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(54) Titre : NOUVEAU BIOMARQUEUR DE TUMEUR

(54) Title: A NOVEL TUMOR BIOMARKER

(57) **Abrégé/Abstract:**

The present invention relates to the diagnosis and treatment of cancer, and specifically to a method of diagnosing the presence or metastasis of cancer by detecting plasma Hsp90 α having the amino acid sequence of SEQ ID No.1 as a tumor marker. In addition, the present invention also relates to a method for the treatment of cancer and metastasis.

Abstract

The present invention relates to the diagnosis and treatment of cancer, and specifically to a method of diagnosing the presence or metastasis of cancer by detecting plasma Hsp90 α having the amino acid sequence of SEQ ID No.1 as a tumor marker. In addition, the present invention also relates to a method for the treatment of cancer and metastasis.

A Novel Tumor Biomarker

Field of Invention

This invention relates to the diagnosis and therapy of tumor, and specifically to a novel
5 tumor biomarker and methods and kits for the detection of cancer occurrence and metastasis.
The invention also relates to methods and medicaments for the treatment of cancer and/or its
metastasis.

Background of Invention

10 Currently, around 11 million people are diagnosed as tumor patients every year
worldwide, and it is speculated that this number will increase to more than 16 million by the
year of 2020. In 2005, among the 58 million deaths, 7.6 million are caused by cancer
(accounting for about 13%). This number is increasing, and it is expected that 9 and 11.4
million people will die of cancer by the year of 2015 and 2030 respectively. (World Health
15 Organization, 2006)

Tumor markers are the substances produced by tumor cells during the progression
caused by gene mutation, including antigens and other bio-active substances, which can be
used for the early detection of cancers as well as the monitoring of disease progression and
response to a treatment (ASCO, 1996). It brings huge benefit for the clinical treatment of
20 cancers, especially when it can be detected before any obvious clinical phenomenon or when
it can be used to monitor the patients' response to certain treatment. At present, in order to
better meet the clinical need, greater efforts on the research and development of tumor
biomarkers are required.

The applications of most tumor biomarkers currently used in clinic are more or less
25 restricted due to the not-so-good sensitivity and specificity. For example, the AFP level and
ultra-sonic examinations are largely used for liver cancer detection. Although their
sensitivities are not very high, they indeed prolong the survival rate of the patients by
diagnosis of the high-risk people. The tumor antigen CA-125 has a higher sensitivity but lacks
specificity. Similarly, the blood tumor biomarker CA15-3 which is used for the detection of
30 breast cancer could hardly be used for early detection due to low sensitivity. Therefore,

methods for the early detection of cancer as well as to distinguish benign and malignant tumors are currently not available in clinic. New technologies as well as new methods are required to be developed to resolve these problems.

The development of tumor proteonomics brings hope for the identification of novel tumor biomarkers. The malignant transformation of tumors always results in the change of protein expressions, which could be quantified at the protein level. Thus, a lot of information and data could be derived, by which potential biomarkers could be identified and evaluated for further development and clinical application.

Hsp90 α (Heat shock protein 90 α , Hsp90 α) is a molecular chaperone, which functions to stabilize its client proteins in their active states. Hsp90 α is one of the most abundant proteins in the eukaryotic cells accounting for about 1-2% of whole cell proteins. The intracellular Hsp90 α mainly functions to stabilize its clients (i.e. estrogen receptor) and assistant their maturation (i.e. some kinases and signal proteins). However, in other physiological conditions, Hsp90 α is also involved in mediating events such as the evolution of mutated proteins, rearrangement of cytoskeleton, translocation of nuclear proteins, cell proliferation and apoptosis, protein degradation, antigen processing and LPS recognition etc. Hsp90 α is also related with many diseases such as cancer, autoimmune disorder and cardiovascular diseases. For example, the monoclonal antibody against the antigen of LKVIRK sequence derived from Hsp90 α can be used to treat fungal-related infection, and this clinic trial is currently ongoing by the Neutec company (Trade name: Mycogrip).

It is also reported that Hsp90 α could be secreted under some stimulus (Liao et al. (2000) J. Biol. Chem. 275, 189-96). As a classical intracellular protein, there is little report regarding the function of extracellular Hsp90 α . In previous reports, Hsp90 α was identified to help the antigen processing in APCs and was one of the four proteins related to the lipid raft. They can interact with LPC thus trigger the intracellular response of cells. (Triantafilou et al. (2002) Trends in Immunology 23, 301-4).

Hsp90 α was also found to be highly expressed in the surface of some tumor cells, including the small-cell-lung cancer cell, melanoma and liver cancer cells (Ferrarini et al. (1992) Int. J. Cancer 51, 613-19). The high expression of cell surface Hsp90 α in these cells were speculated to be related with the antigen processing while direct evidence is not available.

It is also reported that Hsp90 α could help the translocation of transmembrane proteins (Schlatter et al. (2002) Biochem. J. 362, 675-84), and is related with the efflux of some anti-leukemia, lung cancer, cervix cancer drugs (Rappa et al (2002) Oncol. Res. 12, 113-9 and Rappa et al (2000) Anticancer Drug Des 15,127-34).

5 The intracellular Hsp90 α is an important target for the development of anti-cancer drugs, as it is involved in the regulation of many signaling pathways which are critical for the cancer cell transformation. Inhibition of intracellular Hsp90 α could result in the selective degradation of proteins related with cell proliferation, cell cycle control as well as apoptosis. Recently, some known antibiotics such as Geldanamycin, Radicicol and Coumermycin A1 are natural
10 inhibitors of Hsp90 α . A patent (WO 00/53169) describes this mechanism and proposes that preventing the interaction of chaperones with its clients could result in the inhibition of its chaperone activity. Among these antibiotics, Coumarin and its derivatives are believed to have this activity. However, these inhibitors described in patent WO 00/53169 mainly target the intracellular Hsp90 α .

15 The analogue of Geldanamycin 17-AAG is also an inhibitor of Hsp90 α and is currently under clinical trials. However, some reports show that 17-AAG could have non-specific inhibitory effects and cell toxicity by interacting with many other cellular components. In addition, due to the limited knowledge on the physiological functions of Hsp90 α and its clients, direct inhibition of intracellular Hsp90 α is risky.

20 The patent (EP1457499A1) describes the function of extracellular Hsp90 α in promoting tumor cell invasion *via* activating the MMP-2. Based on these mechanisms, the patent proposes that inhibition of extracellular Hsp90 α could prevent the tumor invasion and metastasis, and by detecting the response of tumor cells to the treatment of Hsp90 α inhibitor they can deduce the invasive ability of the cells and their relationship with Hsp90 α .

25 The inventors of patent WO/2008/070472 propose that they can monitor the anti-tumor efficacy of Hsp90 α targeted therapy by detecting the plasma Hsp90 α and other related factors. In this patent, they provide the relationship between the plasma Hsp90 α level and the efficacy of the inhibitors including 17-AAG and 17-DMAG as well as the relationship between the level of plasma Hsp90 α and tumor volume in mouse models. However, they do not provide
30 any evidence about the exact form of plasma Hsp90 α and do not demonstrate the relationship between the plasma Hsp90 α level and tumor malignancy especially tumor metastasis. They do

not propose the application of plasma Hsp90 α as an independent tumor biomarker in tumor diagnosis and prognosis, either.

One group reported that serum Hsp90 α level is related with the stages of non-small-cell lung cancer (Xu et al. (2007) J. Cancer Mol. 3,107-112). The serum level of Hsp90 α in these lung cancer patients was significantly higher than that of normal people or benign tumor patients. However, again this paper did not identify the exact form of serum Hsp90 α as well as its relationship with tumor metastasis. Besides, it only investigated non-small-cell lung cancer, while the relationship between serum Hsp90 α level with breast cancer, liver cancer, and pancreatic cancer is unknown. Moreover, the serum level of Hsp90 α was not quantitatively measured, thus could hardly be translated to clinic development and further application.

Summary of Invention

This invention is based on the discovery that the plasma Hsp90 α level is correlated with the development, malignancy and metastasis of many types of cancer. Accordingly, plasma Hsp90 α can be used as a new tumor biomarker. The inventors found that the plasma Hsp90 α is different from the intracellular Hsp90 α , because the plasma Hsp90 α lacks four amino acid residues at its C-terminus compared with the intracellular Hsp90 α .

Therefore, in one aspect, this invention provides an isolated polypeptide comprising or consisting of the amino acid sequence of SEQ ID No.1.

The polypeptide of this invention may be phosphorylated. In particular, in the polypeptide of this invention, one or more amino acid residues in the amino acid sequence of SEQ ID No.1 selected from the group consisting of Thr90, Ser231, Ser263, Tyr309 and a combination thereof are phosphorylated. Preferably, the Thr90 in the polypeptide of this invention is phosphorylated.

The polypeptide of this invention may serve as a tumor biomarker. Using an agent specifically binding to the polypeptide of this invention, it is possible to detect the plasma level of this polypeptide, and thereby to determine the presence of cancers and the stage and metastasis of cancers.

Accordingly, in another aspect, this invention relates to a method of determining the presence, stage and/or metastasis of a cancer in a subject, the method comprises the step of

detecting the level of a polypeptide comprising or consisting of the amino acid sequence of SEQ ID No.1 in a plasma sample of the subject by using an agent capable of specifically binding to said polypeptide.

In yet another aspect, this invention relates to a method of screening the presence of a cancer in a high-risk population comprising the step of detecting the level of a polypeptide comprising or consisting of the amino acid sequence of SEQ ID No.1 in a plasma sample by using an agent capable of specifically binding to said polypeptide.

In still another aspect, this invention relates to a method of determining the prognosis of a patient having a cancer comprising the step of detecting the level of a polypeptide comprising or consisting of the amino acid sequence of SEQ ID No.1 in a plasma sample of the patient by using an agent capable of specifically binding to said polypeptide.

In a further aspect, this invention relates to method of determining the efficiency of a surgery, radiotherapy or chemotherapy treatment to a patient having a tumor comprising the step of detecting the level of a polypeptide comprising or consisting of the amino acid sequence of SEQ ID No.1 in a plasma sample of the patient by using an agent capable of specifically binding to said polypeptide.

Preferably, the agent capable of specifically binding to the polypeptide of this invention can be a specific antibody against the polypeptide. Preferably, the antibody is a monoclonal antibody or an antigen binding fragment thereof, such as scFv, Fab, Fab' and F(ab')₂. In one specific embodiment, the antibody is MAb E9 or D10 produced by the cell line deposited under CGMCC No. 2903 or 2904, respectively.

According to this invention, the antibody specifically binds to the polypeptide present in plasma. Preferably, the antibody specifically binds to a phosphorylated form of the polypeptide of the invention, said phosphorylated form of the polypeptide contains one or more phosphorylated amino acid residues in the amino acid sequence of SEQ ID No.1 selected from the group consisting of Thr90, Ser231, Ser263, Tyr309 and a combination thereof.. Preferably, the antibody specifically binds to the polypeptide which is phosphorylated at Thr90.

In another aspect, this invention relates to a method of preventing or treating cancer metastasis in a subject comprising the step of administering an inhibitor of the polypeptide of the invention to the subject. In one embodiment of this aspect, the inhibitor is a specific

antibody against a polypeptide comprising or consisting of the amino acid sequence of SEQ ID No.1. Preferably, this antibody is humanized antibody or an antigen binding fragment thereof. In one embodiment, the antibody specifically binds to a phosphorylated form of the polypeptide, said phosphorylated form of the polypeptide contains one or more phosphorylated amino acid residues in the amino acid sequence of SEQ ID No.1 selected from the group consisting of Thr90, Ser231, Ser263, Tyr309 and a combination thereof.. In a preferred embodiment, the antibody specifically binds to the polypeptide which is phosphorylated at Thr90. In one specific embodiment, the antibody is MAb E9 or D10 produced by the cell line deposited under CGMCC No. 2903 or 2904, respectively.

Among the different aspects of this invention, the cancer is selected from the group consisting of lung cancer, liver cancer, gastric cancer, gastrointestinal cancer, esophagus cancer, osteosarcoma, pancreatic cancer, lymphoma, colorectal cancer, breast cancer, prostate cancer, oral cancer, nasopharyngeal cancer, cervical cancer, ovarian cancer, leukemia, malignant melanoma, sarcoma, renal cell carcinoma and cholangiocarcinoma.

This invention also involves antibodies that can specifically bind to the polypeptide of the invention which is present in plasma. In one specific embodiment, the antibody is MAb E9 or D10 produced by the cell line deposited under CGMCC No. 2903 or 2904, respectively. Preferably, the antibody of the invention is a humanized antibody or an antigen binding fragment thereof. In one embodiment, the antibody specifically binds to a phosphorylated form of the polypeptide, said phosphorylated form of the polypeptide contains one or more phosphorylated amino acid residues in the amino acid sequence of SEQ ID No.1 selected from the group consisting of Thr90, Ser231, Ser263, Tyr309 and a combination thereof. In a preferred embodiment, the antibody specifically binds to the polypeptide which is phosphorylated at Thr90.

In another aspect, this invention relates to a method of inhibiting cancer invasiveness and metastasis, comprising the step of inhibiting the phosphorylation of intracellular Hsp90 α in cancer cells. In one embodiment, this invention relates to a method of inhibiting cancer invasiveness and metastasis, comprising the step of inhibiting the phosphorylation of Hsp90 α at Thr90 in cancer cells. In one specific embodiment of this aspect, the method comprises a step of overexpressing a nucleic acid molecule encoding protein phosphatase 5 in cancer cells.

Brief Description of the Drawings

Figure 1: The plasma Hsp90 α level in tumor-bearing mice is significantly increased than in that in normal mice.

Figure 2: The plasma Hsp90 α level in cancer patients is significantly increased compared
5 with that in normal people.

Figure 3: The titer assay of the mouse monoclonal antibody of E9 and D10.

Figure 4: The standard curve of plasma Hsp90 α using mouse monoclonal antibody E9 and rabbit polyclonal antibody S2 (sandwich ELISA).

Figure 5: Quantitative measurement of plasma Hsp90 α level in lung, liver, pancreatic
10 cancer patients as well as benign galactoma and myoma of uterus patients using sandwich ELISA:

A: The plasma Hsp90 α level of liver cancer patients is measured by sandwich ELISA. The plasma Hsp90 α level in benign tumor patients ranges from 2-10 ng/ml, mostly 2-5 ng/ml, while the plasma Hsp90 α level in 69% (20/29) liver cancer patients is above 50 ng/ml, the
15 average of which has more than 10-fold increment compared with that of benign tumor patients, which is consistent with the result of Western blotting. This indicates that the plasma Hsp90 α level is positively correlated with tumor malignancy.

B: The plasma Hsp90 α level of lung cancer patients is measured by sandwich ELISA. The plasma Hsp90 α level in 64% (9/14) lung cancer patients is above 50 ng/ml, the average
20 of which has more than 10-fold increment compared with that of benign tumor patients. This indicates the plasma Hsp90 α level is positively correlated with tumor malignancy.

C: The plasma Hsp90 α level of breast cancer patients is measured by sandwich ELISA. Compared with benign tumor patients, the highest plasma Hsp90 α level is increased by more than 5-fold. Overall, the average plasma Hsp90 α level in breast cancer patients shows
25 significantly increment when compared with that in benign tumor patients.

D: The plasma Hsp90 α level of pancreatic cancer patients is measured by sandwich ELISA. The plasma Hsp90 α level in 100% (10/10) pancreatic cancer patients is above 50 ng/ml, the average of which has more than 10-fold increment compared with that of benign tumor patients. This indicates the plasma Hsp90 α level is positively correlated with tumor
30 malignancy.

Figure 6: Quantitative measurement of plasma Hsp90 α level in the cancer patients with or without metastasis using sandwich ELISA:

A: The liver cancer patients are divided into two groups, one with metastasis and the other one without metastasis, then the plasma Hsp90 α levels in these two groups are compared. The plasma Hsp90 α levels in cancer patients with metastasis are all above 200 ng/ml while those in patients without metastasis range from 50-200 ng/ml.

B: The lung cancer patients are divided into two groups, one with metastasis and the other one without metastasis, then the plasma Hsp90 α levels in these two groups are compared. The plasma Hsp90 α levels in cancer patients with metastasis are all above 200 ng/ml while those in patients without metastasis range from 50-200 ng/ml.

C: The breast cancer patients are divided into two groups, one with metastasis and the other one without metastasis, then the plasma Hsp90 α levels in these two groups are compared. The plasma Hsp90 α levels in cancer patients with metastasis are significantly elevated compared with that in patients without metastasis.

Figure 7: Quantitative measurement of plasma Hsp90 α level in the patients with inflammation (pneumonia and hepatitis), normal people and tumor patients using sandwich ELISA:

A: To ensure that the elevated plasma Hsp90 α level of cancer patients is tumor specific, we compared the plasma Hsp90 α level in pneumonia patients, normal people and tumor patients and found that the plasma Hsp90 α level in pneumonia patients ranges from 2-10 ng/ml, indicating no significant changes compared with that in normal people.

B: The plasma Hsp90 α level in hepatitis patients (Hepatitis A and B) ranges from 2-10 ng/ml, indicating no significant changes compared with that in normal people.

Figure 8: The plasma Hsp90 α is secreted by tumor cells.

Figure 9: The secreted Hsp90 α by tumor cells is in a C-terminal truncated form.

Figure 10: The plasma Hsp90 α lacks the C-terminal four amino acid residues.

Figure 11: The plasma Hsp90 α is phosphorylated.

Figure 12: The Thr90 phosphorylated Hsp90 α level in the tumor patient plasma is elevated.

Figure 13: In the plasma of tumor patient, the increment of Thr90 phosphorylated Hsp90 α level is consistent with that of Hsp90 α level.

Figure 14: Thr90 Phosphorylation of Hsp90 α is a pre-requisite for Hsp90 α secretion.

Figure 15: PP5 dephosphorylates Thr90 phosphorylated Hsp90 α .

A: Purified PP5 and Thr90 phosphorylated Hsp90 α (pT90-Hsp90 α) are incubated together, and the released free phosphate group is quantitated. Peptide is a positive control.

5 The result shows PP5 can directly dephosphorylate Thr90 phosphorylated Hsp90 α .

B: In the human breast cancer cell line MCF-7, overexpression of human PP5 results in the inhibition of Hsp90 α Thr90 phosphorylation (0.55 of that in control group) and siRNA of endogenous human PP5 results in the increase of Hsp90 α Thr90 phosphorylation (1.58 of that in control group)

10 Figure 16: PP5 regulates the secretion of Hsp90 α .

A: In the human breast cancer cell line MCF-7, overexpression of human PP5 results in the inhibition of Hsp90 α secretion.

B: In the human breast cancer cell line MCF-7, siRNA of endogenous human PP5 results in the increase of Hsp90 α secretion.

15 Figure 17: The correlation of PP5 expression level and the secretion level of Hsp90 α .

Figure 18: The correlation of PP5 expression level and the invasive ability of the tumor cells.

Figure 19: The specific antibody of Hsp90 α could inhibit the migration of tumor cells.

Figure 20: The specific antibody of Hsp90 α could inhibit tumor metastasis.

20

Information of Biological Material Deposition

Mouse hybridoma cell line SP2/0-Ag14 which produces monoclonal antibody E9 was deposited at China General Microbiological Culture Collection Center (CGMCC, Chinese Academy of Sciences Institute of Microbiology, Datun Road, Chaoyang District, Beijing) on
25 February 24, 2009 with the Deposition No. CGMCC No.2903.

Mouse hybridoma cell line SP2/0-Ag14 which produces monoclonal antibody D10 was deposited at China General Microbiological Culture Collection Center (CGMCC, Chinese Academy of Sciences Institute of Microbiology, Datun Road, Chaoyang District, Beijing) on
February 24, 2009 with the Deposition No. CGMCC No.2904.

