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(54) METHODS AND COMPOSITIONS FOR DIAGNOSING BREAST CANCER

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(60) Division of application No. 09/369,912, filed on Aug. 6, 1999, which is a continuation of application No. 09/285,379, filed on Apr. 2, 1999, now Pat. No. 6,451,765, which is a division of application No. 08/943,828, filed on Oct. 3, 1997, now abandoned.

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(51) **Int. Cl.**[7] **G01N 33/574**

(52) **U.S. Cl.** **435/7.23**

(57) **ABSTRACT**

Mammastatin has an approximate molecular weight of 44 kDa in its inactive, non-phosphorylated form. Normal mammary cells express functional phosphorylated forms having approximate molecular weights of 53 kDa and 49 kDa. Metastatic mammary cells either do not express Mammastatin at all, or do not express the 53 kDa or 49 kDa, phosphorylated forms. Mammary cancer cells are inhibited in their growth by the administration of phosphorylated Mammastatin.

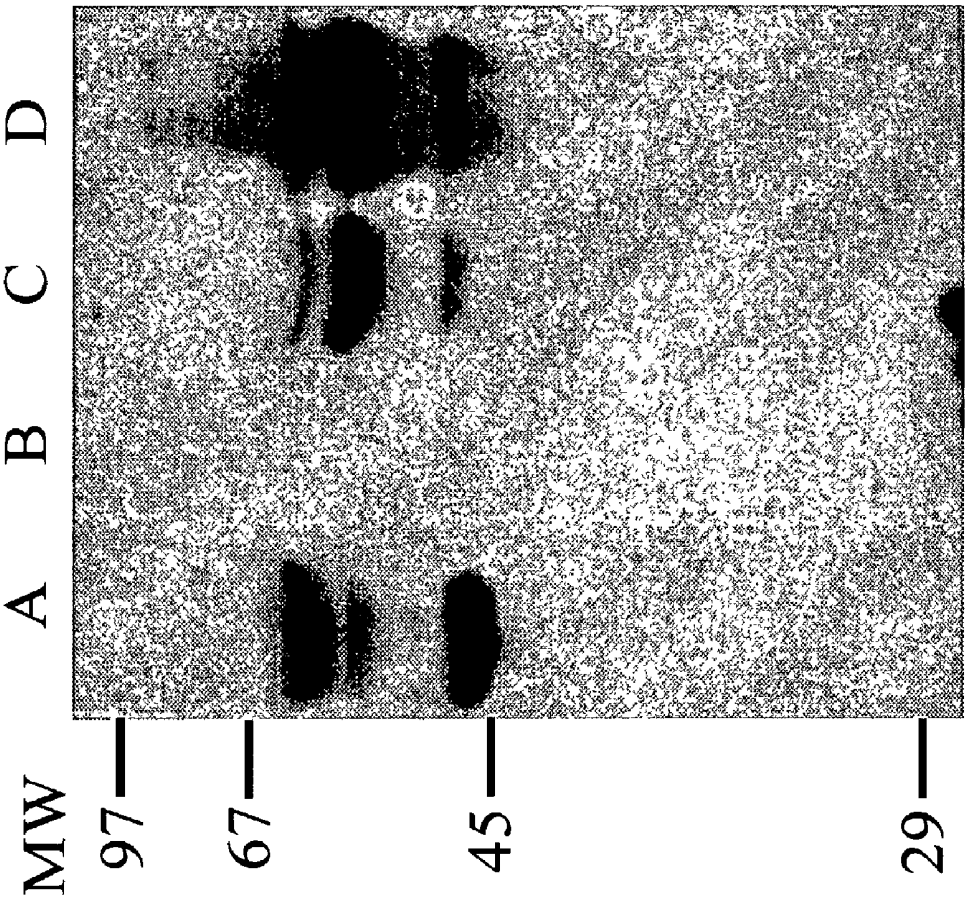


FIG. 1

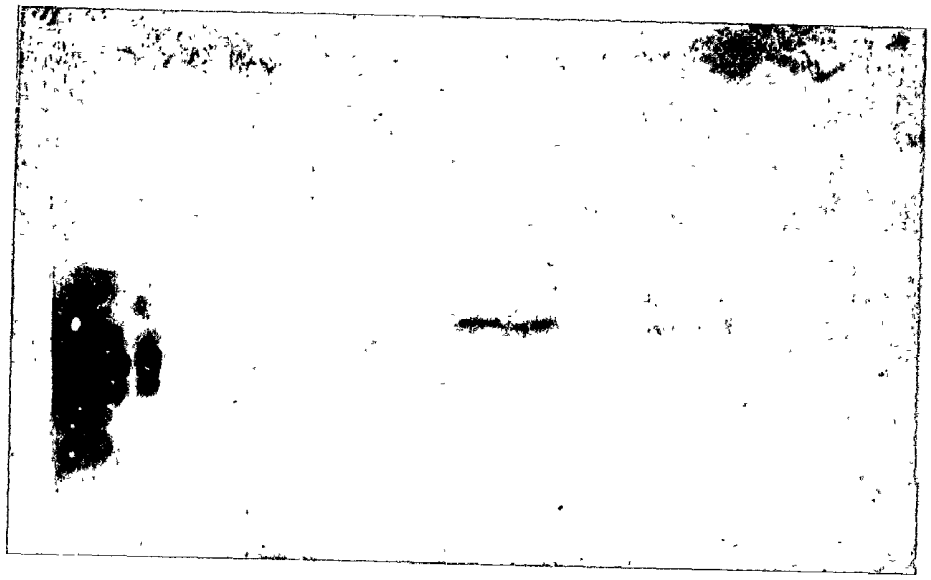

NORMAL CONTROL
High 5 Cells
High 5 cells + pMam I
High 5 cells + pMam I2

FIG. 2

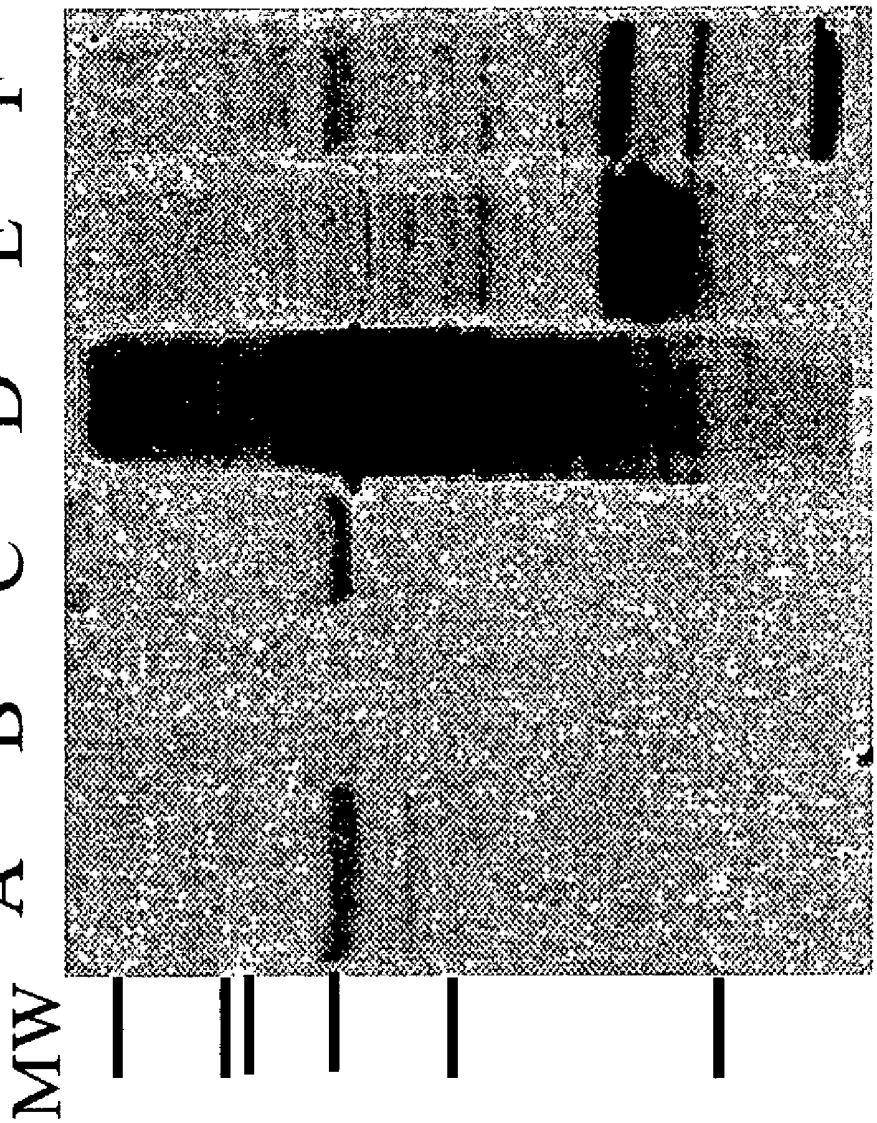


FIG. 3A

FIG. 3B

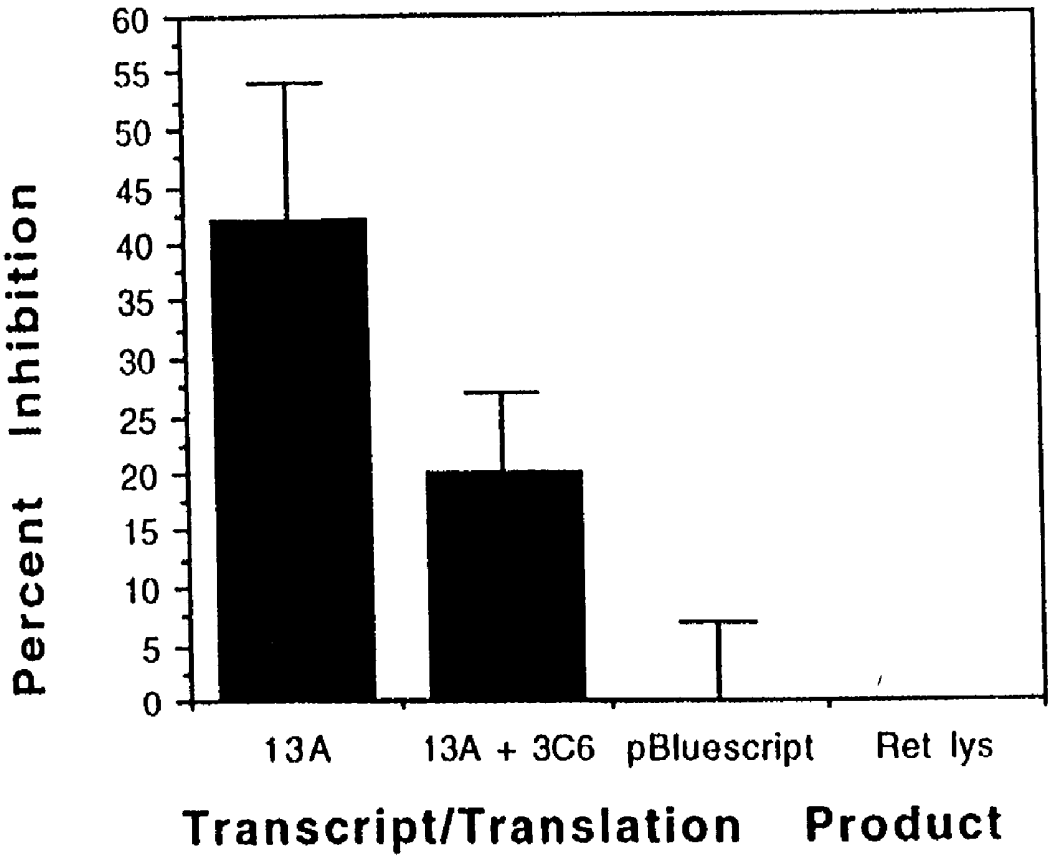

Percent Inhibition
60
55
50
45
40
35
30
25
20
15
10
5
0
13A
13A + 3C6
pBluescript
Ret lys
Transcript/Translation Product

FIG. 4

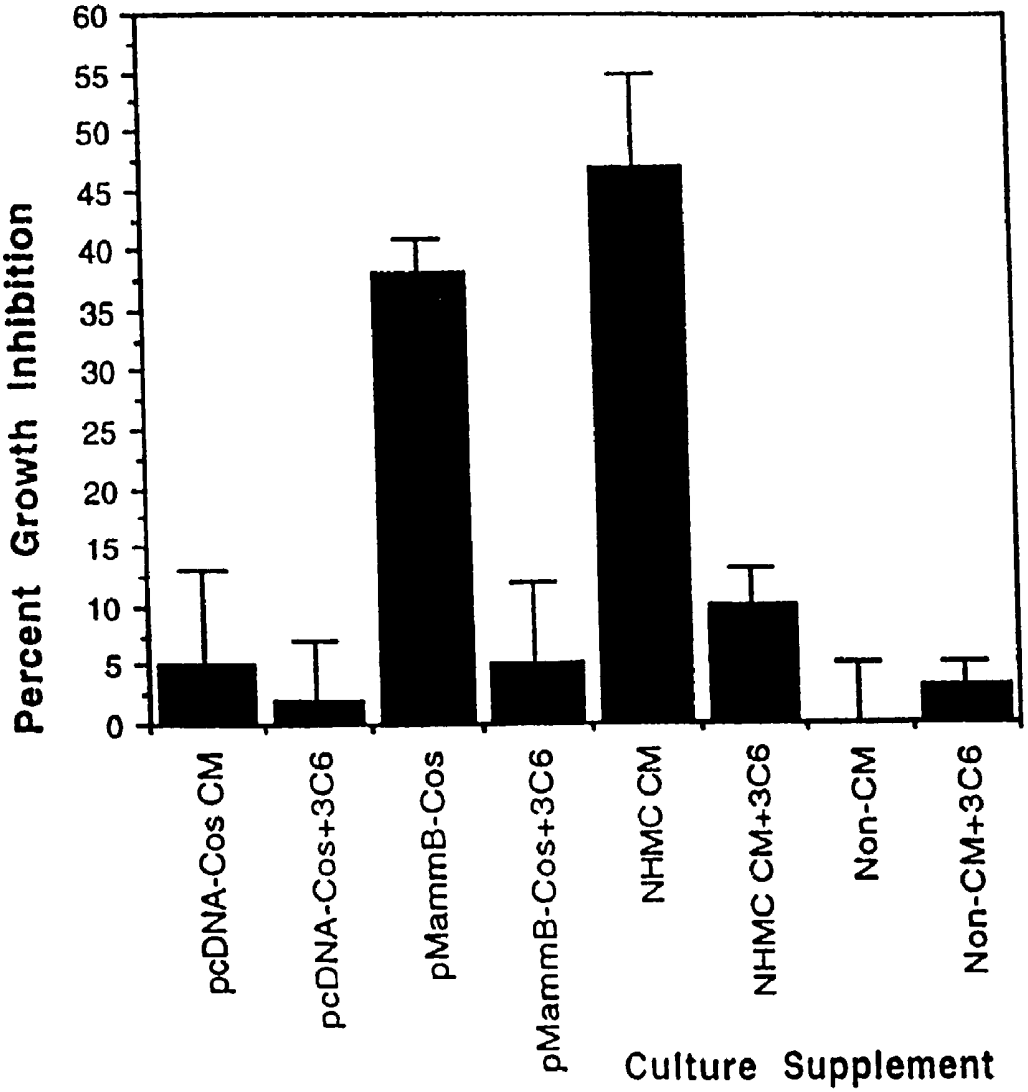
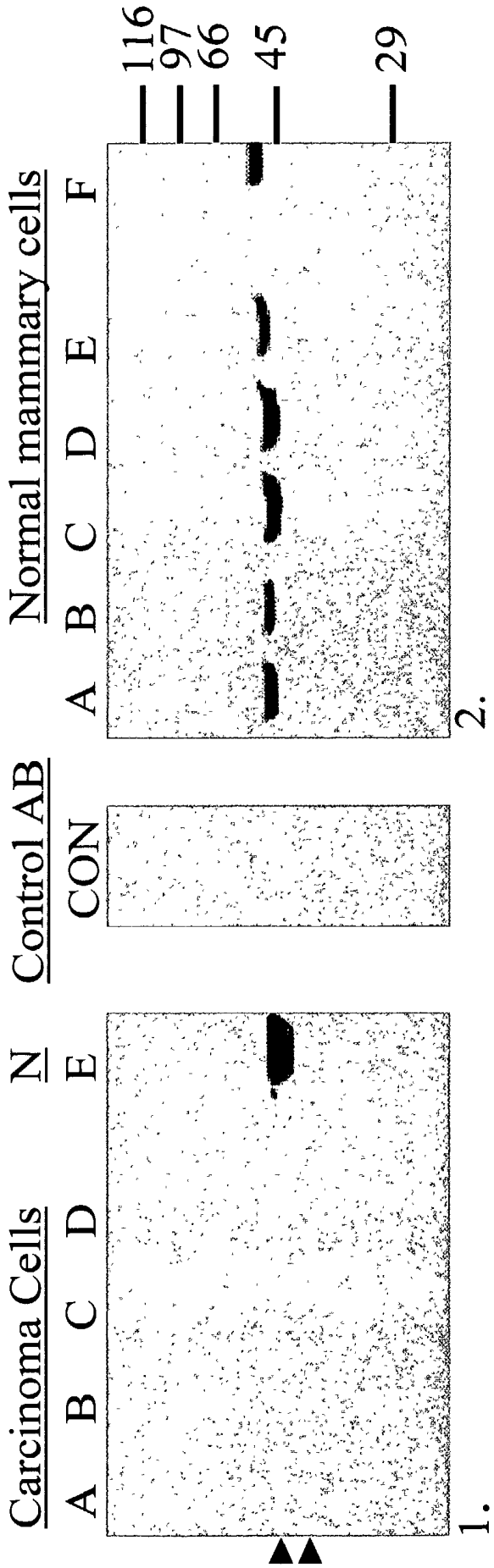

Percent Growth Inhibition
60
55
50
45
40
35
30
25
20
15
10
5
0
pcDNA-Cos CM
pcDNA-Cos+3C6
pMammB-Cos
pMammB-Cos+3C6
NHMC CM
NHMC CM+3C6
Non-CM
Non-CM+3C6
Culture Supplement

FIG. 5


Carcinoma Cells
A B C D E N
Control AB
CON
Normal mammary cells
A B C D E F
116
97
66
45
29
1.
2.

