Description

Title of Invention: CDCA1 EPITOPE PEPTIDES AND VACCINES CONTAINING THE SAME

Technical Field

[0001] The present application claims the benefit of U.S. Provisional Application No. 61/074,062, filed June 19, 2008, and 61/197,599 filed October 28, 2008, the entire contents of which are incorporated by reference herein.

[0002] The present invention relates to the field of biological science, more specifically to the field of cancer therapy. In particular, the present invention relates to novel peptides that are extremely effective as cancer vaccines, and drugs for treating and preventing tumors.

Background Art

[0003] It has been demonstrated that CD8 positive cytotoxic T lymphocytes (CTLs) recognize epitope peptides derived from the tumor-associated antigens (TAAs) found on major histocompatibility complex (MHC) class I molecule, and then kill the tumor cells. Since the discovery of the melanoma antigen (MAGE) family as the first example of TAAs, many other TAAs have been discovered, primarily through immunological approaches (Boon T, Int J Cancer 1993 May 8, 54(2): 177-80; Boon T & van der Bruggen P, J Exp Med 1996 Mar 1, 183(3): 725-9). Some of these TAAs are currently undergoing clinical development as immunotherapeutic targets.

[0004] Identification of new TAAs capable of inducing potent and specific anti-tumor immune responses, warrants further development and clinical application of peptide vaccination strategies for various types of cancer (Harris CC, J Natl Cancer Inst 1996 Oct 16, 88(20): 1442-55; Butterfield LH et al., Cancer Res 1999 Jul 1, 59(13): 3134-42; Vissers JL et al., Cancer Res 1999 Nov 1, 59(21): 5554-9; van der Burg SH et al., J Immunol 1996 May 1, 156(9): 3308-14; Tanaka F et al., Cancer Res 1997 Oct 15, 57(20): 4465-8; Fujie T et al., Int J Cancer 1999 Jan 18, 80(2): 169-72; Kikuchi M et al., Int J Cancer 1999 May 5, 81(3): 459-66; Oiso M et al., Int J Cancer 1999 May 5, 81(3): 387-94). To date, there have been several reports of clinical trials using these tumor-associated antigen derived peptides. Unfortunately, only a low objective response rate has been observed in these cancer vaccine trials so far (Belli F et al., J Clin Oncol 2002 Oct 15, 20(20): 4169-80; Coulie PG et al., Immunol Rev 2002 Oct, 188: 33-42; Rosenberg SA et al., Nat Med 2004 Sep, 10(9): 909-15).

[0005] TAAs which are indispensable for proliferation and survival of cancer cells are valiant as targets for immunotherapy, because the use of such TAAs may minimize the well-described risk of immune escape of cancer cells attributable to deletion, mutation,

or down-regulation of TAAs as a consequence of therapeutically driven immune selection.

[0006] CDCA1, cell division cycle associated 1, was identified as a member of a class of genes that are coexpressed with cell cycle genes, such as CDC2, cyclin, topoisomerase II and the others (Walker et al., Curr Cancer Drug Targets 2001 May;1(1):73-83). CDCA1 in particular was found to be associated with centromeres of mitotic HeLa cells and was therefore considered a functional homologue of yeast Nuf2 (J Cell Biol 2001 Jan 22; 152(2):349-60).

[0007] In addition, through gene expression profile analysis using a genome-wide cDNA microarray containing 23,040 genes (Cancer Res 2006 Nov 1; 66(21):10339-48), CDCA1 has also been identified as a novel molecule up-regulated in breast cancer (WO2005/028676), bladder cancer (WO2006/085684), esophageal cancer (WO2007/013671), small cell lung cancer (SCLC) (WO2007/013665) and non-small cell lung cancer (NSCLC) (WO2005/089735), the contents of such disclosure being incorporated by reference herein. Expression of CDCA1 was particularly up-regulated in SCLC, NSCLC and tumor cell lines, though no expression was detected except testis among 23 normal tissues. Furthermore, down-regulation of CDCA1 expression by siRNA caused cell growth suppression in CDCA1 expressing lung cancer cell lines (WO2005/089735).

[0008] Taken together, this data suggests that CDCA1 is a novel, potentially universal oncoantigen. Accordingly, epitope peptides derived from CDCA1 may be applicable as cancer immunotherapeutics for the treatment of a wide array of cancers.

Summary of Invention

[0009] The present invention is based in part on the discovery of the suitable epitope peptides that may serve as targets of immunotherapy. Recognizing that CDCA1 are up-regulated in a number of cancer types, including breast cancer, bladder cancer, non-small cell lung cancer, small cell lung cancer and esophageal cancer, the present invention targets this cell division cycle associated 1 (CDCA1) (SEQ ID NO: 35 encoded by the gene of GenBank Accession No. NM_145697 (SEQ ID NO: 34)) for further analysis. In particular,CDCA1 gene products containing epitope peptides that elicit CTLs specific to the corresponding molecules were selected. Peripheral blood mononuclear cells (PBMCs) obtained from a healthy donor were stimulated using HLA-A*2402 binding candidate peptides derived from CDCA1. CTLs that specifically recognize HLA-A24 positive target cells pulsed with the respective candidate peptides were established, and HLA-A24 restricted epitope peptides that can induce potent and specific immune responses against CDCA1 were identified. These results demonstrate that CDCA1 is strongly immunogenic and the epitopes thereof are effective targets for

tumor immunotherapy.

[0010] Accordingly, it is an object of the present invention to provide peptides having CTL inducibility as well as an amino acid sequence selected from among SEQ ID NOs: 3, 4, 11, 14, 22 and 23. The present invention contemplates modified peptides, having an amino acid sequence of SEQ ID NOs: 3, 4, 11, 14, 22 or 23, wherein one, two or more amino acids are substituted, incorporated, deleted or added, so long as the modified peptides retain the original CTL inducibility.

[0011] When administered to a subject, the present peptides are presented on the surface of antigen-presenting cells or exosomes and then induce CTLs targeting the respective peptides. Therefore, it is an object of the present invention to provide antigen-presenting cells and exosomes presenting any of the present peptides, as well as methods for inducing antigen-presenting cells.

