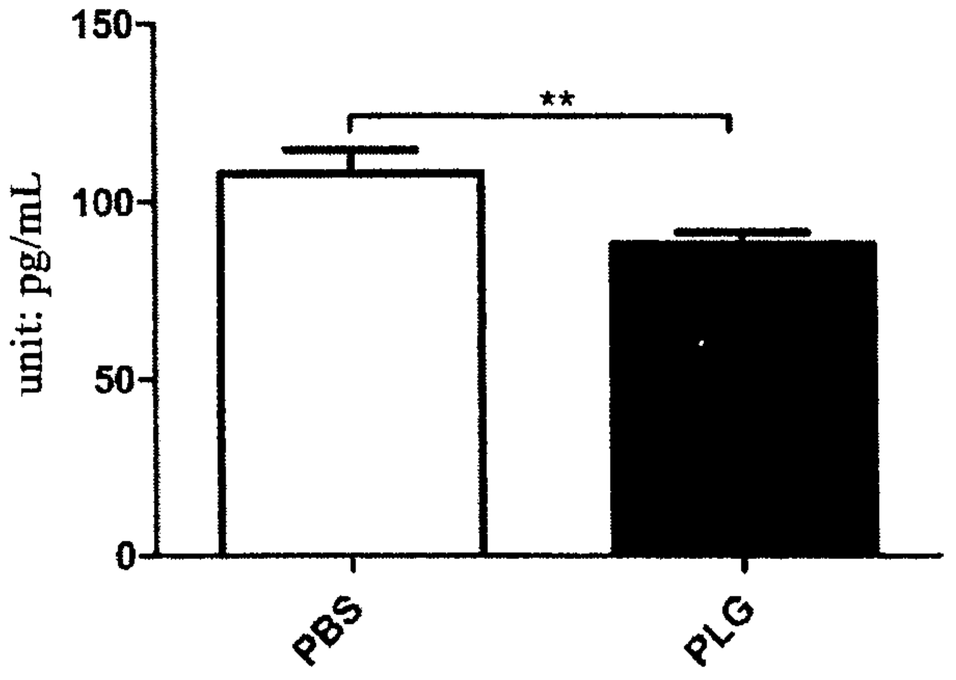

Fig.1

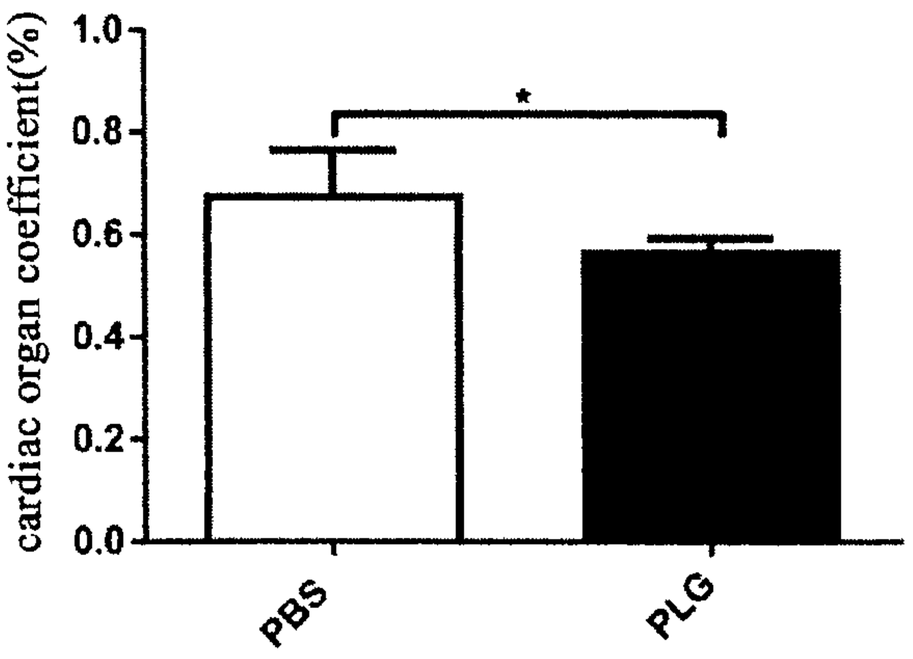

Fig.2

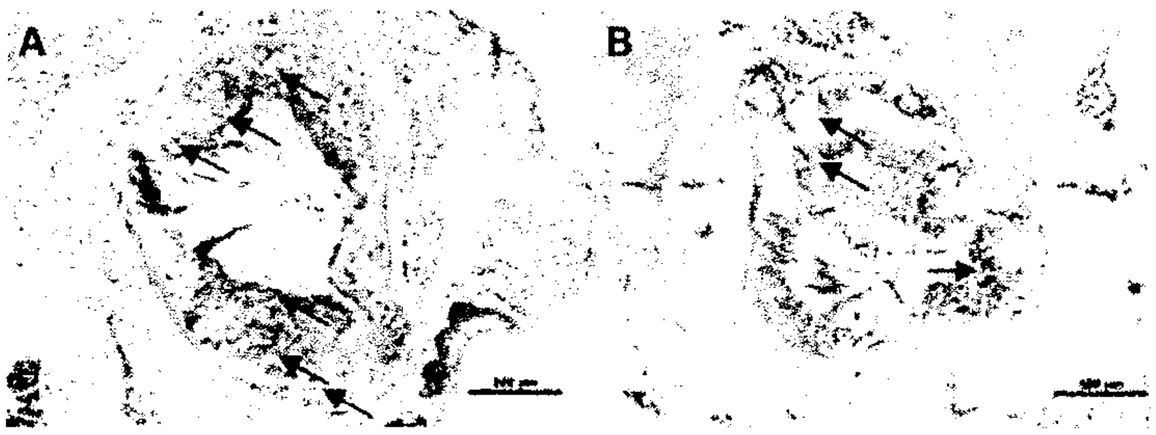