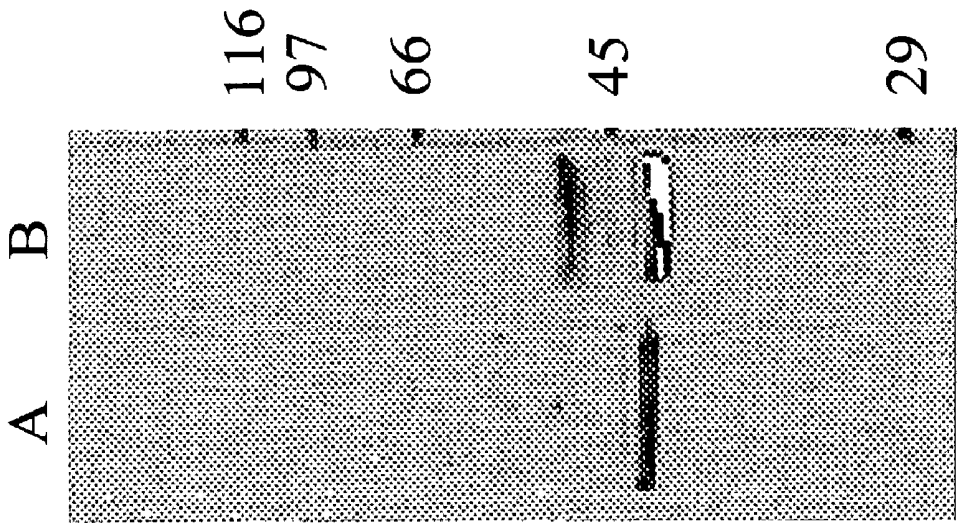
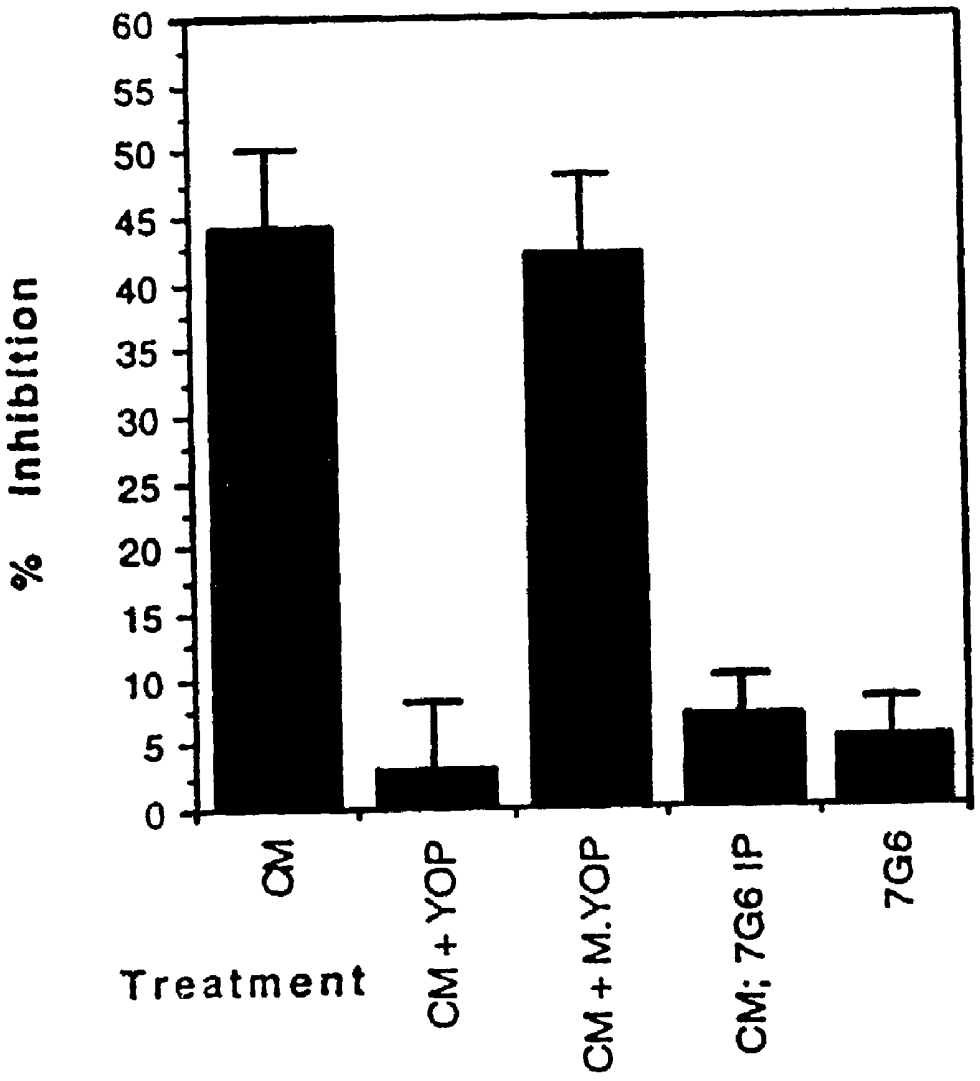


FIG. 6

FIG. 7


% Inhibition
60
55
50
45
40
35
30
25
20
15
10
5
0
CM
CM + YOP
CM + M.YOP
CM; 7G6 IP
7G6
Treatment

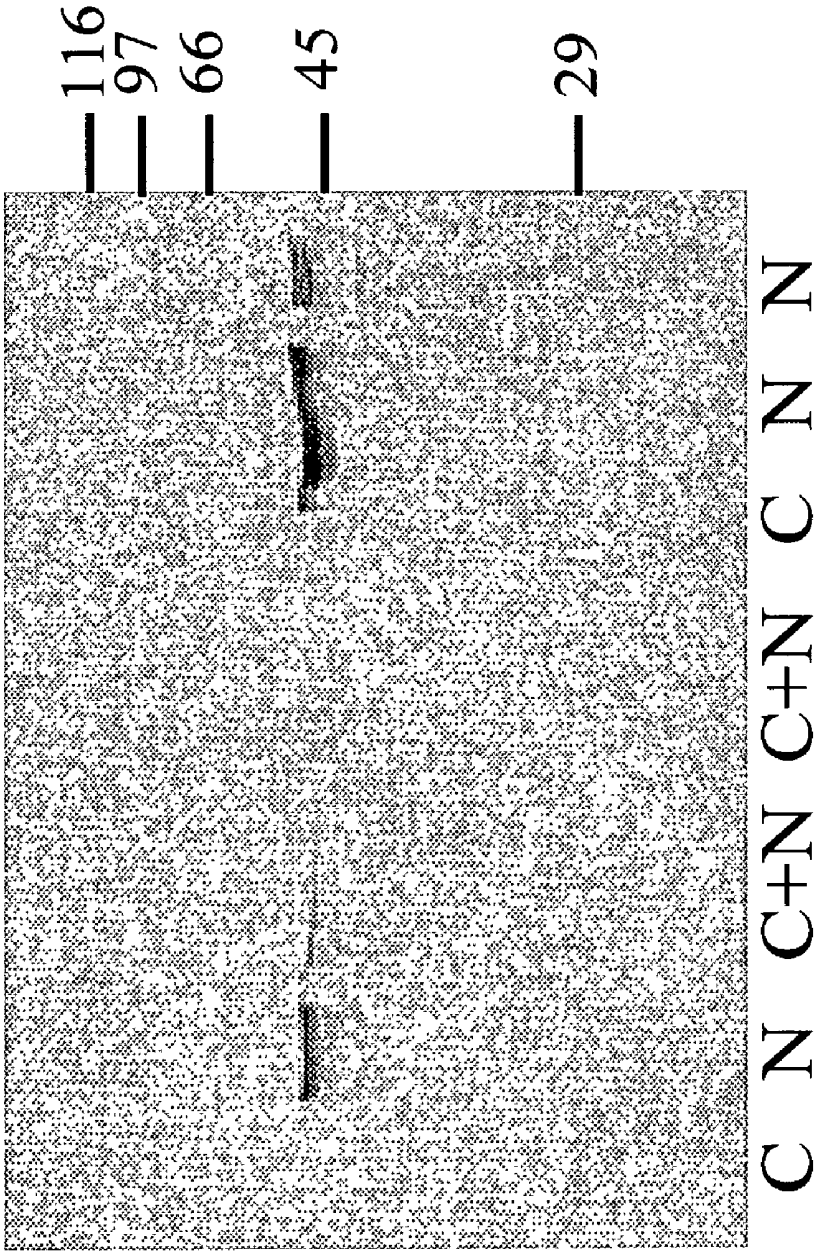


FIG. 8

FIG. 9

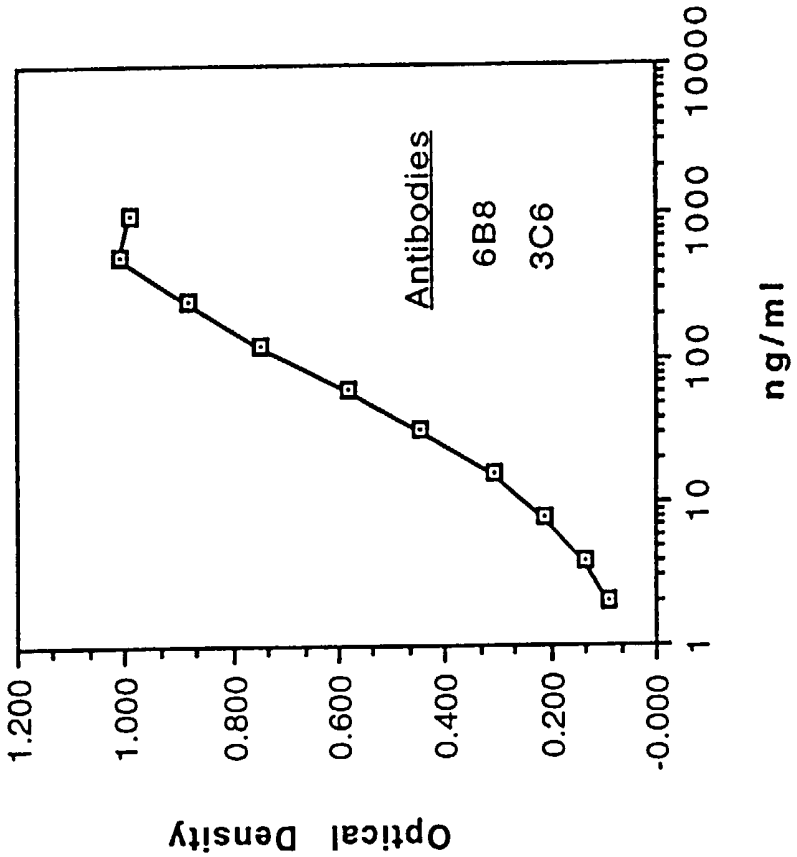

Optical Density
1.200
1.000
0.800
0.600
0.400
0.200
-0.000
1
10
100
1000
10000
ng/ml
Antibodies
6B8
3C6

FIG. 10

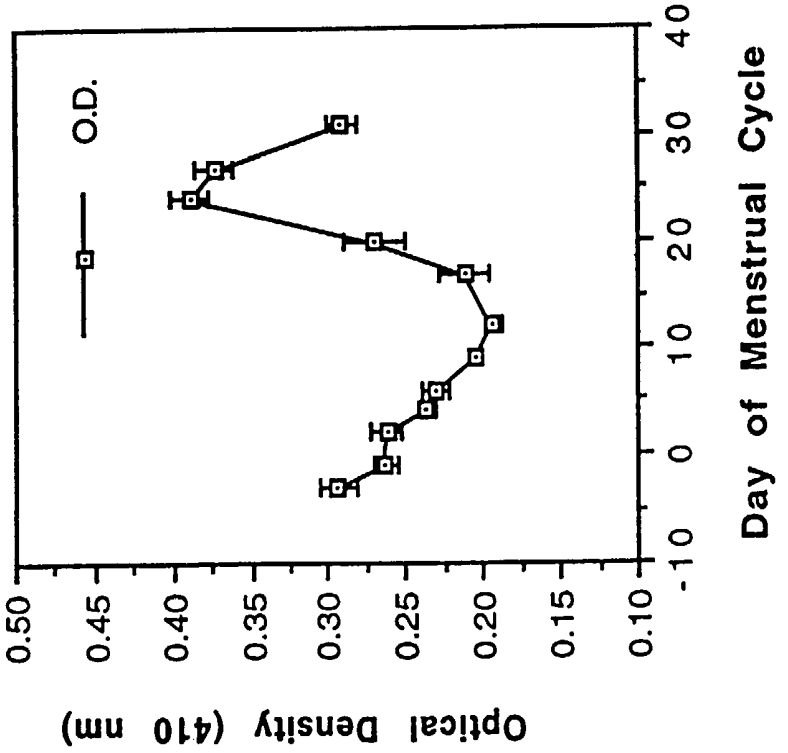
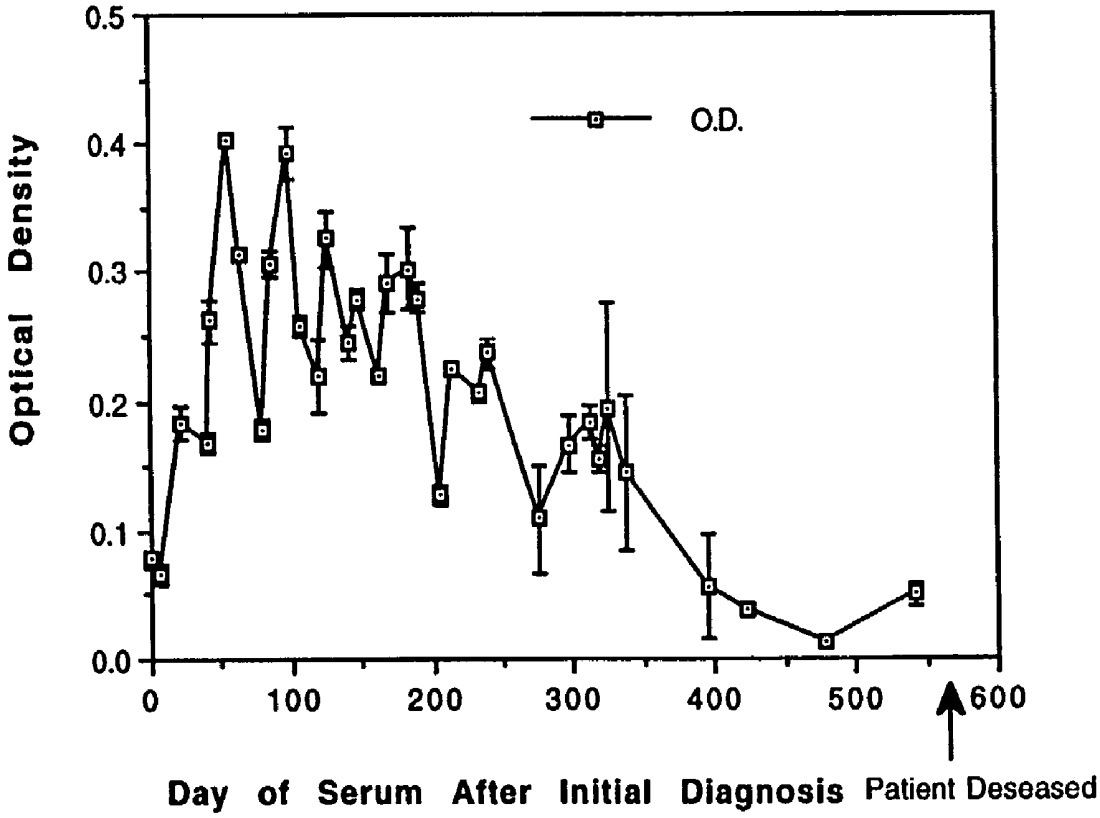

Optical Density (410 nm)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
-10
0
10
20
30
40
Day of Menstrual Cycle
O.D.

