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(54) Titre : IMMUNOREACTIVITE ENVERS L'EXPRESSION D'ONCOGENES ACTIVES POUR LE DIAGNOSTIC ET LE TRAITEMENT DE TUMEURS MALIGNES

(54) Title: IMMUNE REACTIVITY TO EXPRESSED ACTIVATED ONCOGENES FOR DIAGNOSIS AND TREATMENT OF MALIGNANCY

(57) Abrégé/Abstract:
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Methods for the detection, monitoring and treatment of malignancies are disclosed. Detection of the proliferation of T cells in response to *in vitro* exposure to a protein expression product of an acivated oncogene or cancer-related gene associated with a malignancy, or detection of immunocomplexes formed between the protein expression product and antibodies in body fluid, allows the diagnosis of the presence of a malignancy. The present invention also discloses methods and compositions for treating a malignancy.

Description

IMMUNE REACTIVITY TO EXPRESSED ACTIVATED ONCOGENES FOR DIAGNOSIS AND TREATMENT OF MALIGNANCY

Technical Field

The present invention is generally directed toward the detection, monitoring, and treatment of malignancies through the use of a cancer patient's own immune reactivity to the protein expression product of an activated oncogene or cancer-related gene associated with malignancy.

Background of the Invention

Despite enormous investments of financial and human resources, cancer remains one of the major causes of death. A common characteristic of malignancies is uncontrolled cell growth. Cancer cells appear to have undergone a process of transformation from the normal phenotype to a malignant phenotype capable of autonomous growth. Mutation of somatic cell genes is considered to be a common primary event that results in the transformation of normal cells to malignant cells. The malignant phenotypic characteristics encoded by the mutated genes are passed on during cell division to the progeny of the transformed cells. Various genes involved with transformation have been designated as oncogenes. Oncogenes were originally identified as components of the genetic material of oncogenic viruses. The homologous genes on human chromosomes are commonly termed oncogenes or proto-oncogenes.

Ongoing research involving oncogenes has identified at least forty oncogenes operative in malignant cells and responsible for, or associated with, transformation. Oncogenes have been classified into different groups based on the putative function or

location of their gene products (such as the protein expressed by the oncogene).

Proto-oncogenes are believed to be essential for certain aspects of normal cellular physiology. Certain proto-oncogenes appear to be activated to a cellular oncogene through quantitative mechanisms that result from increased or deregulated expression of an essentially normal gene product. For example, the *myc* gene family has been associated with initiation and/or progression of certain human lymphomas and carcinomas, whose transforming activation is the result of quantitative mechanisms. Alternatively, other proto-oncogenes appear to be activated to transforming cellular oncogenes through qualitative mechanisms, including mutation in the coding sequence of the gene. This creates a gene product with an altered primary structure and biochemical properties as a result of one or more differences in the amino acid sequence of the protein. For example, the *ras* gene family, causally associated with the most common forms of human malignancy (e.g., colon cancer) is activated as a result of single codon changes.

Studies to develop cancer therapies have, in general, focused on the use of characteristic differences between normal and malignant cells. Mutated, translocated or otherwise overexpressed proto-oncogenes and the products of such genes represent potential identifiable characteristic differences between normal and malignant cells. The identified differences have been utilized in attempts to develop diagnostic assays or therapeutic regimens.

An approach to developing a diagnostic assay has been to attempt to quantify the expressed product of an oncogene in tissue or body fluids, utilizing antibodies directed toward the unique or abnormal oncogene product. In general, xenogeneic antibodies have been raised against the abnormally expressed proto-oncogene product. Problems in the development of diagnostic assays based on detecting

abnormal oncogene products include the following factors: (1) a lack of antibodies with high specificity, affinity and selectivity for the abnormal product; (2) only small amounts of abnormal oncogene product may be released by tumor cells; (3) oncogenic products may be released only intermittently by tumor cells; (4) the oncogene product may be absorbed out of the body fluid by antibody or may be formed into immune complexes; and (5) the free antigen may be rapidly cleared or degraded.

Due to the difficulties in the current approaches to cancer diagnosis and therapy, there is a need in the art for improved methods and compositions. The present invention fills this need, and further provides other related advantages.

Summary of the Invention

Briefly stated, the present invention provides a variety of methods for the detection of a malignancy in a warm-blooded animal, wherein an activated oncogene or cancer-related gene is associated with the malignancy. The methods may be used on a one time basis when a malignancy is suspected or on a periodic basis to monitor an individual with an elevated risk of acquiring a malignancy. In one embodiment, the method comprises the steps of: (a) incubating T cells, isolated from a warm-blooded animal, with at least one protein expression product of an activated oncogene or cancer-related gene associated with the malignancy; and (b) detecting the presence or absence of proliferation of the T cells, thereby determining the presence or absence of the malignancy. In another embodiment, the method comprises the steps of: (a) contacting a body fluid, suspected of containing antibodies specific for a protein expression product of an activated oncogene or cancer-related gene associated with the malignancy, with at least one protein expression product of an activated oncogene or cancer-related gene associated with the malignancy;

(b) incubating the body fluid under conditions and for a time sufficient to allow immunocomplexes to form; and (c) detecting the presence or absence of one or more immunocomplexes formed between the protein expression product and antibodies in the body fluid specific for the protein expression product, thereby determining the presence or absence of the malignancy.

In another aspect, the present invention provides methods for monitoring the effectiveness of cancer therapy in a warm-blooded animal with a malignancy, wherein an activated oncogene or cancer-related gene is associated with the malignancy. In one embodiment, the method comprises the steps of: (a) contacting a first body fluid sample, taken from the warm-blooded animal prior to initiation of therapy, with at least one protein expression product of an activated oncogene or cancer-related gene associated with the malignancy; (b) incubating the body fluid under conditions and for a time sufficient to allow immunocomplexes to form; (c) detecting immunocomplexes formed between the protein expression product and antibodies in the body fluid specific for the protein expression product; (d) repeating steps (a), (b), and (c) on a second body fluid sample taken from the animal subsequent to the initiation of therapy; and (e) comparing the number of immunocomplexes detected in the first and second body fluid samples, thereby monitoring the effectiveness of the therapy in the animal.

The present invention is also directed toward methods for treating a malignancy in a warm-blooded animal, wherein an activated oncogene or cancer-related gene is associated with the malignancy. In one embodiment, the method comprises the steps of: (a) isolating T cells from a warm-blooded animal; (b) incubating the T cells in the presence of at least one protein expression product of an activated oncogene or cancer-related gene associated with the malignancy, such

that the T cells proliferate; and (c) administering to the warm-blooded animal an effective amount of the proliferated T cells. In another embodiment, the method comprises the steps of: (a) isolating T cells from a warm-blooded animal; (b) incubating the T cells in the presence of at least one protein expression product of an activated oncogene or cancer-related gene associated with the malignancy, such that the T cells proliferate; (c) cloning one or more cells that proliferated in the presence of the protein expression product; and (d) administering to the warm-blooded animal an effective amount of the cloned T cells. In a third embodiment, the method comprises immunizing the animal with at least one protein expression product of an activated oncogene or cancer-related gene associated with the malignancy.

Within a related aspect, the present invention provides anti-cancer therapeutic compositions comprising T cells proliferated in the presence of at least one protein expression product of an activated oncogene or cancer-related gene associated with a malignancy, in combination with a physiologically acceptable carrier or diluent. Such T cells are useful in the manufacture of a medicament for treating a malignancy in a warm-blooded animal.