Fig.3

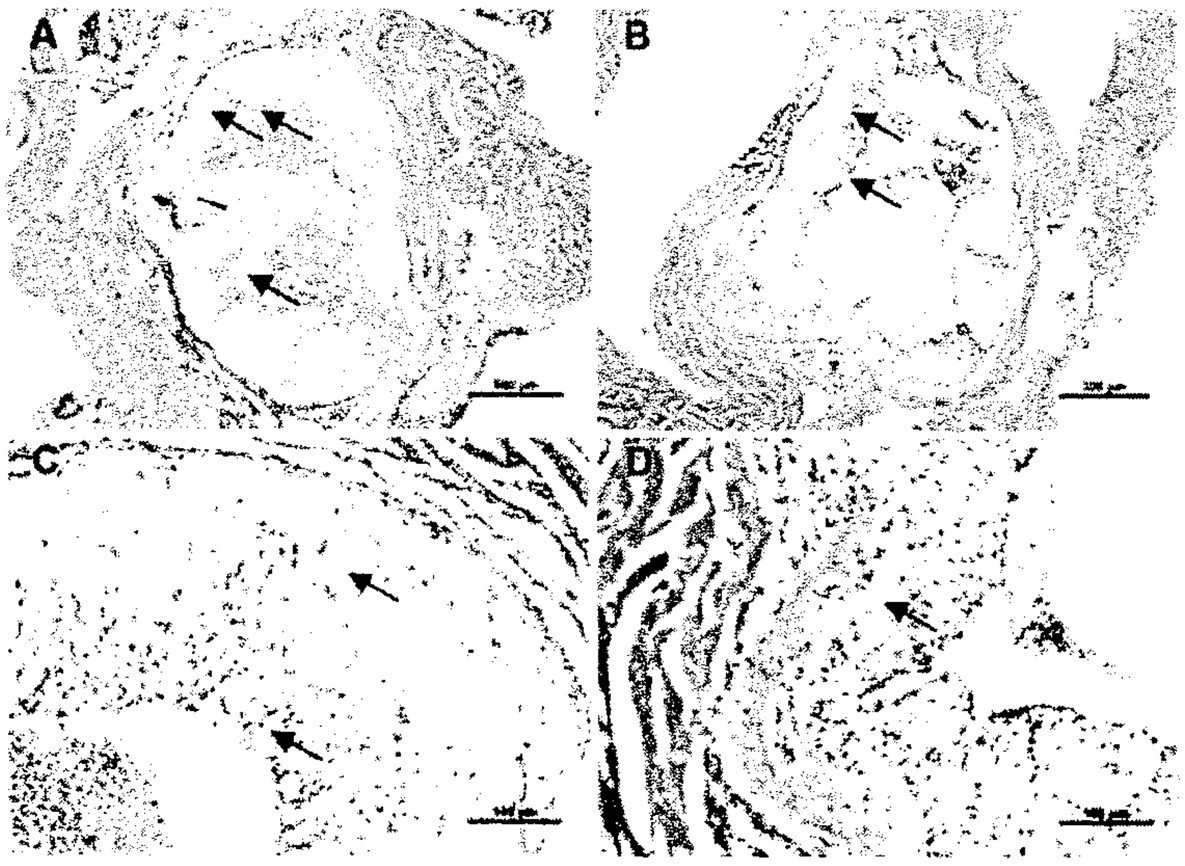

Fig.4

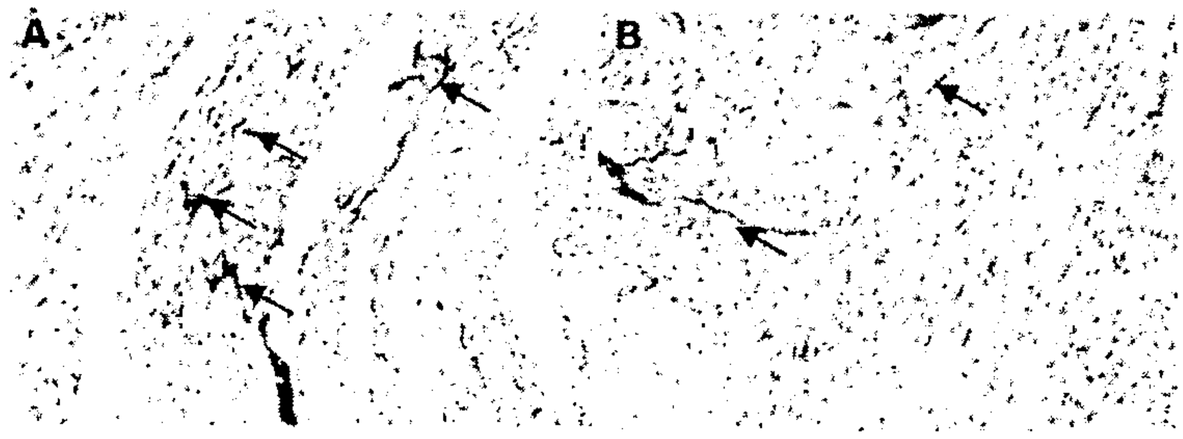

Fig.5