30

Detailed Description of the Invention

Carcinogenesis is caused by changes of certain intracellular signal transduction pathways, accompanied by changes of protein expression, modification and distribution. These changes could be used to monitoring of tumor development and progression, and these proteins are named as tumor marker. With the development of proteomics technology, it becomes possible to monitor the changes of tumor proteome qualitatively or quantitatively. So many new tumor markers have been found to provide more accurate and credible evidences for the tumor clinical diagnosis and prognosis.

This invention is based on a discovery of a novel blood tumor marker, i.e., plasma Hsp90 α . Compared to intracellular Hsp90 α (the amino acid sequence is SEQ ID No.3, coding nucleic acid sequence is SEQ ID No.4), the Hsp90 α in plasma has a deletion of 4 amino acids in the C terminus.

Hence, in one aspect, this invention provides an isolated polypeptide, which is Hsp90 α found in serum or plasma. In this application, the term “polypeptide of the invention” used herein refers to Hsp90 α found in serum or plasma, which comprises or consists of the amino acid sequence of SEQ ID No.1. Preferably, the term “polypeptide of the invention” used herein refers to the polypeptide consisting of the amino acid sequence of SEQ ID No.1 sequence. In this application, the term “Hsp90 α in plasma” or “Hsp90 α in serum” can be used equally to refer to the protein Hsp90 α in the blood but not intracellular or on cell surface. In this application, term “polypeptide” and “protein” can be used interchangeably.

The present invention also provides a polynucleotide encoding a polypeptide composing or consisting of the amino acid sequence of SEQ ID No.1. In a specific embodiment, the polynucleotide comprises or consists of the amino acid sequence of SEQ ID No.2.

The inventors also found that the polypeptide of the invention is in a phosphorylated form in plasma. Specifically, one or more amino acid residues in the amino acid sequence of SEQ ID No.1 selected from the group consisting of Thr90, Ser231, Ser263, Tyr309 and a combination thereof are phosphorylated. Preferably, the Thr90 in the polypeptide of this invention is phosphorylated.

The special form of plasma Hsp90 α (C-terminal truncated and phosphorylated) has not been described. Meanwhile, plasma Hsp90 α also has never been reported to be related to tumor development and progression. EP1457499A1 describes the extracellular form of Hsp90 α , and suggests that the inhibitors of Hsp90 α can be used to treat tumor metastasis, to

detect tumor invasiveness and to determine the dependence of tumor invasiveness on Hsp90 α . However, the method described in EP1457499A1 is used to detect cell surface Hsp90 α , but not related to plasma Hsp90 α . Nor did EP1457499A1 disclose that plasma Hsp90 α can be used to determine the degree and stage of malignancy, or to monitor the therapeutic response and prognosis of cancer by measuring the level of Hsp90 α in plasma. WO/2008/070472 reported that the effects of the anti-cancer treatment targeting Hsp90 α could be determined through detecting Hsp90 α and its related factors in plasma, but it did not mention Hsp90 α as an independent tumor marker in cancer diagnosis and prognosis.

The inventors examined the blood samples from nearly a hundred tumor patients (with breast cancer, liver cancer, pancreatic cancer, lung cancer and so on), and found that the level of Hsp90 α in plasma is correlated to tumor malignancy, particularly metastasis; while the inflammatory response does not influence plasma level of Hsp90 α . Therefore, plasma Hsp90 α can serve as a tumor marker, which can be used for the diagnosis and prognosis of tumors and metastasis.

Additionally, the invention provides a kit examining the plasma levels of the polypeptide of the invention. The kit of the invention contains an agent capable of specifically binding to the polypeptide of the invention, which can be used to detect the level of plasma Hsp90 α .

The invention also provides a method of detecting the level of plasma Hsp90 α in a plasma sample of the subject by using an agent capable of specifically binding to said polypeptide. The method of the invention can be used to establish the diagnosis of carcinogenesis, malignancy and metastasis; to screening cancer in high-risk population; to determine the prognosis of cancer patients; and to determine the efficacy of surgery, radiotherapy or drug therapy.

As used herein, the term "an agent capable of specifically binding to a polypeptide of the invention" refers to molecules which can bind to the polypeptide of this invention with high-affinity. These agents also include molecules which can bind intracellular and cell surface Hsp90 α . An agent capable of specifically binding to the polypeptide of the invention can be proteins, especially Hsp90 α specific antibodies. In the preferred examples, the above antibody is a monoclonal antibody or antigen binding fragment, such as scFv, Fab, Fab' and F(ab')₂. In a specific embodiment, the antibodies are monoclonal antibody E9 or D10 which is produced by the cell line with deposition number of CGMCC No. 2903 or 2904, respectively.

Monoclonal antibodies are obtained by screening the cells which can secrete the antibodies and then culturing the cells in vitro. The method is well known by the people in this field (Köhler G & Milstein C. (1975) *Nature*. 256, 495-7). The process for Hsp90 α -specific monoclonal antibody preparation is as follows: for the first immunization, recombinant human Hsp90 α (rhHsp90 α , 100 μ g) with Freund's complete adjuvant was injected subcutaneously on the back of BALB/c mice multi-pointly; 3 weeks later, same dose of rhHsp90 α was injected intraperitoneal (i.p.) with Freund's incomplete adjuvant; the third immunization was administered by i.p. injection after 3 weeks with same dose (5 to 7 days later the blood titer was tested); the other 3 weeks later, 200 μ g rhHsp90 α was administered for the booster immunization by intraperitoneal injection. 3 days later, spleen cells were fused with hybridoma SP2/0-Ag14 (SP2/0) (Source: ATCC, number: CRL-1581) using HAT for screening. Then hybridoma cells were limited diluted. immune blot and ELISA methods were used to identify and eventually to select cell lines that can secrete specific Hsp90 α antibodies.

According to the invention, the antibodies used for the preparation of the method or kit can specifically bind to Hsp90 α , and preferably to Hsp90 α in plasma. In an preferred embodiment, the antibodies specifically bind to Hsp90 α with one or more following amino acid residues are phosphorylated: Thr90, Ser231, Ser263, Tyr309 and the combination thereof. In the preferred embodiment, antibodies described herein can specifically bind to Hsp90 α with phosphorylated Thr90.

The invention also provides a method for detecting the level of plasma polypeptide. The level of plasma Hsp90 α can be detected by any suitable methods. The methods described here include both direct and indirect means for detecting the polypeptide which can be used for the diagnosis of tumor development, malignancy and metastasis.

Direct measurements include methods of detecting the described polypeptide of the invention using its an agent capable of specifically binding to said polypeptide, for example using specific antibodies of the polypeptides by Western blot or ELISA.

The concentration of Hsp90 α can also be indirectly determined by detecting the activity of Hsp90 α . An example is the assay of thermal induced denaturation of luciferase, which can be used to detect the chaperone activity of Hsp90 α (Johnson et al. (2000) *J. Biol. Chem.*, 275, 32499-32507).

Preferably, the level of plasma Hsp90 α can be detected by ELISA or Western blot,

comprising the steps as follows:

- a) collecting the whole blood of cancer patients, and obtaining plasma or serum by centrifugation;
- b) using ELISA or Western blot to detect the Hsp90 α level of plasma or serum obtained from the step a), in which plasma of healthy people is used as the negative control, while plasma of patients with malignant tumors is used as the positive control, optionally generating an Hsp90 α concentration standard curve;
- c) determining the tumor malignancy and stage according to the level of plasma Hsp90 α , thereby determining tumor diagnosis, prognosis or efficacy of treatment.

In step b) other methods can also be used, such as methods based on antigen-antibody reactions as well as methods based on other principles directly or indirectly reflecting the concentrations of Hsp90 α , for example the examination of the concentration of Hsp90 α by detecting the activity of Hsp90 α .

Standard Hsp90 α used for the standard curve of ELISA is purified from the plasma of cancer patients and can also be obtained by recombinant construction, including the full length Hsp90 α , fragments, and other recombinant proteins or conjugates containing the sequence of the Hsp90 α . "the standard curve of Hsp90 α concentration" refers to the correlation curve between Hsp90 α concentration and absorbance values detected in the ELISA using standard Hsp90 α samples. "Hsp90 α standard" refers to the plasma Hsp90 α protein, recombinant Hsp90 α protein, fragments and derivatives with the purity of more than 95%.

"Determining the malignancy of tumor" refers to making a judgment of tumor malignancy by examining the Hsp90 α concentration in the plasma samples of patients and comparing this value with negative and positive controls.

Both sandwich and competitive ELISA can be used to detect the level of Hsp90 α in plasma. The competitive ELISA with higher sensitivity is preferred.

The general steps of Sandwich ELISA include: a) immobilizing a specific antibody onto a solid support, and removing the unbound antibodies and impurities by one or more washing steps; b) adding samples to be tested and incubating for a period of time, allowing the antigen in the samples to bind to the antibody immobilized on the solid support and form solid-phase antigen-antibody immune complexes, then removing the unbound substances; c) adding an

enzyme-conjugated-antibody which can bind to the antigen in the solid phase immune complexes, and then removing the unbound enzyme-conjugated-antibody by thorough washes (the amounts of enzyme-conjugated-antibody bound to the solid support are positively correlated to the amount of antigen); and d) adding substrate and quantifying the amount of antigen according to the color reaction.

The general steps of competitive ELISA include: a) immobilizing a specific antibody onto a solid support and washing thoroughly; b) adding the mixture of the sample to be tested and a certain amount of enzyme-conjugated-antigen, and incubating for enough time and wash thoroughly. (If there is no antigen in the sample, the enzyme-conjugated-antigen can bind to the solid phase antibody without competition. If there are antigens in the sample, then the antigens in the sample compete with the enzyme-labeled-antigens to bind the immobilized antibody, and the amount of enzyme-labeled-antigen bound to immobilized antibody decreases. As a control, the reference tubes only contain the enzyme-labeled antigen); c) adding substrate and obtaining the absorbance value for each tube. The value of the reference tube is highest, and the difference between the reference tube and the sample tube represents the amount of antigens in the sample. The lighter the color is, the more antigens the sample contains.

If Sandwich ELISA is used, the antibodies are two different species of plasma Hsp90 α specific antibodies. The immobilized antibody can be a rabbit polyclonal antibody with strong binding capacities, while the detection antibody is a mouse monoclonal antibody with high specificity. These two antibodies should have no cross-reaction.

If competitive ELISA is used, the antibodies should be the specific antibodies against plasma Hsp90 α , which should have strong binding capacities and high specificity to both the competitive substance and Hsp90 α .

If competitive ELISA is used, the competitive substances can be a labeled plasma Hsp90 α standard protein. And the labeling does not interfere with the binding of Hsp90 α standard protein to its antibody.

If Western blot method is used, the first antibody used is a specific antibody against plasma Hsp90 α ; the secondary antibody can be conjugated with horseradish peroxidase, or alkaline phosphatase; the substrate can be DAB or fluorescent substrate. The fluorescence substrate with high sensitivity is preferred.

The sensitivity of above methods should be 10 ng/ml or more sensitive.

The antibody specific for plasma Hsp90 α used in this present invention can be a whole antibody, or its fragments and derivatives.

The antibodies of this invention can also be replaced by other agents capable of specifically binding to Hsp90 α , wherein the agents include small molecule compounds, peptides and their derivatives.

The competitive plasma Hsp90 α standard proteins can be labeled by biotin and various fluorescent labeling reagents. Biotin is preferred.

The cancers which can be detected by the kit or method described in this invention include, but are not limited to, lung cancer, liver cancer, gastric cancer, esophageal cancer, osteosarcoma, pancreatic cancer, lymphoma, colon cancer, breast cancer, prostate cancer, oral cancer, nasopharyngeal cancer, cervical cancer, leukemia, malignant melanoma, sarcoma, renal cancer, cholangiocarcinoma. "Tumor and its malignancy" refers to whether the tumor is benign, malignant, or metastasis.

The inventors demonstrated that, the plasma Hsp90 α level in non-cancer human is 2-50 ng/ml, most in the range of 2-10 ng/ml. The level of plasma Hsp90 α in patients diagnosed with cancer is higher than the normal level, while the plasma Hsp90 α level in the patients having cancer metastasis is higher than 50 ng/ml, mostly higher than 200 ng/ml. This makes the plasma Hsp90 α a new tumor marker, which would be helpful for the diagnosis of cancer, especially metastasis.

Thus, in an embodiment, the kit or method of this invention can be used to determine the existence of tumor, especially malignant tumors and tumor metastasis. To this end, the kit or method of this invention can be used to measure the Hsp90 α level of plasma samples from potential tumor patients or potential tumor metastasis patients, and optionally compared with normal controls, and then determine the possibility of patients with tumor or tumor metastasis according to the Hsp90 α level in the sample. The elevated Hsp90 α level in plasma suggests higher possibility that the patients have suffered from malignant tumor, and for patients with known cancer, an elevated Hsp90 α level strongly suggests possibility of tumor metastasis.

In another embodiment, the kit or method of the invention can be used to detect the level of plasma Hsp90 α so as to screen high-risk populations. To this end, the kit or method of the invention can be used to detect plasma Hsp90 α level in samples from high-risk populations,

and optionally compared with normal controls, and then one can determine whether an individual within the population may have tumor according to the level of the sample. Elevated Hsp90 α level indicates the higher possibility of the presence of a malignant tumor. It is well-known for the people in this field how to determine different high-risk groups depending on the type of cancer to be screened, individual factors such as age, family history, lifestyle, work environment, history of exposure to harmful compounds and so on. For example, patients having chronic hepatitis B or hepatitis C are at high risk of HCC.

In another embodiment, the kit or method of the invention can be used to detect the level of plasma Hsp90 α to predict the prognosis of cancer patients. To this end, the kit or method of this invention can be used to detect plasma Hsp90 α level in samples from cancer patients, and optionally compared with normal controls, and then one can determine the prognosis of cancer patients according to the level of Hsp90 α in plasma samples. The maintenance of Hsp90 α in a high level or further increase may relate to the poor prognosis. Therefore, the clinicians can be alerted to provide more closely observation to the patients, and if necessary, change the current treatment.

In another embodiment, the kit or method of the invention can be used to detect the plasma level of Hsp90 α , which is thus used to determine whether the treatment such as the surgery, radiotherapy or chemotherapy on cancer patients is effective. To this end, the kit or method of this invention can be used to detect plasma Hsp90 α level in samples from cancer patients, and optionally compared with normal controls, and then one can determine the prognosis of cancer patients according to the level of Hsp90 α in plasma samples. According to the level of the Hsp90 α , one can determine whether the surgery, radiotherapy or chemotherapy on cancer patients is effective and/or whether the treatment should be continued.

The inventors further demonstrated that the Hsp90 α in plasma is secreted by tumor cells and is different from that within the tumor cells. Therefore, it is assumed that the tumor development and metastasis may be suppressed by inhibiting the secretion of Hsp90 α into plasma. This point was demonstrated by the mouse tumor metastasis model using the specific antibody against plasma Hsp90 α . Therefore, the secretion of Hsp90 α can be used as a new target for screening new anticancer drugs.

In another aspect, the invention provides a method for the preventing or treating tumor

metastasis comprising administering to a cancer patient an inhibitor of the polypeptide of the invention.

According to one embodiment of this invention, the aforementioned inhibitor is a specific antibody of the polypeptide. Preferably, the antibody is a humanized antibody or its
5 fragments. In one embodiment, these antibodies specifically bind to a phosphorylated form of the polypeptide of the invention, said phosphorylated form of the polypeptide contains one or more phosphorylated amino acid residues in the amino acid sequence of SEQ ID No.1 selected from the group consisting of Thr90, Ser231, Ser263, Tyr309 and a combination thereof. In a preferred embodiment, the antibody can bind to the polypeptide phosphorylated
10 at Thr90. In one specific embodiment, the antibody is MAb E9 or D10 which is produced by the cell line deposited under CGMCC No. 2903 or 2904, respectively. As demonstrated herein, these antibodies can completely inhibit the lymph node metastasis of tumors in mouse model and can inhibit the lung metastasis to an extent up to 56%.

So, in another aspect, this invention also relates to an antibody specifically binds to the
15 Hsp90 α in blood. In a specific embodiment, the antibody is MAb E9 or D10 which is produced by the cell line deposited under CGMCC No. 2903 or 2904, respectively. Preferably, the antibody is a humanized antibody or an antigen binding fragment thereof. In a specific embodiment, the antibody specifically binds to a phosphorylated form of the polypeptide of the invention, said phosphorylated form of the polypeptide contains one or
20 more phosphorylated amino acid residues in the amino acid sequence of SEQ ID No.1 selected from the group consisting of Thr90, Ser231, Ser263, Tyr309 and a combination thereof. In one preferred embodiment, the antibody specifically binds to the polypeptide phosphorylated at Thr90. Preferably, the antibody inhibits tumor growth, especially metastasis. This invention also related to a conjugate comprising the antibody and a diagnosis
25 or treatment moiety. For example, the diagnosis moiety is a fluorophore, while the treatment moiety is a chemotherapeutic agent.

The inventor also found the amount of Hsp90 α secreted by tumor cells is related to the level of Protein phosphatase 5 (PP5). In benign tumor, secreted Hsp90 α is low but PP5 expression level is high. In malignant tumor, secreted Hsp90 α is high but PP5 expression
30 level is low. Therefore, the level of secreted Hsp90 α is negatively interrelated with the level of PP5. As a result, by detecting the expression level of PP5, it is possible to predict the amount

of secreted Hsp90 α .

The inventors also found that the secretion of Hsp90 α can be inhibited by cellular PP5. Over-expression of a nucleic acid molecule encoding PP5 in the cell can inhibit Hsp90 α secretion, while a decrease in the expression level of PP5 will result in an increase in Hsp90 α secretion. So by over expressing PP5, Hsp90 α secretion can be inhibited and the tumor progression and metastasis may be inhibited. According to our experiment, we found that over expression of PP5 inhibits the metastasis of MCF-7. So PP5 can be a new therapeutic target for tumor treatment.

So, in a further aspect, this invention provides a method for inhibiting tumor invasiveness and metastasis, wherein a step of inhibiting the phosphorylation of Hsp90 α within tumor cells. In one embodiment, this method comprises a step of inhibiting Thr90 phosphorylation of Hsp90 α in tumor cells. In one specific embodiment, this method comprises a step of over-expressing a nucleic acid molecule encoding PP5 in tumor cells. Preferably, the over-expression of PP5 is achieved by the means of gene introduction. In one embodiment, this method comprises a step of over-expressing a nucleic acid molecule encoding PP5 having an amino acid sequence of SEQ ID No.5. In one specific embodiment, the nucleic acid molecule comprises the nucleotide sequence of SEQ ID No.6. This invention also provides a method of inhibiting the phosphorylation of Hsp90 α in tumor cells comprising a step of over-expressing PP5 in tumor cells using a vector carrying a polynucleotide encoding PP5 operably linked to a promoter. The method can be used to inhibit tumor invasiveness and metastasis.

This invention also provides methods and models for screening for anti-tumor drugs by using plasma Hsp90 α and its derivatives. Such anti-tumor drugs includes, but not limited to, plasma Hsp90 α binding proteins, small peptides, and small compounds aswell as inhibitors which can suppress the activity of plasma Hsp90 α .

Examples

Example 1: The collection and preparation of mouse plasma samples, and the detection of plasma Hsp90 α .