[0012] An anti-tumor immune response is induced by the administration of the present CDCA1 polypeptides or polynucleotide encoding the polypeptides, as well as exosomes and antigen-presenting cells which present the CDCA1 polypeptides. Therefore, it is an object of the present invention to provide pharmaceutical agents containing the polypeptides of the present invention or polynucleotides encoding them, as well as the exosomes and antigen-presenting cells containing such as their active ingredients. The pharmaceutical agents of the present invention find particular utility as vaccines.

[0013] It is a further object of the present invention to provide methods for the treatment and/or prophylaxis of (i.e., preventing) cancers (tumors), and/or prevention of post-operative recurrence thereof, as well as methods for inducing CTLs, methods for inducing anti-tumor immunity, which methods include the step of administering the CDCA1 polypeptides, polynucleotides encoding CDCA1 polypeptides, exosomes or the antigen-presenting cells presenting CDCA1 polypeptides or the pharmaceutical agents of the invention. In addition, the CTLs of the invention also find use as vaccines against cancer. Examples of cancers contemplated by the present invention include, but are not limited to breast cancer, bladder cancer, esophageal cancer, small cell lung cancer (SCLC) and non-small cell lung cancer (NSCLC).

[0014] In addition to the above, other objects and features of the invention will become more fully apparent when the following detailed description is read in conjunction with the accompanying figures and examples. However, it is to be understood that both the foregoing summary of the invention and the following detailed description are of exemplified embodiments, and not restrictive of the invention or other alternate embodiments of the invention. In particular, while the invention is described herein with reference to a number of specific embodiments, it will be appreciated that the description is illustrative of the invention and is not constructed as limiting of the

invention. Various modifications and applications may occur to those who are skilled in the art, without departing from the spirit and the scope of the invention, as described by the appended claims. Likewise, other objects, features, benefits and advantages of the present invention will be apparent from this summary and certain embodiments described below, and will be readily apparent to those skilled in the art. Such objects, features, benefits and advantages will be apparent from the above in conjunction with the accompanying examples, data, figures and all reasonable inferences to be drawn therefrom, alone or with consideration of the references incorporated herein.

Brief Description of Drawings

[0015] Various aspects and applications of the present invention will become apparent to the skilled artisan upon consideration of the brief description of the figures and the detailed description of the present invention and its preferred embodiments which follows.

[fig.1]Figure 1 is composed of a series of photographs, (a) to (g), depicting the results of an IFN-gamma ELISPOT assay on CTLs that were induced with peptides derived from CDCA1. The CTLs in well numbers #8 stimulated with CDCA1-A24-10-119 (SEQ ID NO: 3) (a), #1 with CDCA1-A24-10-335 (SEQ ID NO: 4) (b), #1 with CDCA1-A24-10-48 (SEQ ID NO: 11) (c), #4 with CDCA1-A24-10-5 (SEQ ID NO: 14) (d), #2 with CDCA1-A24-9-8 (SEQ ID NO: 22) (e) and #2 with CDCA1-A24-9-56 (SEQ ID NO: 23) (f) showed potent IFN-gamma production as compared with the control, respectively. In contrast, no specific IFN-gamma production against peptide-pulsed target cells was detected in the CTLs stimulated with CDCA1-A24-10-74 (SEQ ID NO: 2) (g). The cells in the wells denoted with a rectangular box were expanded to establish CTL lines. In the figures, "+"indicates the IFN-gamma production against target cells pulsed with the appropriate peptide, and "-"indicates the IFN-gamma production against target cells not pulsed with any peptides.

[fig.2]Figure 2 is composed of a series of line graphs, (a) to (g), representing the results of an IFN-gamma ELISA assay on CTL lines established with CDCA1-A24-10-119 (SEQ ID NO: 3) (a), CDCA1-A24-10-335 (SEQ ID NO: 4) (b), CDCA1-A24-10-48 (SEQ ID NO: 11) (c), CDCA1-A24-10-5 (SEQ ID NO: 14) (d), CDCA1-A24-9-8 (SEQ ID NO: 22) (e) and CDCA1-A24-9-56 (SEQ ID NO: 23) (f) in the above IFN-gamma ELISA assay. The results demonstrate that CTL lines established by stimulation with each peptide showed potent IFN-gamma production as compared with the control. In contrast, no specific IFN-gamma production against peptide-pulsed target cells was observed in the CTL line established with CDCA1-A24-10-74 (SEQ ID NO: 2) (g). In the figures, "+"indicates the IFN-gamma production against target cells pulsed with the appropriate peptide, and "-"indicates the IFN-gamma production

against target cells not pulsed with any peptides.

[fig.3]Figure 3 is a line graph depicting the IFN-gamma production of the CTL clone established by limiting dilution from the CTL line stimulated with SEQ ID NO: 23. The results demonstrate that the CTL clone established by stimulation with SEQ ID NO: 23 showed potent IFN-gamma production as compared with the control. In the figure, "+" indicates the IFN-gamma production against target cells pulsed with SEQ ID NO: 23s and "-" indicates the IFN-gamma production against target cells not pulsed with any peptides.

[fig.4]Figure 4 is a line graph depicting the specific CTL activity against the target cells that exogenously express CDCA1 and HLA-A*2402. The CTL clone established with CDCA1-A24-9-56 (SEQ ID NO: 23) showed high specific CTL activity against COS7 cells transfected with both CDCA1 and HLA-A*2402 (lozenge). In contrast, no significant specific CTL activity was detected against target cells expressing either HLA-A*2402 (triangle) or CDCA1 (circle).

Description of Embodiments

[0016] Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of embodiments of the present invention, the preferred methods, devices, and materials are now described. However, before the present materials and methods are described, it is to be understood that the present invention is not limited to the particular sizes, shapes, dimensions, materials, methodologies, protocols, etc. described herein, as these may vary in accordance with routine experimentation and optimization. It is also to be understood that the terminology used in the description is for the purpose of describing the particular versions or embodiments only, and is not intended to limit the scope of the present invention which will be limited only by the appended claims.