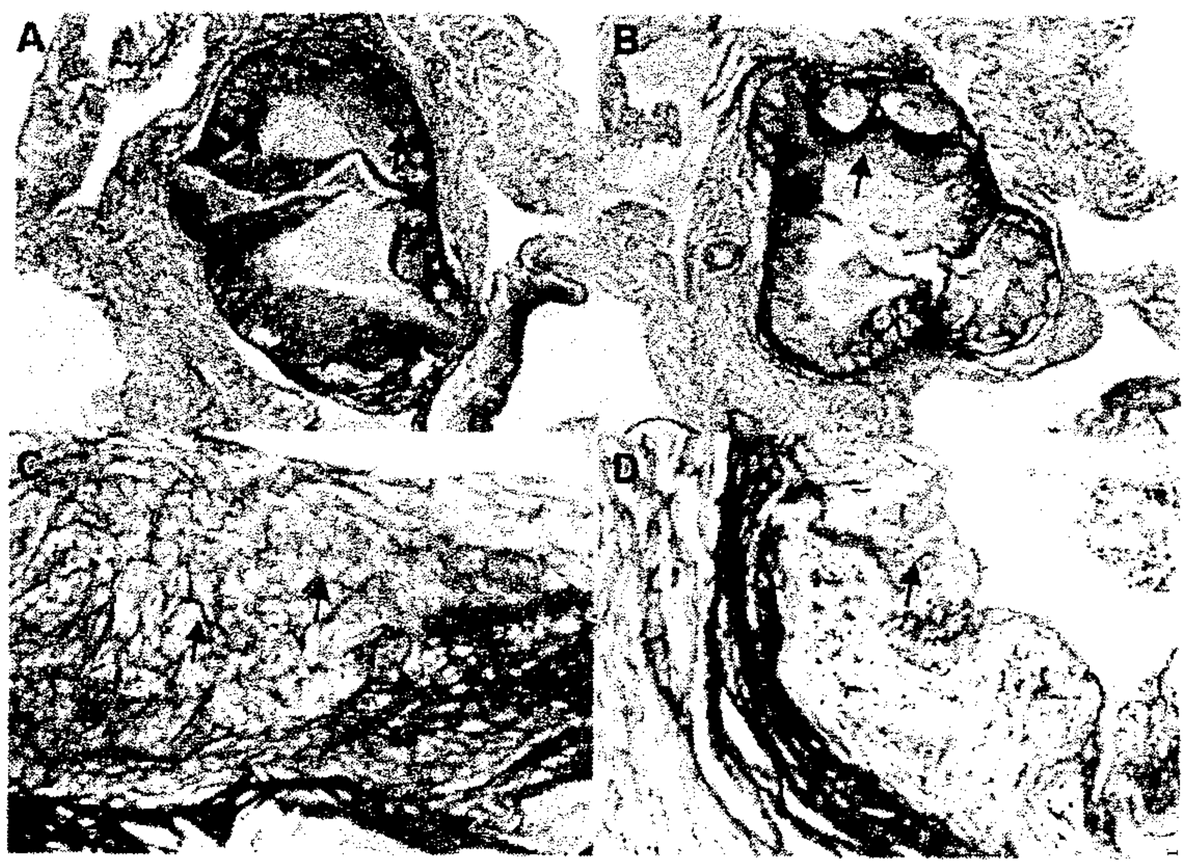

Fig.6

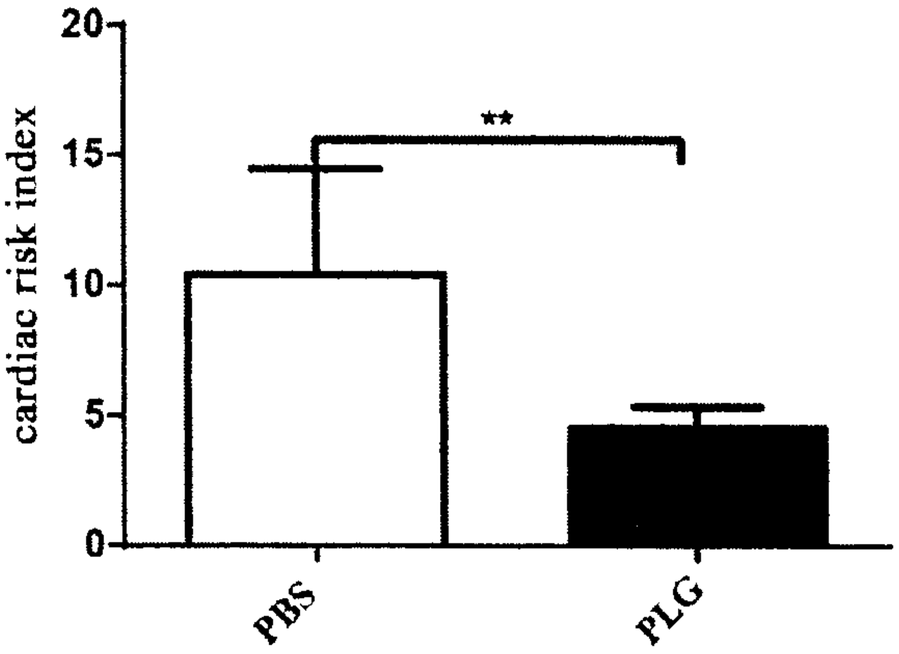
cardiac risk index
20
15
10
5
0
**
PBS
PLG