FIG. 11


0.5
0.4
0.3
0.2
0.1
0.0
Optical Density
O.D.
0
100
200
300
400
500
600
Day of Serum After Initial Diagnosis
Patient Deseased

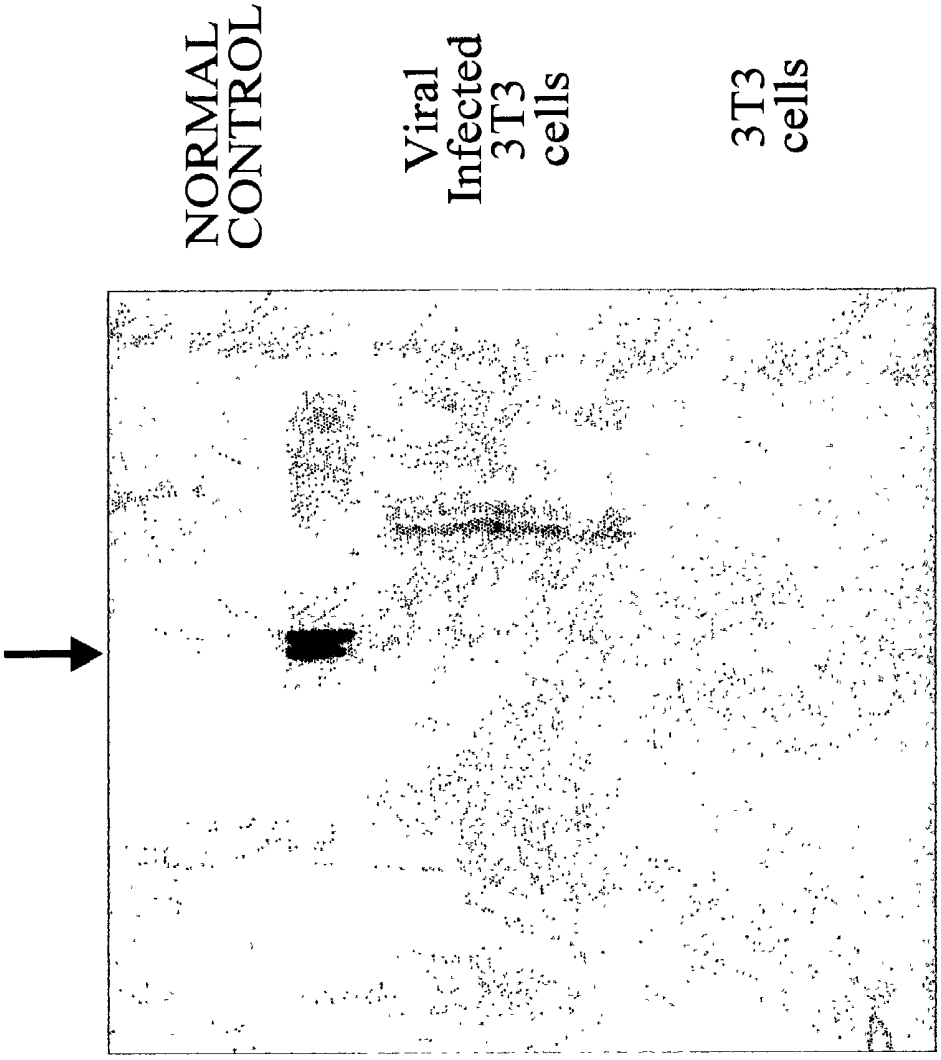


FIG. 12

FIG. 13B

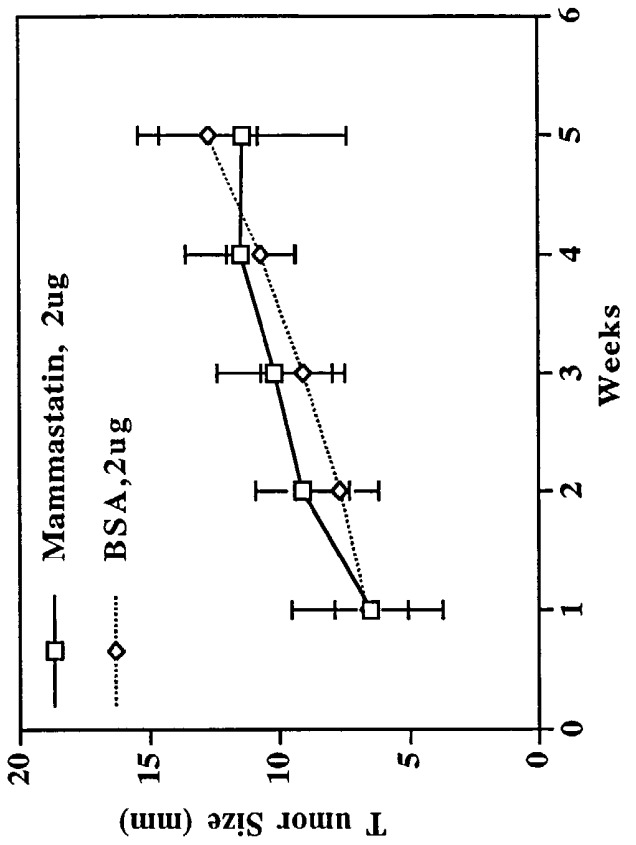


FIG. 13A

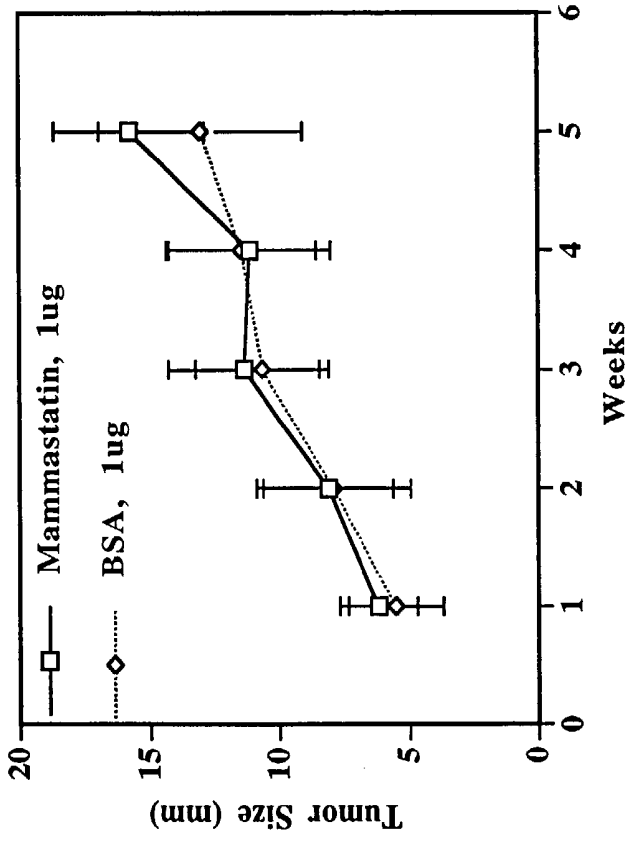


FIG. 13C

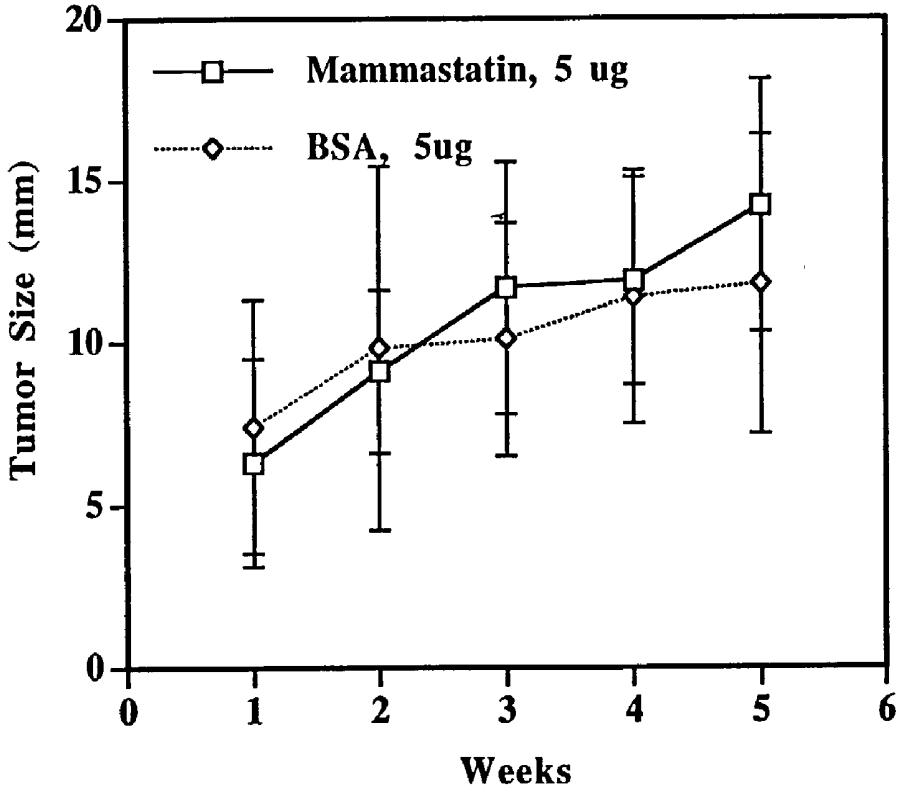

Mammastatin, 5 ug
BSA, 5ug
Tumor Size (mm)
20
15
10
5
0
0
1
2
3
4
5
6
Weeks

FIG. 14B

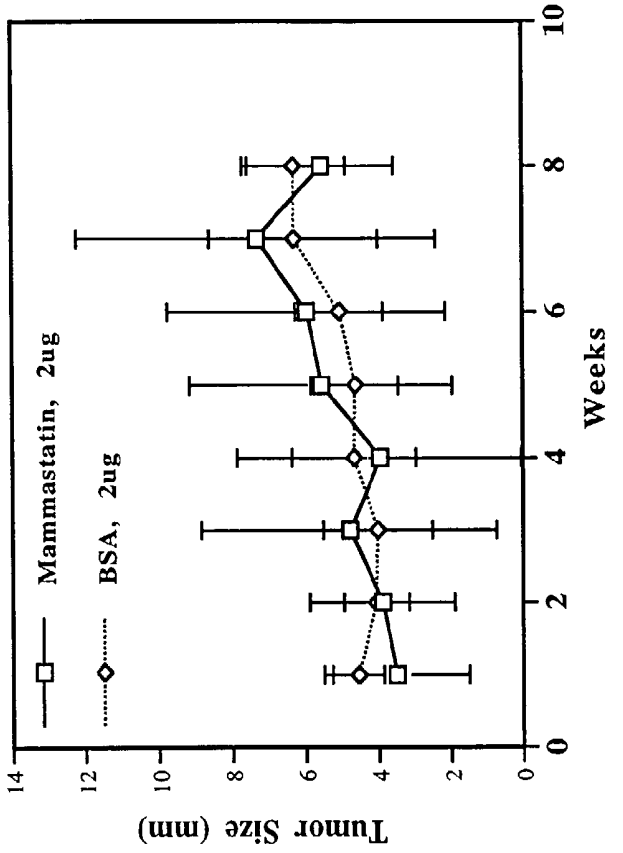


FIG. 14A

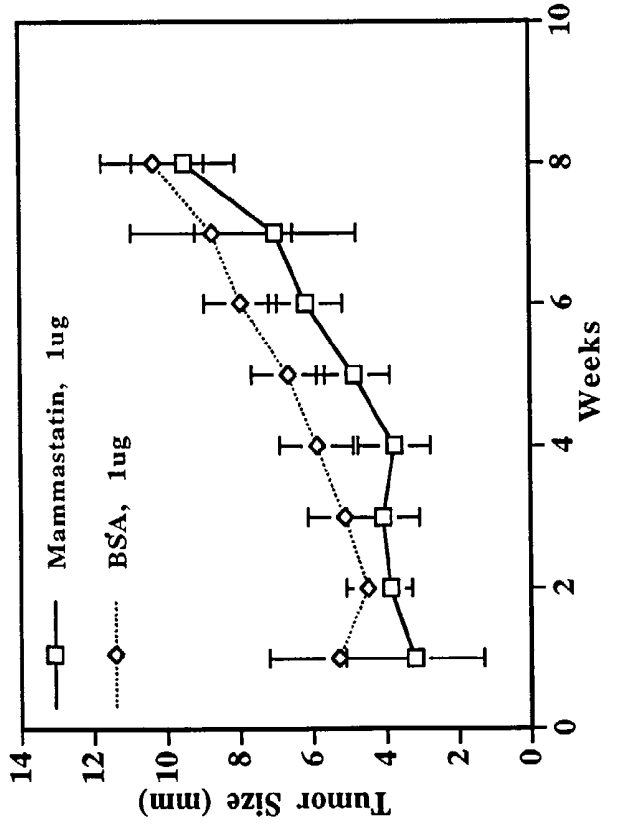


FIG. 14C

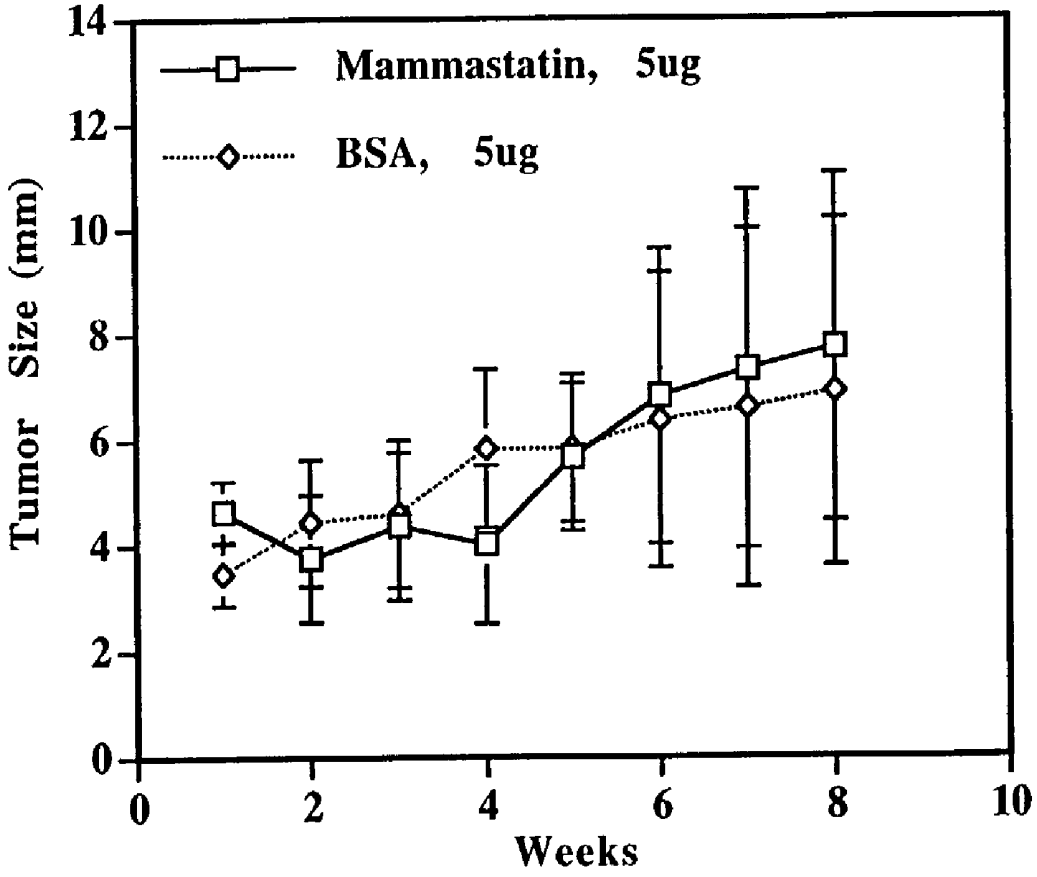
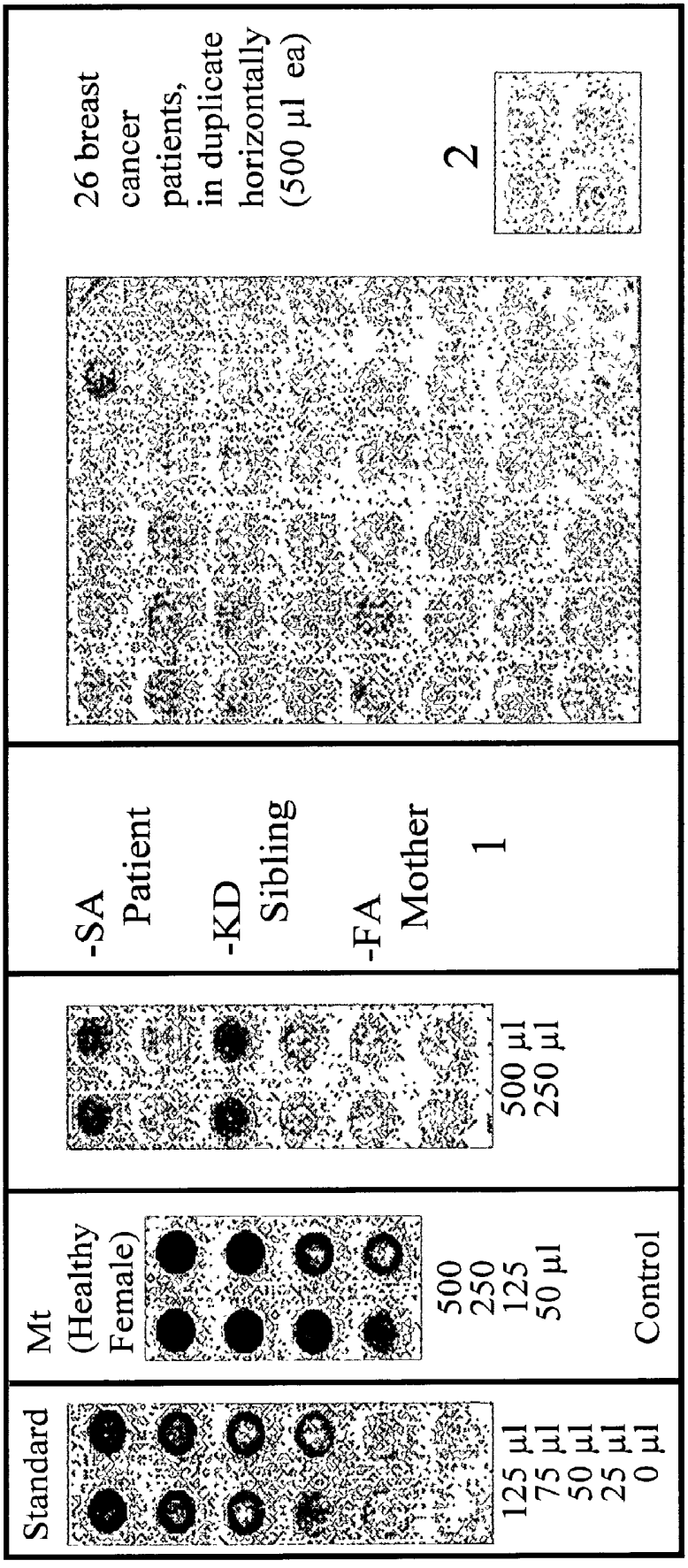


FIG. 15


Serum Mammastatin Dot Blot Assay
Standard
125 µl
75 µl
50 µl
25 µl
0 µl
Mt
(Healthy
Female)
500
250
125
50 µl
Control
500 µl
250 µl
-SA
Patient
-KD
Sibling
-FA
Mother
1
26 breast
cancer
patients,
in duplicate
horizontally
(500 µl ea)
2