[0017] The disclosure of each publication, patent or patent application mentioned in this specification is specifically incorporated by reference herein in its entirety. However, nothing herein is to be construed as an admission that the invention is not entitled to antedate such disclosure by virtue of prior invention.

[0018] I. Definitions

Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the present invention belongs. However, in case of conflict, the present specification, including definitions, will control.

The words "a", "an", and "the" as used herein mean "at least one" unless otherwise specifically indicated.

[0019] The terms "polypeptide", "peptide" and "protein" are used interchangeably herein to

refer to a polymer of amino acid residues. The terms apply to amino acid polymers in which one or more amino acid residue is a modified residue, or a non-naturally occurring residue, such as an artificial chemical mimetic of a corresponding naturally occurring amino acid, as well as to naturally occurring amino acid polymers.

[0020] The term "amino acid" as used herein refers to naturally occurring and synthetic amino acids, as well as amino acid analogs and amino acid mimetics that similarly function to the naturally occurring amino acids. Naturally occurring amino acids are those encoded by the genetic code, as well as those modified after translation in cells (e.g., hydroxyproline, gamma-carboxyglutamate, and O-phosphoserine). The phrase "amino acid analog" refers to compounds that have the same basic chemical structure (an alpha carbon bound to a hydrogen, a carboxy group, an amino group, and an R group) as a naturally occurring amino acid but have a modified R group or modified backbones (e.g., homoserine, norleucine, methionine, sulfoxide, methionine methyl sulfonium). The phrase "amino acid mimetic" refers to chemical compounds that have different structures but similar functions to general amino acids.

[0021] Amino acids may be referred to herein by their commonly known three letter symbols or the one-letter symbols recommended by the IUPAC-IUB Biochemical Nomenclature Commission.

[0022] The terms "gene", "polynucleotide", "nucleotide" and "nucleic acid" are used inter-changeably herein and, unless otherwise specifically indicated, are referred to by their commonly accepted single-letter codes.

[0023] Unless otherwise defined, the term "cancer" refers to cancers overexpressing CDCA1 gene, including, for example, breast cancer, bladder cancer, esophageal cancer, small cell lung cancer (SCLC) and non-small cell lung cancer (NSCLC).

[0024] Unless otherwise defined, the term "cytotoxic T lymphocyte", "cytotoxic T cell" and "CTL" are used interchangeably herein and, otherwise specifically indicated, refer to a sub-group of T lymphocytes that are capable of recognizing non-self cells (e.g., tumor cells, virus-infected cells) and inducing the death of such cells.

[0025] II. Peptides

To demonstrate that peptides derived from CDCA1 function as an antigen recognized by cytotoxic T lymphocytes (CTLs), peptides derived from CDCA1 (SEQ ID NO: 35) were analyzed to determine whether they were antigen epitopes restricted by HLA-A24 which are commonly encountered HLA alleles (Date Y et al., Tissue Antigens 47: 93-101, 1996; Kondo A et al., J Immunol 155: 4307-12, 1995; Kubo RT et al., J Immunol 152: 3913-24, 1994). Candidates of HLA-A24 binding peptides derived from CDCA1 were identified based on their binding affinities to HLA-A24. After in vitro stimulation of T-cells by dendritic cells (DCs) loaded with these peptides, CTLs were successfully established using each of the following peptides:

CDCA1-A24-10-119 (SEQ ID NO: 3),
CDCA1-A24-10-335 (SEQ ID NO: 4),
CDCA1-A24-10-48 (SEQ ID NO: 11),
CDCA1-A24-10-5 (SEQ ID NO: 14),
CDCA1-A24-9-8 (SEQ ID NO: 22),
and
CDCA1-A24-9-56 (SEQ ID NO: 23).

[0026] These established CTLs show potent specific CTL activity against target cells pulsed with respective peptides. These results herein demonstrate that CDCA1 is an antigen recognized by CTLs and that the peptides are epitope peptides of CDCA1 restricted by HLA-A24.

[0027] Since the CDCA1 gene is over-expressed in most cancer tissues, including, for example, breast cancer, bladder cancer, esophageal cancer, small cell lung cancer (SCLC) and non-small cell lung cancer (NSCLC), it represents a good target for immunotherapy. Thus, the present invention provides nonapeptides (peptides consisting of nine amino acid residues) and decapeptides (peptides consisting of ten amino acid residues) corresponding to CTL-recognized epitopes of CDCA1. Particularly preferred examples of nonapeptides and decapeptides of the present invention include those peptides consisting of the amino acid sequence selected from among SEQ ID NOs: 3, 4, 11, 14, 22 and 23.

[0028] Generally, software programs presently available on the Internet, such as those described in Parker KC et al., J Immunol 1994 Jan 1, 152(1): 163-75, can be used to calculate the binding affinities between various peptides and HLA antigens in silico. Binding affinity with HLA antigens can be measured as described, for example, in Parker KC et al., J Immunol 1994 Jan 1, 152(1): 163-75; and Kuzushima K et al., Blood 2001, 98(6): 1872-81. The methods for determining binding affinity is described, for example, in the Journal of Immunological Methods, 1995, 185: 181-190 and Protein Science, 2000, 9: 1838-1846. Thus, the present invention encompasses peptides of CDCA1which are determined to bind with HLA antigens identified using such known programs.

[0029] The nonapeptides and decapeptides of the present invention can be optionally flanked with additional amino acid residues so long as the peptide retains its CTL inducibility. Such peptides having CTL inducibility are typically, less than about 40 amino acids, often less than about 20 amino acids, usually less than about 15 amino acids. The particular amino acid sequence(s) flanking the peptides consisting of the amino acid sequence selected from among SEQ ID NOs: 3, 4, 11, 14, 22 and 23 are not limited and can be composed of any kind of amino acids, so long as it does not impair the CTL inducibility of the original peptide. Thus, the present invention also provides

peptides having CTL inducibility and an amino acid sequence selected from among SEQ ID NOs: 3, 4, 11, 14, 22 and 23.