Fig.7

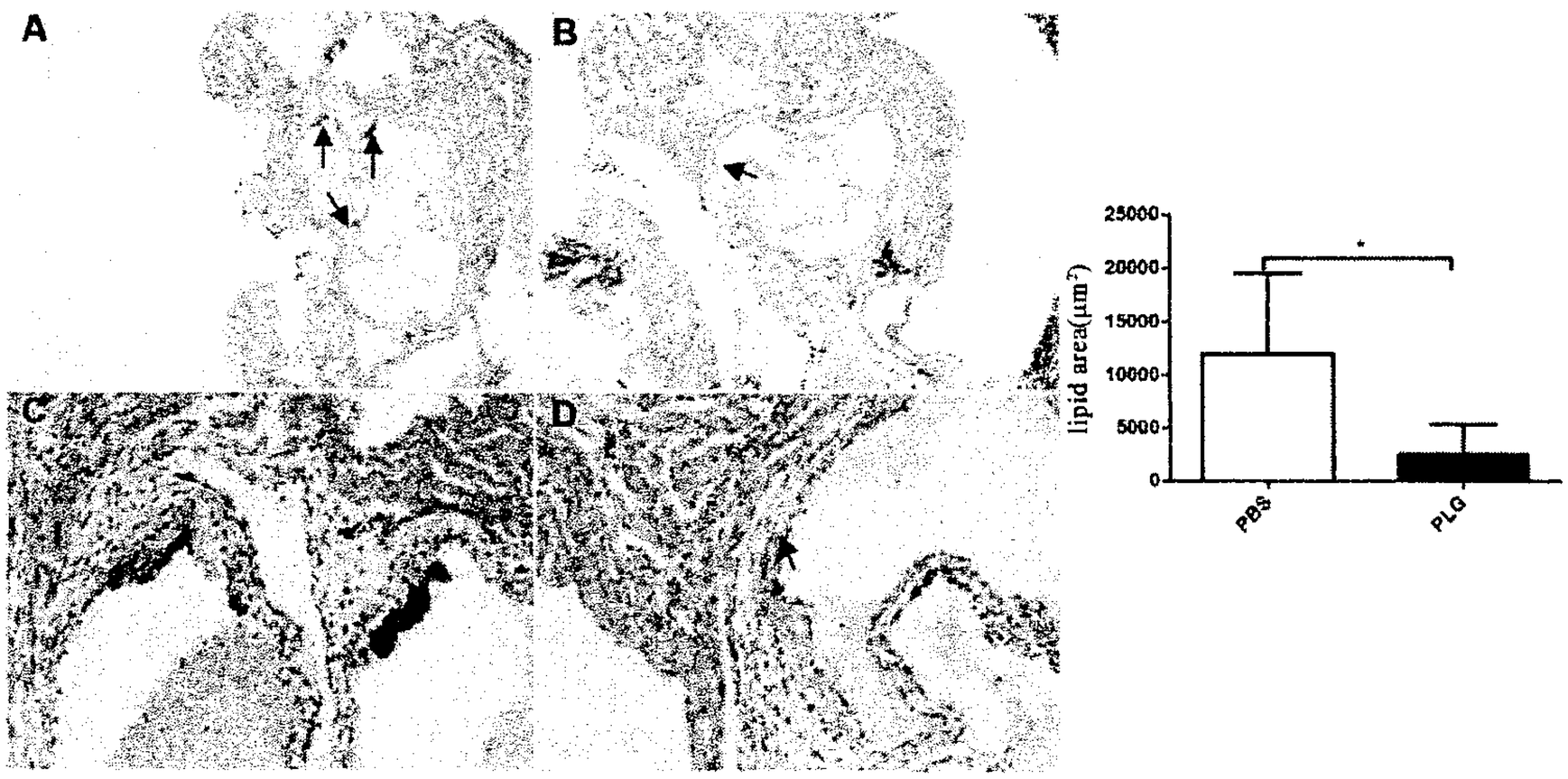
A
B
C
D
lipid area(μm²)
25000
20000
15000
10000
5000
0
*
PBS
PLG