Brief Description of the Drawings

Figure 1 graphically illustrates that specific T cell responses to point-mutated ras peptide can be generated by *in vivo* priming on day 0 with 50 μg of a peptide of 12 amino acid length constructed identically to murine ras-p21 (amino acids 5-16) but with the substitution of arginine for the glycine normally found at position 12 (i.e., position 12 of ras-p21 but position 8 of the peptide). This peptide is denoted as ras p5-16[R12] or as ras-R12. Mice were immunized with ras-R12 peptide plus adjuvant or with adjuvant alone. After 10 days, the draining lymph nodes were harvested and lymphocytes

stimulated *in vitro* with ras-R12 peptide or as specificity controls with similar peptides substituted with serine, cysteine or glycine at position 12 as opposed to arginine, denoted as ras-S12, ras-C12 and ras-G12, respectively. Four days later, cultures were pulsed with [^{3}H]-thymidine (^{3}HTdR) for 8 hours, as described in Example 1 below. Results are represented as ΔCPM.

Figure 2 shows that ras-peptide specific T cells grown long-term *in vitro* in response to intermittent stimulation by ras-peptide retain specific function. T cells derived from mesenteric lymph nodes of C57BL/6 mice primed to ras-R12 (as defined for Figure 1 above) were cultured long-term *in vitro* in response to intermittent stimulation with ras-R12 peptide (5 μg/ml) on irradiated B6 spleen cells (3000 rad) as antigen presenting cells. The specificity of the T cell line was tested on day 85 by stimulating with graded concentrations of various ras peptides (as defined for Figure 1 above) or with trypsinized OVA (TOVA) containing several potential immunogenic peptides. Data is represented as ^{3}HTdR uptake in counts per minute (c.p.m.).

Figure 3 graphically illustrates that T cells specific for a ras peptide respond specifically to intact ras p21 protein containing the same residue substitution. This peptide, denoted as p5-17[R12], consists of 13 amino acid residues and was constructed identically to murine ras-p21 (amino acids 5-17) but with the substitution of arginine (R) for the glycine (G) normally found at position 12 of ras-p21. Cloned B6 T cells specific for the Arg-12 ras peptide were cultured with irradiated B6 spleen cells and either p5-17[R12] or intact ras p21 proteins bearing the designated amino acid at position-12 (1 μg/ml). Proliferative responses were measured after four days (as described in Figure 1). The data represent the mean of triplicate determinations of the c.p.m. of incorporated ^{3}HTdR. The standard deviations were <10% of the c.p.m.

Figure 4 shows that specific T cell responses can be generated by *in vivo* priming with a peptide of 13 amino acid length constructed identically to murine ras-p21 (amino acids 54-66) but with the substitution of leucine (L) for the glutamine (Q) normally found at position 61 of ras-p21. This peptide is denoted as p54-66[L61] or [L61]. C3H/HeN mice were immunized twice subcutaneously at two week intervals with Ribi adjuvant alone or adjuvant emulsified with p54-66[L61] ras peptide (100 μg). Two weeks after the final immunization, spleen cells from mice injected with adjuvant alone (open bar) or adjuvant plus p54-66[L61] ras peptide (black bar) were harvested and tested *in vitro* for proliferative response to the indicated p54-66 ras peptide (100 μg/ml). The peptide containing the substitution of lysine (K) for glutamine at position 61 is denoted as [K61]. The data represent the mean of triplicate determinations of the c.p.m. of incorporated ^{3}HTdR ± S.D.

Figure 5 graphically illustrates that intact ras p21[L61] protein is specifically recognized by a ras peptide-induced T cell line. Specific T cell lines and clones were generated and maintained as described in Example 2 below. A T cell line which exhibits specific reactivity to the ras peptide p54-66[L61] (panel A) and a T cell clone which exhibits specific reactivity to the ras peptide p5-17[R12] (panel B) were stimulated with (a) no antigen, (b) sensitizing ras peptide, or (c) intact ras p21[L61] protein. The ras p54-66[L61] specific T cell line was of C3H origin and the ras p5-17[R12] specific T cell clone was of B6 origin. Proliferative assays were performed with syngeneic irradiated spleen cells as antigen presenting cells (as described in Figure 1). Stimulating peptides and proteins were used at a concentration of 5 μg/ml. The ras p21[L61] protein was produced in *E. coli* HB101 using the prokaryotic expression plasmid pHR-L9 and purified by sequential DEAE-Sephacel*

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and Sephadex* column chromatography. The data represent the mean c.p.m. of incorporated ^{3}HTdR ± S.D.

Detailed Description of the Invention

Prior to setting forth the invention, it may be helpful to an understanding thereof to set forth definitions of certain terms to be used hereinafter.

Activated oncogene - as used herein, refers to proto-oncogenes that have become activated, leading to the expression of protein products with amino acid sequences other than those of the protein products expressed by the normal proto-oncogenes.

Cancer-related gene - as used herein, refers to any altered gene (other than an oncogene) associated with the development or maintenance of the malignant phenotype. Examples of such altered genes include mutants of the p53 tumor suppressor gene.

Protein expression product - as used herein, includes proteins, polypeptides, and peptides; and may be an intact molecule, a fragment thereof, or a functional equivalent thereof; and may be genetically engineered.

Proliferation of T cells - as used herein, includes the multiplication of T cells as well as the stimulation of T cells leading to multiplication, i.e., the initiation of events leading to mitosis and mitosis itself. Methods for detecting proliferation of T cells are discussed below.

As noted above, the present invention is directed toward methods and compositions for the diagnosis, monitoring and treatment of malignancies in a warm-blooded animal, wherein activated oncogenes or cancer-related genes are associated with the malignancies. The disclosure of the present invention shows that the protein expression products of activated oncogenes and cancer-related genes can be recognized by thymus-dependent lymphocytes (hereinafter "T cells") and, therefore, the

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autochthonous immune response can be utilized to diagnose and treat malignancies expressing such protein expression products.

Activation of proto-oncogenes is associated with or leads to transformation and expression of the malignant phenotype. Activation by mechanisms such as mutation or chromosomal translocation (gene rearrangement) creates a gene product with altered primary structure, i.e., a protein expression product with one or more amino acid differences relative to the normal protein expressed by the proto-oncogene. Mutation mechanisms include point mutation of nucleotides, recombination, deletion and insertion. Examples of activation of proto-oncogenes through mutation include activation of ras and neu proto-oncogenes. Chromosomal translocation results in a fused protein, such as that associated with chronic myeologenous leukemia. Similarly, cancer-related genes express abnormal protein products with altered amino acid sequences. For example, mutation of the p53 tumor suppressor gene results in amino acid substitutions.

As disclosed within the present invention, protein products with altered primary structure expressed by activated oncogenes and cancer-related genes are recognized by T cells. Such abnormal protein expression products "turn over" within cells, i.e., undergo a cycle wherein a protein is synthesized, functions and then is degraded and replaced by a newly synthesized molecule. The ensuing peptide fragments from the degraded protein bind to major histocompatibility complex (MHC) antigens. By display of an abnormal peptide bound to MHC antigen on the cell surface and recognition by host T cells of the combination of abnormal peptide plus self MHC antigen, a malignant cell will be immunogenic to T cells. The exquisite specificity of the T cell receptor enables individual T cells to discriminate between fragments of proteins which differ by a single amino acid residue.

During the immune response to an abnormal peptide, T cells expressing a T cell receptor with high affinity binding of the peptide-MHC complex will bind to the peptide-MHC complex and thereby become activated and induced to proliferate. In the first encounter with an abnormal peptide, small numbers of immune T cells will proliferate and differentiate into effector and memory T cells. The primary immune response will occur *in vivo* but is not detected *in vitro*. Subsequent encounter with the same antigen by the memory T cell will lead to a faster and more intense immune response. The secondary response will occur either *in vivo* or *in vitro*. The *in vitro* response is easily gauged by measuring the degree of proliferation of the T cell population re-exposed in the antigen. Proliferation of the T cell population in response to a particular antigen is considered to be indicative of prior exposure or priming to the antigen.