[0030] In general, the modification of one, two, or more amino acids in a protein will not influence the function of the protein, and in some cases will even enhance the desired function of the original protein. In fact, modified peptides (i.e., peptides composed of an amino acid sequence in which one, two or several amino acid residues have been modified (i.e., substituted, added, deleted or inserted) as compared to an original reference sequence) have been known to retain the biological activity of the original peptide (Mark et al., Proc Natl Acad Sci USA 1984, 81: 5662-6; Zoller and Smith, Nucleic Acids Res 1982, 10: 6487-500; Dalbadie-McFarland et al., Proc Natl Acad Sci USA 1982, 79: 6409-13). Thus, in one embodiment, the peptides of the present invention may have both CTL inducibility and an amino acid sequence selected from among SEQ ID NO: 3, 4, 11, 14, 22 and 23, wherein one, two or even more amino acids are added, inserted, deleted and/or substituted.

[0031] Those of skilled in the art recognize that individual additions or substitutions to an amino acid sequence which alter a single amino acid or a small percentage of amino acids tend to result in the conservation of the properties of the original amino acid side-chain. As such, they are often referred to as "conservative substitutions" or "conservative modifications", wherein the alteration of a protein results in a modified protein having a function analogous to the original protein. Conservative substitution tables providing functionally similar amino acids are well known in the art. Examples of properties of amino acid side chains are hydrophobic amino acids (A, I, L, M, F, P, W, Y, V), hydrophilic amino acids (R, D, N, C, E, Q, G, H, K, S, T), and side chains having the following functional groups or characteristics in common: an aliphatic side-chain (G, A, V, L, I, P); a hydroxyl group containing side-chain (S, T, Y); a sulfur atom containing side-chain (C, M); a carboxylic acid and amide containing side-chain (D, N, E, Q); a base containing side-chain (R, K, H); and an aromatic containing side-chain (H, F, Y, W). In addition, the following eight groups each contain amino acids that are conservative substitutions for one another:

1) Alanine (A), Glycine (G);
2) Aspartic acid (D), Glutamic acid (E);
3) Aspargine (N), Glutamine (Q);
4) Arginine (R), Lysine (K);
5) Isoleucine (I), Leucine (L), Methionine (M), Valine (V);
6) Phenylalanine (F), Tyrosine (Y), Tryptophan (W);
7) Serine (S), Threonine (T); and
8) Cysteine (C), Methionine (M) (see, e.g., Creighton, Proteins 1984).

[0032] Such conservatively modified peptides are also considered to be peptides of the

present invention. However, peptides of the present invention are not restricted thereto and can include non-conservative modifications, so long as the modified peptide retains the CTL inducibility of the original peptide. Furthermore, modified peptides should not exclude CTL inducible peptides of polymorphic variants, interspecies homologues, and alleles of CDCA1.

[0033] To retain the requisite CTL inducibility one can modify (insert, add, deletion and/or substitute) a small number (for example, 1, 2 or several) or a small percentage of amino acids. Herein, the term "several" means 5 or fewer amino acids, for example, 3 or fewer. The percentage of amino acids to be modified is preferably 20% or less, more preferably, 15% of less, even more preferably 10% or less or 1 to 5%.

[0034] Homology analysis of preferred peptides of the present invention, CDCA1-A24-10-119 (SEQ ID NO: 3), CDCA1-A24-10-335 (SEQ ID NO: 4), CDCA1-A24-10-48 (SEQ ID NO: 11), CDCA1-A24-10-5 (SEQ ID NO: 14), CDCA1-A24-9-8 (SEQ ID NO: 22) and CDCA1-A24-9-56 (SEQ ID NO: 23), confirmed that these peptides do not have significant homology with peptides derived from any other known human gene products. Thus, the possibility of these peptides generating unknown or undesired immune responses when used for immunotherapy is significantly lowered. Accordingly, these peptides are expected to be highly useful for eliciting immunity in cancer patients against CDCA1.

[0035] When used in the context of immunotherapy, the peptides of the present invention should be presented on the surface of a cell or exosome, preferably as a complex with an HLA antigen. Therefore, it is preferable to select peptides that not only induce CTLs but also possess high binding affinity to the HLA antigen. To that end, the peptides can be modified by substitution, insertion, deletion and/or addition of the amino acid residues to yield a modified peptide having improved binding affinity. In addition to peptides that are naturally displayed, since the regularity of the sequences of peptides displayed by binding to HLA antigens is already known (J Immunol 1994, 152: 3913; Immunogenetics 1995, 41: 178; J Immunol 1994, 155: 4307), modifications based on such regularity can be introduced into the immunogenic peptides of the invention. For example, it may be desirable to substitute the second amino acid from the N-terminus with phenylalanine, tyrosine, methionine, or tryptophan, and/or the amino acid at the C-terminus with phenylalanine, leucine, isoleucine, tryptophan, or methionine in order to increase the HLA-A24 binding affinity. Thus, peptides having an amino acid sequence selected from among SEQ ID NOs: 3, 4, 11, 14, 22 and 23 wherein the second amino acid from the N-terminus of the amino acid sequence of the SEQ ID NOs is substituted with phenylalanine, tyrosine, methionine, or tryptophan, and/or wherein the C-terminus of the amino acid sequence of the SEQ ID NOs is substituted with phenylalanine, leucine, isoleucine, tryptophan, or methionine are en-

compassed by the present invention. Substitutions can be introduced not only at the terminal amino acids but also at the position of potential TCR recognition of peptides. Several studies have demonstrated that amino acid substitutions in a peptide can be equal to or better than the original, for example CAP1, $p53_{(264-272)}$, Her-2/$neu_{(369-377)}$ or $gp100_{(209-217)}$ (Zaremba et al. Cancer Res. 57, 4570-4577, 1997, T. K. Hoffmann et al. J Immunol. (2002) Feb 1;168(3):1338-47., S. O. Dionne et al. Cancer Immunol immunother. (2003) 52: 199-206 and S. O. Dionne et al. Cancer Immunology, Immunotherapy (2004) 53, 307-314).