Fig.8

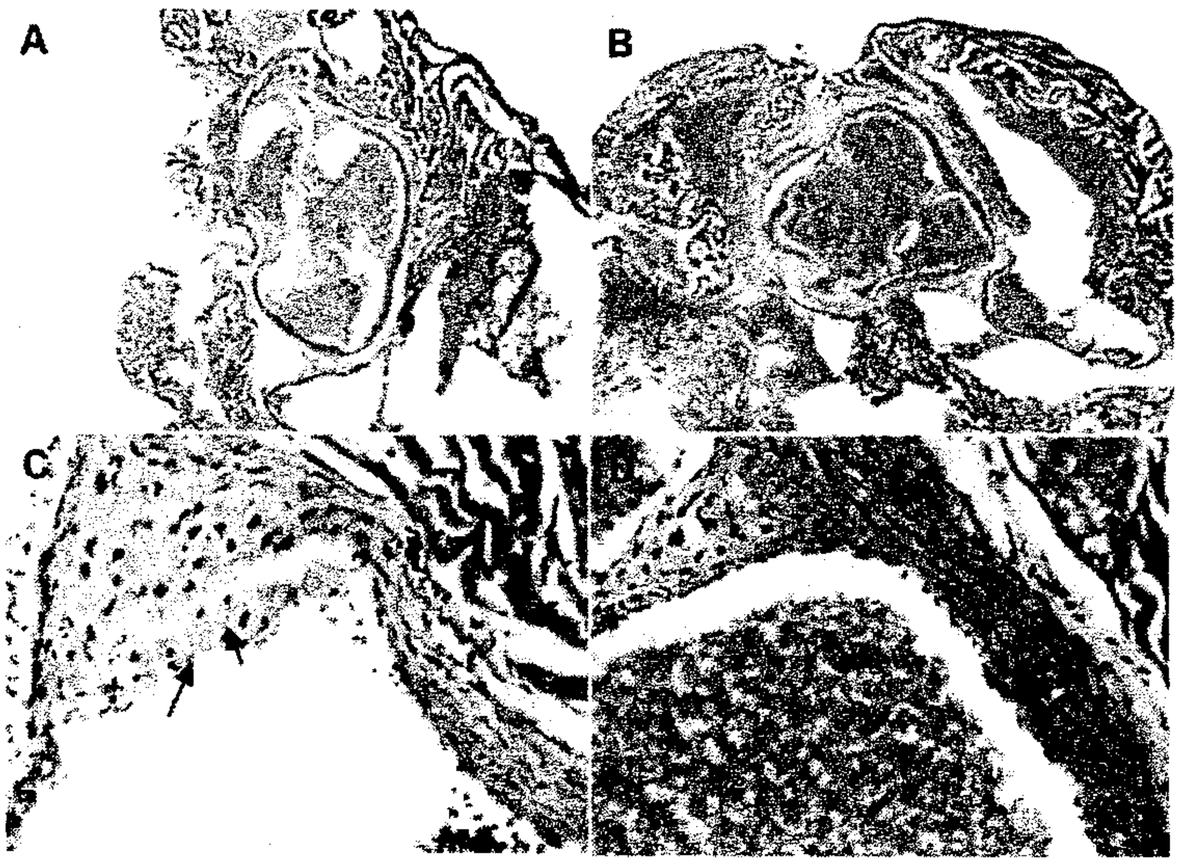

Fig.9

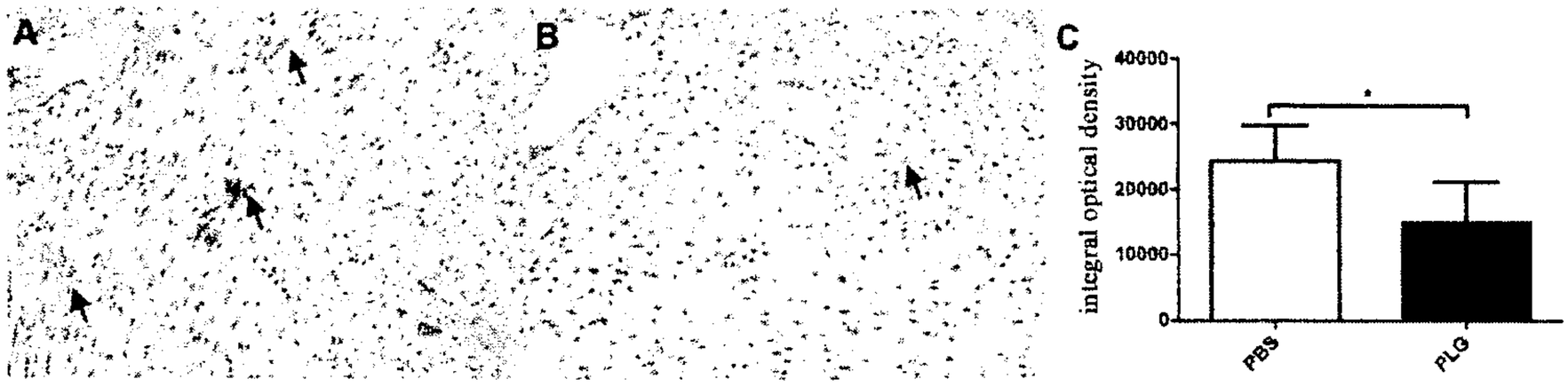

Fig.10

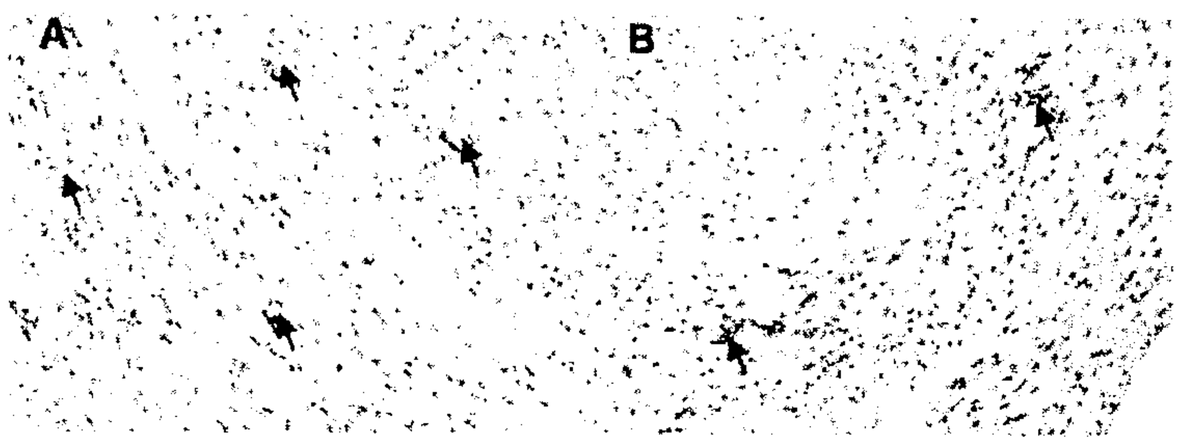

Fig.11