Balb/c mice with average body weight of 20 gram (purchased from Beijing Vital River Laboratory Animal Technology Co., Ltd.) were randomized divided into two groups, 3 for

each. The mice of experiment group were inoculated with 10^6 H22 (CCTCC ID: GDC091) cells, while the mice in control group were not inoculated. When the diameter of tumor reached about 2 cm (about 20 days), blood was collected from eye down veniplex. Anticoagulant was added and hemolysis was prevented. If hemolysis occurred, the blood would be recollected. The blood sample was centrifuged at 4°C with 6000g for twice, and supernatant was saved. The amount of plasma Hsp90 α was detected by Western blotting using Rabbit anti-human Hsp90 α pAb (Labviation). BCA method was used to determine the total amount of proteins in samples, which ensured that the loading amounts of different samples were equal. The result is shown in Fig.1. Compared to control mice, the plasma Hsp90 α was elevated in tumor bearing mice.

Example 2: The collection and preparation of plasma samples from normal people and tumor patients, and the detection of plasma Hsp90 α .

The blood of normal people and cancer patients were collected and delivered to lab within 24 hours at 4°C . If hemolysis occurred, the samples should be recollected. The samples were centrifuged at 4°C , 6000g twice and supernatant was saved. The amount of Hsp90 α was determined by Western blotting. If the samples could not be examined immediately, the samples should be stored at -80°C . By comparing the results with clinical diagnosis, the correlation between Hsp90 α and tumor malignancy was confirmed.

The protocol for Western blotting: the plasma samples were mixed 1:1 with loading buffer. 1-2 μl sample is loaded for SDS-PAGE. Primary antibody is the one which can specifically recognize plasma Hsp90 α (rat mAb SPA-840, Stressgen). The secondary antibody is goat anti-rat antibody conjugated with HRP (purchased from Zhongshanjinqiao). As the result shows in Fig.2, the amount of Hsp90 α in HCC patients is 10-fold higher than that of normal people (A), while it is elevated by 2-fold in benign galactoceles and hysteromyoma patients compared with that of normal people.

Example 3: Preparation of rabbit pAb and mouse mAb against Hsp90 α

Primers with the following sequences were used to clone the gene of Hsp90 α :
Hsp90 α -Sal1-Re: ACGCGTCGACTTAGTCTACTTCTTCCATGC (SEQ ID No.8) and
Hsp90 α -Sph1-For: ACATGCATGCATGCCTGAGGAAAC CCAGACC (SEQ ID No.9).

Primers were synthesized by Invitrogen. Pfu DNA polymerases (NEB) were used to amplify Hsp90 α from human liver cDNA library (Stratagene). Sph1 and Sal1 (NEB) were used to digest the amplified PCR products and pQE80L vector (Qiagen). Then T4 ligases were used for ligation. The products were transformed into Top10 cells (Transgen) for amplification and validation. The validated plasmids were further transformed into BL21DE3 cells (Transgen) for expression. The recombinant Hsp90 α proteins were purified by ion-exchange chromatography SP HP, pH6.8, collecting 10 ms/ml peak and Q HP, pH7.8, collecting 19 ms/ml peak.

Recombinant human Hsp90 α with a purity higher than 95% was used to immune adult male New Zealand Rabbit by dorsal subcutaneous multi-point injection at 100 μ g for each time. Two weeks later, the secondary immunization was conducted according to the same method, except that the amount of Hsp90 α injection was reduced to 50 μ g. Boost injections were conducted every 1 week after the secondary immunization for twice. The titer of antibody in serum was determined 7-10 days after the boost immunizations. Eight days after the last immunization, serum was collected and stored at -20°C. Affinity chromatography conjugated with antigen was used to purify the antibody from the serum. Purified rabbit pAb was named as S2.

BALB/C mice were immunized by recombinant human Hsp90 α . Primary immunity: 100 μ g antigen and Freund's complete adjuvant was injected dorsal subcutaneously multipoint. The second immunity was conducted 3 weeks later with Freund's incomplete adjuvant using the same dose and *i.p.* injection. The third immunization was operated 3 more weeks later without adjuvant (blood was collected for test after 5-7 days). Three more weeks later, 200 μ g antigen was injected *i.p.* as the boost immunization. 3 days later, spleen cells were collected and fused with SP2/0-Ag14(SP2/0) hybridomas (ATCC: CRL-1581). HAT was used for the screening. Limited dilution was used to colonize hybridomas. Western blotting and ELISA were used for identification. Finally, E9 and D10, which secrete specific antibody against Hsp90 α , were obtained and stored as CGMCC No.2903 and 2904 on February 24, 2009.

Indirect ELISA was used to determine the titers of E9 and D10. Shown as Fig.3, the average titers of E9 and D10 respectively reaches 500,000, which is qualified to be used in the detection of plasma Hsp90 α . Indirect ELISA: recombinant human Hsp90 α was plated at 4°C overnight with the concentration of 10 μ g/ml. Then the plate was blocked at 37°C for 1 hour.

E9 or D10 with 1:400、1:1600、1:6400、1:25600、1:102400、1:509600 dilutions was added and incubated for 2 hours at RT. Then goat anti-mouse antibody conjugated with HRP was added and incubated for 1 hour at room temperature, then o-phenylendiamine was added and absorbance at OD 490 nm was detected.

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Example 4: Measurement of the concentration of Hsp90 α by E9, S2 and sandwich ELISA

In the method of sandwich ELISA to test the concentration of plasma Hsp90 α , two antibodies from distinct species were used. S2 with high binding capacity (the preparation of S2 was described in example 3) was used as the coating antibody and E9 (the preparation of E9 was described in example 3) with high binding specificity was used as the detecting antibody. There is no cross reaction between these two antibodies. The method is repeatable and sensitive. Fig.4 shows that the sensitivity of this method is 5 ng/ml.

Example 5: The collection and preparation of human plasma, the detection of plasma Hsp90 α and determination of tumor malignancy (sandwich ELISA).

The blood of normal persons, cancer patients and inflammation patients was delivered to lab at low temperature within 24 hours. If hemolysis occurs, the blood should be re-collected. The samples were centrifuged at 4°C, 6000g twice and supernatant was saved. The amount of plasma Hsp90 α was determined by ELISA. The samples were stored at -80°C if they were not examined immediately. By comparing the results with clinical diagnosis, the correlation between Hsp90 α and tumor malignancy was confirmed.

Two different Hsp90 α antibodies were used in sandwich ELISA. S2 was coated on the plate and incubated overnight at 4°C. The plate was blocked for 1 hour at 37°C. The samples were diluted by 10 folds and were added to the plate (100 μ l/well). After 2 hours incubation at 37°C, E9 was added and incubated at 37°C for 2 more hours. Goat anti-mouse antibody conjugated with HRP was added to incubate for another 1 hour. O-phenylendiamine was added and absorbance at OD490 nm was detected. The results were shown as Fig.5, 6 and 7. The standard curve comprises a serial of samples containing the gradient concentration of standard Hsp90 α proteins and 10% of negative plasma in each sample, which was used to exclude the background of plasma.

As shown in Fig.5, the amount of plasma Hsp90 α in benign tumor patients (including

benign galactocoele and hysterromyoma patients, seven cases) is between 2-10 ng/ml, mainly in 2-5 ng/ml. 69% (20/29) liver cancer patients have plasma Hsp90 α above 50 ng/ml, which is in average 10 folds higher than that of benign tumor patients, $p=0.00263$, student t test (A); 64% (9/14) lung cancer patients have plasma Hsp90 α above 50 ng/ml. The average concentration is 10 folds higher than that of benign tumor patients, $p=0.0497$, student t test (B). 78% (25/32) breast cancer patients have plasma Hsp90 α above 50 ng/ml. The average is 10 folds higher than that of benign tumor patients, $p<0.001$, student t test (C). 100% (10/10) pancreatic cancer patients have plasma Hsp90 α above 50 ng/ml. The average is 10 folds higher than that of benign tumor patients, $p<0.05$, student t test (D).

As shown in Fig.6, in liver cancer (17 cases, 7 metastasis) (A), lung cancer (10 cases, 2 metastasis) (B) and breast cancer (21 cases, 10 metastasis) (C) patients, the levels of Hsp90 α in metastasis patients were significantly higher than those in patients without metastasis. Liver cancer $p=0.003$, breast cancer $p=0.002$, student t test.

As shown in Fig.7, inflammation patients, including 10 pneumonia cases (A), 10 hepatitis cases (type A 5 cases, type B 5 cases) (B) have plasma Hsp90 α between 2-10 ng/ml, which shows no significant difference when compared with that of normal persons (3 cases), $p=0.2988$, 0.5177, 0.138 by student t test, respectively.

The normal people's samples were collected from healthy volunteers, while tumor patients and inflammation patients' samples were collected from Beijing Cancer Hospital and Xiamen First Hospital.

Example 6: The plasma Hsp90 α was secreted by tumor cells

Nude mice (purchased from Beijing Vital River Laboratory Animal Technology Co., Ltd.) with average body weight of 20 g were divided into two groups, 6 mice for each group. Each mouse was injected with 10^6 Hela cells (ATCC: CCL-2). Control group were normal mice without tumor. When the diameter of tumor reached 2 cm (about 20 days), blood was collected from eye veniplex. Hsp90 α antibody (rat mAb, Stressgen) that specifically recognizes human Hsp90 α but not mouse Hsp90 α was used to detect the plasma Hsp90 α . As shown in Fig.8, the plasma Hsp90 α in the tumor-bearing mice is specifically recognized by human but not mouse Hsp90 α antibody, which indicates that the plasma Hsp90 α was secreted by the xenograft tumor cells.

Example 7: The Hsp90 α secreted by tumor cells was C-terminally truncated.

Using Hsp90 α -pc3.1-Nhe1-For-Myc: GCTAGCTAGCGCCACCATGGA
ACAAAAACTCATCTCAGAAGAGGATCTGCCTGAGGAAACCCAGACCCAAGAC

5 (SEQ ID No.10) and Hsp90 α -pc3.1-Xho1-Re-nostop: CCCGCTCGA
GTGTCTACTTCTTCCATGCGTGATG (SEQ ID No.12) as primers (synthesized by
Invitrogen) and Pfu DNA polymerase (NEB) to amplify Hsp90 α from the template of
pQE80L-Hsp90 α (obtained in example 3). The products were digested and inserted into
pcDNA3.1/Myc-His(-) (Invitrogen) to obtain Hsp90 α with Myc tag at the N terminus, which
10 was named as Myc-H. Similarly, His-Myc-H with N-terminal tandem His-Myc tags was
amplified by Hsp90 α -pc3.1-Nhe1-For-His-Myc:
GCTAGCTAGCGCCACCATGCATCATCATCATCATGAACAAAACTCATCTCAG
AAGAGGATCTGCCTGAGGAAACCCAGACCCAAGAC (SEQ ID No.11) and SEQ ID
No.12 primers. These two plasmids were transiently transfected into MCF-7 to observe the
15 secretion of exogenous Hsp90 α . Antibodies against Hsp90 α , Myc and His were used to detect
the secreted Hsp90 α . The result shows that the secreted Hsp90 α was C-terminally truncated
(Fig.9A).

Using Myc-His-H as a template, the mutations of the final four amino acids (EEVD) of
Hsp90 α C-terminus was constructed. EE-> AA represents the mutation of two EE to two Ala
20 (using SEQ ID No.11 and Hsp90 α -EE- AA:
GGCCGCTCGAGTGTCTACTGCTGCCATGCGTGATGTG (SEQ ID No.13) as primers),
VD-> AA means that VD were mutated to two Ala (using SEQ ID No.11 and
Hsp90 α -VD-AA: GGCCGCTCGA GTTGCTGCTTCTTCCATGCGTGATGTG (SEQ ID
No.14) as primers). All Ala represents the mutation of EEVD to four Ala (using SEQ ID
25 No.11 and Hsp90 α -EEVD-AAAA: GGCCGCTCGAGTTGCTGCTGCTGCCATGCG
TGATGTG (SEQ ID No.15) as primers), Δ 4 represents the deletion of last EEVD four
amino acids (using SEQ ID No.11 and Hsp90 α - Δ 4-Xho:
CCGCTCGAGTCATGCGTGATGTGTCGTCATCTC (SEQ ID No.16) as primers). Human
breast cancer cell line MCF-7 was transiently transfected with these types of mutants to
30 observe the secretion of exogenous Hsp90 α (over-expressed Hsp90 α , which is different from
the endogenous one). The antibody against Hsp90 α was used to detect the changes of secreted

Hsp90 α in the extracellular medium. The results show that four C-terminal amino acid residues regulate the secretion of Hsp90 α . Any site-directed mutation or deletion of these four amino acid residues can lead to the secretion of Hsp90 α without C-terminal truncation, which suggests that four C-terminal amino acid residues EEVD are deleted in the secreted
 5 extracellular Hsp90 α (Figure 9B).

Example 8: Examination of the existing form of Hsp90 α in human plasma

We collected whole blood samples of liver cancer patients, which were centrifuged twice within 24 hours after collection, then detected Hsp90 α in plasma using the method of
 10 immunoprecipitation and immunoblotting. First, specific rabbit polyclonal antibody against Hsp90 α (Source: Labvision) was used for immunoprecipitation, and then a rabbit polyclonal antibody which can specifically recognize the Hsp90 α C-terminal four amino acid residues EEVD (lab stock, antigen used for immunization used is a carrier protein coupled with three-repeated peptides of EEVD, synthesized from the SBS Genetech Co., Ltd.) was used to
 15 detect Hsp90 α in plasma. As shown in Figure 10, the EEVD antibody specifically recognize Hsp90 α from whole cell lysate, but does not recognize Hsp90 α in plasma, which indicates that intracellular Hsp90 α is different from plasma Hsp90 α , which lacks the four C-terminal amino acid residues EEVD. (Figure 10).

Example 9: Detection of the phosphorylated form of Hsp90 α in plasma

Whole blood samples of the liver cancer patients were centrifuged twice to extract the plasma within 24 hours after collection. Then Hsp90 α in plasma was detected using the method of immunoprecipitation and immunoblotting. First, specific rabbit polyclonal antibody against Hsp90 α (Source: Labvision) was used to immunoprecipitate plasma Hsp90 α ,
 25 then an antibody (Rabbit anti-phospho-(Ser/Thr) PKA substrate pAb, Cell signaling) which can specifically recognize the Thr90 phosphorylated Hsp90 was used to detect the Thr90 phosphorylation status of plasma Hsp90. As shown in Figure 11, the Hsp90 α in plasma is Thr90 phosphorylated.

Example 10: Detect the concentration of Thr90 phosphorylated Hsp90 in plasma

Whole blood samples of both liver cancer patients and normal people were centrifuged

twice to extract the plasma within 24 hours after collection . The relative level of Hsp90 α in the plasma was detected using the method of sandwich ELISA. Protocol: firstly, using self-made rabbit polyclonal antibody S2 to coat the plate overnight at 4 $^{\circ}$ C, then added 10-fold diluted plasma samples at 100 μ l per well. After incubation at 37 $^{\circ}$ C for 2 hours, antibody which can specifically recognize the Thr90 phosphorylated Hsp90 α (cell signal) was added. The plate is incubated at 37 $^{\circ}$ C for 2 hours; and then horseradish peroxidase conjugated goat anti-rabbit secondary antibodies were added and incubated for 1 hour. Finally o-phenylenediamine was added to detect the absorption at OD490nm. The results show that the levels of Hsp90 α in liver cancer patients are higher than those of normal people, P=0.003, Student t test, which indicates that the level of Thr90 phosphorylated Hsp90 is increased in liver cancer patients (Figure 12).

Example 11: Detection of the consistency of the Thr90 phosphorylated Hsp90 level in plasma and the total Hsp90 α content.

The levels of the Thr90 phosphorylated Hsp90 and the total amount of Hsp90 α in liver cancer patients plasma (8 cases) were detected. The method to detect the total amount of plasma Hsp90 α was the same as that used in example 5; the method to detect the level of Thr90 phosphorylated Hsp90 was the same as that used in example 10. The results show that the level of Thr90 phosphorylated plasma Hsp90 is consistent with the total amount of plasma Hsp90 α , which further indicates that the phosphorylation of plasma Hsp90 α is on Thr90, and the increment of the total amount of Hsp90 α can represent the increment of Thr90 phosphorylated Hsp90 α (Figure 13).

Example 12: The phosphorylation of Thr90 is necessary for the secretion of Hsp90 α

Using pcDNA3.1-Myc-His-Hsp90 α plasmid as the template (Also known as wild-type Hsp90 α (WT Hsp90 α)), mutant Hsp90 α (T90A, threonine mutated to alanine) was constructed by quickchange PCR using the following primers: Hsp90 α -T89A-Sense: GATCGAACTCTTGCAATTGTGGATACTGGAATTGGAATG (SEQ ID No.17) and Hsp90 α -T89-AntiSense: CATTCGAATTCCAGTATCCACAATTGCAAGAGT TCGATC (SEQ ID No.18). T90A Hsp90 α mutant can not be phosphorylated at Thr90. Human breast cancer cell line MCF-7 (purchased from ATCC, No. HTB-22) was transfected with

wild-type Hsp90 α (WT) or mutant Hsp90 α (T90A). The medium was then collected and the secretion of exogenous Hsp90 α was detected by anti-Hsp90 α antibody.

The results show that overexpressed exogenous wild-type Hsp90 α can be detected in the extracellular medium, while the T90A mutant can not be detected, which indicates that phosphorylation at residue Thr90 is a prerequisite for Hsp90 α secretion.(Figure 14).

Example 13: PP5 is responsible for the dephosphorylation of pT90-Hsp90 α

The preparation of the Thr90 phosphorylated Hsp90 α (pT90-Hsp90 α): The recombinant human Hsp90 α protein and recombinant protein kinase A (Promega Corporation USA) were incubated in a reaction buffer (NEB UK company) at 30 °C for 1 h, then pT90-Hsp90 α protein was purified. After removing free phosphate by dialysis , the purified pT90-Hsp90 α protein mixed with recombinant human PP5 protein were incubated at 30 °C, the free phosphate released from the pT90-Hsp90 α was detected using the non-radioactive serine/threonine phosphatase assay kit (Promega Corporation USA). Peptide substrate is a composition of the kit and was used as the positive control. As shown in Figure 15A, when PP5 was incubated with the peptide substrate, the release of free phosphate was significantly increased, P value <0.005, Student t test, indicating that PP5 can directly dephosphorylate the peptide substrate (positive control). However, when PP5 was incubated with pT90-Hsp90 α protein, the release of free phosphate was also significantly increased, P value <0.005, Student t test, indicating that PP5 can directly dephosphorylate pT90-Hsp90 α .

The nucleotide sequence of PP5 (SEQ ID No.6) was amplified from human liver cDNA library and constructed into the pcDNA3.1/Myc-His (-) (vector source: Invitrogen). The PP5 vector was transfected into and overexpressed in human breast cancer cell line MCF-7. On the other side, using the RNA interference technology, the expression of PP5 can also be knocked down using the siRNA with the sequence of 5'-ACTCGAACACCTCGCTAAAGAGCTC-3' (SEQ ID No.7) (synthesized by Invitrogen). Then the status of Hsp90 α Thr90 phosphorylation was examined with the overexpression or knock down of PP5. As shown in Figure 15B, with overexpression of human PP5, the Thr90 phosphorylated Hsp90 α (pT90-Hsp90 α) was significantly reduced (0.55 of the control). When the expression of human PP5 was suppressed, the Thr90 phosphorylated Hsp90 α (pT90-Hsp90 α) was significantly increased (1.58 of the control).

Example 14: Regulation of the secretion of Hsp90 α by promoting or inhibiting the expression of PP5

PP5 can dephosphorylate Thr90 phosphorylated Hsp90 α . Primers as follows were used to amplify PP5 from human liver cDNA library: PP5-NheI-For: CTAGCTAGCATGTACCCATACGACGTCCCAGACTACGCT (SEQ ID No.19) and PP5-XhoI-Re: CCGCTCGAGTTAATGATGATGATGATG ATGCACGTGTACC (SEQ ID No.20). The full length human PP5 was cloned into pcDNA3.1/Myc-His (-) (vector source: Invitrogen). Human breast cancer cell line MCF-7 was transfected with PP5 vector, then the secretion of Hsp90 α from the cells was examined. The results showed that after overexpression of human PP5, the secretion of Hsp90 α was significantly decreased (Figure 16A).