[0036] The present invention also contemplates the addition of one to two amino acids to the N and/or C-terminus of the described peptides. Such modified peptides having high HLA antigen binding affinity and retained CTL inducibility are also included in the present invention.

[0037] However, when the peptide sequence is identical to a portion of the amino acid sequence of an endogenous or exogenous protein having a different function, side effects such as autoimmune disorders and/or allergic symptoms against specific substances may be induced. Therefore, it is preferable to first perform homology searches using available databases to avoid situations in which the sequence of the peptide matches the amino acid sequence of another protein. When it becomes clear from the homology searches that there exists not even a peptide with 1 or 2 amino acid differences as compared to the objective peptide, the objective peptide can be modified in order to increase its binding affinity with HLA antigens, and/or increase its CTL inducibility without any danger of such side effects.

[0038] Although peptides having high binding affinity to the HLA antigens as described above are expected to be highly effective, the candidate peptides, which are selected according to the presence of high binding affinity as an indicator, are further examined for the presence of CTL inducibility. Herein, the phrase "CTL inducibility" indicates the ability of the peptide to induce cytotoxic T lymphocytes (CTLs) when presented on antigen-presenting cells. Further, "CTL inducibility" includes the ability of the peptide to induce CTL activation, CTL proliferation, promote CTL lysis of target cells, and to increase CTL IFN-gamma production.

[0039] Confirmation of CTL inducibility is accomplished by inducing antigen-presenting cells carrying human MHC antigens (for example, B-lymphocytes, macrophages, and dendritic cells (DCs)), or more specifically DCs derived from human peripheral blood mononuclear leukocytes, and after stimulation with the peptides, mixing with CD8-positive cells, and then measuring the IFN-gamma produced and released by CTL against the target cells. As the reaction system, transgenic animals that have been produced to express a human HLA antigen (for example, those described in BenMohamed L, Krishnan R, Longmate J, Auge C, Low L, Primus J, Diamond DJ,

Hum Immunol 2000 Aug, 61(8): 764-79, Related Articles, Books, Linkout Induction of CTL response by a minimal epitope vaccine in HLA A*0201/DR1 transgenic mice: dependence on HLA class II restricted T(H) response) can be used. For example, the target cells can be radiolabeled with ^{51}Cr and such, and cytotoxic activity can be calculated from radioactivity released from the target cells. Alternatively, CTL inducibility can be assessed by measuring IFN-gamma produced and released by CTL in the presence of antigen-presenting cells (APCs) that carry immobilized peptides, and visualizing the inhibition zone on the media using anti-IFN-gamma monoclonal antibodies.

[0040] As a result of examining the CTL inducibility of the peptides as described above, it was discovered that those having high binding affinity to an HLA antigen did not necessarily have high CTL inducibility. However, of those peptides identified and assessed, nonapeptides or decapeptides having the amino acid sequence selected from among SEQ ID NOs: 3, 4, 11, 14, 22 and 23 were found to exhibit particularly high CTL inducibility as well as high binding affinity to an HLA antigen. Thus, these peptides are exemplified as preferred embodiments of the present invention.

[0041] In addition to the above-described modifications, the peptides of the present invention can also be linked to other substances, so long as the resulting linked peptide retains the CTL inducibility of the original peptide. Examples of suitable substances include, for example: peptides, lipids, sugar and sugar chains, acetyl groups, natural and synthetic polymers, etc. The peptides can contain modifications such as glycosylation, side chain oxidation, or phosphorylation, etc., provided the modifications do not destroy the biological activity of the original peptide . These kinds of modifications can be performed to confer additional functions (e.g., targeting function, and delivery function) or to stabilize the polypeptide.

[0042] For example, to increase the in vivo stability of a polypeptide, it is known in the art to introduce D-amino acids, amino acid mimetics or unnatural amino acids; this concept can also be adapted to the present polypeptides. The stability of a polypeptide can be assayed in a number of ways. For instance, peptidases and various biological media, such as human plasma and serum, can be used to test stability (see, e.g., Verhoef et al., Eur J Drug Metab Pharmacokin 1986, 11: 291-302).

[0043] The peptides of the present invention are presented on the surface of a cell (e.g. antigen presenting cell) or an exosome as complexes in combination with HLA antigens and then induce CTLs. Therefore, the peptides forming complexes with HLA antigens on the surface of a cell or an exsosomes are also included in the present invention. Such exosomes can be prepared, for example using the methods detailed in Japanese Patent Application Kohyo Publications Nos. Hei 11-510507 and WO99/03499, and can be prepared using APCs obtained from patients who are subject

to treatment and/or prevention. The exosomes or cells presenting the peptides of the present invention can be inoculated as vaccines.

[0044] The type of HLA antigens contained in the above complexes must match that of the subject requiring treatment and/or prevention. For example, in the Japanese population, HLA-A24, particularly HLA-A2402, is prevalent and therefore would be appropriate for treatment of a Japanese patient. The use of the A24 type that is highly expressed among the Japanese and Caucasian is favorable for obtaining effective results, and subtypes such as A2402 also find use. Typically, in the clinic, the type of HLA antigen of the patient requiring treatment is investigated in advance, which enables the appropriate selection of peptides having high levels of binding affinity to the particular antigen, or having CTL inducibility by antigen presentation.

[0045] When using the A24 type HLA antigen for the exosome or cell, the peptides having the amino acid sequence selected from among SEQ ID NO: 3, 4, 11, 14, 22 and 23 are preferably used.

[0046] Herein, the peptides of the present invention can also be described as "CDCA1 peptide(s)" or "CDCA1 polypeptide(s)".

[0047] III. Preparation of CDCA1 peptides

The peptides of the invention can be prepared using well known techniques. For example, the peptides can be prepared synthetically, using recombinant DNA technology or chemical synthesis. Peptide of the invention can be synthesized individually or as longer polypeptides composed of two or more peptides. The peptides can be then be isolated, i.e., purified, so as to be substantially free of other naturally occurring host cell proteins and fragments thereof, or any other chemical substances.