Within one aspect of the present invention, a malignancy in which an activated oncogene or cancer-related gene is associated with the malignancy may be detected. An immune response to an abnormal protein expressed by an activated oncogene or cancer-related gene, once generated, can be long-lived and can be detected long after immunization, regardless of whether the protein is present or absent in the body at the time of testing. In one embodiment, prior exposure of a warm-blooded animal, such as humans, to the protein expression product of an activated oncogene or cancer-related gene can be detected by examining for the presence or absence of T cell proliferative responses. More specifically, T cells isolated from an individual by routine techniques are incubated with a protein expression product of an activated oncogene or cancer-related gene. Examples of oncogenes include ras, src, abl, fgr, rel, yes, fes, net, mos, raf, erb B, erb A, fms, neu, ros, kit, sea, sis, myc, myb, fos, ski, jun and ets. Alternatively, more than one protein expression product can be examined with the T cell

sample. It may be desirable to incubate individual aliquots of a T cell sample with only one protein expression product if such a protein interferes with another protein expression product.

Detection of the proliferation of T cells may be accomplished by a variety of known techniques. For example, T cell proliferation can be detected by measuring the rate of DNA synthesis. T cells which have been stimulated to proliferate exhibit an increased rate of DNA synthesis. A typical way to measure the rate of DNA synthesis is, for example, by pulse-labeling cultures of T cells with tritiated thymidine, a nucleoside precursor which is incorporated into newly synthesized DNA. The amount of tritiated thymidine incorporated can be determined using a liquid scintillation spectrophotometer. Other ways to detect T cell proliferation include measuring increases in interleukin-2 (IL-2) production, Ca^{2+} flux, or dye uptake, such as 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl-tetrazolium.

A representative example of an activated oncogene that expresses a protein product capable of immunizing T cells is the ras oncogene. Ras proto-oncogenes encode a highly conserved family of 21Kd proteins (189 amino acids in length) collectively designated as "p21". p21 proteins bind to the inner aspect of the cell membrane, associate with guanosine nucleotides and have intrinsic GTPase activity. p21 proteins have been implicated as important intermediary signalling proteins which regulate cell growth and differentiation. Ras oncogenes were first detected as genetic material in the transforming Harvey and Kirsten murine sarcoma retroviruses. In animals, carcinogens induce very specific and predictable mutations, usually involving codons 12, 13, 59 and/or 61, which impair the intrinsic GTPase activity of the p21 molecule and confer transforming activity. The human genome contains at least three ras proto-oncogene homologs of the viral ras

oncogene denoted as K-ras, H-ras and N-ras which are located on three separate human chromosomes. Each of the three ras genes can become activated through specific mutation. Mutations of one of the three ras proto-oncogenes occurs commonly in a variety of human malignancies including pancreas adenocarcinoma, thyroid follicular carcinoma, colon adenocarcinoma, seminoma, lung adenocarcinoma, liver adeno carcinoma, melanoma, myeloid leukemia, and myeloma. The disclosure of the present invention shows that once mutated, the expressed protein product of any of the three ras genes by virtue of a single amino acid substitution may be recognized by autochthonous T cells.

For example, within the present invention, peptides consisting of 12 or 13 amino acid residues which corresponded to the amino acid sequence from residues 5-16, 5-17, or 4-16 of p21 were constructed to contain either the normal glycine (termed Gly-12 or G-12), or arginine (termed Arg-12 or R-12), or serine (termed Ser-12 or S-12), or cysteine (termed Cys-12, or C-12). C57BL/6 mice were immunized with a single dose of the Arg-12 peptide. Lymphocytes from immunized mice were subsequently tested for proliferative response to the above peptides *in vitro* and, as shown in Figure 1, were found to proliferate specifically in response to the Arg-12 peptide, but not the Gly-12, Cys-12, or Ser-12 peptides. In addition, the lymphocytes from mice immunized with the Arg-12 peptide were shown (Figure 3) to proliferate specifically in response to stimulation by the intact p21 protein containing this same amino acid substitution (Oncogene Science, Inc., Manhasset, New York).

Another example of a peptide suitable within the present invention is ras p54-66[L61]. This peptide consists of 13 amino acid residues which correspond to the amino acid sequence from residues 54-66 of p21, except leucine (L) has been substituted for the glutamine (Q) normally found at position 61. Lymphocytes from mice

immunized with p54-66[L61] were found to proliferate *in vitro*, as shown in Figure 4, specifically in response to the Leu-61 peptide, but not to Gln-61 or Lys-61 peptides. In addition, the lymphocytes from mice immunized with the Leu-61 peptide were shown (Figure 5) to proliferate specifically in response to stimulation by the intact p21 protein containing the same amino acid substitution.

Similarly, proteins (or peptides based upon or derived therefrom) other than p21 may be isolated or constructed by a variety of known techniques. It will be appreciated by those skilled in the art that it may be desirable to increase the length of an overall peptide or of the native flanking regions to facilitate the induction of T cell responses. As discussed above, protein expression products of activated oncogenes other than ras, or cancer-related genes (i.e., with an amino acid sequence different from that of the proteins expressed by normal proto-oncogenes or normal genes) are suitable for use within the methods described herein.

For therapeutic purposes, T cells that proliferate in the presence of one or more protein expression products of activated oncogenes or cancer-related genes can be expanded in number either *in vitro* or *in vivo*. Proliferation of such T cells *in vitro* may be accomplished in a variety of ways. For example, the T cells can be re-exposed to one or more protein expression products. It may be desirable to repeat the exposure of T cells to the protein to induce proliferation. As shown in Figure 2, protein expression product-specific T cells can be grown to large numbers *in vitro* with retention of specificity in response to intermittent restimulation with the immunizing peptide.

Alternatively, one or more T cells that proliferate in the presence of a protein expression can be expanded in number by cloning. Methods for cloning cells are well known in the art. For example, T cell lines may be established *in vitro* and cloned by limiting dilution.

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Responder T cells are purified from the peripheral blood of sensitized patients by density gradient centrifugation and sheep red cell rosetting and established in culture by stimulating with the nominal antigen in the presence of irradiated autologous filler cells. In order to generate CD4+ T cell lines, intact ras p21 protein bearing the relevant amino acid substitution is used as the antigenic stimulus and autologous peripheral blood lymphocytes (PBL) or lymphoblastoid cell lines (LCL) immortalized by infection with Epstein Barr virus are used as antigen presenting cells. In order to generate CD8+ T cell lines, autologous antigen-presenting cells transfected with an expression vector which produces relevant mutated ras p21 protein are used as stimulator cells. Established T cell lines are cloned 2-4 days following antigen stimulation by plating stimulated T cells at a frequency of 0.5 cells per well in 96-well flat-bottom plates with 1 x 10^6 irradiated PBL or LCL cells and recombinant interleukin 2 (rIL2) (50 U/ml). Wells with established clonal growth are identified at approximately 2-3 weeks after initial plating and restimulated with appropriate antigen in the presence of autologous antigen-presenting cells, then subsequently expanded by the addition of low doses of rIL2(10 U/ml) 2-3 days following antigen stimulation. T cell clones are maintained in 24-well plates by periodic restimulation with antigen and rIL2 approximately every two weeks.

Regardless of how an individual's T cells are proliferated *in vitro*, the T cells may be administered to the individual for therapeutic attack against a tumor. Thus, a patient's own T cells (autochthonous T cells) can be used as reagents to mediate specific tumor therapy. Typically, about 1 X 10^9 to 1 X 10^{11} T cells/M^2 will be administered intravenously or intracavitary, e.g., in pleural or peritoneal cavities, or in the bed of a resected tumor. It will be evident to those skilled in the art that the number and frequency of administration

will be dependent upon the response of the patient. Suitable carriers or diluents for T cells include physiological saline or sera. It will be recognized by one skilled in the art that the composition should be prepared in sterile form.