On the other side, when the expression of human PP5 in MCF-7 cells was knocked down by RNA interference (against human PP5, Invitrogen), the secretion of Hsp90 α was significantly increase (Figure 16B).

Example 15: The level of PP5 and the tumor malignancy

The relationship between the expression level of PP5 and the secretion of Hsp90 α was examined in human breast cancer cell lines MCF-7, SKBR3, MDA-MB-453, 435s and 231 (ATCC, number, respectively HTB-22, -30, -131, -129, and HTB-26) using the method of Western blotting. MCF-7, SKBR3 breast cancer cell lines are less malignant cell lines. In the nude mice tumor model, these two cell lines can form primary tumors, but do not metastasize. MDA-MB-453, 435s and 231 are more malignant, They can not only form primary tumors, but also metastasize to distant organs in the nude mice tumor models. Thus MDA-MB-435s and 231 are often used to establish tumor metastasis models. In Figure 17, secretion levels of Hsp90 α by these five breast cancer cell lines correlate with their malignancy.

The results show that the cells, which express high level of PP5, secrete low level of Hsp90 α ; whereas cells with low expression of PP5 can secrete more Hsp90 α (Figure 17). Meanwhile, the results also show that the level of secreted Hsp90 α is positively correlated, whereas the expression level of PP5 is negatively correlated with the tumor malignancy (Figure 17). The level of secreted Hsp90 α and its regulatory factors such as PP5 can be used to

determine the tumor malignancy.

Example 16: The expression level of PP5 is linked to tumor invasiveness

The wound healing model was employed to examine the relationship between the expression level of PP5 and tumor cell migration.

Human breast cancer cell line MCF-7 was transfected with human PP5 vector or PP5 siRNA. Then the cells were inoculated into 12-well plate. When the cells grew to confluence, pippete tips were used to scrape cells to form a "wound". The scraped cells were washed away, and the rest part of cells were cultured in fresh DMEM medium (GIBCO) at 37 °C in an incubator with 5% of CO₂. The images of the "wound" at the time of 0 h, 12 h, and 24 h were captured (Figure 18A). The effect of PP5 expression on cell migration was examined by analyzing the "wound" healing rate. The results show that overexpression of PP5 inhibits MCF-7 cell migration, while PP5 siRNA can promote MCF-7 cell migration (Figure 18B).

Example 17: The effect of plasma Hsp90α specific antibodies on tumor cell migration

The wound healing model was used to detect the effect of plasma Hsp90α specific antibody on tumor cell migration.

MCF-7 or MDA-MB-231 cells (ATCC, No. HTB-22, respectively, and HTB-26) were inoculated into 12-well plate. When the cells grow to confluence, pippete tips were used to scrape cells to form a "wound". The scraped cells were washed away, and the rest part of cells were moved into fresh DMEM medium (GIBCO). Meanwhile, E9 (20 μg/ml), the specific mouse monoclonal antibody against Hsp90α, or control IgG (20 μg/ml) was added. Then the plate was incubated at 37 °C, with 5% CO₂. Images of the "wound" after 0 h, 6 h, 12 h, 24 h, 48 h, and 72 h of incubation were captured (Figure 18A). The effect of plasma Hsp90 specific antibodies on tumor cells migration was examined by monitoring the "wound" healing rate. As shown in Figure 19, the specific antibody against plasma Hsp90α can significantly inhibit the migration of both MDA-MB-231 (Figure 19A) and MCF-7 (Figure 19B) (Inhibitory activity>40%).

Example 18: Detect the effect of plasma Hsp90α specific antibody on tumor metastasis

Nude mice with an average body weight of 20 g were purchased from Beijing Vital River

Laboratory Animal Technology Co., Ltd. B16/F10 mouse melanoma cells (ATCC, number: CRL-6475) (2×10^5) were injected into the mice *via* tail vein. Next day the mice were randomly divided into two groups ($n = 8$): the control group (IgG was administered) and the Hsp90 α Ab (mouse monoclonal antibody E9) treated group. The antibodies were administered
5 once every other day with a dosage of 40 μ g/mouse/time. Metastasis was detected 15 days after inoculation. As shown in Figure 20, the specific antibody against plasma Hsp90 α can completely inhibit the lymph node metastasis of B16/F10 cells (A), and 56% of the lung metastasis can be inhibited (B).

We claim:

1. An isolated polypeptide consisting of the amino acid sequence of SEQ ID No.1.
2. The polypeptide according to claim 1, wherein one or more amino acid residues in the amino acid sequence of SEQ ID No.1 selected from the group consisting of Thr90, Ser231, Ser263, Tyr309 and a combination thereof are phosphorylated.
3. The polypeptide according to claim 2, wherein the Thr90 is phosphorylated.
4. A method of determining the presence and/or metastasis of a cancer in a subject comprising the step of detecting the level of a polypeptide consisting of the amino acid sequence of SEQ ID No.1 in a plasma sample of the subject by using an antibody specifically binding to a polypeptide of anyone of claim 1-3, wherein an elevated plasma level of SEQ ID NO:1 in the subject compared with normal controls indicates the presence of cancer, an elevated plasma level of SEQ ID NO:1 in the subject with known cancer indicates the presence of cancer metastasis.
5. A method of screening the presence of a cancer in a high-risk population comprising the step of detecting the level of a polypeptide consisting of the amino acid sequence of SEQ ID No.1 in a plasma sample by using an antibody specifically binding to a polypeptide of any one of claim 1-3, wherein an elevated plasma level of SEQ ID NO:1 in the subject compared with normal controls indicates the presence of cancer.
6. A method of determining the prognosis of a patient having a cancer comprising the step of detecting the level of a polypeptide consisting of the amino acid sequence of SEQ ID No.1 in a plasma sample of the patient by using an antibody specifically binding to a polypeptide of any one of claim 1-3, wherein a maintained or elevated plasma level of SEQ ID NO:1 compared with normal controls in a cancer patient indicates poor prognosis.
7. A method of determining the efficiency of a surgery, radiotherapy or chemotherapy treatment to a patient having a cancer comprising the step of detecting the level of a

polypeptide consisting of the amino acid sequence of SEQ ID No.1 in a plasma sample of the patient by using an antibody specifically binding to a polypeptide of any one of claim 1-3, wherein a maintained or elevated plasma level of SEQ ID NO:1 in a cancer patient compared with normal controls indicates ineffective cancer treatment.

8. The method according to any one of claims 4-7, wherein the cancer is lung cancer, liver cancer, pancreatic cancer, breast cancer, or cervical carcinoma.

9. The method according to any one of claims 4-7, wherein the antibody is a monoclonal antibody or an antigen binding fragment thereof.

10. The method according to claim 9, wherein the antigen-binding fragment is selected from scFv、 Fab、 Fab' and F(ab')₂.

11. The method according to claim 9, wherein the antibody is MAb E9 or D10 produced by the cell line deposited under CGMCC No. 2903 or 2904, respectively.

12. The method according to any one of claims 4-7, wherein the antibody specifically binds to the polypeptide present in plasma.

13. The method according to any one of claims 4-7, wherein the antibody specifically binds to a phosphorylated form of the polypeptide, said phosphorylated form of the polypeptide contains one or more phosphorylated amino acid residues in the amino acid sequence of SEQ ID No.1 wherein the one or more phosphorylated amino acid residues are Thr90, Ser231, Ser263, Tyr309 or a combination thereof.

14. The method according to claim 13, wherein the antibody specifically binds to the polypeptide which is phosphorylated at Thr90.

15. Use of an antibody specifically binding to a polypeptide of any one of claims 1-3 in preparation of a medicament for preventing or treating cancer metastasis.

16. The use according to claim 15, wherein the antibody is a specific antibody against a polypeptide consisting of the amino acid sequence of SEQ ID No.1.
17. The use according to claim 16, wherein the antibody is a humanized antibody or an antigen binding fragment thereof.
18. The use according to claim 16, wherein the antibody specifically binds to a phosphorylated form of the polypeptide, said phosphorylated form of the polypeptide contains one or more phosphorylated amino acid residues in the amino acid sequence of SEQ ID No.1 wherein the one or more phosphorylated amino acid residues are Thr90, Ser231, Ser263, Tyr309 or a combination thereof.
19. The use according to claim 18, wherein the antibody specifically binds to the polypeptide which is phosphorylated at Thr90.
20. The use according to claim 16, wherein the antibody is MAbs E9 or D10 produced by the cell line deposited under CGMCC No. 2903 or 2904, respectively.
21. The use according to any one of claims 16-20, wherein the cancer is lung cancer, liver cancer, pancreatic cancer, breast cancer, or cervical carcinoma.