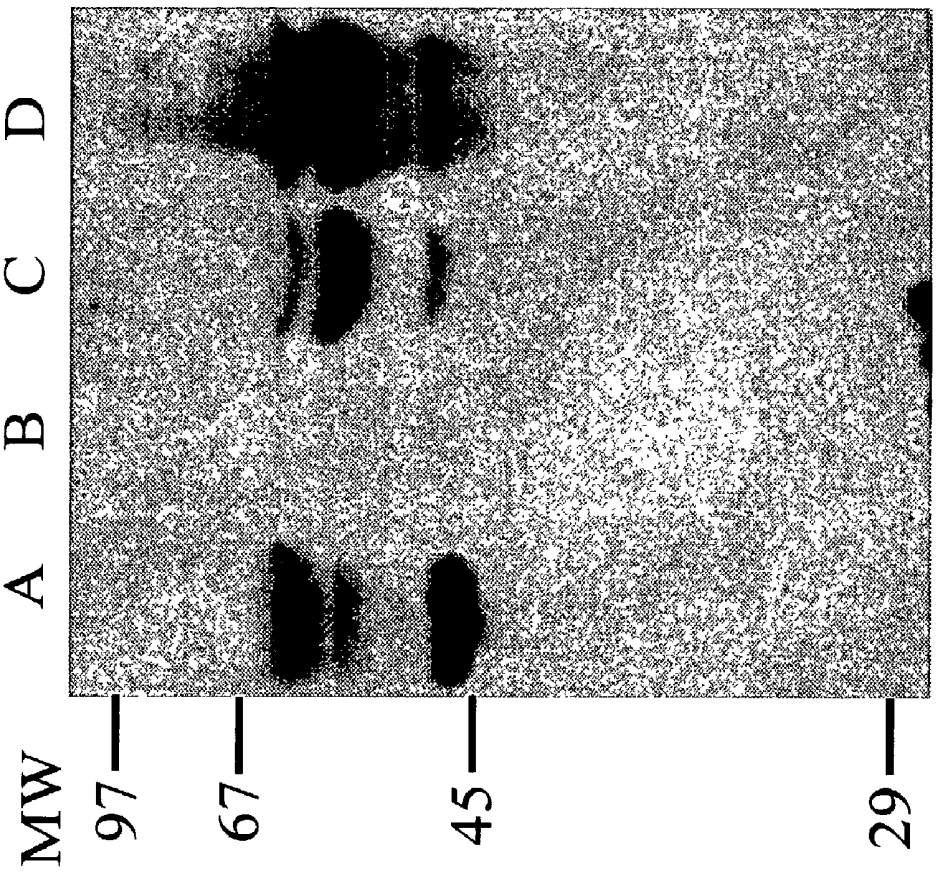


FIG. 16

METHODS AND COMPOSITIONS FOR DIAGNOSING BREAST CANCER

RELATED APPLICATIONS

[0001] This application is a divisional of Ser. No. 09/369,912, filed Aug. 6, 1999, which is a continuation of Ser. No. 09/285,379, filed Apr. 2, 1999, which is a divisional of Ser. No. 08/943,828, filed Oct. 3, 1997, now abandoned, which claims the benefit of priority to U.S. Provisional Patent Application Serial No. 60/027,315, filed Oct. 3, 1996, now abandoned, all of which are hereby incorporated in their entirety.

BACKGROUND OF THE INVENTION

[0002] Breast cancer is a disease that kills over 45,000 women each year in the United States alone. Over 180,000 new cases of breast cancer are diagnosed annually, and it is estimated that one in eight women will develop breast cancer. These numbers indicate that breast cancer is one of the most dangerous diseases facing women today. Cancer research has been unable to determine the cause of breast cancer, and has not found a suitable method of therapy or prevention.

[0003] A woman diagnosed with breast cancer may be treated with surgery, hormone therapy, chemotherapy, and radiation. If the patient develops metastatic disease, radiation and high dose chemotherapy are required to ablate the cancer in remote areas such as the brain, bone, and liver.

[0004] The current therapies available for the treatment of breast cancer are toxic, dangerous, costly, and many are ineffective, especially in the treatment of metastatic disease. The table below was extracted from Churchill Livingston, Clinical Oncology, 1995, and summarizes data available on the current methods of treatment and expected survival rates.

[0005] Currently, there are no therapies that are effective for long term treatment of breast cancer that has metastasized to lymph nodes or distal sites. Local disease can be effectively treated by surgery, if all of the cancer can be removed. A new therapy for the effective treatment of breast cancer that could stop the growth of breast cancer and of cells derived from metastatic cancer is urgently needed. Such a therapy would be useful in the treatment of localized breast cancer, in long term treatment of metastatic disease, and as a follow-up treatment after surgical removal of tumors. Other applications include a growth inhibitor as a primary therapy and for preventative use.

[0006] Detection methods for breast cancer, such as mammogram, physical exam, CAT-scan, and ultrasound, have significantly improved early detection of breast cancer. However, with these methods, a suspected tumor must still be surgically removed for pathological examination to determine if the tumor is benign or malignant, and to attempt to determine the tissue type and grade of the malignancy. This pathological diagnosis helps to determine what subsequent treatment protocols may be used.

[0007] For breast cancer, these methods are generally inconclusive, as adequate breast cancer tumor markers are not available. Available markers such as CA 15-3 and CA 27-29 are used as indicators of metastases, however, they are not specific. There is a great need for diagnostic tools and methods that can effectively and reliably diagnose breast cancer, e.g., using new and specific breast cancer markers. In addition, a reliable and simple method for the early detection and diagnosis of breast cancer is greatly needed. Preferably, such an early detection method would identify breast cancer in its early stages, track progression of breast cancer through advanced metastatic disease, and diagnose the propensity of a patient to develop breast cancer or to develop advanced

Treatment	Method	Effect	Toxicity	Result	Survival
adriamycin	bolus	kill cancer cells	high	can induce remission	+14 months
cyclophosphate	bolus	kill cancer cells	high	can induce remission	+16 months
methotrexate	infusion	kill cancer cells	high	can induce remission	+16 months
5F uracil	infusion	kill cancer cells	high	can induce remission	+18 months
mix of above	mixed	kill cancer cells	high	can induce remission	+22 months
taxol	bolus	kill cancer cells	high	can induce remission	+12 months
estrogen	oral	may stop growth	low	can induce remission	+6 months
tamoxifen	oral	may stop growth	low	may stop progression	+12 months
mastectomy	surgery	remove tumor	low	may eliminate cancer	+5 years*
lumpectomy	surgery	remove tumor	low	may eliminate cancer	+5 years*
surgery and tamoxifen	combination	combination	low	may eliminate cancer	+7–10 years*
radiation	mechanical	kill cancer cells	high	can induce remission	+14 months

*assumes there are no micrometasteses

disease. Most preferably, the diagnostic method could be used without tissue biopsy, e.g., by analysis of a body fluid such as blood.

[0008] Human mammary tissues undergo a burst of proliferative activities at the onset of menarche and during each menstrual cycle. Studies on the effects of estrogen on mammary tissues and tumors indicate that estrogen is a primary growth-initiating factor for mammary tissues. Estradiol-sensitive growth factors have been characterized. In addition, mammary cell growth factors which are not hormonal in nature have also been described.

[0009] Specific growth factors which have been shown to have a stimulating effect on mammary tissue growth include platelet-derived growth factor (PDGF), insulin-like growth factor (IGF-1) and transforming growth factor (TGF) alpha. TGF-beta, on the other hand, has been shown to suppress mammary tissue growth.

[0010] The regulation of mammary cell growth is of great importance in the diagnosis and treatment of breast cancer. Neoplastic growth of mammary tissues, if unchecked, can develop into uncontrollably-proliferating malignant tumors, which are the cause of death of thousands of women yearly. A growth inhibition factor capable of specifically suppressing mammary cell growth would provide a dynamic tool for use in the diagnosis and treatment of breast cancer.

[0011] Thus, it would be of great utility to isolate and characterize a specific mammary cell growth inhibitor, to identify its nucleic acid sequence and amino acid sequence, and to recombinantly express the inhibitor as a purified protein. Diagnostic and therapeutic methods using the nucleic acid sequence and/or recombinantly produced inhibitor would be of great utility in the diagnosis and treatment of breast cancer.

SUMMARY OF THE INVENTION

[0012] A specific mammary cell growth inhibitor, Mammastatin, has been isolated from normal human mammary cells and characterized. It has now been found that Mammastatin is produced by normal mammary cells, but not by breast cancer cells. Furthermore, it has now been found that the reduction or absence of Mammastatin in the blood correlate with the presence of breast cancer. Administration of active Mammastatin prevents growth of breast cancer cells.

[0013] The nucleic acid sequence encoding Mammastatin has now been cloned, sequenced, and expressed recombinantly in host cells as an active inhibitor of mammary cell growth. The isolated and characterized nucleic acid sequence (SEQ ID NO.: 1) and its deduced amino acid sequence provide unique and specific tools for use in the diagnosis and treatment of breast cancer.

[0014] The present invention provides an isolated and purified nucleic acid sequence encoding Mammastatin, a specific protein inhibitor of mammary cell growth, and particularly of mammary cancer cell growth. The invention also includes plasmids and vectors containing the Mammastatin nucleic acid sequence, amino acid sequence of Mammastatin, and methods, kits, and compositions utilizing the Mammastatin nucleic acid or amino acid sequences to produce purified mammary cell growth inhibitor and in the diagnosis and treatment of breast cancer. The inventive compositions include probes and primers that specifically hybridize to the Mammastatin nucleic acid sequence and its RNA products.

[0015] The invention further includes a method for treating breast cancer by administering Mammastatin.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] **FIG. 1** is a Western Blot showing expression of recombinant Mammastatin in Eucaryotic Cos-7 cells.

[0017] **FIG. 2** is an immunoblot showing expression of Mammastatin in insect cells.

[0018] **FIG. 3A** is an autoradiograph showing expression of recombinant Mammastatin produced by in vitro transcription and translation and used in the growth inhibition assays of **FIG. 3B**. **FIG. 3B** is a graph showing inhibition of mammary cell growth by recombinant Mammastatin produced by in vitro transcription and translation.

[0019] **FIG. 4** is a graph showing growth inhibition in human mammary cancer cell growth by treatment with conditioned medium of Cos-7 cells transfected with Mammastatin cDNA.

[0020] **FIG. 5** is a Western Blot showing relative amounts of 53, 49 and 44 kD Mammastatin in normal and cancerous human mammary cells.

[0021] **FIG. 6** is an immunoblot showing phosphatase digestion of Mammastatin.

[0022] **FIG. 7** is a graph showing the effect of phosphatase on the activity of Mammastatin.

[0023] **FIG. 8** is a Western Blot showing Mammastatin from normal and cancerous human mammary cells, as well as in mixed cultures of normal and cancerous cells.

[0024] **FIG. 9** is a graph showing a Mammastatin ELISA standard curve.

[0025] **FIG. 10** is a graph showing Mammastatin in normal human serum as analyzed by ELISA.

[0026] **FIG. 11** is a graph showing Mammastatin levels in breast cancer patients over the course of treatment.

[0027] **FIG. 12** is a Western blot showing expression of Mammastatin induced by retrovirus.

[0028] **FIGS. 13A, 13B** and **13**C are graphs showing the effect of Mammastatin treatment on MCF7 tumor cells in nude mice.

[0029] **FIGS. 14A, 14B** and **14**C are graphs showing the effect of Mammastatin treatment on tumor cells in nude mice.

[0030] **FIG. 15** is a dot blot assay showing Mammastatin in blood from normal females versus the absence of Mammastatin in blood from breast cancer patients.

[0031] **FIG. 16** is a Western blot showing recombinant Mammastatin expression in Cos-7 cells.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0032] Mammastatin

[0033] Mammastatin is a protein growth inhibitor produced and secreted by normal human mammary epithelial cells. A mammary cell growth inhibitor was first described as an inhibitory protein activity present in media conditioned by the growth of normal human mammary cells. The inhibitory activity was identified in conditioned medium from normal human mammary cells, but not in media conditioned by the growth of human mammary cancer cells. The inhibitory activity was determined by bioassay and antibody development to reside in three proteins, having the approximate molecular weights of 53, 49 and 44 kD (Ervin, Paul R., Doctoral Dissertation University of Michigan, 1995).

[0034] It has now been determined that a specific mammary cell growth inhibitor, Mammastatin, is expressed as a 44 kD protein which is phosphorylated increasing the molecular weight to 49 kD and 53 kD. The non-phosphorylated 44 kD form is not an active inhibitor, whereas the phosphorylated 49 kD and 53 kD forms inhibit growth of breast cancer cells. The active 53 and/or 49 kD phosphoprotein is expressed by normal human mammary cells, but is not generally produced by human mammary carcinoma cells. Some carcinoma cells make the 44 kD protein that lacks phosphorylation and is inactive.

[0035] The table below summarizes data showing expression and activity of Mammastatin in normal and cancerous cells and tissues.

Cell Type*	Number	44 kDa**	53/49 kDa**	produce inhibitor	are inhibited
Normal primary cultures	42	+/−	++++	42/42	2/2
Normal breast tissue	5	+	++		
Mammary Cell Line	16			0/16	12/12
Type A	11	+	−	0/11	8/8
Type B	5	−	−	0/5	4/4
Breast tumor lysate	25				
Type A	17	+	−		
Type B	8	−	−		
Non-mammary cell lines	8			0/2	0/8
Type A	3	+	−***	0/1	0/3
Type B	5	−	−***	0/1	0/5

*Carcinoma cells in which 44 kDa Mammastatin was detected (Type A) or not (Type B)
**(−) No expression (++++) intense expression
***Two cell lines, BxPc3 and A253 expressed proteins identified as 53/49 kD, but neither cell line produced inhibitory activity.

[0036] Dose response studies with human mammary carcinoma cells indicates that carcinoma cell growth is 50-70% inhibited with 10 ng/ml of Mammastatin and blocked completely with 25-50 ng/ml. Highly metastatic cells such as MDA-MB-435 and MDA-MB-231 required 50 ng/ml to stop growth. In vitro and in vivo clinical data experiments indicate the effect is reversible, and that repeated administration of the inhibitor is required to arrest carcinoma cell growth at the lower concentrations. At doses above 50 ng/ml, however, Mammastatin appears to induce apoptosis, as indicated by histology, e.g. cell necrosis.

[0037] Since Mammastatin is a natural growth inhibitor that blocks mammary carcinoma cell growth, and since no tumors make active Mammastatin, Mammastatin replacement therapy is ideal for therapeutic treatment of breast cancer. The clinical data provided in the examples below demonstrate the effectiveness of Mammastatin replacement therapy.

[0038] The nucleic acid sequence encoding Mammastatin protein has now been isolated, characterized, sequenced (SEQ ID NO.:1), determined to encode all three (53, 49, and 44 kD) molecular weight proteins, and given the name "Mammastatin". Differences in the molecular weight of the three forms has been determined to be caused by the extent of the protein's phosphorylation. Mammastatin produced by normal human mammary cells (NHMC) in culture and recombinantly expressed Mammastatin inhibit the growth of human mammary carcinoma cells, and is useful as a therapeutic agent in the treatment of breast cancer.

[0039] Analysis of human sera from normal women and from breast cancer patients indicates that decreased blood levels of Mammastatin correlate with advancing breast cancer. Screening and monitoring blood serum for the presence of this active inhibitor as described in the examples below provides a specific and effective diagnostic tool.

[0040] Nucleic Acid Sequence

[0041] The Mammastatin DNA nucleic acid (SEQ ID NO.:1) is shown in the table below, and was identified by cloning and sequencing of Mammastatin cDNA from a normal human mammary cell cDNA library, as described more fully in the Examples below. Chromatographically purified inhibitor had not previously been sufficiently isolated to permit its amino acid analysis, and early attempts to sequence the protein inhibitor by standard techniques failed. Attempts to screen a cDNA library using antibodies raised against chromatographically purified inhibitor protein failed to generate an active clone. To overcome these problems, the gene encoding Mammastatin was identified by peptide sequencing and degenerate oligonucleotide screening of a normal human mammary cell cDNA library.

[0042] Concentrated protein produced by normal human mammary cells was affinity purified using an anti-Mammastatin antibody raised against chromatographically purified inhibitor. Purified protein fractions were supplemented with a small amount 10^5 cpm) of ^{32}P labeled as tracers. The labeled tracer protein was purified from conditioned media of cells grown in the presence of ^{32}P, as described more fully in the examples below. The protein was cleaved with cyanogen bromide, and cleaved fragments were identified as Mammastatin by autoradiographic analysis of ^{32}P-labeled protein. The most abundant labeled peptides generated by the cleavage were sequenced.

[0043] Two peptides, selected as having unique amino acid sequences (SEQ ID NOS.: 2 and 3), were used to produce degenerate oligonucleotides. The degenerate oligonucleotides were then used to screen a normal human mammary cell cDNA library.

[0044] One clone, labeled pMammA, hybridized to oligonucleotides from both selected peptides. This clone was further characterized, and was shown to express protein recognized by anti-Mammastatin antibodies. The clone has been verified as encoding Mammastatin by Northern blot analysis, in vitro transcription and translation assays, and growth inhibition assays. A pcDNA3 clone containing the

Mammastatin cDNA insert (pMammB) was deposited with the American Type Culture Collection and given Accession Number 97451. The recombinant protein expressed from pMammB has been detected by immunoblot of transfected mammalian cell lines and has been demonstrated to possess growth inhibitory activities against mammary cancer cells. The cDNA clone has been completely sequenced (see Example 3) and found to be unique to the BLAST DNA database.

[0045] The nucleic acid sequence of the invention (SEQ ID NO.: 1) encodes human Mammastatin, which functions to inhibit the growth of human mammary cells, normal and cancerous. The term "human" is not intended to limit the source of the protein nor to limit its inhibitory effects only to human cells and tissues. It is understood that the nucleic acid sequence and amino acid sequence of Mammastatin in individuals may vary somewhat, without altering the structure or function of the protein. Further, one skilled in biochemistry will appreciate that modifications of the nucleic acid or amino acid sequence may be made without altering the structure and/or function of the molecule. For example, the nucleic acid sequence may be modified to permit optimal expression of the desired amino acid sequence using known optimal codons for a particular cellular host.

[0046] The nucleic acid sequence of the invention is useful in producing large quantities of highly purified Mammastatin protein for use in therapeutic and diagnostic methods in the treatment of breast cancer.

[0047] Anti-Mammastatin Antibodies

[0048] Several anti-Mammastatin antibodies have been produced and characterized. See, for example, PCT application WO 89/11491 published Nov. 30, 1989. These antibodies were raised against chromatographically purified inhibitor protein, and have been demonstrated to block the inhibitory effect of Mammastatin protein on mammary cell growth.