T cells may also be proliferated *in vivo*. For example, immunization of an individual with one or more protein expression products of activated oncogenes or cancer-related genes can induce continued expansion in the number of T cells necessary for therapeutic attack against a tumor. It may be desirable to administer the protein expression product repetitively.

The present invention also discloses that the protein expression products of activated oncogenes or cancer-related genes, in addition to being immunogenic to T cells, appear to stimulate B-cells to produce antibodies capable of recognizing these proteins. Detection of such antibodies provides another way to diagnose a malignancy in which an activated oncogene or cancer-related gene is associated with the malignancy. Antibodies specific (i.e., which exhibit a binding affinity of about 10^7 liters/mole or better) for one or more protein expression products may be found in a variety of body fluids including sera and ascites. Detection of one or more immunocomplexes formed between a protein expression product and antibodies specific for the protein may be accomplished by a variety of known techniques, such as radioimmunoassays (RIA) and enzyme linked immunosorbent assays (ELISA).

Suitable immunoassays include the double monoclonal antibody sandwich immunoassay technique of David et al. (U.S. Patent 4,376,110); monoclonal-polyclonal antibody sandwich assays (Wide et al., in Kirkham and Hunter, eds., Radioimmunoassay Methods, E. and S. Livingstone, Edinburgh, 1970); the "western blot" method of Gordon et al. (U.S. Patent 4,452,901); immunoprecipitation of labeled ligand (Brown et al., J.

Biol. Chem. 255:4980-4983, 1980); enzyme-linked immunosorbent assays as described by, for example, Raines and Ross (J. Biol. Chem. 257:5154-5160, 1982); immunocytochemical techniques, including the use of fluorochromes (Brooks et al., Clin. Exp. Immunol. 39: 477, 1980); and neutralization of activity [Bowen-Pope et al., Proc. Natl. Acad. Sci. USA 81:2396-2400 (1984)], all of which are hereby incorporated by reference. In addition to the immunoassays described above, a number of other immunoassays are available, including those described in U.S. Patent Nos.: 3,817,827; 3,850,752; 3,901,654; 3,935,074; 3,984,533; 3,996,345; 4,034,074; and 4,098,876.

For detection purposes, the protein expression products ("antigens") may either be labeled or unlabeled. When unlabeled, the antigens find use in agglutination assays. In addition, unlabeled antigens can be used in combination with labeled molecules that are reactive with immunocomplexes, or in combination with labeled antibodies (second antibodies) that are reactive with the antibody directed against the protein expression product, such as antibodies specific for immunoglobulin. Alternatively, the antigens can be directly labeled. Where they are labeled, the reporter group can include radioisotopes, fluorophores, enzymes, luminescers, or dye particles. These and other labels are well known in the art and are described, for example, in the following U.S. patents: 3,766,162; 3,791,932; 3,817,837; 3,996,345; and 4,233,402.

Typically in an ELISA assay, antigen is adsorbed to the surface of a microtiter well. Residual protein-binding sites on the surface are then blocked with an appropriate agent, such as bovine serum albumin (BSA), heat-inactivated normal goat serum (NGS), or BLOTTO (buffered solution of nonfat dry milk which also contains a preservative, salts, and an antifoaming agent). The well is then incubated with a sample suspected of containing specific antibody. The sample can be applied

neat, or, more often, it can be diluted, usually in a buffered solution which contains a small amount (0.1-5.0% by weight) of protein, such as BSA, NGS, or BLOTTO.* After incubating for a sufficient length of time to allow specific binding to occur, the well is washed to remove unbound protein and then incubated with an anti-species specific immunoglobulin antibody labeled with a reporter group. The reporter group can be chosen from a variety of enzymes, including horseradish peroxidase, beta-galactosidase, alkaline phosphatase, and glucose oxidase. Sufficient time is allowed for specific binding to occur, then the well is again washed to remove unbound conjugate, and the substrate for the enzyme is added. Color is allowed to develop and the optical density of the contents of the well is determined visually or instrumentally.

In one preferred embodiment of this aspect of the present invention, a reporter group is bound to the protein expression product. The step of detecting immunocomplexes involves removing substantially any unbound protein expression product and then detecting the presence or absence of the reporter group.

In another preferred embodiment, a reporter group is bound to a second antibody capable of binding to the antibodies specific for a protein expression product. The step of detecting immunocomplexes involves (a) removing substantially any unbound antibody, (b) adding the second antibody, (c) removing substantially any unbound second antibody and then (d) detecting the presence or absence of the reporter group. Where the antibody specific for the protein expression product is derived from a human, the second antibody is an anti-human antibody.

In a third preferred embodiment for detecting immunocomplexes, a reporter group is bound to a molecule capable of binding to the immunocomplexes. The step of detecting involves (a) adding the molecule, (b) removing substantially any unbound molecule, and then (c) detecting

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the presence or absence of the reporter group. An example of a molecule capable of binding to the immunocomplexes is protein A.

It will be evident to one skilled in the art that a variety of methods for detecting the immunocomplexes may be employed within the present invention. Reporter groups suitable for use in any of the methods include radioisotopes, fluorophores, enzymes, luminescers, and dye particles.

In a related aspect of the present invention, detection of immunocomplexes formed between a protein expression product of an activated oncogene, or cancer-related gene, and antibodies in body fluid which are specific for the protein may be used to monitor the effectiveness of cancer therapy. Samples of body fluid taken from an individual prior to and subsequent to initiation of therapy may be analyzed for the immunocomplexes by the methodologies described above. Briefly, the number of immunocomplexes detected in both samples are compared. A substantial change in the number of immunocomplexes in the second sample (post-therapy initiation) relative to the first sample (pre-therapy) reflects successful therapy.

The following examples are offered by way of illustration and not by way of limitation.

EXAMPLES

Example 1

Elicitation of Specific Class-II Restricted T-Cell Response to Mutated Ras Oncogene Products

A. Immunization

C57BL/6 and B6.C-H-2^{bm12} mice (Jackson Laboratories, Bar Harbor, Me.) were inoculated with a synthetic peptide (Amino acid sequence: KLVVVGARGVGK;

Microbiological Associates, Bethesda, Md.) which corresponds to residue 5-16 of the p21 protein product of mutated ras proto-oncogene encoding a residue 12 substitution of Arginine (R) for Glycine (G). The peptide was solubilized in distilled water at 1 mg/ml, emulsified in complete Freunds adjuvant (Sigma Co., St. Louis, Mo.) at a ration of 1:1, then injected subcutaneously into the base of the tail using a 25 gauge needle. Alternatively peptide was emulsified with Ribi MPL+TDM+CWS adjuvant (Ribi Immunochem. Res., Hamilton, Mt.) and injected subcutaneously into both hindquarters. Total amount of peptide injected was 50 μg per mouse. Seven days later animals were sacrificed and draining periaortic and inguinal lymph nodes were removed. Lymph nodes, suspended in buffered saline in petri dishes, were teased apart with 18 gauge needles. Dislodged lymphocytes were collected and washed with buffered saline then suspended at 1 X 10^6 cells per ml in culture medium for use in proliferation assays.