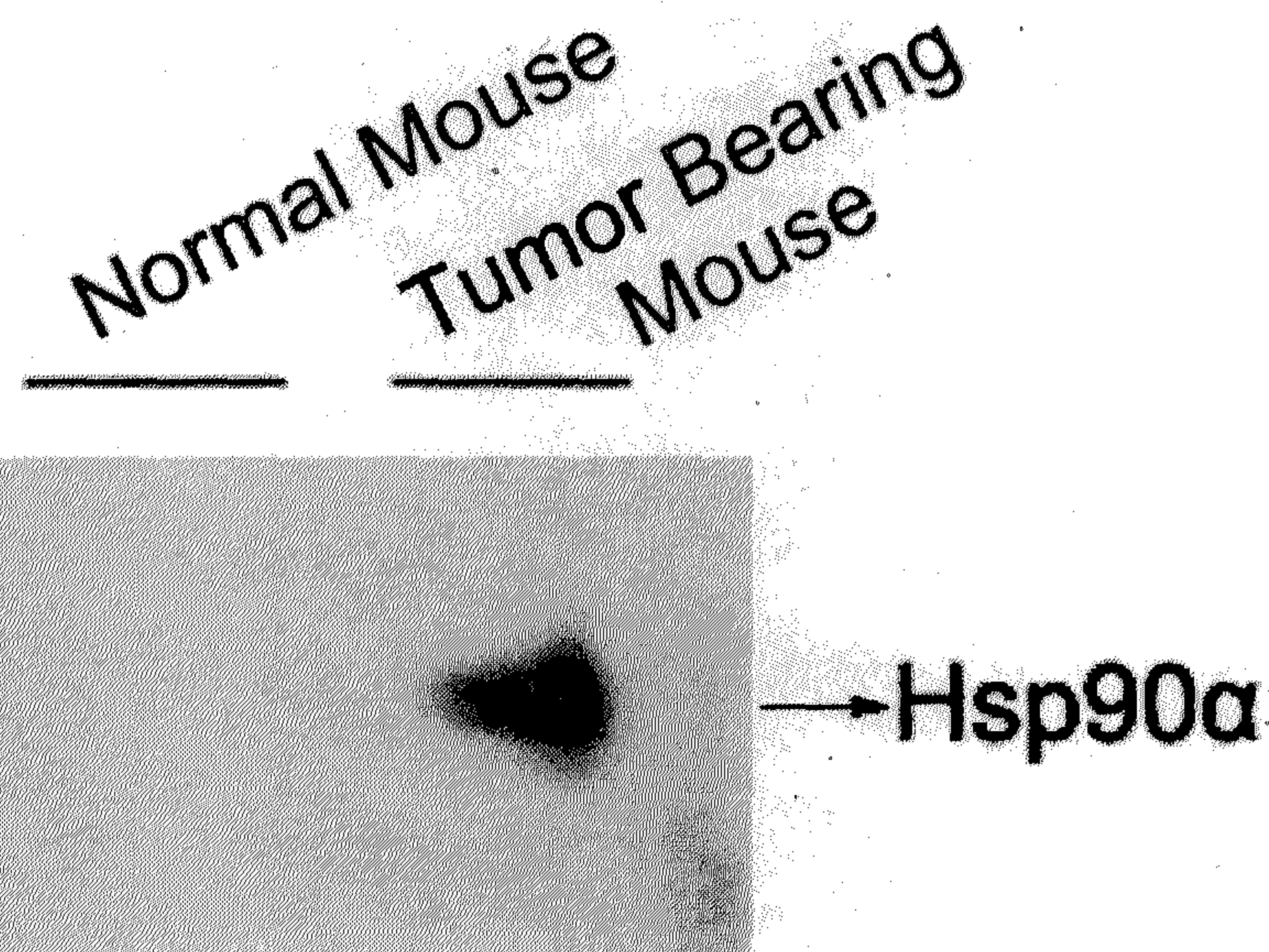


Fig. 1

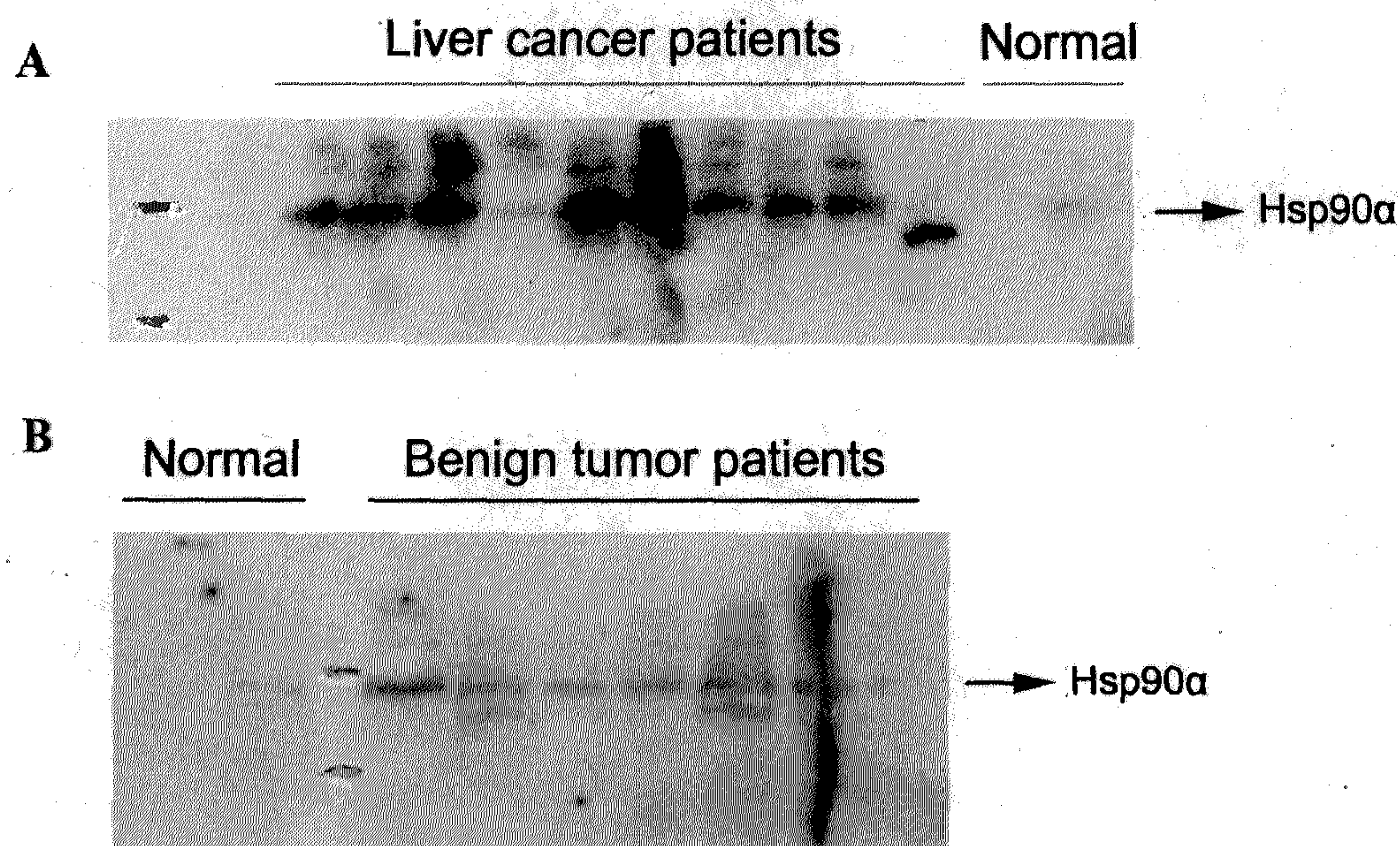


Fig. 2

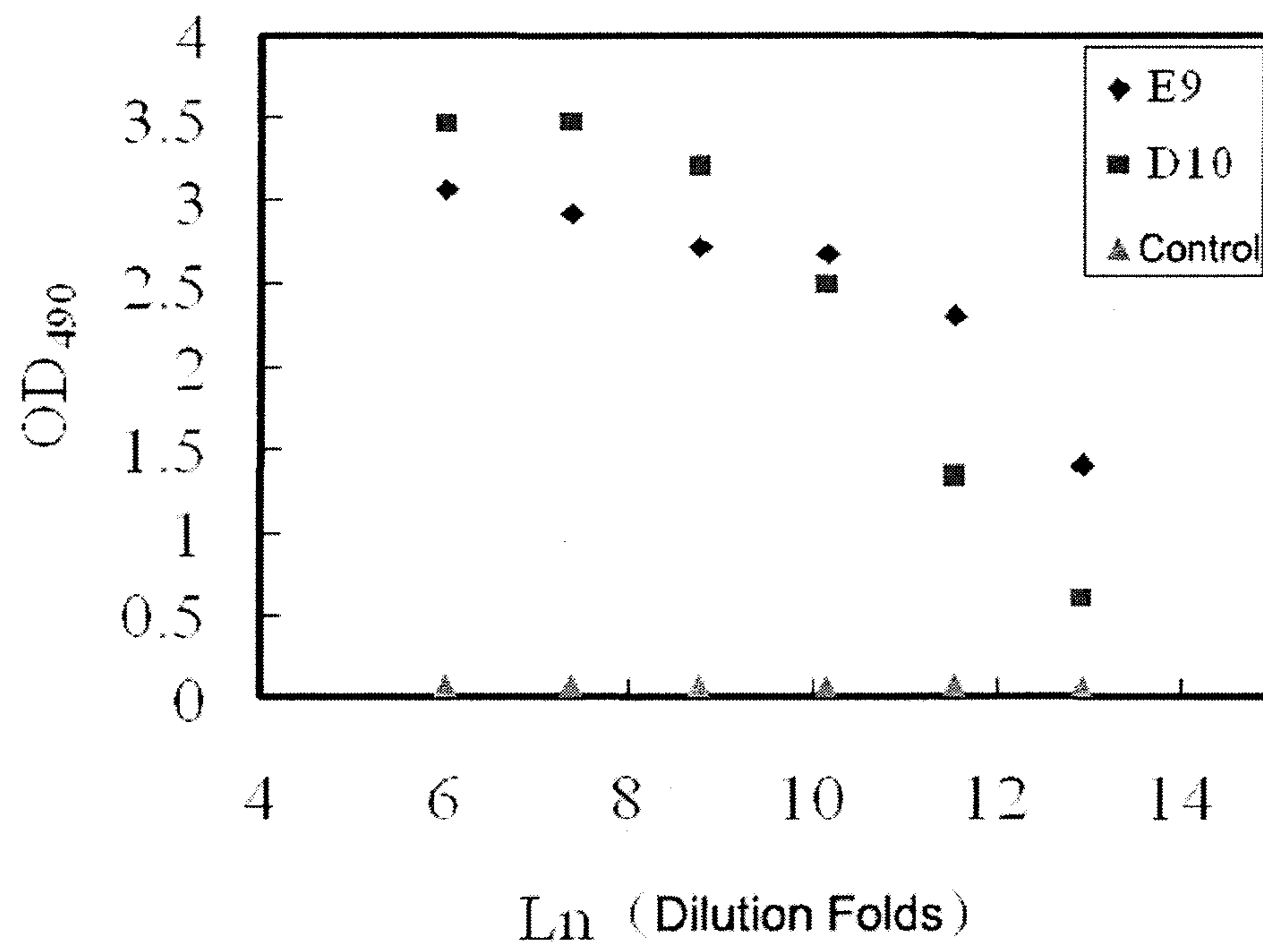


Fig. 3

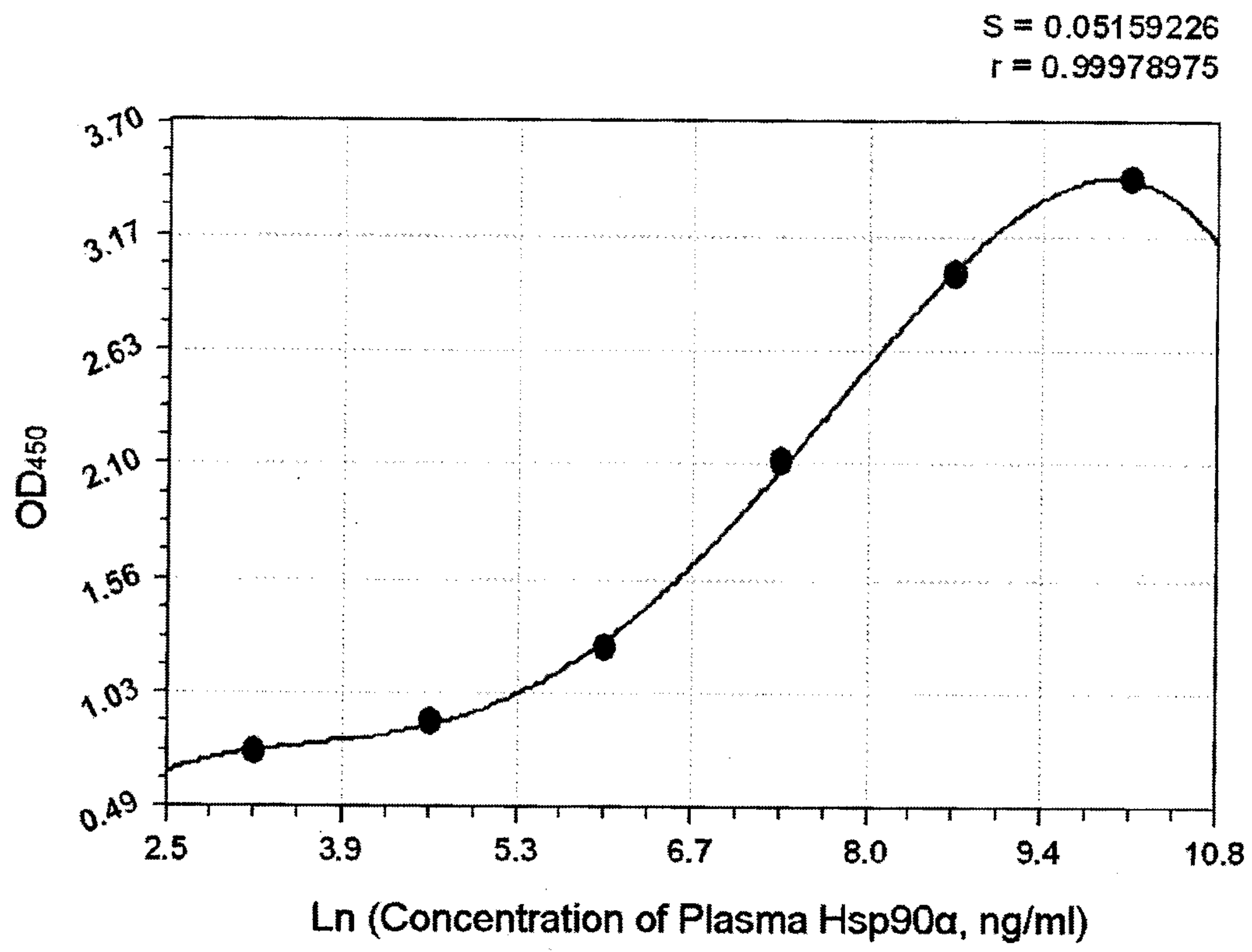


Fig. 4

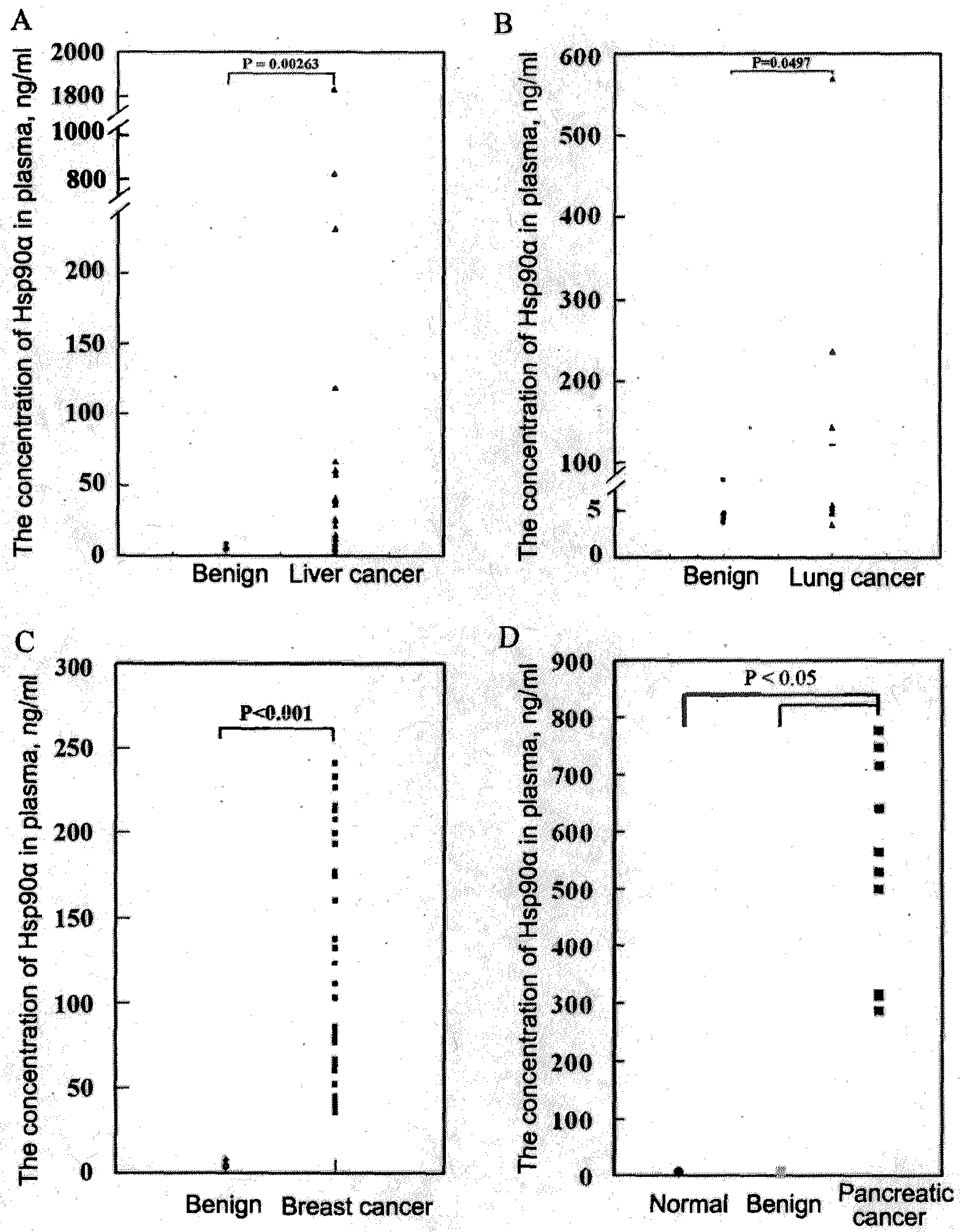


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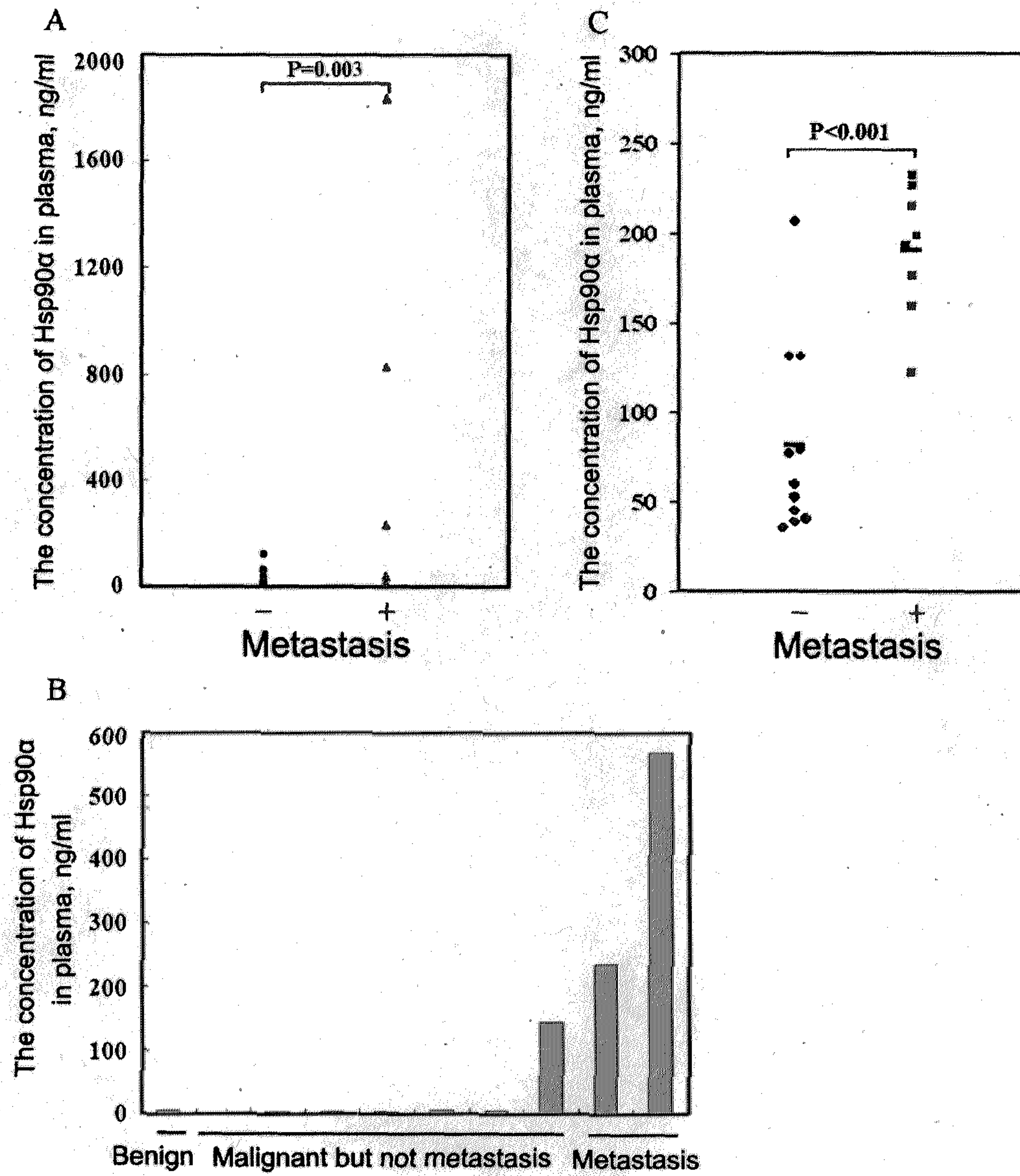


Fig. 6

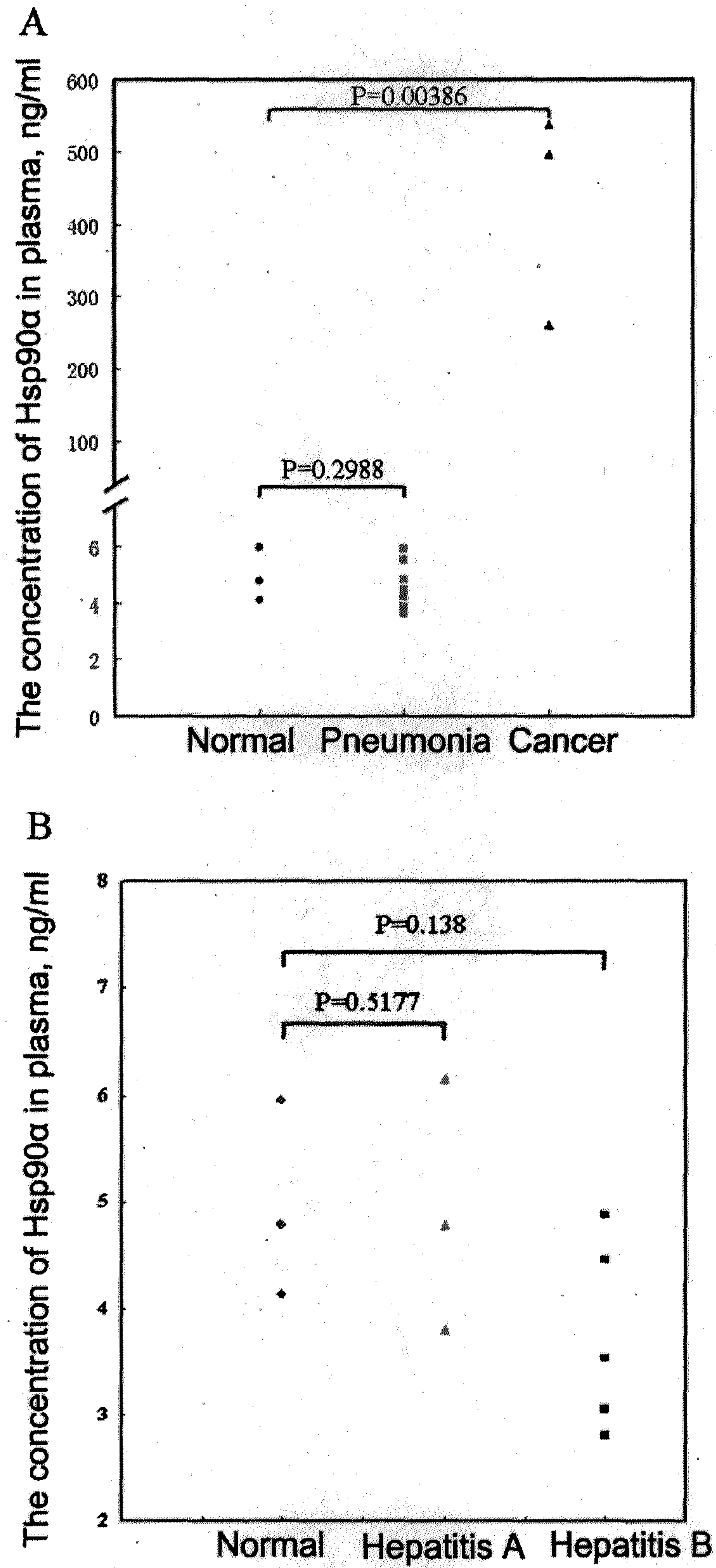


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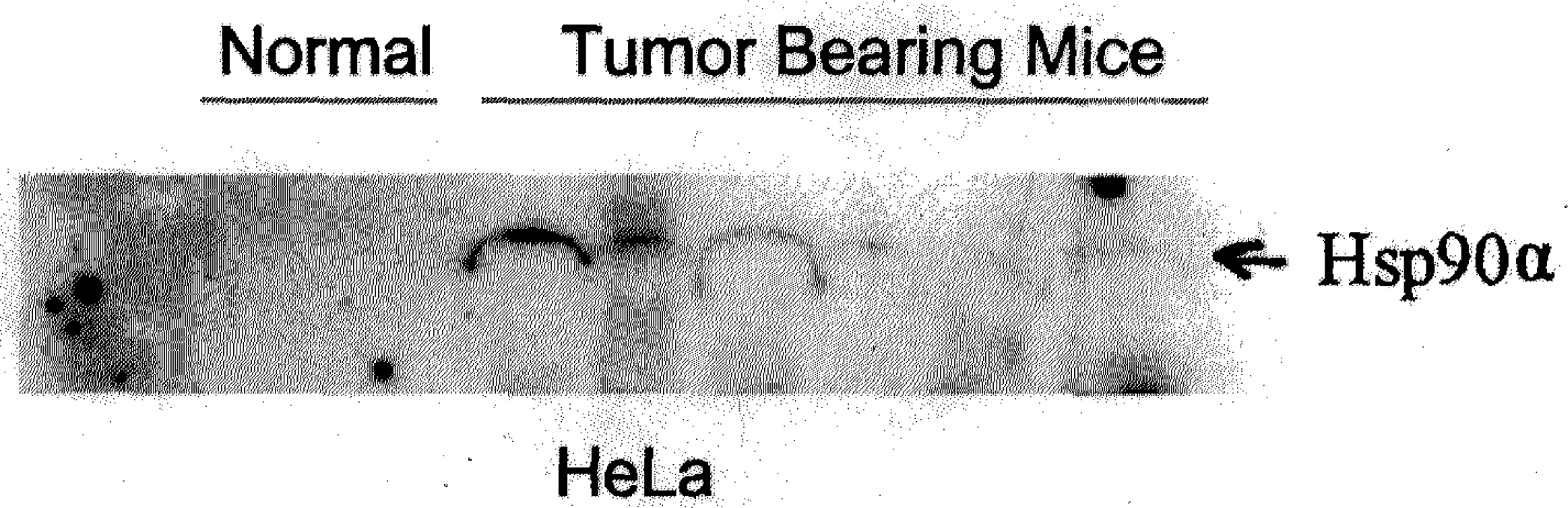