[0049] Available anti-Mammastatin antibodies include 7G6 and 3C6, commercially available from Neomarkers (Freemont, Calif.) and 6B8. Hybridoma cells producing 6B8 antibody are available from the American Type Culture Collection (ATCC No. HB 10152). Each of these antibodies binds to all three molecular weight forms of Mammastatin and are useful in immunological assays, including dot blots and Western blots. The 7G6 antibody is preferred for Western blot analysis or for ELISA analysis of denatured protein samples. The antibodies 3G6 and 6B8 may be used in ELISA assays, e.g., under conditions specified in the examples.

[0050] Additional antibodies can be produced using standard methods known for producing monoclonal or polyclonal antibodies. The antigen used to produce antibodies may be derived from culture of NHMC or from recombinantly expressed Mammastatin.

[0051] Diagnostic Method

[0052] The invention further provides an in vitro assay for detecting active, inhibitory Mammastatin in patient samples, including tissues, cells, and fluids. Breast cancer disease and advancing metastatic disease is diagnosed by correlating the presence and type of Mammastatin protein in a patient's sample with that of normal or cancerous human mammary cells. A patient's blood or tissue sample is analyzed for Mammastatin protein, e.g., for the abundance of Mammastatin protein and/or for the molecular weight forms of Mammastatin. As discussed below, the absence or loss of Mammastatin, particularly of the higher molecular weight, phosphorylated forms of Mammastatin, is correlated with breast cancer and indicative of advancing metastatic disease.

[0053] Analysis of Mammastatin is preferably by immunoassay, including ELISA or Western Blot analysis of a patient's blood samples, using anti-Mammastatin antibodies. Preferably, recombinant Mammastatin standards are used to provide a standard curve for reliable quantitation of inhibitor levels. Such immunoassays are exemplified by the dot-blot assays and Western blot assays shown in the examples below. In an alternative preferred embodiment of the invention, tissue samples, such as tumor biopsies, are analyzed by immunohistochemistry, or by culturing a patient's tumor cells and examining the cultures for expression of Mammastatin.

[0054] In a particularly preferred embodiment, an assay for the diagnosis of breast cancer includes at least two specific antibodies: an antibody to identify the sampled breast tissue as epithelial tissue, such as an anti-cytokeratin antibody, and an anti-Mammastatin antibody. For example, using an immunoblot format, tissue suspected of containing breast cancer cells is homogenized, separated on an SDS/PAGE gel, transferred to membrane, and probed with both anti-keratin and anti-Mammastatin antibodies. Isotype specific second antibodies that are conjugated to a suitable marker system such as peroxidase or alkaline phosphatase are used to detect bound antibodies. Membranes containing bound first and second antibodies are then developed using known colorometric or fluorometric techniques and quantitated by known methods.

[0055] In the most preferred embodiment, the sample is analyzed for the phosphorylated forms of Mammastatin, such as by Western Blot, using anti-Mammastatin antibodies. A decline or absence of the high molecular weight (53/49 kD) Mammastatin correlates with advancing breast cancer.

[0056] Recombinant Expression Vectors and Transformed Cells

[0057] Recombinant expression vectors of the invention are useful for production and amplification of purified Mammastatin protein and portions thereof, and for easy isolation of Mammastatin protein and portions thereof to be used in diagnostic and therapeutic methods.

[0058] A target sequence, such as all or a portion of the 2.4 kb Mammastatin cDNA (SEQ ID NO.:1), is cloned into a suitable nucleic acid sequence expression vector such as pUC18, pKC30, pBR322, pKK177-3, pET-3, pcDNA3 (Invitrogen) for COS and CHO cells, and pAcG3X baculovirus expression vector (PharMingen, San Diego, Calif.) for expression in insect cells, and like, known expression systems by standard methods. Commercially available expression vectors provide for cloning of a target sequence into a site of the vector such that the target sequence is operably linked to transcriptional and translational control regions.

[0059] The expression vector is then introduced into suitable host cells using known methods such as calcium

phosphate precipitation, liposome mediated transformation, protoplast transformation, electroporation, and the like. Suitable host cells include COS and CHO cells, High 5 and SF9 insect cells, baclovirus, and yeast cells. Other host cells include *E. coli* strains such as *E. coli* DH5α, and avirulent isogenic Salmonella spp. such as *S. typhimurium* deletion mutants lacking adenylate cyclase and cAMP receptor protein, Salmonella mutants in aro genes, and other Salmonella vaccine strains as described in *Bio/Tech,* 6:693 (1988).

[**0060**] Preferably, the cellular host is a Eukaryotic cell, capable of expressing the protein with proper folding and kinase activity to produce a phosphorylated, active inhibitor. Host cells may be screened by transfection with cDNA encoding Mammastatin. Analysis of the protein produced by the transformed cells, e.g. by immunoblot, and the ability of the protein to inhibit mammary cell growth, for example MCF7 cell growth, as described in the examples recited below, can be used to screen potential host cell systems.

[**0061**] Host cells transformed with the target nucleic acid sequence are screened by a variety of methods including colony hybridization or reactivity with antibodies specific for Mammastatin protein. A transformed cell is a suitable host cell carrying a pcDNA3 or other plasmid or vector containing a nucleic acid sequence encoding Mammastatin. One such plasmid is the pcDNA plasmid (pMammB) carrying the 2.4 kb BamHI-XhoI insert from pMammA, deposited with the American Type Culture Collection in 10801 University Boulevard, Manassa, Va. 20110-2209 on Feb. 22, 1996, and was given Accession No. 97451. (See Example 5.)

[**0062**] An expression vector containing the specific target DNA sequence is used to generate all or a portion of Mammastatin protein, by in vitro transcription and translation by insertion into cellular hosts for protein production. Proteins produced from the expression vector system inhibit the growth of mammary cells, normal and cancerous (See Example 7.) Eucaryotic cells, e.g., Cos7 host cells, transfected with the vector express and secrete Mammastatin into the conditioned medium. Conditioned medium inhibited the growth of normal and cancerous mammary cells. (See Example 8.)

[**0063**] Amino Acid Sequence

[**0064**] The Mammastatin protein is a polypeptide having the sequence deduced from the nucleic acid sequence (SEQ ID NO.: 1) and shown in Table 1. Protein synthesized from the cloned Mammastatin nucleic acid sequence (SEQ ID NO.:1) inhibits breast cancer cell (MCF-7) growth.

[**0065**] Recombinant Mammastatin protein can be efficiently produced in purified form and in large quantities. Purified recombinant Mammastatin is useful as a reliable standard for diagnostic assays of the inhibitor in patient samples. Recombinant Mammastatin protein is also useful as a purified therapeutic agent to inhibit or prevent the growth of breast cancer cells.

[**0066**] Therapeutic Use

[**0067**] Mammastatin protein for therapeutic use is produced from NHMC cultures under serum free conditions or by recombinant means. Mammastatin phosphoprotein is used therapeutically to inhibit mammary cell growth, e.g., in the treatment of breast cancer. Preferably, Mammastatin is produced in higher eucaryotic cells to achieve phosphorylation of the protein. Recombinant Mammastatin protein is produced in host cells or by synthetic means.

[**0068**] Functional Mammastatin is administered to patients by known methods, for the administration of phosphoprotein, preferably by injection, to increase inhibitor levels in the bloodstream and increase the inhibitor's interactions with mammary cells.

[**0069**] The protein may be delivered to the patient by methods known in the field for delivery of phosphorylated protein therapeutic agents. In general, the inhibitor is mixed with a delivery vehicle and administered by injection.

[**0070**] The dosage of inhibitor to be administered may be determined by one skilled in the art, and will vary with the type of treatment modality and extent of disease. Since Mammastatin inhibits approximately 50% of mammary cancer cell growth at a concentration of 10 ng/ml and stops growth at about 20-25 ng/ml in vitro, a useful therapeutic dosage range is about 2.5 ug to about 250 ug administered daily dose. Preferred is approximately 125 ug daily administered dose. The aim of the administration is to result in a final body dose that is in the physiological or slightly higher range (50-75 ng/ml). Higher doses of inhibitor (>50 ng/ml) appear to induce apoptosis, as seen in histology of treated cells. For clinical use, the preferred dosage range is about 500 ng/ml for initial treatment of metastatic disease, followed by a maintenance dosage of about 50 ng/ml. Initial clinical studies, reported in the examples below, indicate an administered daily dose of about 50 ng/ml to about 750 ng/ml is sufficient to induce remission in Stage IV breast cancer patients.

[**0071**] Since active Mammastatin is a phosphorylated protein, it is anticipated that multiple doses of the inhibitor will be required to maintain growth inhibiting levels of Mammastatin in the patient's blood. Also, since Mammastatin generally acts as a cytostatic agent rather than a cytocidal agent, it is expected that a maximum effect of the inhibitor will require regular maintenance of inhibitor levels in breast cancer patients.

[**0072**] In its preferred use, Mammastatin is administered in high dosages (>50 ng/ml, preferably about 50-500 ng/ml) to induce tumor regression. Lower, maintenance doses (<50 ng/ml, preferably 20-50 ng/ml) are used to prevent cancer cell growth.

[**0073**] Clinical experience with administered Mammastatin in Stage IV breast cancer patients indicates a useful dose is that which maintains physiological levels of Mammastatin in the blood. Administration is preferably daily, but, may be, for example, by continuous infusion, by slow release depot, or by injection once every 2-3 days. Anecdotal evidence suggests continuous administration may induce feedback inhibition, thus, a preferred administration scheme is to administer daily dose of Mammastatin for approximately 25-28 days, followed by 2-5 days without administration.

[**0074**] Diagnostic Use

[**0075**] Assays of the present invention for detecting the presence of the functional inhibitor in human tissue and serum are useful in screening patients for breast cancer, for screening the population for those at high risk of developing breast cancer, for detecting early onset of breast cancer, and for monitoring patient levels of inhibitor during treatment.

For example, analysis of a patient's blood Mammastatin may indicate a reduced amount of high molecular weight, phosphorylated Mammastatin, as compared with a normal control or with the patient's prior Mammastatin profile. Such a change is correlated with increased risk of breast cancer, with early onset of breast cancer, and with advancing metastatic breast cancer. Diagnostic assay for phosphorylated, active, 49/53 kD Mammastatin preferably is by Western blot immunoassay, e.g. ELISA, or using specific anti-Mammastatin antibodies. Screening, for example, in serum, is preferably by immunoassay, e.g., dot blot assay.

[0076] For best results, the patient samples should be assayed within a short time of sampling (within one week), stored at 4° C. (less than one year), or frozen for long term storage. Most preferably, samples are frozen until time of assay.

[0077] Assay Kit

[0078] In a specific embodiment of the invention, an assay kit for the detection of Mammastatin in a patient's fluid and/or breast tissue is provided. The preferred screening assay is an immunoassay such as a dot blot assay to detect or quantitate Mammastatin in blood serum. Such a screening kit includes anti-Mammastatin antibodies and optionally a control antibody and/or Mammastatin controls or standards. A second screening assay analyzes Mammastatin in breast tissue. Preferably, the assay kit contains necessary reagents and tools for reacting the tissue with an antibody to specifically determine that the tissue is breast epithelium, e.g., an anti-cytokeratin antibody, and a specific anti-Mammastatin antibody. The commercially available antibody mixture, pan-keratin (Sigma) is a preferred anti-cytokeratin antibody.

[0079] A negative assay for Mammastatin could be caused by either the presence of a breast cancer tumor, or by non-epithelial breast tissue. Use of the anti-cytokeratin antibody guards against false positive assays. Epithelial cells of the breast that do not stain with the anti-Mammastatin antibody or which only express the 44 kD Mammastatin are transformed cells. Thus, by first identifying the tissue as breast epithelium, e.g., isolated from breast tissue and positive with the anti-cytokeratin antibody, and then identifying a second positive reaction with anti-Mammastatin antibody, false positives are avoided.

[0080] Because about 30% of the breast cancer cells studied to date express non-phosphorylated inactive, 44 kD Mammastatin, the preferred method of analysis is to differentiate between the 53/49 kD and 44 kD forms, e.g. by Western blot analysis.

[0081] The invention is further defined by reference to the following examples:

EXAMPLE 1

Human Mammary Cell cDNA Library

[0082] A cDNA library was prepared from human mammary cells obtained from reduction mammoplasties (UM Hospital). Total RNA was isolated from the mammary cells by cesium chloride gradient. From the total RNA preparation, mRNA was isolated. The methods used were those described in Garner I., "Isolation of total and poly A+ RNA from animal cells", *Methods Mol. Biol.* (1994) 28:41-7.

[0083] Reverse transcriptase in the presence of the isolated mRNA produced cDNA that was then ligated to EcoRI linkers. The cDNA was inserted into EcoRI cut T4 DNA ligase-treated Lambda Zap, and amplified in XL1-blue *E. coli*, following the method described in Short J M., et al. (1988) *Nucleic Acids Research* 16: 7583.

EXAMPLE 2

Preparation of Mammastatin Oligonucleotides

[0084] The normal human mammary cell cDNA library prepared in Example 1 was screened for the presence of nucleic acids encoding Mammastatin using degenerate oligonucleotides. The degenerate oligonucleotides were derived as follows:

[0085] Normal human mammary cells were obtained from the Plastic Surgery Department of the University of Michigan Hospital or from the Cooperative Human Tissue Network. The tissue was reduced by collagenase treatment generally following the procedure described in Soule, et al., *In Vitro,* 22:6 (1986).

[0086] Mammary cells were grown to confluence in 175 cm^2 flasks in DMEM/F12 low calcium media formulated with 40 μM $CaCl_2$ and supplemented with 5% CHELEX treated equine serum (Sigma), 0.1 μg/ml cholera toxin (Sigma), 0.5 μg/ml hydrocortisone (Sigma), 10 ng/ml epidermal growth factor (EGF, Collaborative Research, Bedford Mass.), 10 μg/ml insulin, and 1 μg/ml penicillin/streptomycin following the method described in Soule, et al., *In vitro* 22:6(1986). Equine serum was treated with CHELEX resin for three hours at room temperature to remove serum calcium.

[0087] Cell lysates were prepared by rinsing cells with TBS and scraping from the flask with a Teflon scraper. Cells were collected by centrifugation and lysed with 8M Urea, 50 mM TRIS pH 7.5, 0.5% Beta-mercaptoethanol, 0.5% TRITON X-100 (lysis buffer) and three minutes of sonication on ice.

[0088] The cell lysates were fractionated on DEAE-Sephacel anion exchange resin (Sigma) equilibrated with lysis buffer. Lysates were loaded onto the resin filled columns (50 ml disposable, Bio Rad) and washed with ten column volumes of the lysis buffer. Material flowed through the columns with only gravity feed. Fractions were eluted with a salt gradient produced by continuous gravity feed of elution buffer containing 5M NaCl into a closed mixing chamber initially containing elution buffer (250 ml of 8M urea and 50 mM TRIS pH 7.5) in the absence of salt.

[0089] Elution fractions (2 ml) were collected with a Gibson fraction collector, and were analyzed for the presence of mammary cell growth inhibitor by dot blot with the anti-Mammastatin antibody, 7G6, described above.

[0090] Positive fractions were pooled and dialyzed into lysis buffer with 50 mM NaCl, and were again separated on an identical ion exchange column and eluted with a continuous decreasing pH gradient (pH 8 to pH 3) in elution buffer with 50 mM NaCl. (To produce the pH gradient, pH 3 buffered urea was continuously mixed with the initial pH 8 buffer.) Fractions (2 ml) were collected and analyzed with the 7G6 antibody as described above.

[0091] Positive fractions were again pooled and concentrated to 1/10 the original volume by filtered centrifugation (Amicon Centriprep, 10 kD cutoff). The concentrated pool was size fractionated by preparative SDS polyacrylamide gel electrophoresis (PAGE) along with prestained molecular weight standards (Sigma).

[0092] Protein contained in the molecular weight range between 40 and 60 kD was excised from the gel in 0.5 cm strips or fractions. Electroelution of the protein from each gel strip was carried out by placing the gel strip in 1 ml of running buffer (192 mM glycine, 25 mM TRIS pH 8.3, 0.1% SDS) in dialysis tubing. The tubing was placed in a submarine electrophoresis apparatus and electroeluted overnight at 25 volts. Current was reversed for 2 minutes and running buffer, now containing the electroeluted protein, was removed. Purity of the eluted protein was checked by analytic SDS PAGE with silver-staining, and also by immunoblot with the 7G6 antibody, following the procedure described in Towbin et al., *J.Clin. Chem. Clin. Biochem.* 27:495-501 (1989). Fractions that were at least 70% pure as determined by silver-stained PAGE were pooled, concentrated, and lyophilized to powder form.

[0093] The pooled protein was cleaved with cyanogen bromide by resuspending lyophilized powder in 500 μl of 70% formic acid and incubating overnight at room temperature (about 20 hours) with 20 mg/ml of cyanogen bromide (Sigma). The methods used are described in Freemont, et al., *Arch. Biochem. Biophys.* 228:342-352 (1986). Cyanogen bromide-cleaved protein samples were dialyzed into double distilled, deionized water and again concentrated and lyophilized to powder.

[0094] Cyanogen bromide cleavage generated multiple peptides from the original protein sample, which were separated by preparative 15% SDS PAGE and transferred onto PVDF membrane by electroelution.

[0095] In addition to the protein obtained from mammary cell lysates, protein was also isolated from normal human mammary cell conditioned medium. Normal cells were incubated with 8 ml DMEM lacking phosphates and supplemented with 200 μCi/ml ^{32}P-ortho-phosphate and 1% dialyzed fetal bovine sera. Cells were allowed to grow for 24 hours in the presence of the ^{32}P before conditioned media was collected.