[0048] A peptide of the present invention can be obtained through chemical synthesis based on the selected amino acid sequence. Examples of conventional peptide synthesis methods that can be adapted for the synthesis include:

(i) Peptide Synthesis, Interscience, New York, 1966;

(ii) The Proteins, Vol. 2, Academic Press, New York, 1976;

(iii) Peptide Synthesis (in Japanese), Maruzen Co., 1975;

(iv) Basics and Experiment of Peptide Synthesis (in Japanese), Maruzen Co., 1985;

(v) Development of Pharmaceuticals (second volume) (in Japanese), Vol. 14 (peptide synthesis), Hirokawa, 1991;

(vi) WO99/67288; and

(vii) Barany G. & Merrifield R.B., Peptides Vol. 2, "Solid Phase Peptide Synthesis", Academic Press, New York, 1980, 100-118.

[0049] Alternatively, the present peptides can be obtained adapting any known genetic engineering method for producing peptides (e.g., Morrison J, J Bacteriology 1977, 132: 349-51; Clark-Curtiss & Curtiss, Methods in Enzymology (eds. Wu et al.) 1983, 101:

347-62). For example, first, a suitable vector harboring a polynucleotide encoding the objective peptide in an expressible form (e.g., downstream of a regulatory sequence corresponding to a promoter sequence) is prepared and transformed into a suitable host cell. The host cell is then cultured to produce the peptide of interest. The peptide can also be produced in vitro adopting an in vitro translation system.

[0050] IV. Polynucleotides

The present invention also provides a polynucleotide which encodes any of the aforementioned peptides of the present invention. These include polynucleotides derived from the natural occurring CDCA1 gene (GenBank Accession No. NM_145697 (SEQ ID NO: 34)) as well as those having a conservatively modified nucleotide sequence thereof. Herein, the phrase "conservatively modified nucleotide sequence" refers to sequences which encode identical or essentially identical amino acid sequences. Due to the degeneracy of the genetic code, a large number of functionally identical nucleic acids encode any given protein. For instance, the codons GCA, GCC, GCG, and GCU all encode the amino acid alanine. Thus, at every position where an alanine is specified by a codon, the codon can be altered to any of the corresponding codons described without altering the encoded polypeptide. Such nucleic acid variations are "silent variations," which are one species of conservatively modified variations. Every nucleic acid sequence herein which encodes a peptide also describes every possible silent variation of the nucleic acid. One of ordinary skill will recognize that each codon in a nucleic acid (except AUG, which is ordinarily the only codon for methionine, and TGG, which is ordinarily the only codon for tryptophan) can be modified to yield a functionally identical molecule. Accordingly, each silent variation of a nucleic acid that encodes a peptide is implicitly described in each disclosed sequence.

[0051] The polynucleotide of the present invention can be composed of DNA, RNA, and derivatives thereof. A DNA is suitably composed of bases such as A, T, C, and G, and T is replaced by U in an RNA.

[0052] The polynucleotide of the present invention can encode multiple peptides of the present invention with or without intervening amino acid sequences in between. For example, the intervening amino acid sequence can provide a cleavage site (e.g., enzyme recognition sequence) of the polynucleotide or the translated peptides. Furthermore, the polynucleotide can include any additional sequences to the coding sequence encoding the peptide of the present invention. For example, the polynucleotide can be a recombinant polynucleotide that includes regulatory sequences required for the expression of the peptide or can be an expression vector (plasmid) with marker genes and such. In general, such recombinant polynucleotides can be prepared by the manipulation of polynucleotides through conventional recombinant techniques using, for example, polymerases and endonucleases.

[0053] Both recombinant and chemical synthesis techniques can be used to produce the polynucleotides of the present invention. For example, a polynucleotide can be produced by insertion into an appropriate vector, which can be expressed when transfected into a competent cell. Alternatively, a polynucleotide can be amplified using PCR techniques or expression in suitable hosts (see, e.g., Sambrook et al., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, New York, 1989). Alternatively, a polynucleotide can be synthesized using the solid phase techniques, as described in Beaucage SL & Iyer RP, Tetrahedron 1992, 48: 2223-311; Matthes et al., EMBO J 1984, 3: 801-5.

[0054] V. Antigen-presenting cells (APCs)

The present invention also provides antigen-presenting cells (APCs) that present complexes formed between HLA antigens and the peptides of the present invention on its surface. The APCs that are obtained by contacting the peptides of the present invention, or introducing the nucleotides encoding the peptides of the present invention in an expressible form can be derived from patients who are subject to treatment and/or prevention, and can be administered as vaccines by themselves or in combination with other drugs including the peptides of the present invention, exosomes, or cytotoxic T cells.

[0055] The APCs are not limited to a particular kind of cells and include dendritic cells (DCs), Langerhans cells, macrophages, B cells, and activated T cells, which are known to present proteinaceous antigens on their cell surface so as to be recognized by lymphocytes. Since DC is a representative APC having the strongest CTL inducing action among APCs, DCs find use as the APCs of the present invention.

[0056] For example, an APC can be obtained by inducing DCs from peripheral blood monocytes and then contacting (stimulating) them with the peptides of the present invention in vitro, ex vivo or in vivo. When the peptides of the present invention are administered to the subjects, APCs that present the peptides of the present invention are induced in the body of the subject. The phrase "inducing APC" includes contacting (stimulating) a cell with the peptides of the present invention, or nucleotides encoding the peptides of the present invention to present complexes formed between HLA antigens and the peptides of the present invention on cell's surface. Alternatively, after introducing the peptides of the present invention to the APCs to allow the APCs to present the peptides, the APCs can be administered to the subject as a vaccine. For example, the ex vivo administration can include steps of:

a: collecting APCs from a first subject:,

b: contacting with the APCs of step a, with the peptide and

c: administering the peptide-loaded APCs to a second subject.