Fig. 8

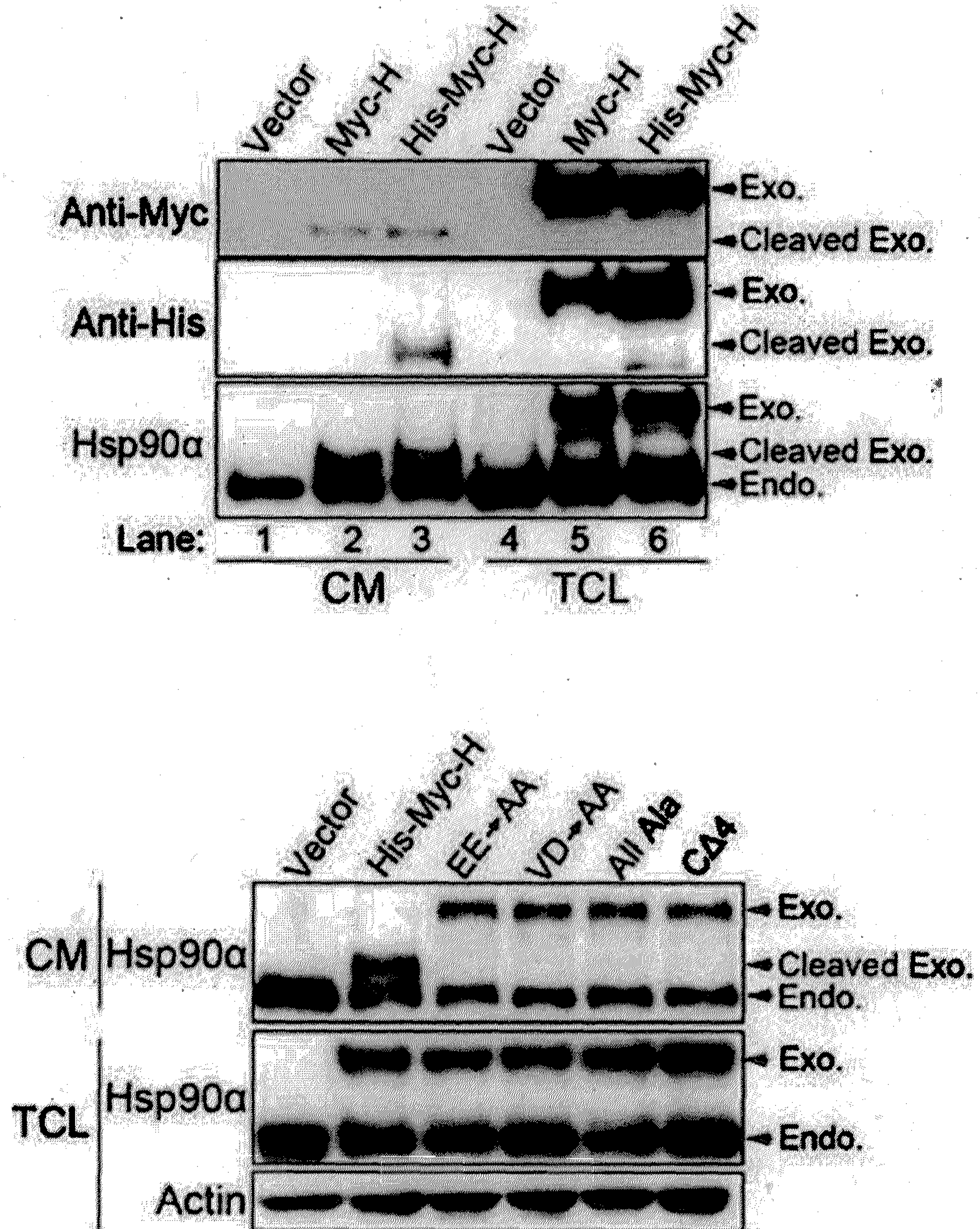


Fig. 9

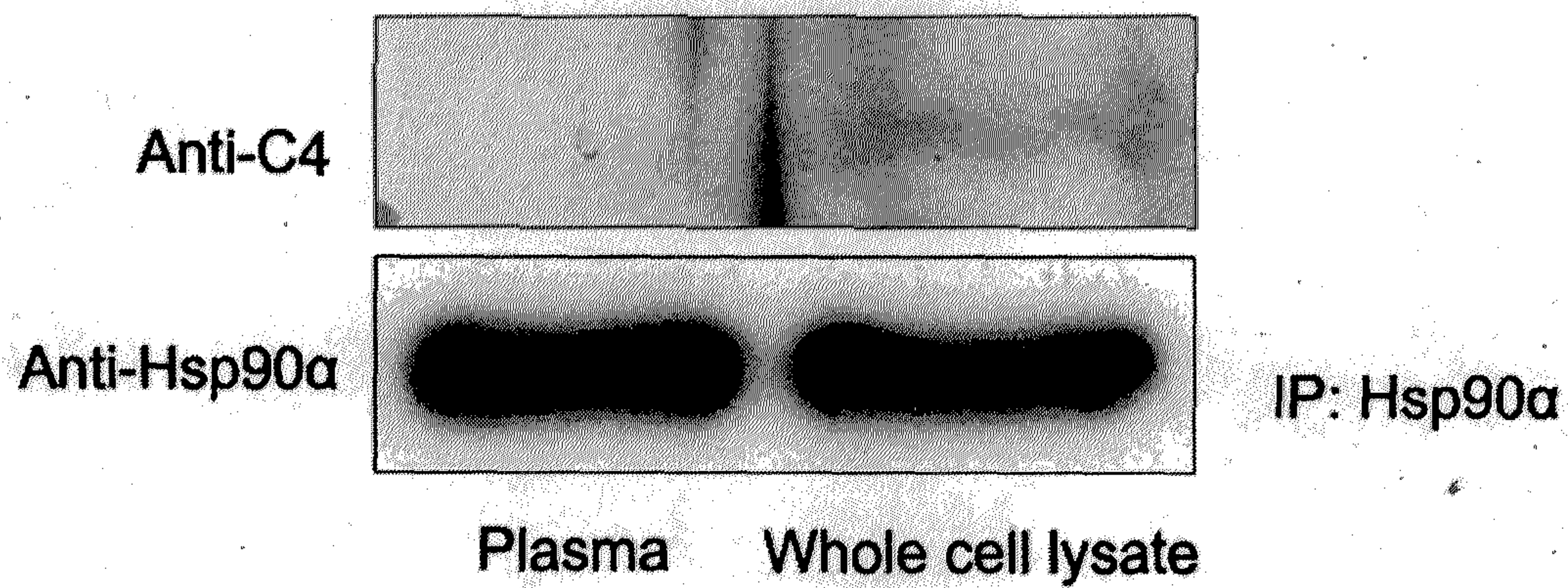


Fig. 10

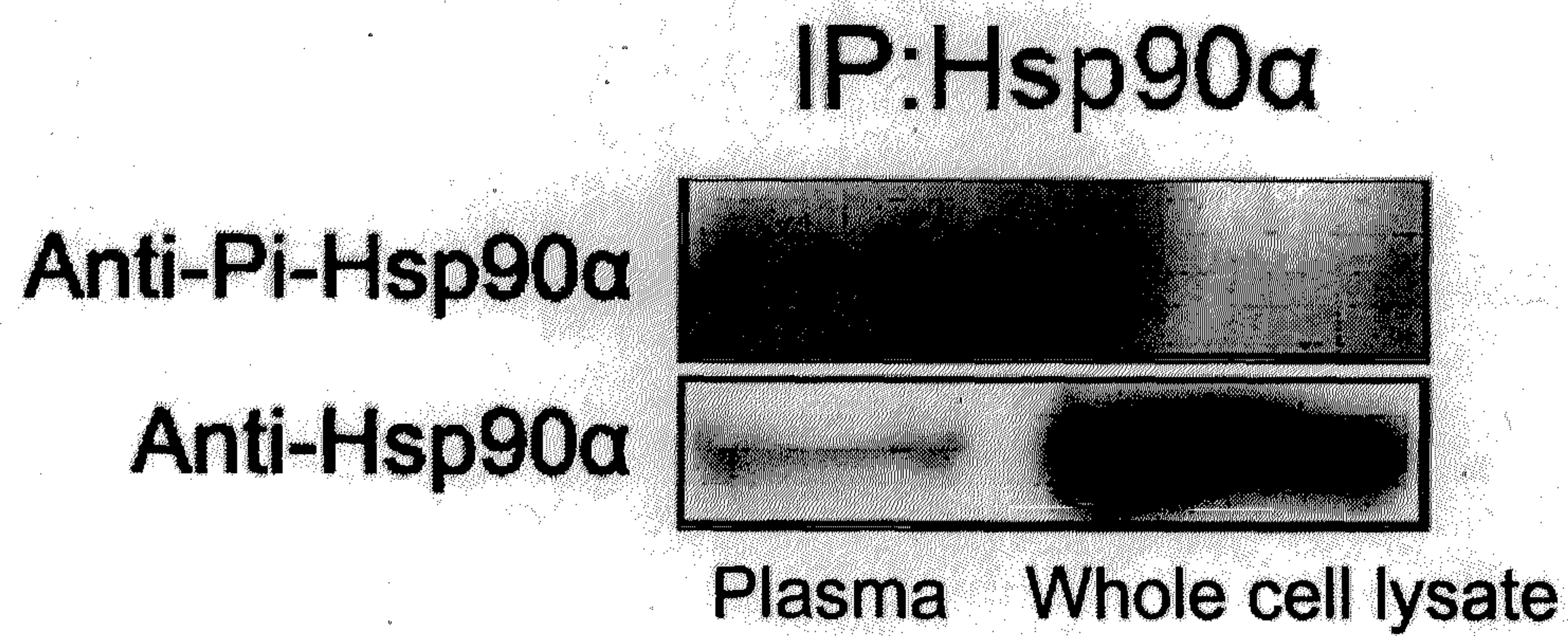


Fig. 11

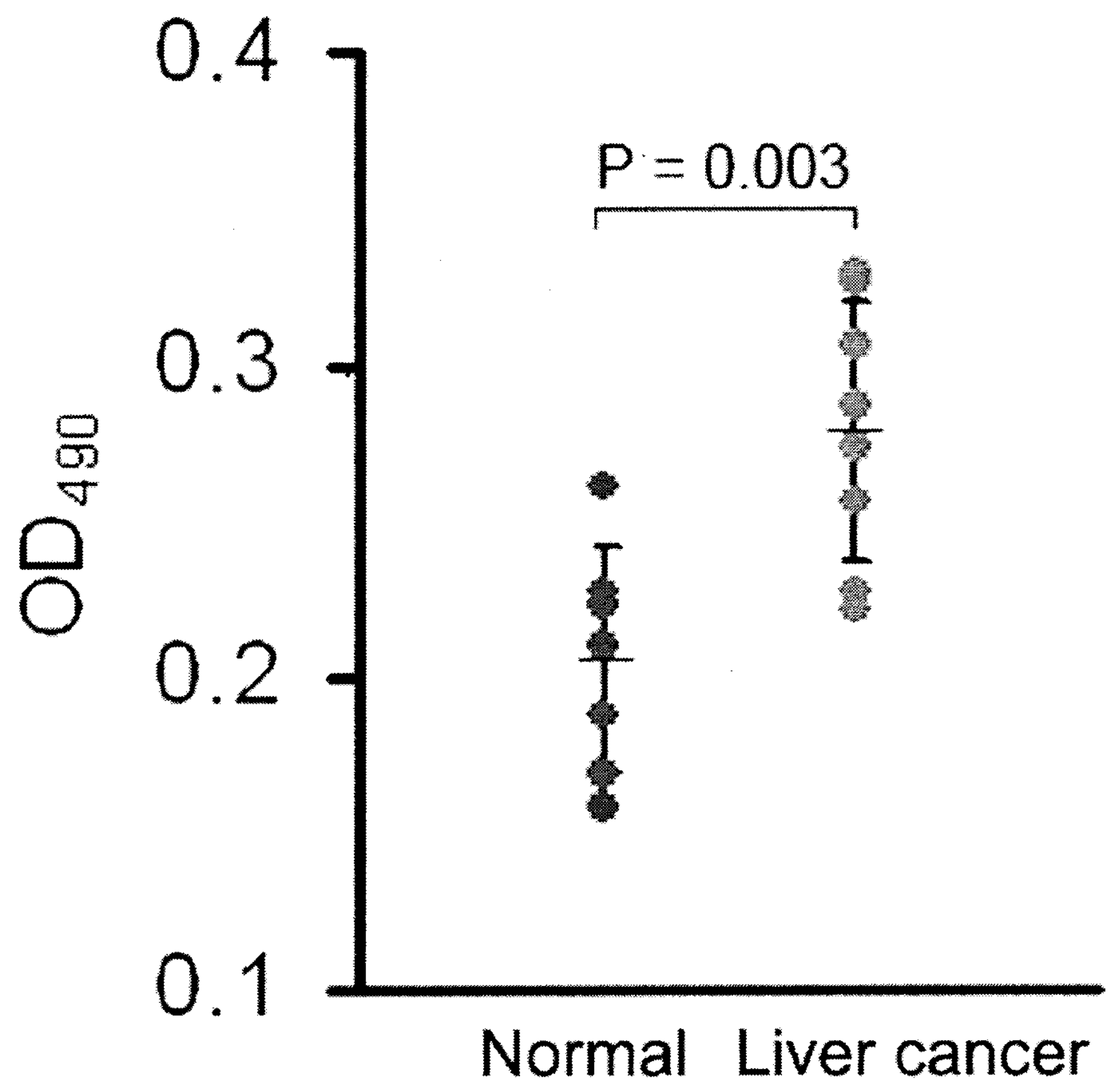


Fig. 12

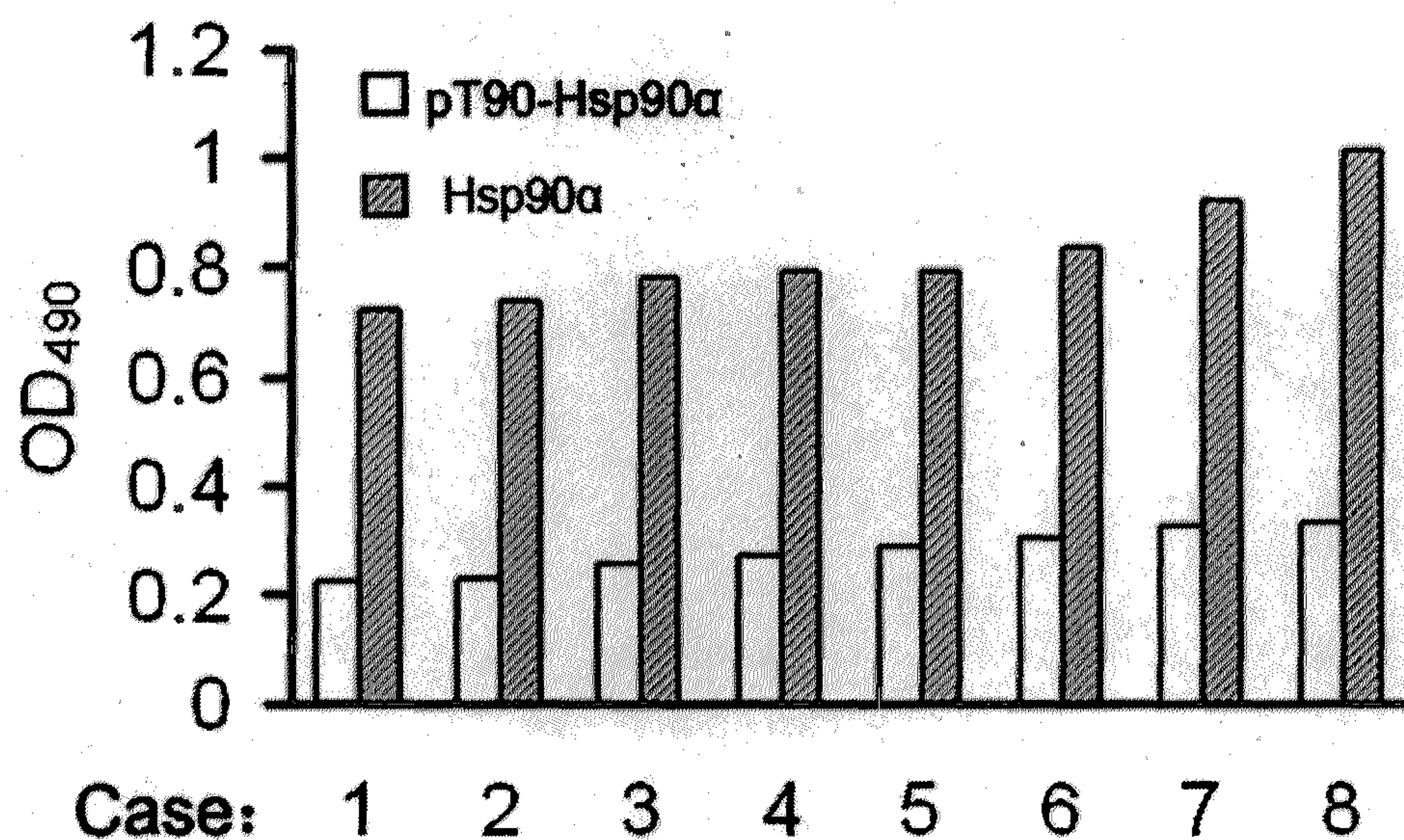


Fig. 13

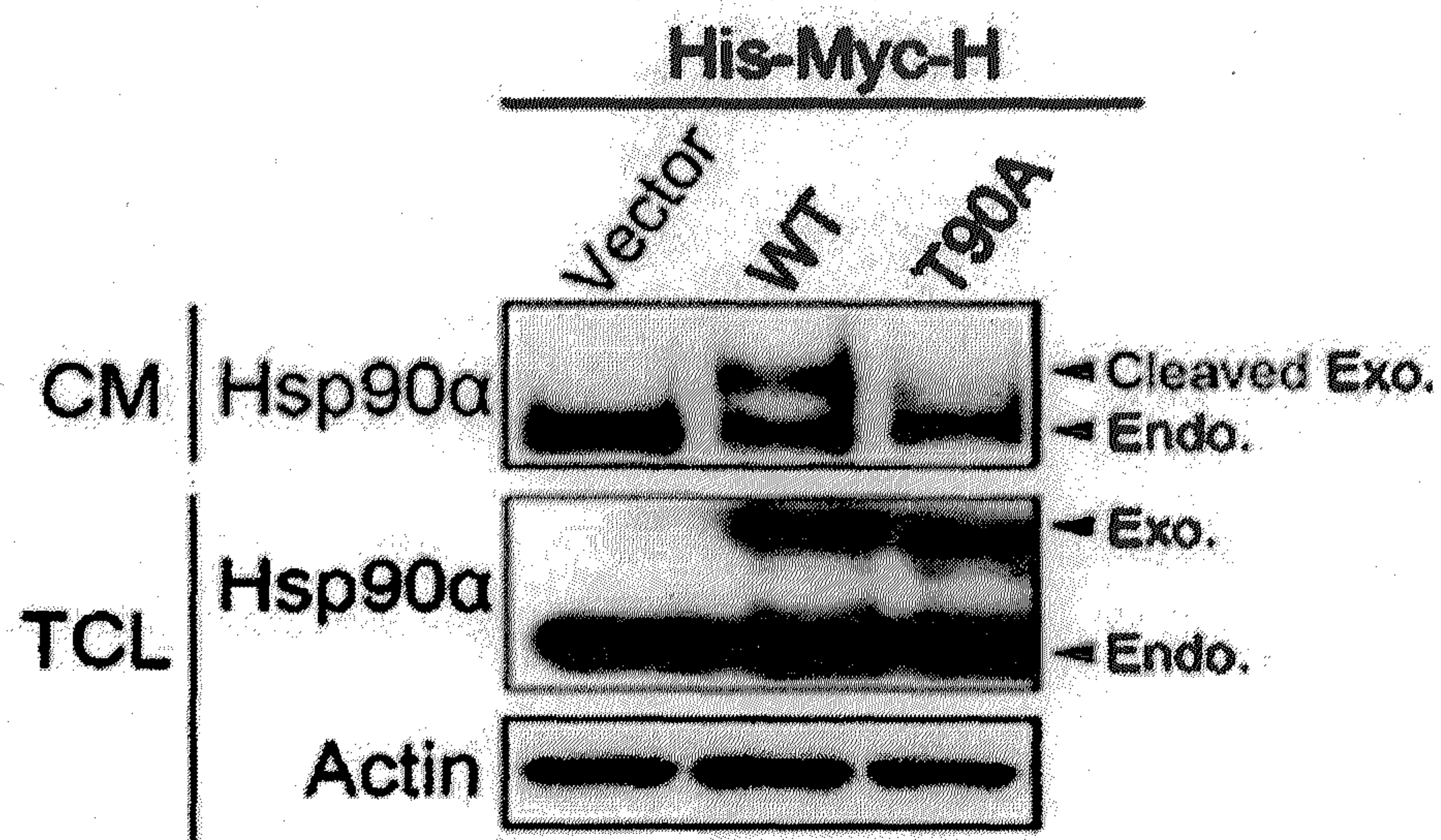
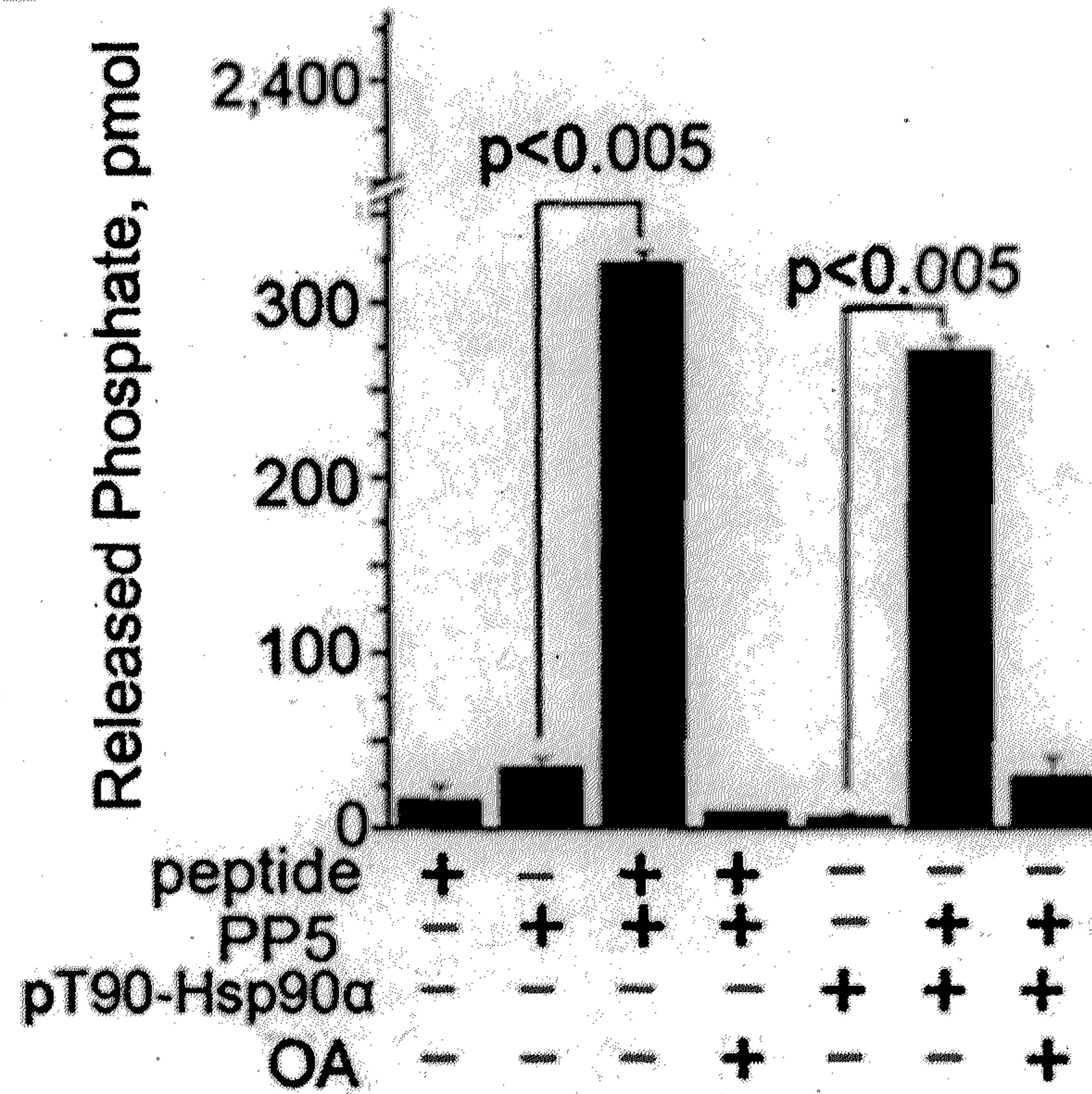