B. Proliferation Assay

Lymphocytes obtained from immunized mice were suspended in culture medium (consisting of RPMI 1640 Gibco supplemented with 10% fetal calf serum, 2 mM L-glutamine, 100 U/ml streptomycin, 100 U/ml penicillin and 2.5 X 10^{-5} M 2-mercaptoethanol) and were plated in 96-well flat bottom microtiter plates (Costar Co., Cambridge, Mass.) at 1 X 10^5 cells per well. Syngeneic spleen cells which had been irradiated to 3000 rads were added at 2 X 10^5 cells per well to serve as antigen presenting cells. The immunizing peptide and indicated control peptides (50 μg/ml) were added to triplicate wells (final volume of 200 μl/well). The plates were incubated at 37°C in humidified air containing 5% CO_2 for 72 hours then pulsed for 6 hr with 1 μCi per well of tritiated thymidine (^{3}H-TdR; 20 Ci/mmol from NEN Products, Boston, Ma.). Lymphocytes from individual wells were collected onto

filter paper disks using a multi-channel harvester then transferred to scintillation fluid in individual counting tubes. β emission was measured using a Beckmann liquid scintillation spectrophotometer. The data presented in Figure 1 represents the mean of triplicate determinations.

Example 2

Generation of T Cell Lines and Clones With Specificity for the Protein Product of Mutated Ras Proto-Oncogene

Lymphocytes obtained from draining lymph nodes of immunized mice as described above were plated (4×10^6 cells per well) in 24-well culture plates (Costar Co.) with irradiated syngeneic spleen cells (10,000 rads; 2×10^6 cells per well) and immunizing peptide (5 µg/well) to give a final volume of 2 ml (culture medium). Plates were cultured for 5 days (37°C, 5% Co_2), then split 1:2 onto replicate plates. After ten days lymphocytes were restimulated by plating 5×10^5 cultured lymphocytes with 4×10^6 irradiated syngeneic spleen cells and peptide at 5 µg/ml. After three days, individual wells were redistributed into 2-4 wells of culture medium containing 10 units of Interleukin-2 (human recombinant from Hoffmann-LaRoche) to facilitate cell expansion. Lines were restimulated with antigen and subsequently IL-2 as described above, every 3-4 weeks.

Immune lymphocytes which had been twice stimulated with antigen *in vitro* were cloned at day 13 following initiation of culture (3 days following Ag restimulation) by plating immune T cells at a frequency of 0.5 cells per well in 96-well flat-bottom plates with irradiated syngeneic spleen cells (1×10^6 cells per well) and Interleukin-2 at 50 U/ml. Wells with clonal growth were expanded and tested for immune specificity as shown in Figure 2. Specific T cell clones were maintained as described for T cell lines.

From the foregoing, it will be evident that, although specific embodiments of the invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit and scope of the invention.

WE CLAIM:

1. A method for the detection of a malignancy in a warm-blooded animal, wherein an activated oncogene or cancer-related gene is associated with the malignancy, comprising the steps of:

(a) incubating T cells, isolated from a warm-blooded animal, with at least one protein expression product having an altered primary sequence of an activated oncogene or cancer-related gene associated with the malignancy; and

(b) detecting the presence or absence of proliferation of the T cells, thereby determining the presence or absence of the malignancy.

2. The method of claim 1 wherein the step of detecting comprises measuring the rate of DNA synthesis of the T cells.

3. A method for the detection of a malignancy in a warm-blooded animal, wherein an activated oncogene or cancer-related gene is associated with the malignancy, comprising the steps of:

(a) contacting a body fluid, suspected of containing antibodies specific for a protein expression product of an activated oncogene or cancer-related gene associated with the malignancy, with at least one protein expression product having an altered primary sequence of an activated oncogene or cancer-related gene associated with the malignancy;

(b) incubating the body fluid under conditions and for a time sufficient to allow immunocomplexes to form; and

(c) detecting the presence or absence of one or more immunocomplexes formed between the protein expression product and antibodies in the body fluid specific for the protein expression product, thereby determining the presence or absence of the malignancy.

4. A method for monitoring the effectiveness of cancer therapy in a warm-blooded animal with a malignancy, wherein an activated oncogene or cancer-related gene is associated with the malignancy, comprising the steps of:

(a) contacting a first body fluid sample, taken from the warm-blooded animal prior to initiation of therapy, with at least one protein expression product having an altered primary sequence of an activated oncogene or cancer-related gene associated with the malignancy;

(b) incubating the body fluid under conditions and for a time sufficient to allow immunocomplexes to form;

(c) detecting immunocomplexes formed between the protein expression product and antibodies in the body fluid specific for the protein expression product;

(d) repeating steps (a), (b), and (c) on a second body fluid sample taken from the animal subsequent to the initiation of therapy; and

(e) comparing the number of immunocomplexes detected in the first and second body fluid samples, thereby monitoring the effectiveness of the therapy in the animal.

5. The method of any one of claims 3 or 4 wherein a reporter group is bound to a second antibody capable of binding to the antibodies, and wherein the step of detecting comprises:

(a) removing substantially any unbound antibody;

(b) adding the second antibody;

(c) removing substantially any unbound second antibody; and

(d) detecting the presence or absence of the reporter group.

6. The method of claim 5 wherein the second antibody is an anti-human antibody.

7. The method of claim 3 wherein a reporter group is bound to a molecule capable of binding to the immunocomplexes, and wherein the step of detecting comprises:

(a) adding the molecule;

(b) removing substantially any unbound molecule; and

(c) detecting the presence or absence of the reporter group.

8. The method of claim 4 wherein a reporter group is bound to a molecule capable of binding to the immunocomplexes, and wherein the step of detecting comprises:

(a) adding the molecule;

(b) removing substantially any unbound molecule; and

(c) detecting the presence or absence of the reporter group.

9. The method of claim 7 wherein the molecule capable of binding to the immunocomplexes is protein A.

10. The method of claim 8 wherein the molecule capable of binding to the immunocomplexes is protein A.

11. The method of claim 3 wherein a reporter group is bound to the protein expression product, and wherein the step of detecting comprises removing substantially any unbound protein expression product and thereafter detecting the presence or absence of the reporter group.

12. The method of claim 4 wherein a reporter group is bound to the protein expression product, and wherein the step of detecting comprises removing substantially any unbound protein expression product and thereafter detecting the presence or absence of the reporter group.

13. The method of any one of claims 6-12 wherein the reporter group is selected from the group consisting of radioisotopes, fluorophores, enzymes, luminescers, and dye particles.

14. The method of claim 5 wherein the reporter group is selected from the group consisting of radioisotopes, fluorophores, enzymes, luminescers, and dye particles.

15. The method of any one of claims 1-4 and 6-12 wherein the protein expression product having an altered primary sequence of an activated oncogene

is a protein encoded by an oncogene selected from the group consisting of ras, src, abl, fgr, rel, yes, fes, net, mos, raf, erb B, erb A, fms, neu, ros, kit, sea, sis, myc, myb, fos, ski, jun and ets.

16. The method of claim 5 wherein the protein expression product having an altered primary sequence of an activated oncogene is a protein encoded by an oncogene selected from the group consisting of ras, src, abl, fgr, rel, yes, fes, net, mos, raf, erb B, erb A, fms, neu, ros, kit, sea, sis, myc, myb, fos, ski, jun and ets.

17. The method of claim 13 wherein the protein expression product having an altered primary sequence of an activated oncogene is a protein encoded by an oncogene selected from the group consisting of ras, src, abl, fgr, rel, yes, fes, net, mos, raf, erb B, erb A, fms, neu, ros, kit, sea, sis, myc, myb, fos, ski, jun and ets.

18. The method of claim 14 wherein the protein expression product having an altered primary sequence of an activated oncogene is a protein encoded by an oncogene selected from the group consisting of ras, src, abl, fgr, rel, yes, fes, net, mos, raf, erb B, erb A, fms, neu, ros, kit, sea, sis, myc, myb, fos, ski, jun and ets.