[0057] The first subject and the second subject may be the same individual, or can be

different individuals. Alternatively, according to the present invention, use of the peptides of the present invention for manufacturing a pharmaceutical composition inducing antigen-presenting cells is provided. In addition, the present invention provides a method or process for manufacturing a pharmaceutical composition inducing antigen-presenting cells, wherein the method comprises the step for admixing or formulating the peptide of the present invention with a pharmaceutically acceptable carrier. Further, the present invention also provides the peptides of the present invention for inducing antigen-presenting cells. The APCs obtained by step (b) can be administered to the subject as a vaccine.

[0058] According to an aspect of the present invention, the APCs have a high level of CTL inducibility. In the term of "high level of CTL inducibility", the high level is relative to the level of that by APC contacting with no peptide or peptides which can not induce the CTL. Such APCs having a high level of CTL inducibility can be prepared by a method which includes the step of transferring genes containing polynucleotides that encode the peptides of the present invention to APCs in vitro. The introduced genes can be in the form of DNAs or RNAs. Examples of methods for introduction include, without particular limitations, various methods conventionally performed in this field, such as lipofection, electroporation, and calcium phosphate method can be used. More specifically, it can be performed as described in Cancer Res 1996, 56: 5672-7; J Immunol 1998, 161: 5607-13; J Exp Med 1996, 184: 465-72; Published Japanese Translation of International Publication No. 2000-509281. By transferring the gene into APCs, the gene undergoes transcription, translation, and such in the cell, and then the obtained protein is processed by MHC Class I or Class II, and proceeds through a presentation pathway to present peptides.

[0059] VI. Cytotoxic T cells

A cytotoxic T cell induced against any of the peptides of the present invention strengthens the immune response targeting cancer cells in vivo and thus can be used as vaccines, in a fashion similar to the peptides per se. Thus, the present invention also provides isolated cytotoxic T cells that are specifically induced or activated by any of the present peptides.

[0060] Such cytotoxic T cells can be obtained by (1) administering the peptides of the present invention to a subject, collecting cytotoxic T cells from the subject or (2) contacting (stimulating) subject-derived APCs and CD8-positive cells, or peripheral blood mononuclear leukocytes in vitro with the peptides of the present invention and then isolating cytotoxic T cells.

[0061] The cytotoxic T cells, which have been induced by stimulation with APCs that present the peptides of the present invention, can be derived from patients who are subject to treatment and/or prevention, and can be administered by themselves or in

combination with other drugs including the peptides of this invention or exosomes for the purpose of regulating effects. The obtained cytotoxic T cells act specifically against target cells presenting the peptides of the present invention, for example, the same peptides used for induction. The target cells can be cells that endogenously express CDCA1, or cells that are transfected with the CDCA1 gene; and cells that present a peptide of the present invention on the cell surface due to stimulation by the peptide can also serve as targets of activated CTL attack.

[0062] VII. T cell receptor (TCR)

The present invention also provides a composition containing nucleic acids encoding polypeptides that are capable of forming a subunit of a T cell receptor (TCR), and methods of using the same. The TCR subunits have the ability to form TCRs that confer specificity to T cells against tumor cells presenting CDCA1. By using the known methods in the art, the nucleic acids of alpha- and beta- chains as the TCR subunits of the CTL induced with one or more peptides of the present invention can be identified (WO2007/032255 and Morgan et al., J Immunol, 171, 3288 (2003)). The derivative TCRs can bind target cells displaying the CDCA1 peptide with high avidity, and optionally mediate efficient killing of target cells presenting the CDCA1 peptide in vivo and in vitro.

[0063] The nucleic acids encoding the TCR subunits can be incorporated into suitable vectors e.g. retroviral vectors. These vectors are well known in the art. The nucleic acids or the vectors containing them usefully can be transferred into a T cell, for example, a T cell from a patient. Advantageously, the invention provides an off-the-shelf composition allowing rapid modification of a patient's own T cells (or those of another mammal) to rapidly and easily produce modified T cells having excellent cancer cell killing properties.

[0064] Also, the present invention provides CTLs which are prepared by transduction with the nucleic acids encoding the TCR subunits polypeptides that bind to the CDCA1 peptide e.g. SEQ ID NOs: 3, 4, 11, 14, 22 and 23 in the context of HLA-A24. The transduced CTLs are capable of homing to cancer cells in vivo, and can be expanded by well known culturing methods in vitro (e.g., Kawakami et al., J Immunol., 142, 3452-3461 (1989)). The T cells of the invention can be used to form an immunogenic composition useful in treating or the prevention of cancer in a patient in need of therapy or protection (WO2006/031221).

[0065] Prevention and prophylaxis include any activity which reduces the burden of mortality or morbidity from disease. Prevention and prophylaxis can occur "at primary, secondary and tertiary prevention levels." While primary prevention and prophylaxis avoid the development of a disease, secondary and tertiary levels of prevention and prophylaxis encompass activities aimed at the prevention and prophylaxis of the pro-

gression of a disease and the emergence of symptoms as well as reducing the negative impact of an already established disease by restoring function and reducing disease-related complications. Alternatively, prevention and prophylaxis include a wide range of prophylactic therapies aimed at alleviating the severity of the particular disorder, e.g. reducing the proliferation and metastasis of tumors, reducing angiogenesis.

[0066] Treating and/or for the prophylaxis of cancer or , and/or the prevention of post-operative recurrence thereof includes any of the following steps, such as surgical removal of cancer cells, inhibition of the growth of cancerous cells, involution or regression of a tumor, induction of remission and suppression of occurrence of cancer, tumor regression, and reduction or inhibition of metastasis. Effectively treating and/or the prophylaxis of cancer decreases mortality and improves the prognosis of individuals having cancer, decreases the levels of tumor markers in the blood, and alleviates detectable symptoms accompanying cancer. For example, reduction or improvement of symptoms constitutes effectively treating and/or the prophylaxis include 10%, 20%, 30% or more reduction, or stable disease.