Fig. 14

A



B

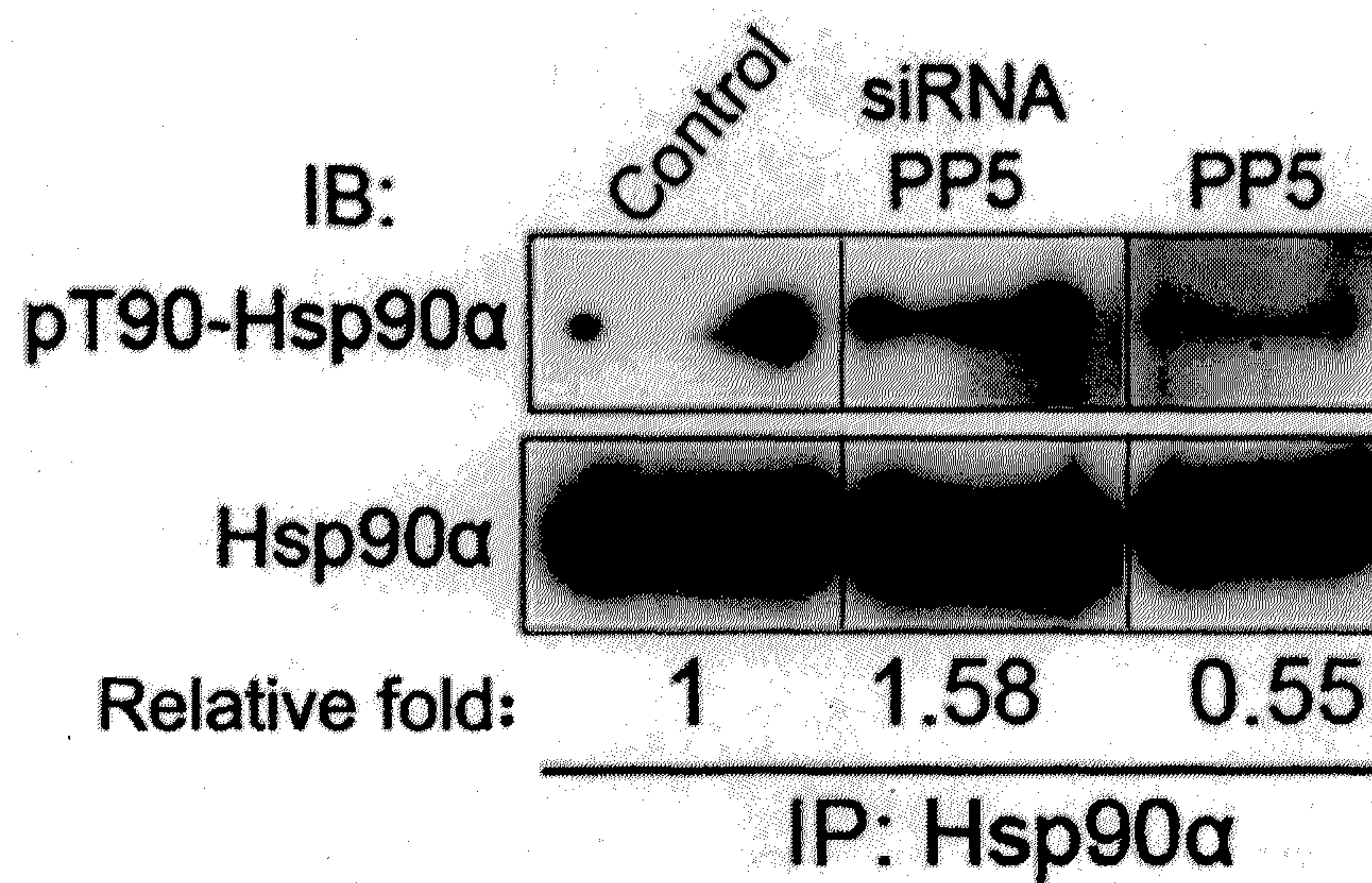
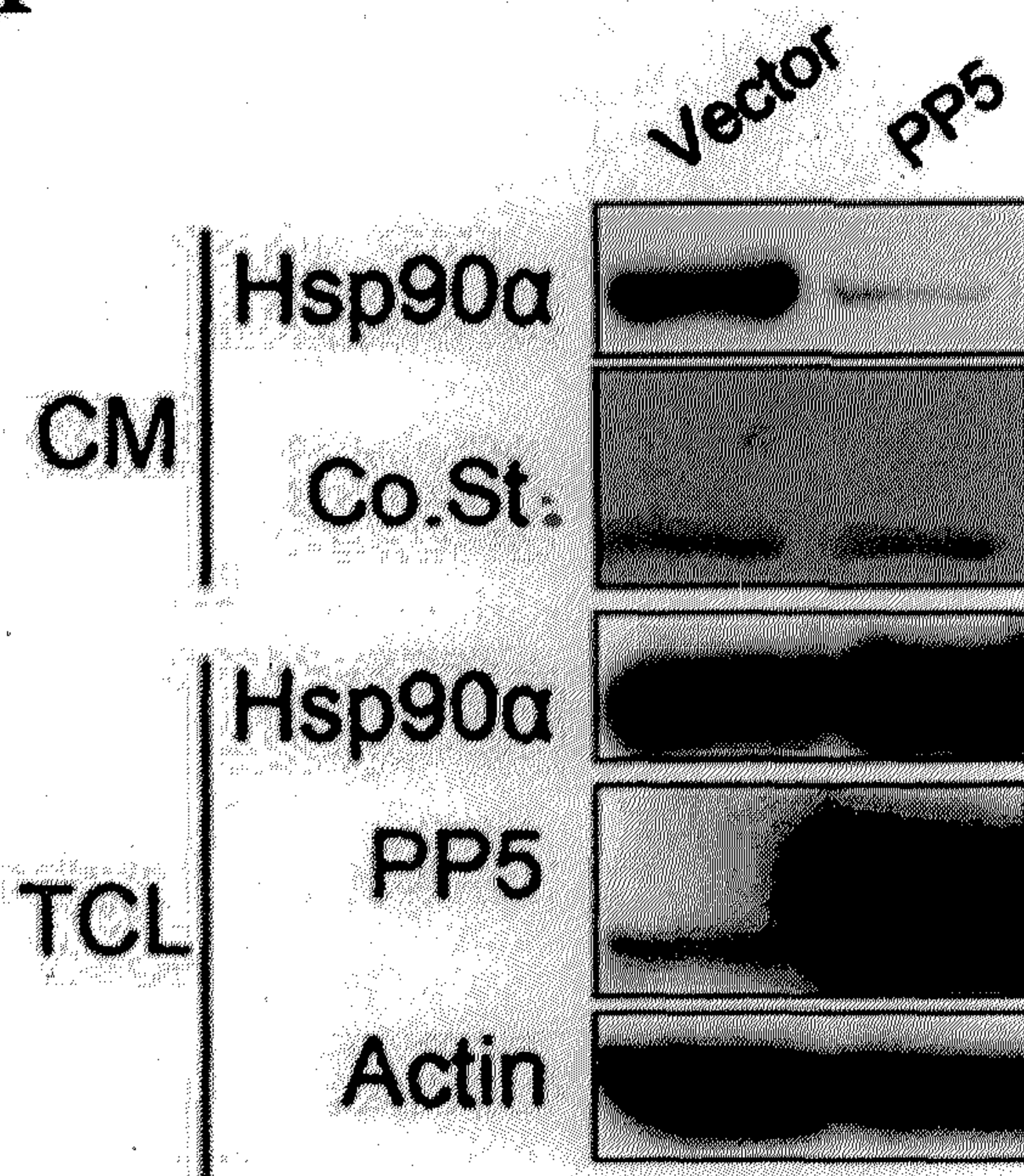