19. T cells isolated from a warm-blooded animal, said T cells proliferated *ex vivo* in the presence of at least one protein expression product having an altered primary sequence of an activated oncogene or cancer-related gene associated with a malignancy, for use in the manufacture of a medicament for treating a malignancy in the warm-blooded animal.

20. The T cells of claim 19 wherein the protein expression product of the activated oncogene is a protein encoded by an oncogene selected from the group consisting of ras, src, abl, fgr, rel, yes, fes, net, mos, raf, erb B, erb A, fms, neu, ros, kit, sea, sis, myc, myb, fos, ski, jun and ets.

21. An anti-cancer composition comprising T cells isolated from a warm-blooded animal, together with a diluent or carrier therefor, said T cells proliferated *ex vivo* in the presence of at least one protein expression product having an altered primary sequence of an activated oncogene or cancer-related gene associated with a malignancy.

22. A malignancy regulant composition comprising T cells isolated from a warm-blooded animal, together with a diluent or carrier therefor, said T cells proliferated *ex vivo* in the presence of at least one protein expression product having an altered primary sequence of an activated oncogene or cancer-related gene associated with a malignancy.

23. A warm-blooded animal malignancy regulant composition comprising T cells isolated from a warm-blooded animal, together with a diluent or carrier therefor, said T cells proliferated *ex vivo* in the presence of at least one protein expression product having an altered primary sequence of an activated oncogene or cancer-related gene associated with a malignancy.

24. A composition comprising T cells isolated from a warm-blooded animal, together with a diluent or carrier therefor, said T cells proliferated *ex vivo* in the presence of at least one protein expression product having an altered primary sequence of an activated oncogene or cancer-related gene associated with a malignancy, for use in anti-cancer treatment.

25. A composition comprising T cells isolated from a warm-blooded animal, together with a diluent or carrier therefor, said T cells proliferated *ex vivo* in the presence of at least one protein expression product having an altered primary sequence of an activated oncogene or cancer-related gene associated with a malignancy, for use in regulating a malignancy.

26. A composition comprising T cells isolated from a warm-blooded animal, together with a diluent or carrier therefor, said T cells proliferated *ex vivo* in the

presence of at least one protein expression product having an altered primary sequence of an activated oncogene or cancer-related gene associated with a malignancy, for use in regulating a malignancy in a warm-blooded animal.

27. The composition defined in any one of claims 21-26, wherein the protein expression product of the activated oncogene is a protein encoded by an oncogene selected from the group consisting of ras, src, abl, fgr, rel, yes, fes, net, mos, raf, erb B, erb A, fms, neu, ros, kit, sea, sis, myc, myb, fos, ski, jun and ets.

28. T cells isolated from a warm-blooded animal, said T cells proliferated *ex vivo* in the presence of at least one protein expression product having an altered primary sequence of an activated oncogene or cancer-related gene associated with a malignancy, for use in anti-cancer treatment.

29. T cells isolated from a warm-blooded animal, said T cells proliferated *ex vivo* in the presence of at least one protein expression product having an altered primary sequence of an activated oncogene or cancer-related gene associated with a malignancy, for use in regulating a malignancy.

30. T cells isolated from a warm-blooded animal, said T cells proliferated *ex vivo* in the presence of at least one protein expression product having an altered primary sequence of an activated oncogene or cancer-related gene associated with a malignancy, for use in regulating a malignancy in a warm-blooded animal.

31. The T cells defined in any one of claims 28-30, wherein the protein expression product of the activated oncogene is a protein encoded by an oncogene selected from the group consisting of ras, src, abl, fgr, rel, yes, fes, net, mos, raf, erb B, erb A, fms, neu, ros, kit, sea, sis, myc, myb, fos, ski, jun and ets.