[0096] The collected conditioned media was concentrated 5× by Amicon filtration with 10 kD exclusion limit. Concentrated media was rinsed once with PBS on filtration membranes to remove excess unincorporated phosphate and was further fractionated by S-200 SEPHACRYL (Pharmacia, Upsala, Sweden) molecular sieve chromatography (100 cm×0.75 cm column) eluted with PBS. Both the filter and the column permit removal of unincorporated ^{32}P from the sample. One ml fractions were collected from the column, and labeled fractions identified by scintillation counting. Radioactive fractions were pooled and analyzed by SDS PAGE with silver staining and autoradiography. The pooled protein was concentrated, lyophilized to powder, and combined with the larger mass of unlabeled protein purified as described above, before cyanogen bromide cleavage. The addition of labeled protein provided a convenient means of tracing cyanogen bromide cleavage fragments containing phosphorylated Mammastatin peptides. Cleaved peptides were separated on preparative PAGE as described above.

[0097] After radioactive proteins were cyanogen bromide cleaved, separated, transferred to PVDF membrane, and exposed to X-ray film, two labeled bands of approximately 20 and 22 kD were seen. These two peptides were excised from membranes and sequenced by Edman degradation methods at the University of Michigan Biomedical Research Core Facility using methods described in Ullah Alt et. all., *Biochem. Biophys. Res. Comm.* 203:182-189 (1994). The amino acid sequences of each of the two peptides were compared with known database sequences using the NIH "BLAST" server. The two peptides appeared to be unique.

[0098] A particularly unique portion of each sequence was used to produce degenerate oligonucleotides, using the standard third position degeneracy according to the method described in Jerala, *Biotechniques* 13:564-567 (1992). From the 20 kD peptide, the sequence "gly-gln-leu-glu-tyr-gln-asp-leu-arg" (SEQ ID NO.:2) was used; from the 22 kD peptide, the sequence "tyr-glu-arg-asp-leu-lys-gly-arg-asp-pro-val-ala-ala" (SEQ ID NO.:3) was used to generate multiple species of oligonucleotides. The degenerate oligonucleotides were purified by high pressure liquid chromatography.

SEQ ID NO.:	Peptide
2	gly gln leu glu tyr gln asp leu arg
3	tyr glu arg asp leu lys gly arg asp pro val ala ala

[0099] The degenerate oligonucleotides were end-labeled with ^{32}P-gamma ATP and T4 DNA polynucleotide kinase (BRL, Bethesda, Md.) and resuspended in T4 DNA kinase buffer (60 mM TRIS pH 7.8, 10 mM $MgCl_2$, 15 mM beta-mercaptoethanol) at 1.5 mg/ml. Oligonucleotides (250 μM) were then incubated with 0.33 μM ATP, 5 units kinase in 25 μl kinase buffer, for two hours at 37° C. Incorporation of ^{32}P-phosphate was determined by TCA precipitation (15% TCA, 4° C., 15 minutes). Typical incorporation was 10^9 cpm/μg DNA.

EXAMPLE 3

Screening Mammary Cell cDNA Library with Degenerate Oligonucleotides

[0100] Bacteria infected with phage prepared for Example 1, containing a normal mammary cell cDNA insert, were plated on 15 cm NZCYM (10 g, NZ amine (Bohringer Manheim), 5 g NaCl, 5 g yeast extract, 2 g $MgSO_4$, 1 g casamino acids) plates in top agar (1/10 dilution of infected bacterial cultures to 6 ml of 7% NZYM top agar) and allowed to incubate eight hours at 37° C. Plates containing plaques were overlaid with nitrocellulose for 15 minutes before denaturation of phage. Phage was denatured by blotting filters (DNA side up) on Whatman paper saturated with 0.5 M NaOH, 1.5 M NaCl for 5 minutes. Filters were rinsed with H_2O before incubating for 5 minutes in 1 M TRIS pH 7.0, 1.5 M NaCl followed by 20×SSC and 2×SSC, each for 5 minutes. Filters were dried and baked for 1 hour at 80° C. or placed under ultraviolet light to immobilize

DNA. Baked filters were washed for 30 minutes in 2×SSC with 1% SDS and then prehybridized with 50% deionized formamide, 5×Denhart's solution, 1% SDS, 5×SSC and 100 μg/ml sheared salmon sperm DNA overnight at 37° C.

[0101] Filters were hybridized with the labeled degenerate oligonucleotide prepared as described for Example 2 in prehybridization buffer to which 10^7 cpm/ml of heat-denatured (95° C., 5 minutes) labeled degenerate oligonucleotide had been added. Hybridizations were performed at 37° C. for 24 hours. Filters were washed with 2×SSC for thirty minutes at 37° C. followed by 3 washes in 2×SSC plus 1% SDS at 50° C. for thirty minutes. Filters were rinsed with 2×SSC briefly, dried and exposed to Kodak AR-5 film for 24-48 hours to identify positive plaques.

[0102] Positive plaques were isolated from agar plugs excised using a reversed 200 μl sterile pipette tip, and resuspended in SM buffer overnight at 4° C. Secondary and tertiary plates (10 cm) were made using XL1-B infected with $\frac{1}{10,000}$ dilution of phage containing SM buffer, to bacteria, in NZCYM (with 1 mM MgSO4). Plaques were produced by incubating infected bacteria for 8 hours as described above, and were then transferred to nitrocellulose before screening with labeled degenerate oligonucleotides. Screening was performed essentially as described in Kroczek R A., *J Chromatogr* 20 618:133-45(1993), using 10^7 cpm/ml of labeled DNA for hybridizations and a final wash stringency of 2×SSC at 50° C. for thirty minutes.

[0103] The clone selected for further analysis was one recognized by both of the degenerate oligonucleotides. This clone was given the name "pMammA".

EXAMPLE 4

Sequencing of Mammastatin cDNA

[0104] The positive clone obtained in Example 3, pMammA, was sequenced by an automated sequencer at the Biomedical Research Core Facility at the University of Michigan and also by dideoxy DNA sequencing using 15% DNA sequencing gels and radiolabeling the DNA fragments with ^{35}S nucleotides. The methods used are described in Lasken R S., et al. *Proc Natl Acad Sci USA* 82:1301-5 (1985). The nucleic acid sequence obtained is shown below in Table 1 (SEQ ID NO.: 1).

[0105] The recognized error rate of automatic sequences is about 5%. Therefore, the clone deposited is resequenced for confirmation of the nucleotide sequence, particularly mindful of areas suspected of potential errors, as noted.

EXAMPLE 5

Subcloning the Mammastatin cDNA into an Expression Vector

[0106] The Mammastatin cDNA insert, pMammA, was subcloned into the expression vector, pcDNA 3 (Invitrogen). The Mammastatin cDNA was isolated by digesting the pMammA plasmid obtained as described for Example 4 with BamHI and XhoI restriction endonucleases. The restriction enzymes cut the plasmid at the ends of the Mammastatin clone insert, creating a linear plasmid fragment and a linear insert fragment. The digested sample was placed in the wells of a 1.2% agarose gel submerged in an electrophoresis apparatus, a 50V current was applied for two hours. Electrophoresis separates DNA fragments on the basis of size with the larger plasmid DNA fragment having the slower migration rate on the gel. The portion of the agarose gel containing the 2.4 kb was visualized by ethidium bromide staining and observing the gel over an ultra-violet light box. The 2.4 kb Mammastatin fragment was cut from the gel and placed into dialysis tubing and the DNA was electroeluted into tris-borate buffer, TBE: (0.089M Tris-borate, 0.089M boric acid, 0.002M EDTA) that was collected and precipitated with ethanol.

[0107] The pcDNA3 plasmid DNA was modified to accept the Mammastatin cDNA fragment during ligation. pcDNA3 plasmid was digested with BamHI and XhoI restriction endonucleases and after digestion was complete, the DNA was incubated for one hour in the presence of calf intestinal phosphatase to remove 5'phosphates. The pcDNA3 sample was then phenol extracted and ethanol precipitated.

[0108] The pcDNA3 and the Mammastatin 2.4 kB cDNA fragment were ligated together. The 2.4 kb Mammastatin fragment and the linear pcDNA3 plasmid were mixed in a 3:1 ratio in the presence of T4 DNA ligase. The ligation reaction was allowed to incubate for one hour and then stored at 4° C. overnight. After the ligation reaction was completed the DNA was used to transform *E. coli* competent cells. Subcloning was verified by purifying plasmid DNA from ampicillin selected colonies. The plasmids were digested with the restriction endonucleases BamHI and XhoI. The digested DNA samples were placed in an agarose gel and separated by electrophoresis. A plasmid containing the correct size Mammastatin DNA fragment was designated pMammB, and was deposited with the American Type Culture Collection (ATCC) on Feb. 22, 1996, and given accession number: ATCC 97451.

EXAMPLE 6

Transfection and Protein Expression from the Mammastatin cDNA Sequence

[0109] Cos-7 cells do not express immunoreactive proteins that co-migrate with the Mammastatin proteins. pMammB and PcDNA3 were used to transfect Cos-7 monkey fibroblast cells using LIPOFECTIN® (BRL, Life Technologies, Bethesda, Md.) using the manufacturers suggested protocol. The transfected cells were grown for two days prior to harvest. Transfected cells were removed from plates by trypsinizaton of cells using standard protocols. (2.5 mls of Trypsin (0.25% SIGMA) was incubated in flasks of cells at 37° C. for 5 minutes. A 7.5 ml aliquot of RPMI media with 10% FBS (fetal bovine serum) was added and cells were collected by centrifugation.) Cells were counted by hemocytometer and lysed in SDS PAGE sample loading buffer at 10^7 cells/ml. Cell lysates were separated on 8-15% SDS-PAGE gradient gels (Biorad) and transferred to a nylon membrane using methods described in Towbin H., et al., *J. Clin Chem Clin Biochem (August* 1989) 27(8):495-501. The membrane was probed with anti-Mammastatin monoclonal antibody 7G6. Bound antibody was detected with peroxidase conjugated GAM-IgM and developed by ECL (Amersham).

[0110] As shown in **FIG. 1**, Cos-7 cells transfected with pMammB (lanes C,D) expressed immunoreactive proteins that co-migrated with Mammastatin protein (lane A). Cos-7

cells transfected with the empty vector PCDNA3 alone did not express immunoreactive proteins when immunoblot experiments were performed (lane B).

Lane A	NHMC (25 μg) - control
Lane B	Cos pcDNA3 cell lysate (25 μg) - control
Lane C	Cos-pMammB cell lysate (10 μg)
Lane D	Cos-pMammB cell lysate (20 μg)

[0111] The immunoblot experiments illustrate the pMammB clone contains a cDNA insert capable of synthesizing a protein with the size and immunologic characteristics of Mammastatin. In addition, immunoreactive proteins of 44, 49 and 53 kD were expressed in Cos-7 cells transfected with pMammB. These proteins migrated at the same molecular weight as the Mammastatin proteins previously identified in normal human mammary cells. This group of immunoreactive proteins was not identified in Cos-7 cells transfected with the empty vector, pcDNA3.

[0112] In the particular assay shown in **FIG. 1**, the NHMC control shows an unusually high amount of 44 kD Mammastatin. This is an artifact produced by long term (>1 yr) storage of the NHMC standard at 4° C., causing degradation of the higher molecular weight forms, over time. When fresher NHMC samples (<1 yr old) or frozen samples are used, the 44 kD protein is always less abundant than the higher molecular weight forms.

EXAMPLE 7

GST Fusion

[0113] The Mammastatin clone can be similarly subcloned into a baculovirus expression system. The pMammA insert has been subcloned into a pAcG3X vector obtained commercially from Pharmingen (San Diego, Calif.). This vector allows production of Mammastatin as a fusion protein with glutathione S-transferase (GST), having a portion of the GST gene upstream of the coding site.

[0114] The pMammA insert was subcloned by preparing sets of PCR primers that contained BamHI (5') and SmaI (3') restriction enzyme recognition sites, a small, non-specific region, and a portion of the Mammastatin sequence. Three sets of primers, each shifted in reading frame, were prepared. The primers hybridized to the pMammA clones and in a typical PCR reaction with pMammA template DNA, amplified a pMammA PCR product capable of insertion into the reading frame of the GST gene in pAcG3X. The vector was then used to transfect High 5 (Invitrogen) host insect cells, and express a GST-Mammastatin fusion protein that was easily purified from host insect cells using glutathione resin (glutathione agarose, Qiagen, Chatsworth, Calif.).

[0115] To prepare DNA for insertion into the BamHI, SmaI restriction site of pAcG3X(PharMingen, San Diego, Calif.), primer sets were prepared in three reading frames to include, for the 5' primer, the BamH1 recognition site (GGATCC), a portion of the pMammA sequence, and some 5' sequence from the pBluescript vector. The 3' primers were identical, and included the SmaI recognition sequence (GGG CCC), a portion of the pMammA sequence, and some pBluescript sequence.

SEQ ID NO.:	
	5' Primers (in three reading frames)*
4	5'-TGG GAT CCC TTC GCC ACG AGC ACG GTG-3'
5	5'- TGG GAT CCT TCG CCA CGA GCA CGG-3'
6	5'- TGG GAT CCC CTT CGC CAC GAG CAC-3'
	3' Primer
7	5'- TTT TTT TTT TTT GGG CCC TTA AGT-3'**

*BamHI site underlined
**SmaI site underlined

[0116] Only one primer set (SEQ ID NOS.:5 and 7) produced clones capable of coding for active inhibitory Mammastatin. The active clones, when used to transform High 5 cells, produced Mammastatin that was immunologically reactive in the transformed cells (see **FIG. 2**).

[0117] Other known eukaryotic expression systems may similarly be used to produce Mammastatin protein.

EXAMPLE 8

Inhibition Assay with Proteins Produced by in vitro Transcription and Translation

[0118] In vitro transcription of pMammB, Mammastatin cDNA was performed using a Stratagene Express RNA transcription kit to produce Mammastatin RNA. The RNA produced was translated into protein using the Stratagene In Vitro Express translation kit (see **FIG. 3A**). Mammastatin protein produced from translation of the Mammastatin RNA was shown to inhibit mammary cell growth in culture.

[0119] Cultures of MCF-7 cells were treated with protein products produced in the translation assays described above. Protein products (5% by volume, culture medium) were added to cells in 12-well plates containing 1 ml medium per well. Parallel cultures were treated with both the translation product and the anti-Mammastatin antibody 3C6, at 30 μg/ml final concentration.

[0120] As a negative control, cultures were treated with protein products translated with the Stragene In Vitro Express Translation kit incubated in the absence of Mammastatin cDNA (i.e. employ vector). These lysates do not have the proper machinery to produce the Mammastatin protein.

[0121] All cultures were allowed to grow for six days after being treated with the protein products and the cell number of each sample was calculated using a Coulter counter. There were triplicate samples of each culture condition so that the cell number of each sample was averaged and percent inhibition was determined by comparison to the reticulocyte lysate treated control cells.

[0122] As shown in **FIG. 3**B, the protein translation product of pMammB inhibited MCF-7 cell growth. This inhibition was greatly reduced or blocked in the presence of anti-Mammastatin antibody, 3C6.

EXAMPLE 9

Inhibition of Mammary Cells with Proteins Present within Conditioned Media Obtained from Growing Cos-7 Cells Transfected with pMammB

[0123] Mammary cell growth inhibition experiments were performed using conditioned media obtained from Cos-7 cells transfected with pMammB as described for Example 6. Mammastatin is a secreted protein and is found in conditioned media of cells expressing the protein. The growth inhibition caused by conditioned media was blocked by the addition of anti-Mammastatin antibody.

[0124] MCF-7 cells were plated at 10^4 cells/ml in MEM supplemented with 10% non-essential amino acids and FBS (SIGMA). Cells were allowed to attach overnight and were then supplemented with 10% by volume of conditioned media (3 day culture) from either: (1) Cos-7 cells transfected with the empty vector pcDNA (Negative control), (2) Cos-7 cells transfected with pMammB (pMammB-Cos), (3) NHMC-conditioned media, or (4) non-conditioned media. Parallel MCF-7 cultures were supplemented with 30 ug/ml of 3C6 blocking antibody. Treated MCF-7 cells were allowed to grow for six days and were then counted by hemocytometer.

[0125] Inhibition of cell growth was determined by comparing the growth of MCF-7 cells incubated in conditioned media with the growth of MCF-7 cells incubated in control, non-conditioned media. Data are shown in **FIG. 4**, and demonstrate that conditioned media from pMammB-transformed cells inhibited mammary cancer cell growth as efficiently as did normal human mammary cell conditioned media. This inhibition was blocked in the presence of anti-Mammastatin antibody.

EXAMPLE 10

Three Immunologically Reactive Anti-Mammastatin Proteins

[0126] Whole normal human mammary cells (NHMC) and mammary carcinoma cells in tissue culture cells were lysed, and cell lysate proteins were separated by SDS/PAGE as described above and in Ervin, Paul, 1995, Doctoral dissertation, University of Michigan, Chapter 2. Lysed cell samples were separated on 10% SDS-PAGE in a Mini-Protean II apparatus (25 μg/sample). Proteins were transferred to nitrocellulose and probed with the anti-Mammastatin monoclonal antibody 7G6 or IgM control antibody, alkaline phosphatase conjugated second antibody, goat anti-mouse IgM was utilized with an NBT/BCIP substrate system to detect positive antibody reactions colorometrically. The data are shown in **FIG. 5**.

	CARCINOMA CELLS
LANE 1	ZR-75-1
LANE 2	MDA MB 435
LANE 3	4MCF-7
LANE 4	T47D
LANE 5	NHMC-14 positive control
LANE 6	NHMC-14 positive control with the 38C13 antibody

-continued

	NORMAL CELLS
LANE 7	NHMC-17
LANE 8	NHMC-16
LANE 9	NHMC-15
LANE 10	NHMC-14
LANE 11	NHMC-6
LANE 12	NHMC-14 positive control

[0127] As shown in **FIG. 5**, normal human mammary cells expressed a doublet of proteins migrating at 49 and 53 kD that were strongly recognized by the anti-Mammastatin monoclonal antibody and a third weakly immuno-reactive 44 kD protein. The four tumor cell lines tested expressed either a 44 kD immuno-reactive protein alone (lanes 1,4) or no immunoreactive protein at all (lanes 2, 3).

[0128] The above data is representative of experiments performed on normal cells from 42 different reduction mammoplasty patients over a period of several years. Expression of the 44 kD protein in normal cells and cancer cell lines varied in intensity with each preparation.