Fig. 15

A



B

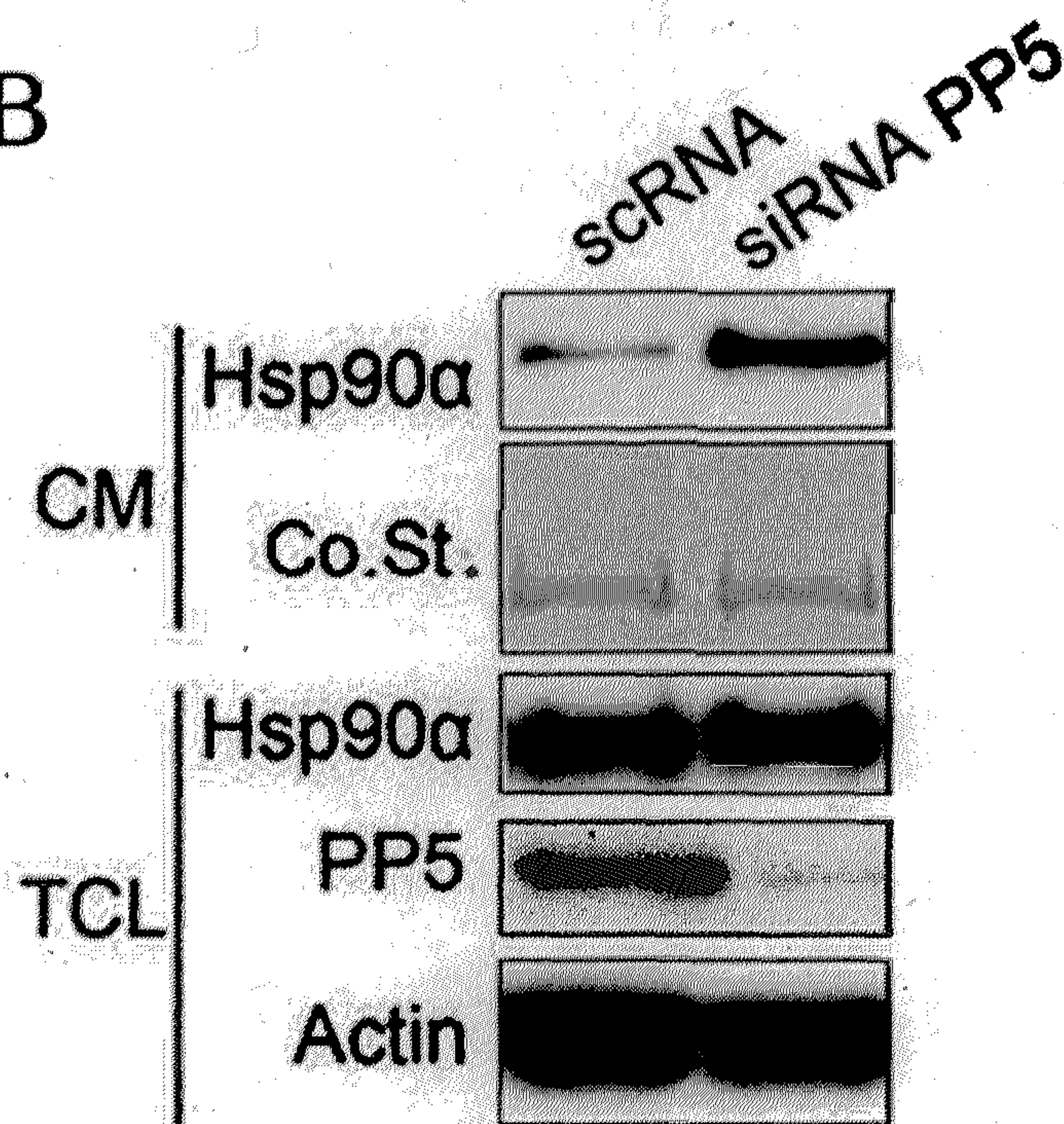


Fig. 16

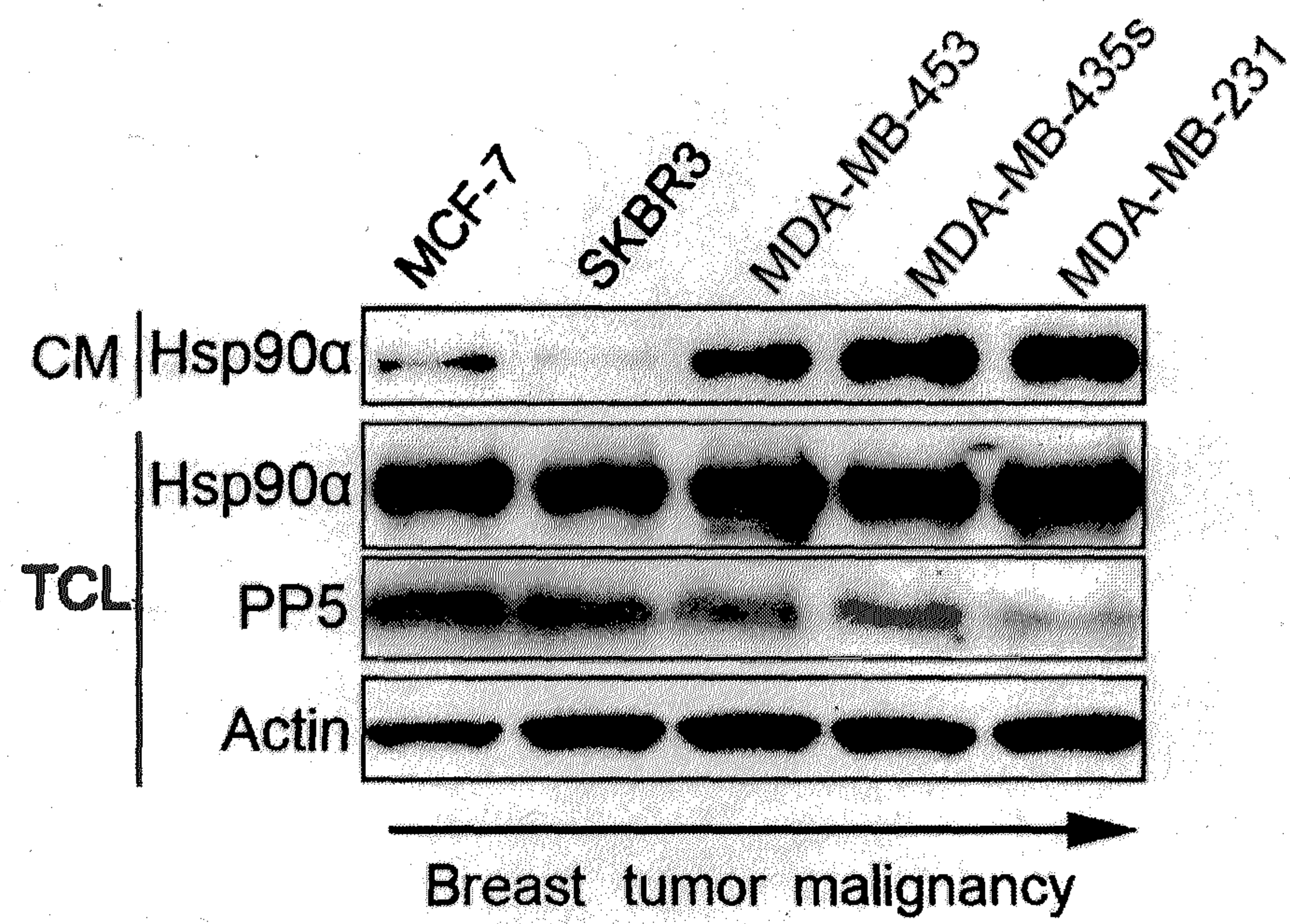


Fig. 17

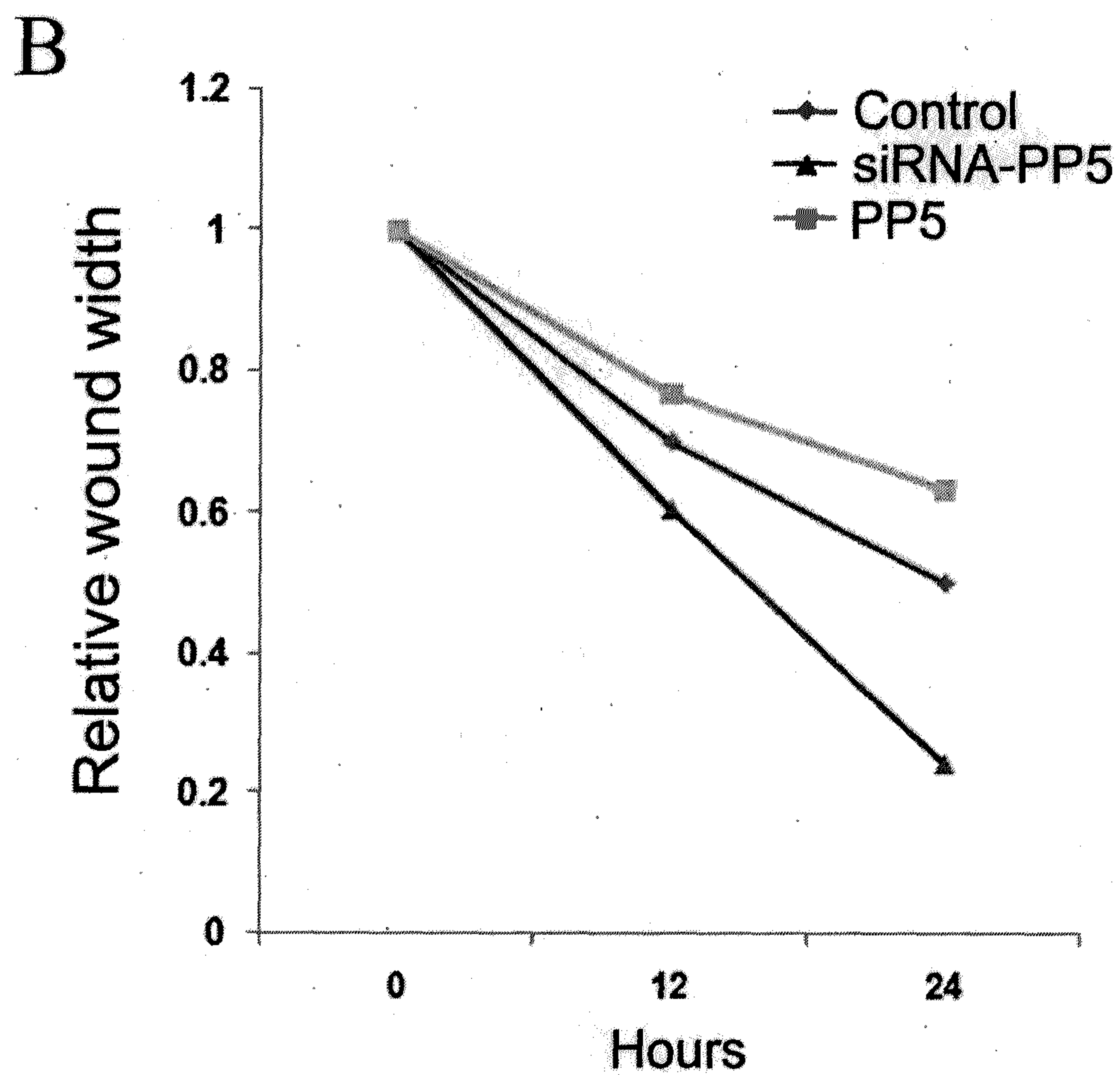
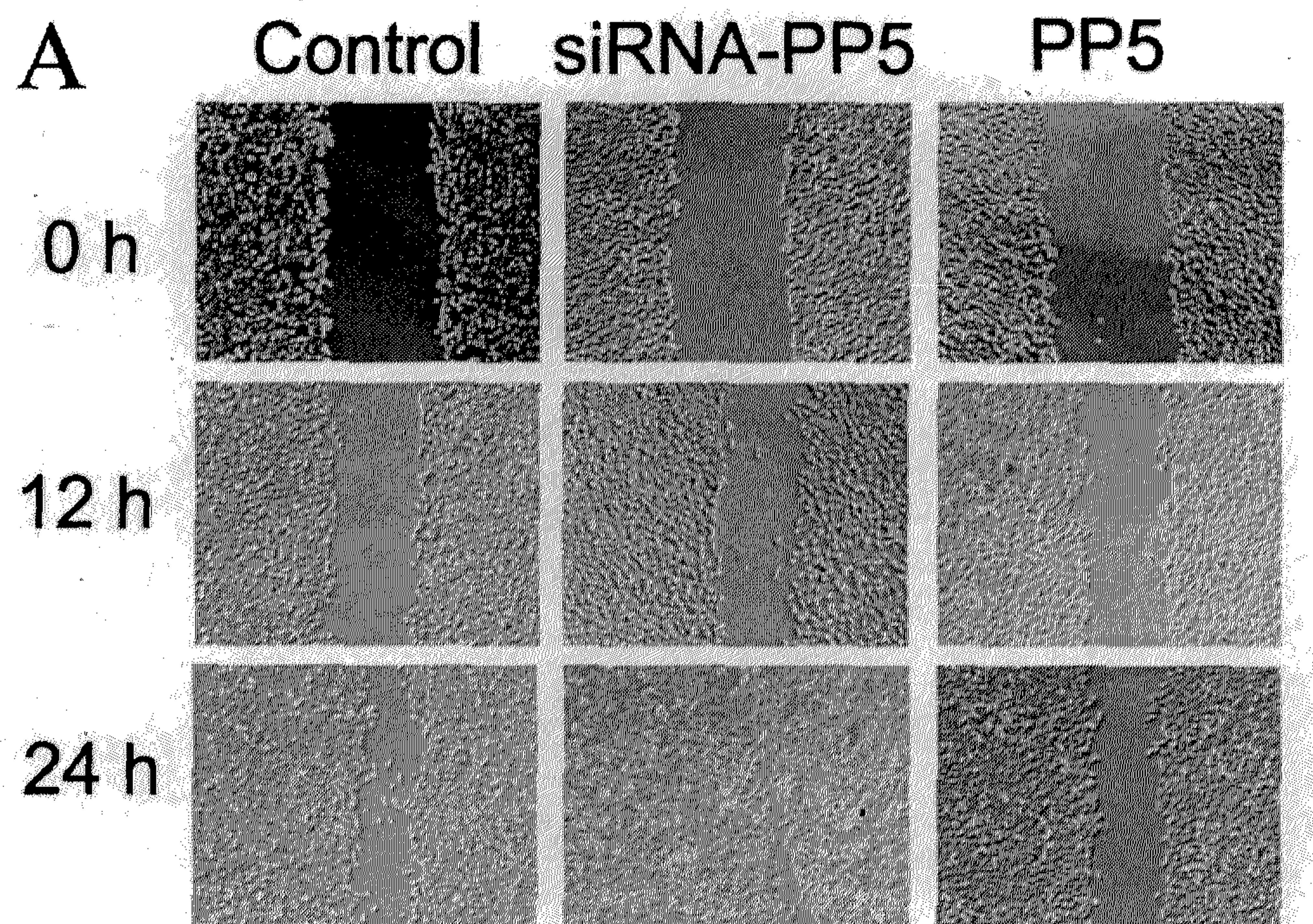
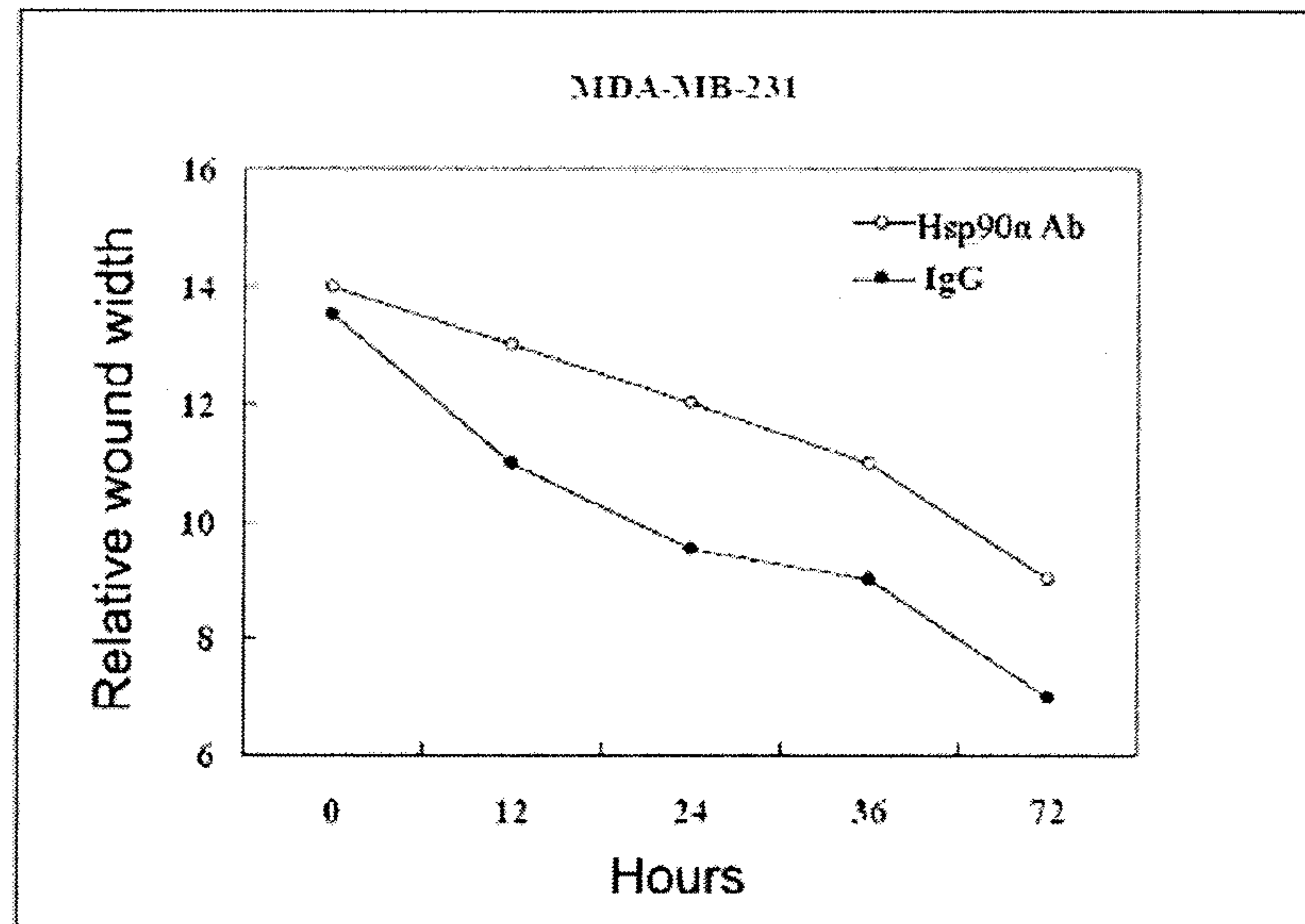


Fig. 18

A



B

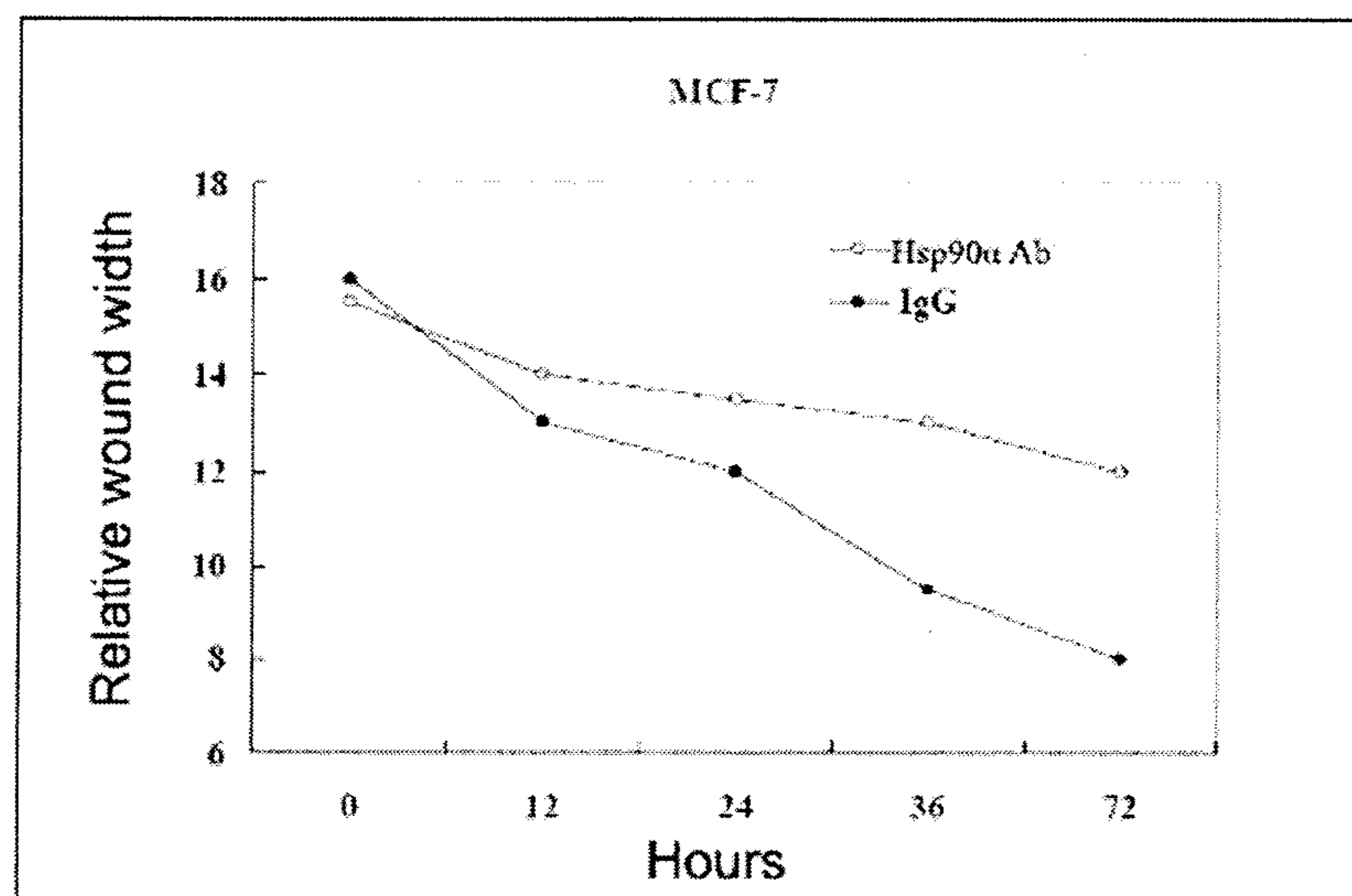
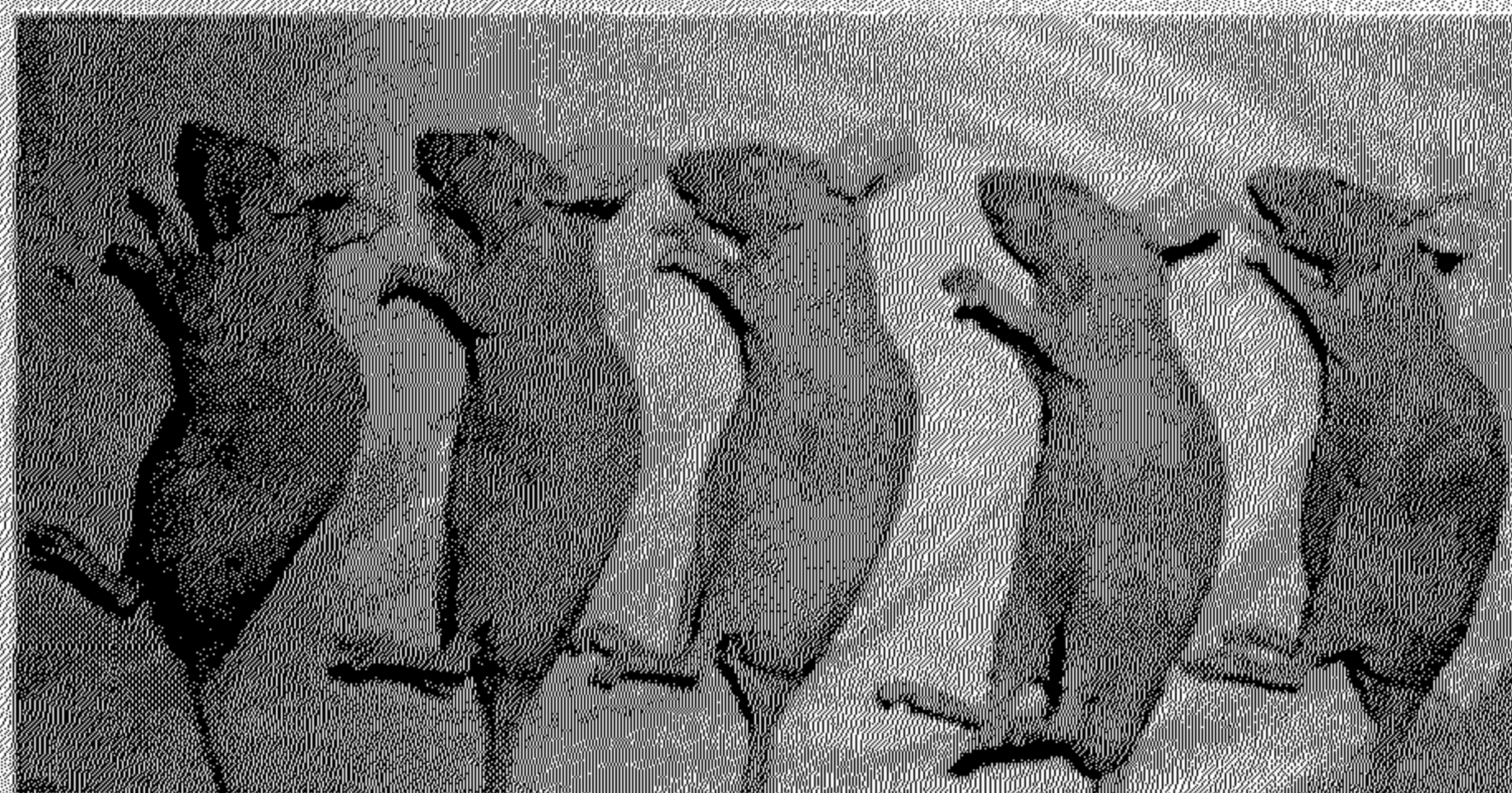


Fig. 19

A

IgG



Hsp90 α Ab



B

IgG



Hsp90 α Ab

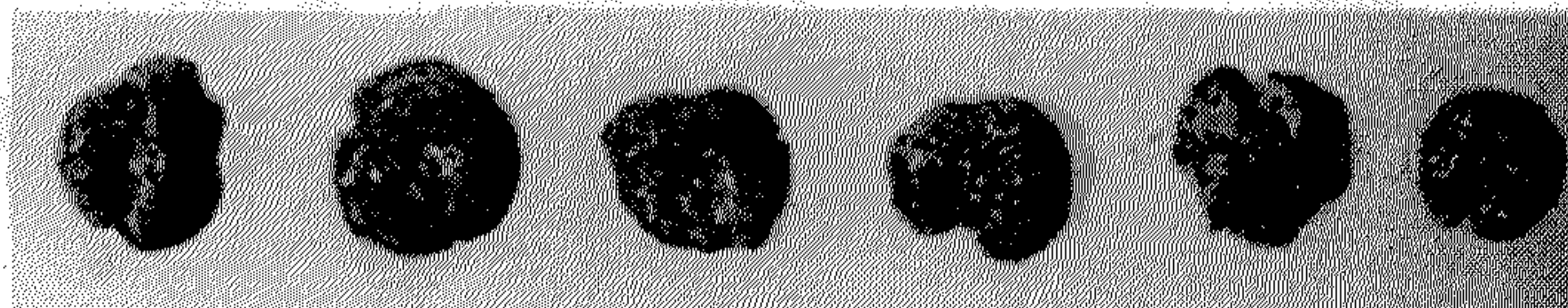


Fig. 20