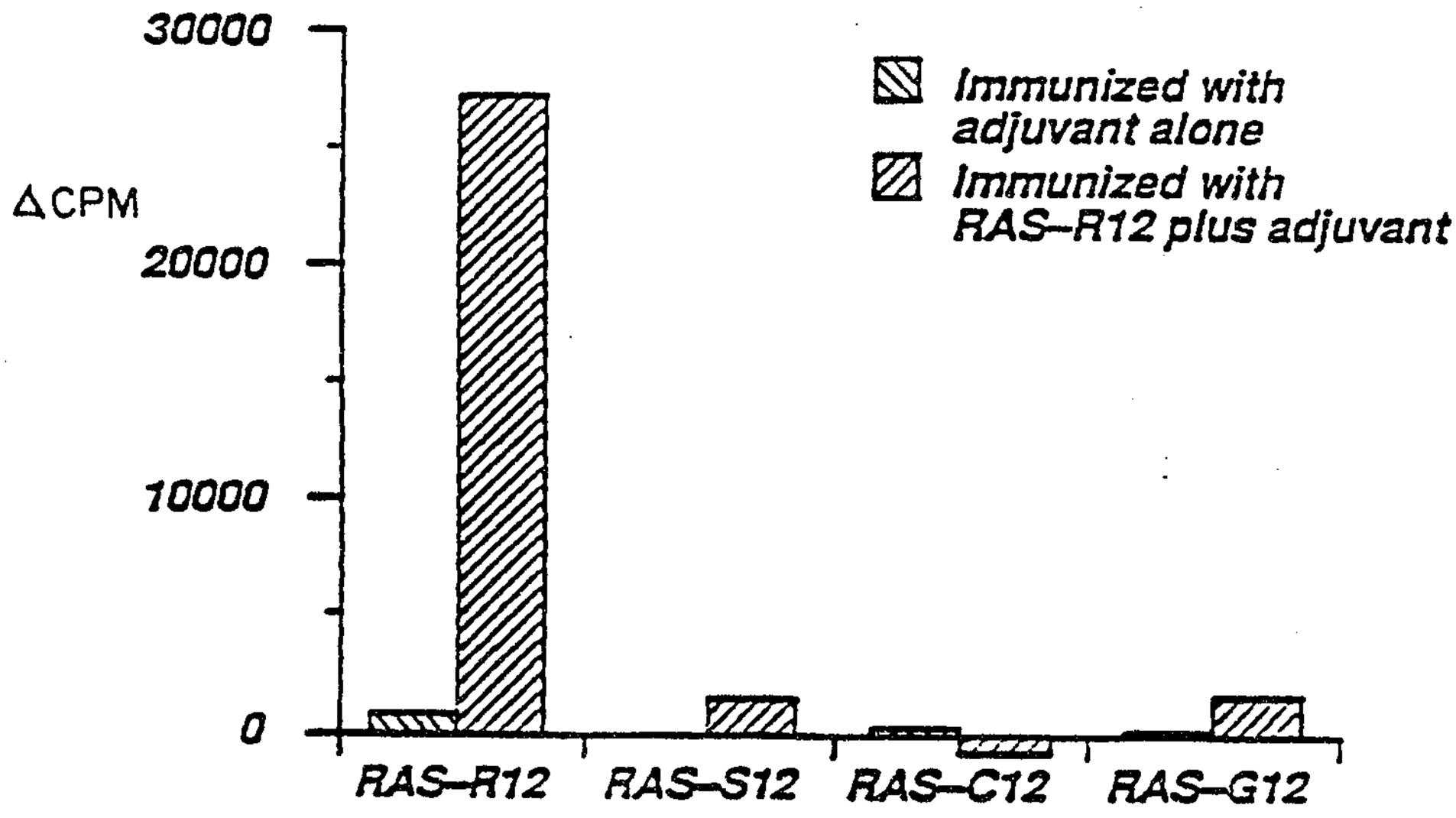

FIG. 1

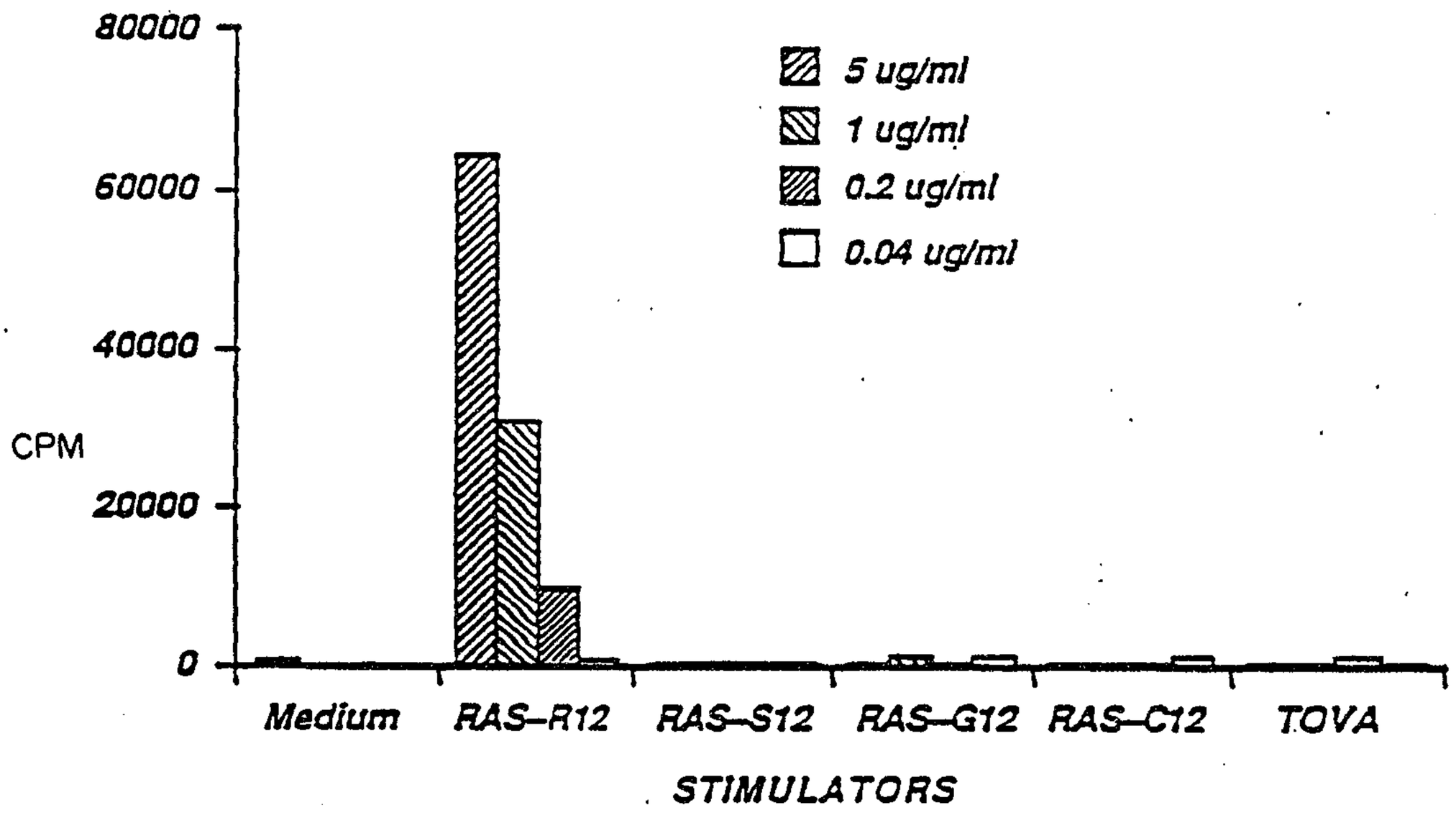

FIG. 2

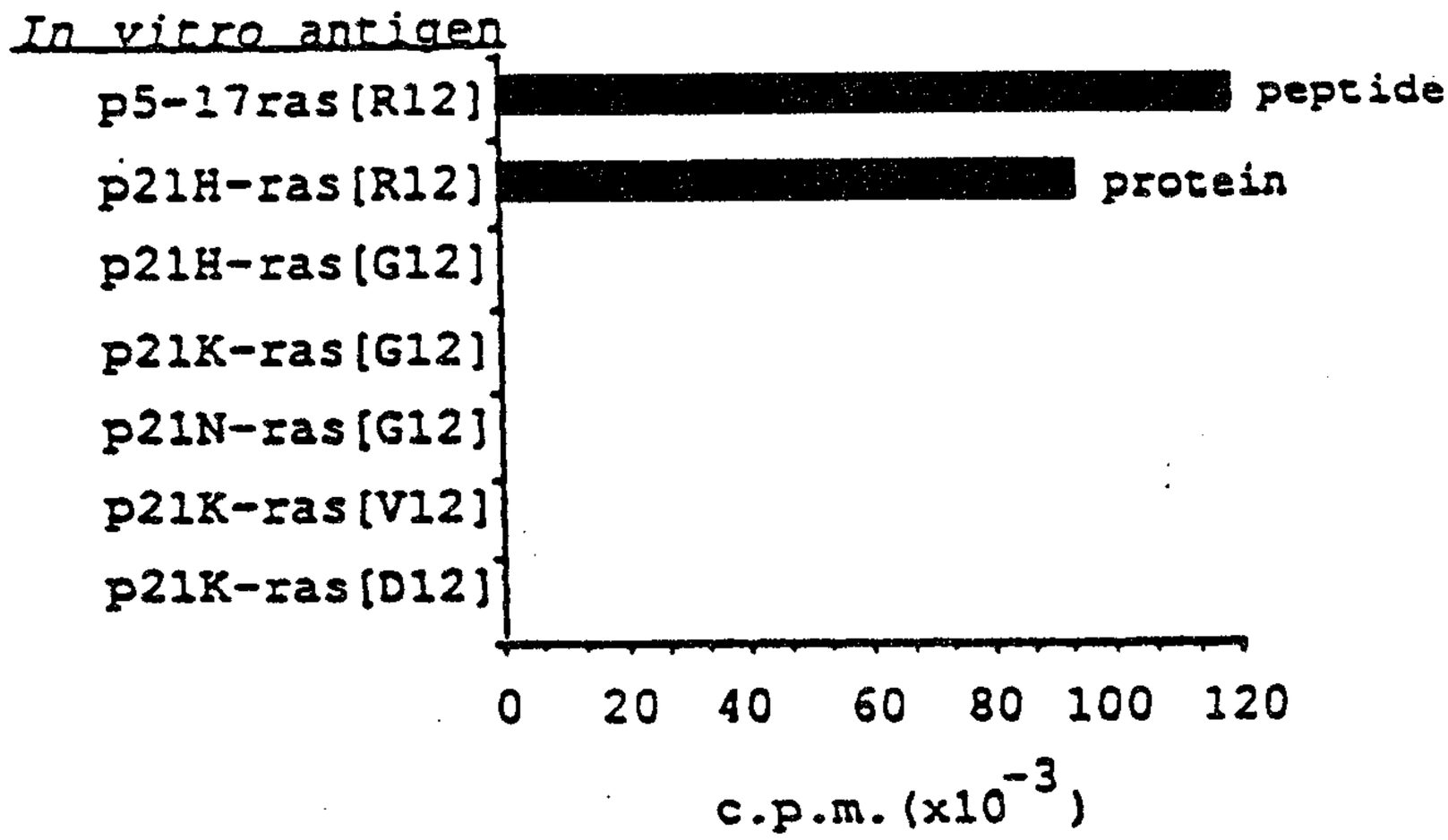

FIG. 3

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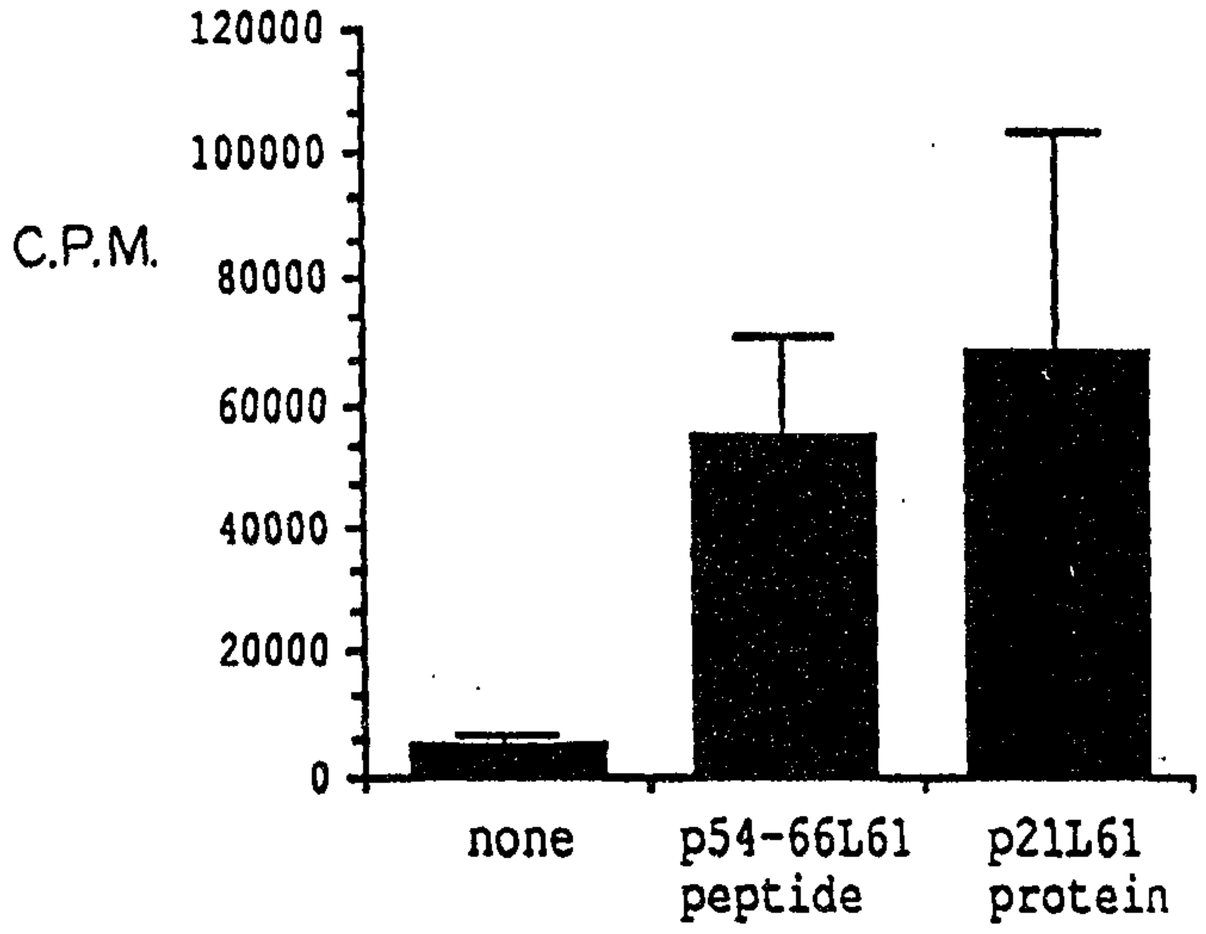
FIG. 4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C.P.M.