EXAMPLE 11

Mammastatin is a Phosphoprotein

[0129] Cellular phosphorylated proteins of mammary cells were labeled with ^{32}P by supplementing normal mammary cell cultures with ^{32}P-orthophosphate (200 μCi/ml) for 24 hours. Conditioned media was concentrated 5× by Amicom Centrifugation with a 30 kD molecular weight restriction. Concentrated media was rinsed once with PBS on filtration membranes to remove excess unincorporated phosphate and fractionated by S-200 SEPHACRYL (Pharmacia, Upsala, Sweden) molecular sieve chromatography (100 cm×0.75 cm column) with PBS elution buffer. Immunoblots were prepared as described above and probed with the 7G6 antibody.

[0130] A radiolabeled 53 kD Mammastatin protein was identified in conditioned media by immunoprecipitation. This analysis indicated Mammastatin is a secreted phosphoprotein. Since secreted phosphoproteins are uncommon, Brefeldin A treatment of cells was utilized to determine whether Mammastatin was present in conditioned media due to secretion or to cell breakage or leaking. Brefeldin A is a fungal compound that blocks the secretion of proteins from eukaryotic cells. Brefeldin A inhibits normal endoplasmic reticulum and golgi function and blocks vesicle formation (Ervin, Paul, 1995, Dissertation, Page 25). Since most secreted proteins are liberated from the cell by a process of exocytosis from membrane bound vesicles, blocking vesicle formation blocks secretion of many proteins. When NHMC are grown in the presence of Brefeldin A, phosphorylated Mammastatin is not identified in conditioned media.

[0131] To determine the amino acid residues that are phosphorylated in Mammastatin protein, radiolabeled 53 kD protein was subjected to phospho-amino acid analysis. NHMC cells were incubated with ^{32}P-orthophosphate for 24 hours. Cell lysates were then immunoprecipitated with the anti-Mammastatin antibody 7G6 and purified as follows. The 53 kD protein was digested with trypsin and hydrolyzed with acid. Two dimensional thin layer chromatography was

used to analyze the phosphorylated amino acids of Mammastatin. ^{32}P-amino acids were mixed with phospho-ser/thr/tyr controls and loaded at the origin (0) of a 2D TLC plate (20 cm). The samples were separated into two dimensions: 1st dimension—pH 1.9 Buffer (50 ml formic acid, 156 ml glacial acetic acid/2000 ml (1794 H_2O), 20 minutes @ 1.5 K volts; rotate clockwise; 2nd dimension—pH 3.5 Buffer (10 ml pyridine, 100 ml's glacial acetic acid:1890 ml H_2O) for 16 minutes @ 1.3 K volts.

[0132] The TLC plates were stained with ninhydrin and exposed to film. Phospho-amino acid analysis demonstrated the 53 kD Mammastatin protein contained three types of phosphorylated amino acid residues by comparing autoradiographs to ninhydrin stained phospho-amino acid standards.

[0133] Threonine (Th) was the most abundant phosphorylated amino acid followed by serine (S) and Tyrosine (Ty), the least abundant phosphorylated species. However, the relative abundance of phosphoamino acid residues may not be representative of that in the native protein, since acid hydrolysis can free phosphate from phosphotyrosyl residues.

EXAMPLE 12

One Mammastatin Protein with Varied Phosphorylation

[0134] Cellular phosphorylation of proteins can be modulated by phosphatases and kinases. Mammastatin is differentially phosphorylated in normal and tumor cell lysates due to differential activities of Mammastatin phosphatases. The effect of phosphatase on Mammastatin in NHMC lysates was examined.

[0135] NHMC were grown to confluence in low calcium media and collected by scraping into TBS. Cells were washed with TBS and resuspended at 2 mg/ml in acetate buffer pH 6.6 with 0.5% Triton X-100. 5 μg/ml of either Yersinia phosphatase (YOP)(Stuckey, et al., *Nature* 370:571-5 (1994)) or Yersinia phosphatase mutant (MYOP) containing an active site mutation was used to digest cell lysates for six hours at 37° C. (YOP and MYOP were gifts from Dr. S. Jack Dixon, University of Michigan, Biochemistry Department). As shown in **FIG. 6**, digestion of normal human mammary cell lysates with Yersinia phosphatase (YOP) resulted in a reduced amount of 53 kD Mammastatin protein identified by anti-Mammastatin immunoblot (lane A). In contrast, digestion with the Yersinia phosphatase mutant (MYOP, lane B), did not alter identification of the 53 kD Mammastatin protein. These results indicate identification of the 53 kD Mammastatin protein by immunoblot is a convenient measure of the state of phosphorylation of the Mammastatin protein.

[0136] Conditioned medium incubated in the presence of Yersinia phosphatase (YOP), as described above, was used to treat MCF-7 cells. As previously observed, NHMC conditioned medium inhibits the growth of MCF-7 cells, and this inhibition is blocked by anti-Mammastatin antibodies. As shown in **FIG. 7**, treatment of NHMC conditioned medium with YOP abrogates this inhibitory activity. As a control, treatment of NHMC conditioned media with a YOP mutant lacking phosphatase activity (M.YOP) was tested. This mutant had no effect on the inhibitory activity of NHMC conditioned media. Immunoprecipitation of the conditioned media with the anti-Mammastatin antibody 7G6 removed the inhibitory activity.

[0137] TCA precipitation indicated that incubation of conditioned media with YOP removed about 50% of incorporated phosphate. As shown above, YOP also removed the 53 kD species from NHMC lysates (**FIG. 6**).

EXAMPLE 13

Phosphorylated Mammastatin Produced by Normal but not Cancerous Mammary Cells

[0138] Normal and transformed mammary cells were labeled with ^{32}P orthophosphate. Carcinoma cell lines were grown in the media as suggested by the ATCC, with the exception of MCF-7 cells which were grown in MEM (Celox) supplemented with 10% FBS, non-essential amino acids, and insulin (10 mg/l). ^{32}P-orthophosphate labeling of cellular proteins was performed in phosphate-free DMEM (ICN) containing 2% dialyzed FBS. Cells were incubated 24 hours at 37° C. with 200 μCi/ml of ^{32}P-phosphate. After 48 hours, conditioned media was collected from cell cultures and concentrated 5×. Conditioned media was washed with TBS and concentrated on Amicon filters with a 10 kD mw cut-off. The cell layer was scraped (using a Teflon cell scraper) into lysis buffer, 1.5 ml/flask (0.5% Triton X-100, 2.01% SDS at deoxycholate) from cell lysates and conditioned media.

[0139] Mammastatin proteins were immunoprecipitated by adding 5 μg 7G6 anti-Mammastatin antibody per 500 μl of 5× concentrated media or cell lysate and incubating at room temperature for 1.5 hours. Goat anti-mouse IgM second antibody (5 μg/0.5 ml) was added and the mixture incubated an additional hour. Protein G PLUS/A agarose® slurry (Oncogene Science) was added and the mixture incubated 1.5 hours at room temperature to immobilize antibody complexes.

[0140] The complexes were washed 6× with lysis buffer, each wash followed by centrifugation at 3000×g. SDS-PAGE loading buffer (50 μl) was added before the sample was heated to 100° C. for 3 minutes. Supernatants were resolved by SDS-PAGE, transferred to nitrocellulose, and exposed to Kodak X-AR film.

[0141] Phosphate labeling of NHMC proteins and subsequent immunoprecipitation identified 49 and 53 kD phosphoproteins in NHMC. The 49 and 53 kD phosphoproteins were not recognized in carcinoma cell lines. Carcinoma cell lines MCF-7, T47D, ZR-75-1 and MDA-MB-435 expressed a 44 kD immunoreactive protein, but this protein did not label with ^{32}P-orthophosphate.

[0142] This study indicates more incorporated phosphate with increasing molecular weight of Mammastatin. Lack of phosphorylation of Mammastatin in transformed cell lines correlates with lack of higher molecular weight forms of the protein and lack of Mammastatin inhibitory activity.

EXAMPLE 14

Mammastatin Kinase & Phosphatase

[0143] Flasks of normal or carcinoma cells were grown to 75% confluence. Cell cultures were washed three times with TBS and then scraped into TBS with a Teflon scraper. Cell

suspensions were pelleted at 1000 g by centrifugation and then resuspended in a small volume of TBS. An aliquot of each type of cell was removed for protein quantitation. Protein concentrations were then equalized at 2 mg/ml in lysis buffer (TBS with 0.5% Triton X-100 and 5 μg/ml each of aprotinin, leupeptin, and PMSF). Equal masses of normal and tumor cell proteins were mixed and incubated at 37° C. for three hours. Parallel mixtures of normal and carcinoma cell lysates were performed in the presence of 10 nM orthovanadate ($NaVO_4$), a phosphatase inhibitor. The mixture was then separated by SDS/PAGE and analyzed by Western Blot using the 7G6 antibody. The data are shown in **FIG. 8**.

LANE A	ZR-75-1 Lysate (30 μg)
LANE B	NHMC Lysate (30 μg)
LANE C	NHMC (30 μg) + ZR 75 (30 μg) + 10 nM $NaVO_4$
LANE D	NHMC (30 μg) + ZR 75 (30 μg)

[0144] As shown in **FIG. 8**, cancer cells (ZR-75-1)(lane A) did not produce 53/49 kD Mammastatin, as compared with NHMC (lane B). Mixing of normal and cancer cell proteins, in the presence of proteinases, reduces the amount of active, 53 kD inhibitor (lane D). However, in the presence of the tyrosine-phosphatase inhibitor $NaVO_4$, the 53 kD species is retained in the mix (lane C). These results indicate that carcinoma cells express phosphatase activity capable of eliminating phosphorylated forms of Mammastatin.

[0145] Expression of Mammastatin in normal and transformed cell lines can be measured quantitatively by Western blot analysis. Using anti-Mammastatin monoclonal antibodies, it has been demonstrated that there is a consistent difference in expression of this protein between mammary carcinoma cells and cells derived from normal mammary epithelium. Mammastatin was recognized in normal human female mammary tissue as 44, 49, and 53 kD species by Western blot analysis with anti-Mammastatin monoclonal antibody 7G6. In mammary carcinoma cells, there was inconsistent recognition of a 44 kD species, but never 49 or 53 kD immunoreactive forms. When the 49 and 53 kD forms are identified in normal cells they are phosphorylated. The 44 kD species is not phosphorylated. It is therefore possible to use immunoblot analysis to determine if Mammastatin is phosphorylated by observing the expression of the 44 and 49, and 53 kD species of Mammastatin.

EXAMPLE 15

Identification of Mammastatin in Human Sera

[0146] An enzyme-linked immunosorbant assay (ELISA) was established to detect Mammastatin, using the purified anti-Mammastatin monoclonal antibodies 6B8 and 3C6.

[0147] The antibody 6B8 was used to coat Immulon 1 96-well microtiter plates (Immulon Corp.) at a concentration of 10 μg/ml or 100 μl/well, for three (3) hours at room temperature, or overnight at 4° C. Plates were blocked with 2% BSA (Sigma) in TBS (150 mM NaCl, 100 mM Tris pH 7.4) for 30 minutes and were then incubated with either purified Mammastatin or sample sera diluted 50% in 2% BSA solution for 1.5 hours at 37° C. Microtiter plates were washed for 5 minutes, three times with 300 μl/well of TBS plus 0.1% Triton X-100 before addition of second antibody.

[0148] Second antibody was biotinylated 3C6. Antibody was biotinylated by incubation with biotin, N-hydroxy succinimate ester (Sigma) in 0.1 M $NaHCO_3$ for two hours at room temperature and 16 hours at 4° C. Antibody was dialyzed into 1M NaCl, 50 mM Tris pH 7.4, 0.02% Azide (NaN_3, Sigma) before use or storage.

[0149] Biotinylated anti-Mammastatin antibody was added at 1 μg/ml and 100 μl/well, in a 2% BSA/TBS solution and incubated for 1.5 hours at 37° C. Microtiter plates were washed 5 times for 5 minutes with TBS plus 0.1% Triton X-100 as described above. Second antibody was identified with alkaline phosphatase conjugated streptavidin (Southern Biotechnology) and incubated for one hour at a dilution of 1/1000 in 2% BSA/TBS, 100 μl/well for all samples.

[0150] ELISA assays were developed colorometrically with PNPP (para-nitrophenyl phosphate Sigma), 1 mg/ml in alkaline phosphatase buffer (10 mM diethanolamine pH 9.5 (Sigma), 0.50 mM $MgCl_2$ (Sigma)). Microtitre plates were read on an ELISA reader at 405 nm at fifteen minute and thirty minute intervals.

[0151] Using chromatographically purified Mammastatin isolated from cell lysates or conditioned media, a standard curve was established for the ELISA indicating sensitivity of the assay for Mammastatin in the low nanogram range. (See **FIG. 9**). Quantitation of Mammastatin levels in normal human volunteer sera was performed in serum samples collected at two day intervals for one month, from a volunteer. Mammastatin levels in normal human female sera were detectable by this assay and varied between about 10 and 50 ng/ml (**FIG. 10**).

[0152] Mammastatin levels were also measured in sera collected from breast cancer patients. Patients diagnosed at the University of Michigan Breast Care Center with node negative breast cancer were tested for Mammastatin expression in sera throughout the course of their treatment. The data are shown in **FIG. 11** and summarized below. Serum samples were collected from breast cancer patients during the entire course of their treatment on a hormonal cycling, combined modality protocol with Cytoxin, Adriamycin, Methotrexate, and 5 Fu. Serum was separated from whole blood, after clotting, by centrifugation and stored at −20° C. until use. ELISA assay using 150 μl serum at 50% in 0.5% NFDM in duplicate were performed, using the 6B8 and 3C6 anti-Mammastatin antibodies in an enzyme linked—"sandwich" assay. The standard curve was generated with chromatographically purified Mammastatin and was comparable to that shown in **FIG. 9**.

[0153] Expression of Mammastatin varied among patients and fluctuated during the course of their treatment. It was consistently observed that Mammastatin levels became undetectable with progression to metastatic disease.

[0154] Patients diagnosed with breast cancer had low levels of Mammastatin in serum at the time of diagnosis as compared with levels in normal patient serum. Mammastatin levels generally rose on the hormonal cycling, adjuvant chemotherapy protocol. Levels of Mammastatin fluctuated on this protocol. Mammastatin levels were undetectable in patients with advanced disease, before death. The patient data sorted into four groups, as shown in the table below.

[0155] I. Group of patients whose serum Mammastatin levels continued to raise during therapy.

[0156] II. Group of patients whose serum Mammastatin levels increased initially during therapy, but then became undetectable.

[0157] III. Group of patients whose serum Mammastatin levels rose during therapy, but then fluctuated widely.

[0158] IV. Group of patients who had low serum Mammastatin levels which became undetectable with therapy.

Summary of Mammastatin Levels in Patient Sera

Group	Number	Days Followed	Outcome
I.	4 p	280 +/- 100	Remission
II.	14 p	500 +/- 220	Deceased
III.	10 p	380 +/- 280	Variable
IV.	5 p	290 +/- 150	Deceased

EXAMPLE 16

In vivo Efficacy of Mammastatin

[0159] CD-1 Nu/Nu homozygate, female, six week old mice (Charles River) were supplemented with Estrogen via slow release pellets, 0.72 mg/pellet, 60 day release of 17-beta estradiol (Innovative Research #SE-121). Estrogen supplemented mice were injected with 3×10^6 MCF-7 cells 100 μl per injection in 60% matrigel. Two injections were administered, one per flank. After seven days of tumor cell growth, Mammastatin was administered. Test mice received 1, 2, or 5 μg of Mammastatin in production media at 2 day intervals for a period of six weeks. Control mice were injected with BSA, or were not injected with tumor, but with the inhibitor alone.

[0160] Tumor size was measured at the point of greatest diameter at weekly intervals and averaged for treatment group. The results are shown in FIGS. **13**A-**13**C, with tumor size plotted as the mean diameter±standard deviation.

[0161] This animal study was repeated using MDA-231 tumor cells. Cells were injected at a concentration of 2×10^6 cells per injection as described above for MCF-7 cells.

[0162] The results are shown in FIGS. **14**A-**14**C.

[0163] The results shown were not as great as expected. The animals were injected by tail vein, resulting in less than the needed blood dose. Subsequent studies using intraperitoneal injection have resulted in more effective treatment. At doses of 5 ug/mouse and higher, tumor growth is abrogated.

EXAMPLE 17

Retrovirus Expression of Mammastatin

[0164] The Mammastatin cDNA (2.4 kilobase (kb) insert) was subcloned into a retroviral expression vector. The vector was used to transfect 3T3 fibroblast cells. Transfected cells were harvested, lysed, and the cell lysate analyzed by Western Blot.

[0165] As shown in **FIG. 12,** 3T3 cells transfected with the Mammastatin-carrying retrovirus, expressed phosphorylated Mammastatin.

EXAMPLE 18

Expression of Mammastatin in Baclovirus and Cos 7 Cells

[0166] **FIG. 16** shows the production of recombinant Mammastatin in Cos-7 Monkey Kidney Cells. Cell lysates were probed with the 7G6, anti-mammastatin monoclonal antibody. Lane A of **FIG. 16** is 25 μg NHMC-20, normal human mammary cell lysate (positive control); lane B is 25 μg Cos-7 cell lysates, transfected with pcDNA3 (negative control); lane C is 10 μg Cos-pMammB cell lysate, transfected with pcDNA3/mammastatin construct; and lane D is 20 μg Cos-pMammB cell lysate. Experiment was repeated 3 times with similar results.

[0167] Induction of recombinant mammastatin expression in Cos-7 cells demonstrates that the mammastatin gene codes for authentic mammastatin. Furthermore, the observation that Cos-7 cells express the different forms of mammastatin associated with phosphorylation of the protein suggests that mammastatin will be phosphorylated and active when produced in eucaryotic cell lines other than human mammary cells. Stable transfectants have been selected to allow perpetual synthesis of recombinant mammastatin.