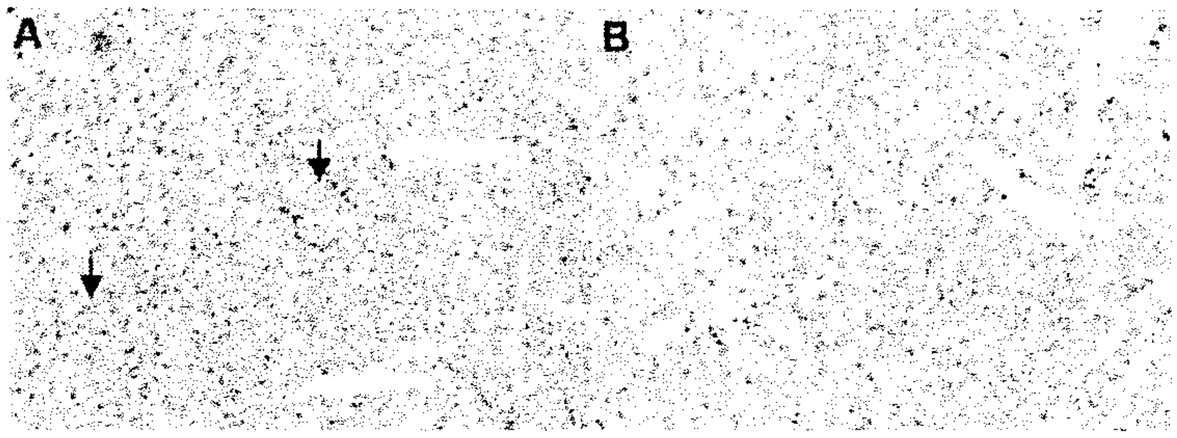

Fig.12

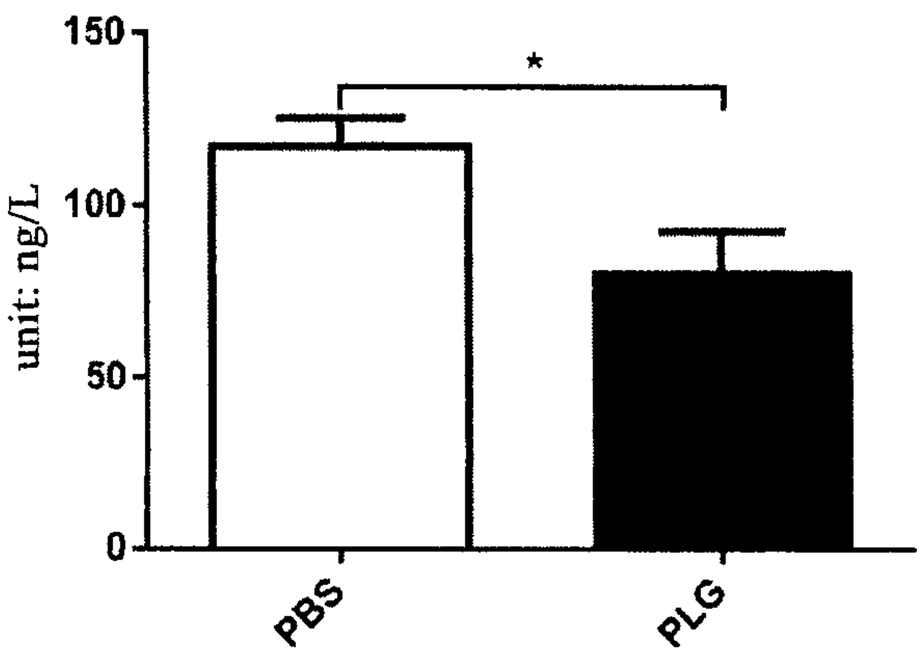

Fig.13

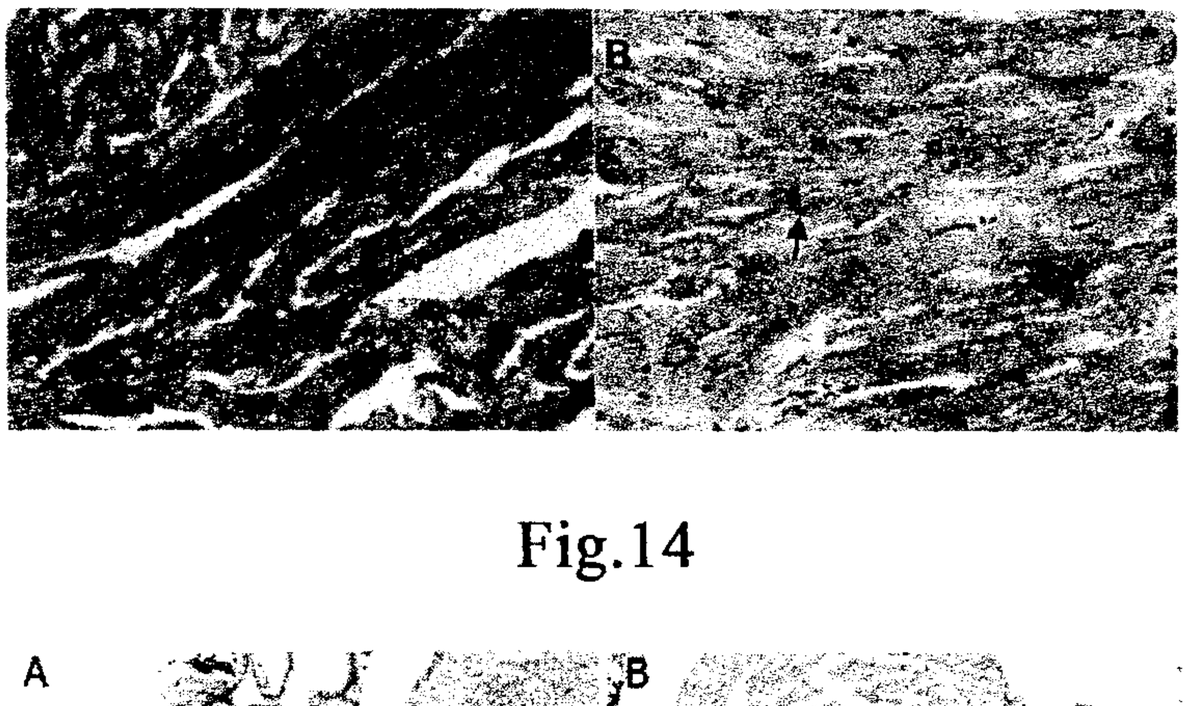

Fig.14