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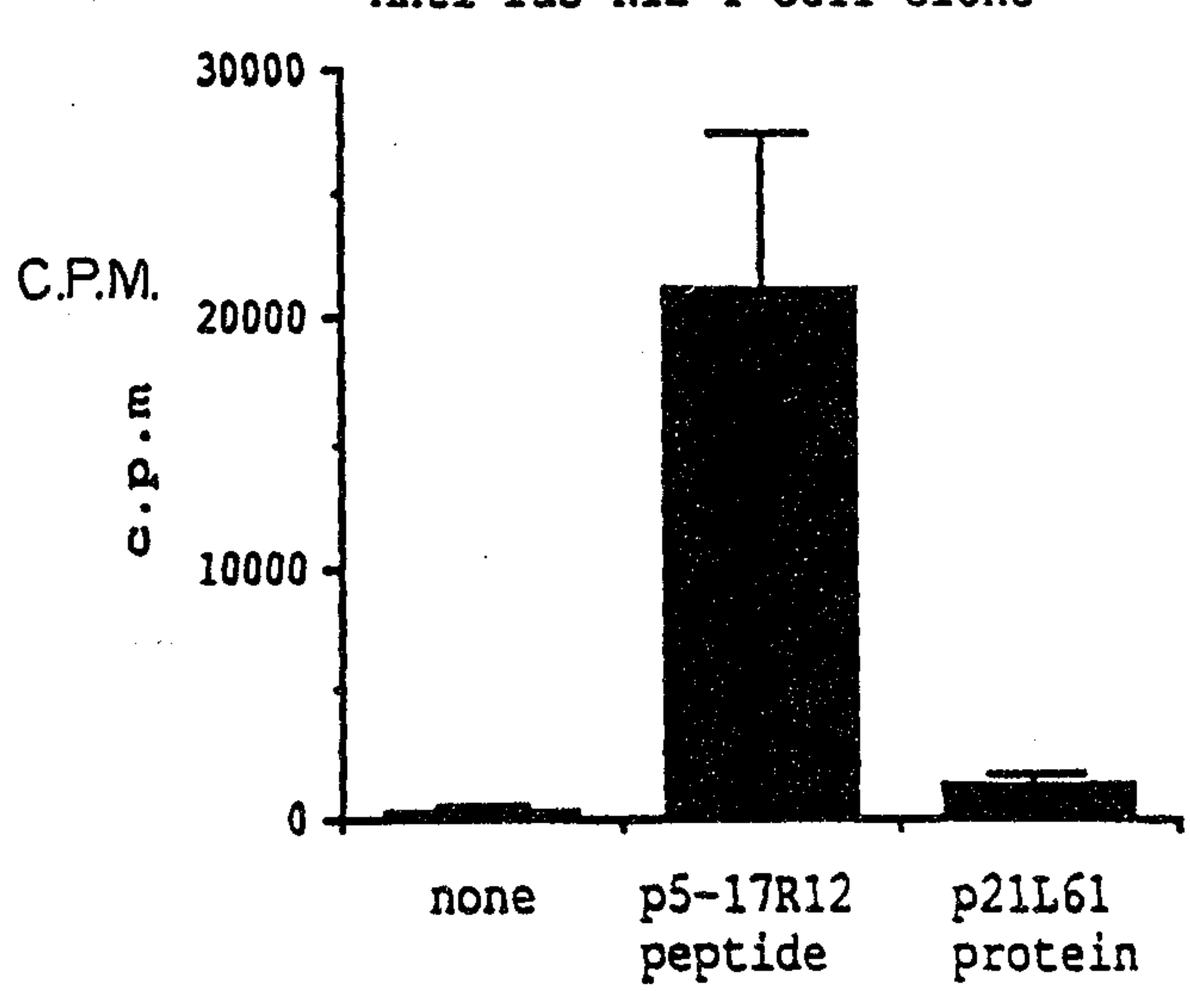
80000
60000
40000
20000
0
none
p54-66L61 peptide
p21L61 protein

FIG. 5A

FIG. 5B


Anti-ras R12 T cell clone
C.P.M.
c.p.m.
30000
20000
10000
0
none
p5-17R12 peptide
p21L61 protein