EXAMPLE 19

Production of Mammastatin by Normal Human Breast Epithelial Cells in Culture

[0168] Healthy breast tissue was obtained from reduction mammoplasty, sterile, and direct from the operating room. The tissue was minced under sterile conditions in a laminar flow hood in a solution containing 4 units per gram of type III collagenase (Life Sciences, Bethesda, Md.). The minced tissue was incubated overnight in a shaking water bath at 37° C. to allow collagenase digestion.

[0169] Collagenase digested breast tissue, a viscous fluid containing a variety of cell types and lipid released from adipose cells, was centrifuged to separate lipid, aqueous solution, and other cell types. The collagenase-digested material was spun at 1000 rpm in a table top centrifuge at room temperature for 5 minutes. Adipose cells and free lipid partitioned to the top half of the centrifuge tube, and were withdrawn by aspiration and discarded. The aqueous supernatant positioned above the cell pellet was also withdrawn by aspiration and discarded. The remaining cell pellet was washed with sterile solutions of mammalian growth media, DMEM, pH 7.4. The washing was continued until the supernatant from the washes was no longer turbid (for example about 4 washes). The washed cells were resuspended in growth media and allowed to settle by gravity for 30 minutes at 40° C. Because red blood cells are enucleated and are less dense than nucleated epithelial cells, this procedure resulted in removal of the red blood cells from the sedimented epithelial cells, by withdrawing the supernatant containing the red blood cells. This sedimentation procedure was repeated until no red color remained in the cell pellet, e.g., about 2 times. The remaining cell pellet was resuspended in a nutrient rich DMEM/F12 growth media containing 5% equine serum, 10 μg/ml epidermal growth factor, 100 ng/ml of cholera toxin, 500 ng/ml hydrocortisone, 10 μg/ml insulin, 100 units/ml penicillin and streptomycin, and 1 mM concentration of calcium chloride. Physiological concentrations of calcium helped to promote cell attachment and outgrowth in cell culture. The cell suspensions were incubated in sterile tissue culture flasks at 37° C. with a 5% CO_2 concentration.

[0170] Initial cultures of normal breast tissue contain a mixed cell population. The adipocytes, neurons, and vascu-

lar tissue are significantly reduced by the differential centrifugation process described above. Connective tissue cells are present in significant amounts. To remove non-epithelial cells, a differential attachment method was used. Fibroblasts, neurons, and other cell types in breast tissue all attach to tissue culture plastic more rapidly than epithelial cells. In addition, all of these cell types are removed from tissue culture plastic by trypsin more rapidly than epithelial cells. To enrich the cultures for breast epithelial cells, cultures beginning to form a monolayer (5-7 days after initial plating) are treated with a trypsin:EDTA solution (250:1) molar ratio. The majority of cells were removed within 5 minutes of incubation at 37° C. The remaining attached cells were more than 90% epithelial breast cells. These cells were saved and returned to the growth medium described above with 40 μM calcium chloride. The fibroblast cells were removed from the trypsinized culture flasks, collected by centrifugation, resuspended in growth medium, and plated onto tissue culture plastic for 30 minutes at 37° C. The attached cells were predominantly fibroblasts. The cells that did not attach were significantly enriched for fibroblast cells (50-80%). These suspended cells were removed and allowed to settle in fresh tissue culture flasks. This process was repeated twice to obtain cell populations that were predominantly epithelial. Because cholera toxin promotes epithelial cell growth and inhibits fibroblast growth, and because fibroblasts do not grow well in reduced calcium, the cultures were approximately 100% epithelial within one week in the low calcium medium described above. These cultures of normal human mammary cells (NHMC) produced Mammastatin into the culture medium.

[0171] Nutrient medium used to grow the NHMC contains 5% equine serum, which is not acceptable for human injection. The equine serum proteins must either be purified away from the mammastatin protein, or the cells grown in medium devoid of the serum. Normal cells can only be maintained in the absence of serum for about seven to ten days. In order to produce a significant quantity of serum free mammastatin over a prolonged period of time, the cells were alternately grown in serum-free and serum-containing medium.

[0172] NHMC were grown to complete confluence in growth media as described above. The cells began to bud in solution as they grew, when cells covered the available surface of the flask, budding cells were collected and transferred to new flasks. Confluent flasks were rinsed three times with sterile saline, with a five minute saline incubation between washes to remove serum protein. Cells were then provided with serum free "production medium" that was essentially the growth medium devoid of serum, cholera toxin, and hydrocortisone. Cells were maintained on the production medium for about 4 days (96 hours), with collection of the medium, and a return of the cells to growth medium for at least four days. The typical batch size for Mammastatin produced in this way was 1-2 liters. Mammastatin has also been produced in a Bioreactor, the Bioflow 3000, New Brunswick Scientific. In this perfusion reactor, cells were attached on tissue culture treated fibracell disks. The cell-attached disks were maintained in a basket in the reaction vessel and perfused with media. When NHMC were introduced to the reactor, they populate the fibracell disks and were fed by the perfusion of media. Conditioned media was harvested from the reactor and refrigerated.

EXAMPLE 20

Dot Blot Serum Assay for Mammastatin

[0173] Serum from a 25 year old healthy female was obtained and compared with serum from a breast cancer patient (Stage IV), an undiagnosed sibling of the patient, and from the patient's mother, whose family has a history of breast cancer. The serum samples were compared in an immunoassay for the presence of Mammastatin. Blood samples from multiple breast cancer patients taken on day of diagnosis were also analized in the immunoassay. Normal human mammary cell (NHMC) conditioned media was used as a standard control. Standard NHMC mammastatin contained approximately 50 ng/ml as determined in a dot blot assay with mammastatin protein standard chromatographically purified.

[0174] Individual blood samples were collected into vacutainer tubes, and the serum separated from whole blood. Serum samples (250 or 500 μl volume) were applied without dilution to nitrocellulose by suction using a 96 well, S&S Dot-Blot manifold. Conditioned medium was prepared as described for Example 19. Samples on the nitrocellulose filters were washed with Triton X-100 in TBS, blocked with non-fat dry milk (5% in TBS) and incubated with 1 μg/ml of first anti-mammastatin antibody (7G6 mouse IgM) in 5% non-fat dry milk for 1.5 hours at room temperature, followed by incubation with 1 μg/ml of second antibody (goat anti-mouse IgM conjugated to alkaline phosphatase) in 5% non-fat dry milk for one hour and room temperature. The alkaline phosphatase color reaction was developed using nitroblue-tetrazolium and BCIP.

[0175] As shown in **FIG. 15**, the amount of Mammastatin in the sample was quantitated against the standard curve obtained from normal breast cell conditioned medium. Serum obtained from healthy females contained readily detectable amounts of Mammastatin, as indicated by darkly colored blots, whereas serum from diagnosed breast cancer patients, and from undiagnosed family members showed little or no Mammastatin. Additional samples were obtained from breast cancer patients on day of diagnosis, from healthy members of a breast cancer patient's family, and from healthy females and males. The serum was processed as described above in order to analyze Mammastatin. The dot blots were evaluated as "negative or low" or "positive or high" to indicate the intensity of the developed color reaction. Data are shown in the following table.

Sample	Number	Negative or Low	Positive or High
Breast Cancer patient	89	83 (93%)	6 (7%)
Healthy female	11	2 (18%)	9 (82%)
Healthy member of high risk family	4	4 (100%)	0
Male	3	2	1

EXAMPLE 21

Treatment of Human Breast Cancer Patients

[0176] Twenty-nine (29) Stage IV breast cancer patients with recurrent breast cancer, who had failed, or were failing on chemotherapeutic regimes were given access to Mamm-

astatin protein. The protein was produced as described above for Example 19, and provided in production medium, with the required dose in a 3 ml injection volume. Patients administered the protein intravenously according to their prescribed regimen. In general, one daily dose was injected. The selected dose was that which provided physiological amounts of Mammastatin in the patient's bloodstream, e.g., 5-50 ng/ml in healthy women. The dosage and frequency for each patient are indicated in the table below.

Patient Number	Dose (ug)	Schedule	Result
1.	125	daily	complete remission followed by relapse*
2.	125	daily	complete remission; pain if therapy stopped
3.	75	daily	non-responder*
4.	75	daily	partial remission; possible immune reaction**
5.	75	daily	non-responder*
6.	125	daily	partial remission
7.	125	daily	partial remission*
8.	75	daily	non-responder*
9.	125	every third day	complete remission
10.	125	daily	non-responder
11.	125	daily	partial remission
12.	125	daily	non-responder#
13.	150	daily	non-responder*
14.	75	daily	non-responder#
15.	125	daily	partial remission
16.	125	daily	partial remission
17.	75	daily	non-responder, infection**
18.	125	daily	partial remission
19.	125	daily	partial remission
20.	125	daily	partial remission
21.	125	every other day	non-responder**; alternative therapy
22.	125	every other day	partial remission
23.	125	every other day	non-responder
24.	125	daily	non-responder
25.	125	daily	non-responder
26.	125	daily	partial remission
27.	125	daily	partial remission
28.	125	every other day	partial remission
29.	125	daily	

Total	Responders	% Responders	% without liver involvement	% without lung or liver involvement
29	17	59	81	89

*patient deceased
**Patient withdrawn from therapy
#evidence of improvement in jaundice prior to death

[0177] Of the group of 29 patients, six, having late stage liver disease, did not survive. These six patients displayed clinical evidence of liver failure before receiving Mammastatin, and were not helped by the treatments. One patient showed signs of decreased jaundice before her liver failed, but all six of these patients appeared to die of nitrogen toxicity common to patients with advanced liver cancer.

[0178] Of the remaining patients, two have died of their disease. One appeared to be disease-free after two months of Mammastatin therapy. This patient was removed from therapy, and relapsed within two months. The patient's disease was never brought back under control and she died of liver involvement. The second patient died after 4 months of treatment, having never shown any sign of response to the therapy. There was no sign of toxicity in any of these patients, although the dose of Mammastatin in these latter two patients was increased ten fold.

[0179] Of the 19 patients currently receiving Mammastatin therapy, the majority show signs of positive benefit and no signs of adverse reaction. It is unclear if three of these patients are receiving any benefit from Mammastatin. The other 16 patients show definite clinical signs of benefit including decreased tumor markers (CA15-3 and CA27-29) to normal levels, decreased size of palpable tumor masses, decreased disease as evidenced on MRI scan, and decreased pain. Several of these patients show improvement to the point of being considered disease free. However, it has consistently been observed that denying these patients protein for periods of three to five days results in resumption of disease activity as evidenced by increased pain, even in patients that show no signs of disease. Resumption of protein treatments decreases or eliminates the symptoms of increased pain within 2-4 hours.

[0180] It has also been observed that Mammastatin levels in the blood decline after long term treatment, suggesting a negative feedback system. This decline in constant blood levels is successfully avoided by providing Mammastatin daily for a period of about 28 days, followed by 2-3 days without protein.

EXAMPLE 22

Recombinant Mammastatin for Human Therapy

[0181] Recombinant Mammastatin has been produced in Cos-7 monkey kidney cells, chinese hamster ovary (CHO) cells, and Sf9 insect cells by transfecting the cells with a plasmid containing the Mammastatin cDNA sequence. The Mammastatin cDNA has been stably integrated into the genomes of these producing cell lines, and secrete protein immunoreactive with growth inhibitory activity.

[0182] To produce Mammastatin from these cells and isolate the protein for human use, the cell lines are grown in serum free medium for approximately 48 to 72 hours. The media is withdrawn and protein purified from conditioned medium, either by ion exchange chromatography in Tris buffer, pH7.5, using a sodium chloride gradient from about 0.1 M to about 0.5 M, collecting the Mammastatin fraction at about 0.2 M. The protein fraction is then dialyzed against normal saline, diluted if necessary, and filter sterilized.

[0183] In an alternative method, Mammastatin is produced as a fusion protein in Cos7 or SF9 cells. The fusion protein contains a histidine tag (six histidine residues) and a Factor X proteinase cleavage site. The Mammastatin expressing cells are cultured, preferably in 1% serum-containing media, the conditioned media is collected and passed over a nickel chelating resin. The His-fusion protein adheres to the column, is washed with 50 mM TRIS, pH 7.5, 0.1 M NaCl, and is slowly eluted with TRIS-NaCl containing 10 Unit/ml Factor X proteinase. This liberates Mammastatin from the His fusion. Mammastatin is separated by molecular sieve chromatography, or by ion exchange chromatography as described above.

[0184] The above specification, examples and data provide a complete description of the manufacture and use of the composition of the invention. Since many embodiments of the invention can be made without departing from the spirit and scope of the invention, the invention resides in the claims hereinafter appended.

TABLE 1

(1)
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(51)
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(101)
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(151)
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(201)
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(251)
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(301)
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(351)
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(401)
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(451)
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(501)
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(551)
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(601)
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(651)
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(701)
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(751)
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(801)
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(851)
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(901)
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(951)
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(1001)
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(1051)
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(1101)
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(1151)
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(1201)
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TABLE 1-continued

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(1351)
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(1401)
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(1501)
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(1601)
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(1801)
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(1851)
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(1901)
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(1951)
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(2101)
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(2151)
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(2201)
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(2250)
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(2300)
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(2350)
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[0185]

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We claim:

1. A method comprising the steps of:

a) determining an amount of mammastatin present in a patient's sample, wherein said mammastatin is a polypeptide having an approximate molecular weight of 53 kD when phosphorylated and is produced by normal human mammary cells or a polypeptide produced by normal breast cancer cells and specifically reactive with monoclonal antibody 7G6 produced from hybridoma ATCC No. HB10152;

b) comparing the amount of determined mammastatin to a control, said control comprising an amount of mammastatin from a normal, non-breast cancer female; and

c) correlating an amount of mammastatin less than the control with the presence of, or predisposition to, breast cancer.

2. The method according to claim 1 wherein the predisposition to breast cancer is an indication of an increased risk of developing breast tumors.

3. The method according to claim 1, wherein the sample comprises mammary tissue, mammary cells, or fluids from the patient.

4. The method according to claim 1 where, in the step of obtaining, the sample comprises blood or blood serum from the patient.

5. The method according to claim 1, where the step of determining comprises use of an immunoassay.

6. The method according to claim 5 wherein the immunoassay is a Western blot.

7. The method according to claim 5 wherein the immunoassay is a dot blot.

8. The method according to claim 5 wherein the immunoassay is an enzyme-linked immunosorbent assay.

9. The method according to claim 1, wherein the control comprises an amount of mammastatin of at least 10 ng/ml.

10. The method according to claim 9, wherein the control comprises an amount of mammastatin in the range of 10 ng/ml to 50 ng/ml.

11. The method according to claim 9, wherein the control comprises 10 ng/ml of mammastatin.

12. The method according to claim 1 wherein the control comprises normal human mammary cells.

13. The method according to claim 1 wherein the control comprises control comprises mammary cells, or mammary tissue, or fluid obtained from a normal, non-breast cancer female.

14. A method for diagnosing a patient, comprising the steps of:

a) quantifying an amount of mammastatin in a first and a second sample of the patient's mammary cells, mammary tissue, or fluids, wherein a) said mammastatin is a polypeptide having an approximate molecular weight of 53 kD when phosphorylated and is produced by normal human mammary cells or a polypeptide produced by normal breast cancer cells and specifically reactive with monoclonal antibody 7G6 produced from hybridoma ATCC No. HB10152, and b) the second sample is obtained after the first sample;

b) comparing the amount of mammastatin in the first sample with the amount mammastatin in the second sample; and

c) correlating a decrease in the amount of mammastatin in the second sample with the presence of, or predisposition to, breast cancer.

15. A method comprising the steps of:

a) determining an amount of mammastatin present in a patient's sample, wherein said mammastatin is a polypeptide having an approximate molecular weight of 53 kD when phosphorylated and is produced by normal human mammary cells or a polypeptide produced by normal breast cancer cells and specifically reactive with monoclonal antibody 7G6 produced from hybridoma ATCC No. HB10152; and

c) correlating an amount of mammastatin less than about 10 ng/ml with the presence of, or predisposition to, breast cancer.

16. A kit comprising:

a) a reagent composition comprising monoclonal antibody 7G6, said monoclonal antibody produced from hybridoma ATCC No. HB10152 and able to specifically bind mammastatin, a polypeptide produced by normal human mammary cells having an approximate molecular weight of about 53 kD when phosphorylated, wherein said reagent composition is configured and arranged to allow for quantitation of mammastatin in a sample; and

b) a protein standard comprising mammastatin, wherein said standard is configured and arranged to allow for quantitation of the amount of said mammastatin in a sample.

* * * * *

专利名称(译)	用于诊断乳腺癌的方法和组合物		
公开(公告)号	US20030108961A1	公开(公告)日	2003-06-12
申请号	US10/192915	申请日	2002-07-09
[标]申请(专利权)人(译)	密歇根大学		
申请(专利权)人(译)	密歇根大学		
当前申请(专利权)人(译)	密歇根大学		
[标]发明人	ERVIN PAUL R JR		
发明人	ERVIN, PAUL R. JR.		
IPC分类号	G01N33/53 A61K38/55 A61K45/00 A61K48/00 A61P35/00 C07K14/47 C07K16/18 C12N15/09 C12N15/12 C12Q1/68 G01N33/574		
CPC分类号	C07K14/4703 A61K48/00		
优先权	60/027315 1996-10-03 US		
其他公开文献	US7332287		
外部链接	Espacenet USPTO		

摘要(译)

乳房抑制素的无活性非磷酸化形式的分子量约为44kDa。正常乳腺细胞表达具有约53kDa和49kDa的近似分子量的功能性磷酸化形式。转移性乳腺细胞或者根本不表达乳房抑制素，或者不表达53kDa或49kDa的磷酸化形式。通过施用磷酸化的乳房抑制素抑制乳腺癌细胞的生长。

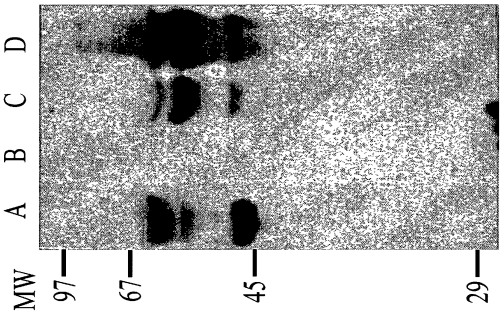

FIG. 1