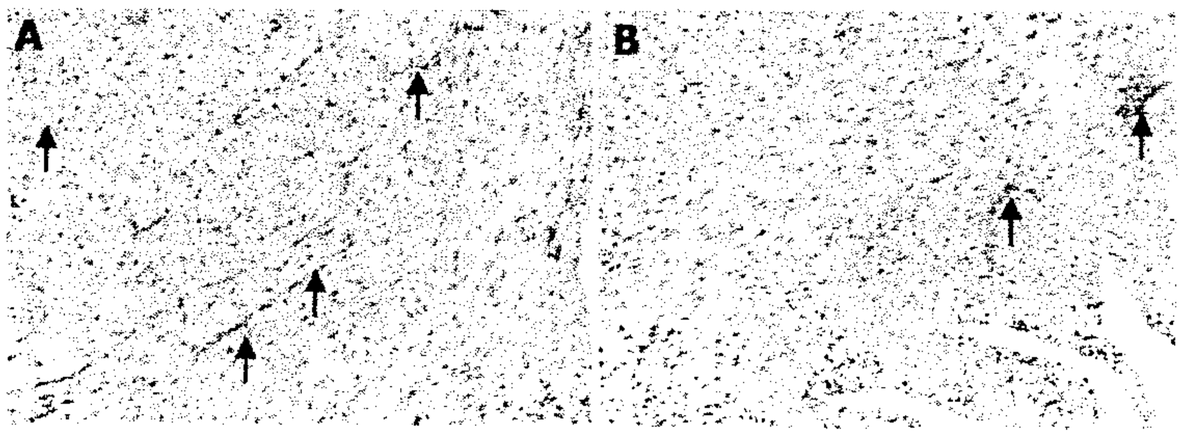

Fig.15

Fig.16

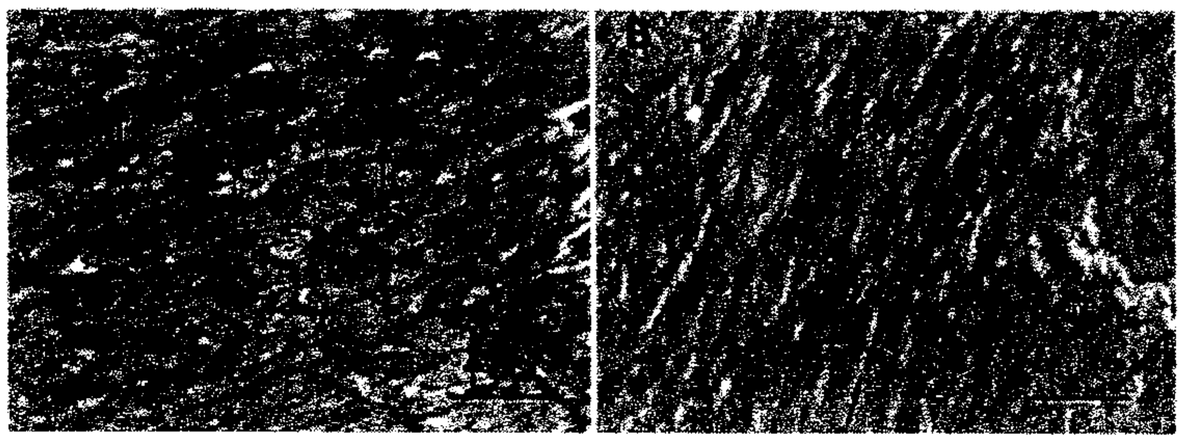

Fig.17

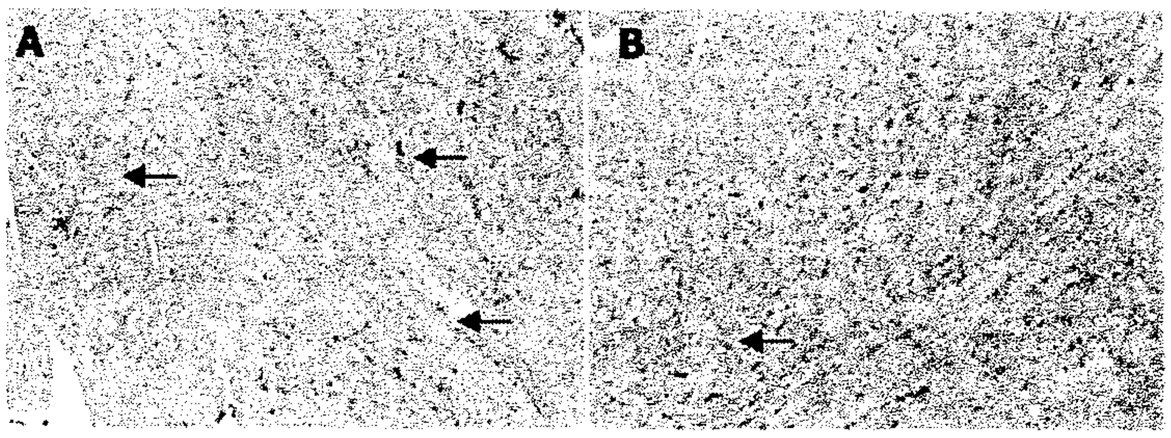

Fig.18

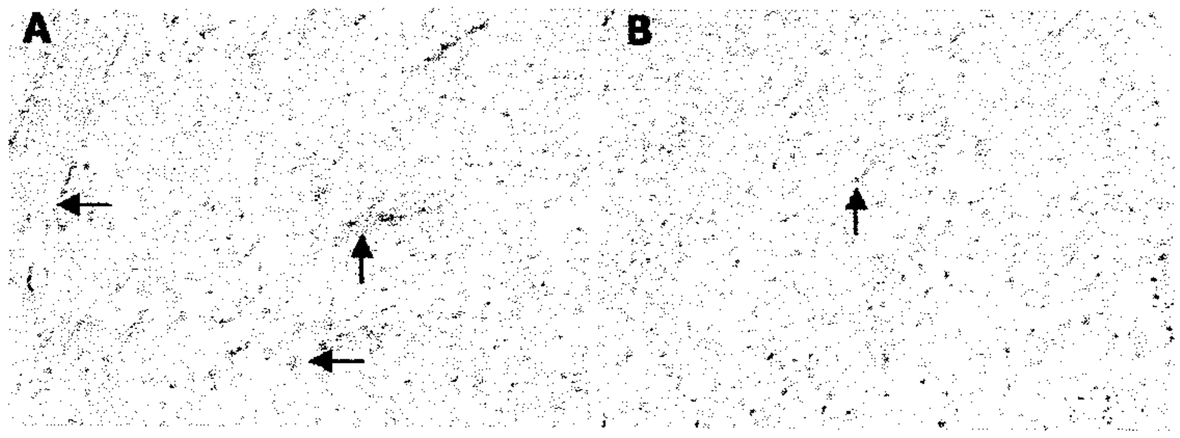

Fig.19

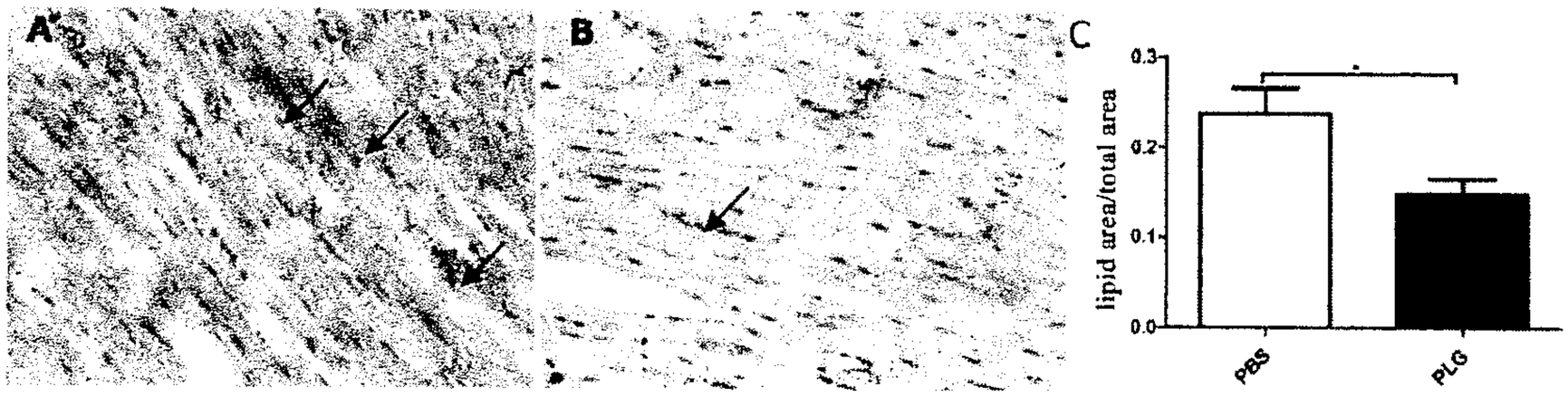

Fig.20

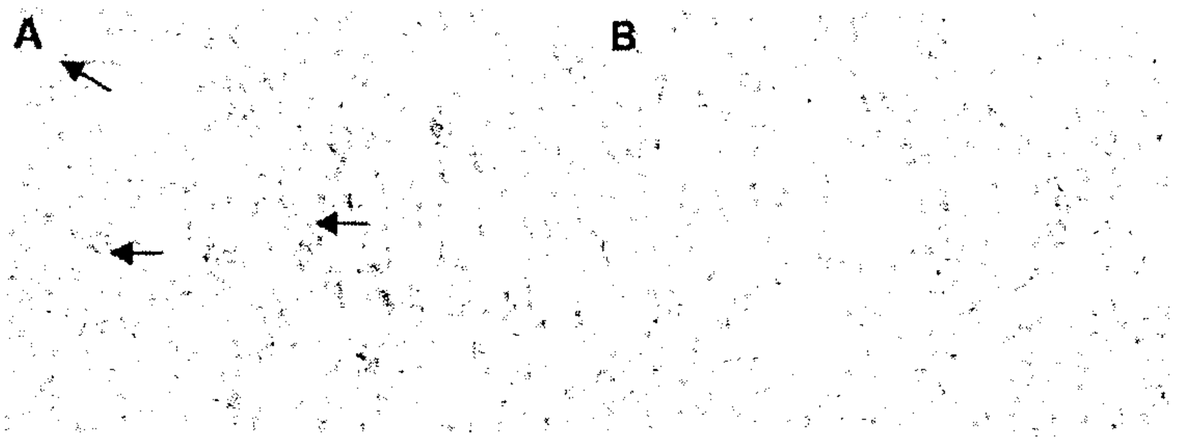

Fig.21