[0067] VIII. Pharmaceutical agents or compositions

Since CDCA1 expression is specifically elevated in several cancer types, including breast cancer, bladder cancer, esophageal cancer, small cell lung cancer (SCLC) and non-small cell lung cancer (NSCLC) as compared with normal tissue (Cancer Res 2006 Nov 1; 66(21):10339-48, WO2005/028676, WO2005/089735, WO2006/085684, WO2007/013665, WO2007/013671), the peptides of the present invention or polynucleotides encoding the peptides can be used for the treatment and/or prophylaxis of cancer or tumor, and/or for the prevention of postoperative recurrence thereof. Thus, the present invention provides a pharmaceutical agent or a composition for treating and/or for the prophylaxis of cancer or tumor, and/or prevention of postoperative recurrence thereof, which comprises one or more of the peptides of the present invention, or polynucleotides encoding the peptides as an active ingredient. Alternatively, the present peptides can be expressed on the surface of any of the foregoing exosomes or cells, such as APCs for the use as pharmaceutical agents or compositions. In addition, the aforementioned cytotoxic T cells which target any of the peptides of the invention can also be used as the active ingredient of the present pharmaceutical agents or compositions.

[0068] In another embodiment, the present invention also provides the use of an active ingredient selected from among:

(a) a peptide of the present invention,

(b) a nucleic acid encoding such a peptide as disclosed herein in an expressible form,

(c) an APC or an exosome presenting a peptide of the present invention on its surface, and

(d) a cytotoxic T cell of the present invention

in manufacturing a pharmaceutical composition or agent for treating cancer or tumor.

[0069] Alternatively, the present invention further provides an active ingredient selected from among:

(a) a peptide of the present invention,

(b) a nucleic acid encoding such a peptide as disclosed herein in an expressible form,

(c) an APC or an exosome presenting a peptide of the present invention on its surface, and

(d) a cytotoxic T cells of the present invention

for use in for treating cancer or tumor.

[0070] Alternatively, the present invention further provides a method or process for manufacturing a pharmaceutical composition or agent for treating cancer or tumor, wherein the method or process includes the step of formulating a pharmaceutically or physiologically acceptable carrier with an active ingredient selected from among:

(a) a peptide of the present invention,

(b) a nucleic acid encoding such a peptide as disclosed herein in an expressible form,

(c) an APC or an exosome presenting a peptide of the present invention on its surface, and

(d) a cytotoxic T cells of the present invention

as active ingredients.

[0071] In another embodiment, the present invention also provides a method or process for manufacturing a pharmaceutical composition or agent for treating cancer or tumor, wherein the method or process includes the step of admixing an active ingredient with a pharmaceutically or physiologically acceptable carrier, wherein the active ingredient is selected from among:

(a) a peptide of the present invention,

(b) a nucleic acid encoding such a peptide as disclosed herein in an expressible form,

(c) an APC or an exosome presenting a peptide of the present invention on its surface, and

(d) a cytotoxic T cells of the present invention.

[0072] Alternatively, the pharmaceutical composition or agent of the present invention may be used for either or both the prophylaxis of cancer or tumor and prevention of postoperative recurrence thereof.

[0073] The present pharmaceutical agents or compositions find use as a vaccine. In the context of the present invention, the phrase "vaccine" (also referred to as an immunogenic composition) refers to a substance that has the function to induce anti-tumor immunity upon inoculation into animals.

[0074] The pharmaceutical agents or compositions of the present invention can be used to

treat and/or prevent cancers or tumors, and/or prevention of postoperative recurrence thereof in subjects or patients including human and any other mammal including, but not limited to, mouse, rat, guinea-pig, rabbit, cat, dog, sheep, goat, pig, cattle, horse, monkey, baboon, and chimpanzee, particularly a commercially important animal or a domesticated animal.

[0075] According to the present invention, polypeptides having an amino acid sequence selected from among SEQ ID NO: 3, 4, 11, 14, 22 and 23 have been found to be HLA-A24 restricted epitope peptides or candidates that can induce potent and specific immune response. Therefore, the present pharmaceutical agents which include any of these polypeptides having the amino acid sequences of SEQ ID NOs: 3, 4, 11, 14, 22 and 23 are particularly suited for the administration to subjects whose HLA antigen is HLA-A24. The same applies to pharmaceutical agents or compositions which contain polynucleotides encoding any of these polypeptides.

[0076] Cancers or tumors to be treated by the pharmaceutical agents or compositions of the present invention are not limited and include all kinds of cancers or tumors wherein CDCA1 is involved, including for example, breast cancer, bladder cancer, esophageal cancer, small cell lung cancer (SCLC) and non-small cell lung cancer (NSCLC).

[0077] The present pharmaceutical agents or compositions can contain in addition to the aforementioned active ingredients, other peptides which have the ability to induce CTLs against cancerous cells, other polynucleotides encoding the other peptides, other cells that present the other peptides, or such. Herein, the other peptides that have the ability to induce CTLs against cancerous cells are exemplified by cancer specific antigens (e.g., identified TAAs), but are not limited thereto.

[0078] If needed, the pharmaceutical agents or compositions of the present invention can optionally include other therapeutic substances as an active ingredient, so long as the substance does not inhibit the antitumoral effect of the active ingredient, e.g., any of the present peptides. For example, formulations can include anti-inflammatory agents, pain killers, chemotherapeutics, and the like. In addition to including other therapeutic substances in the medicament itself, the medicaments of the present invention can also be administered sequentially or concurrently with the one or more other pharmacologic agents. The amounts of medicament and pharmacologic agent depend, for example, on what type of pharmacologic agent(s) is/are used, the disease being treated, and the scheduling and routes of administration.

[0079] It should be understood that in addition to the ingredients particularly mentioned herein, the pharmaceutical agents or compositions of the present invention can include other agents conventional in the art having regard to the type of formulation in question.

[0080] In one embodiment of the present invention, the present pharmaceutical agents or

compositions can be included in articles of manufacture and kits containing materials useful for treating the pathological conditions of the disease to be treated, e.g, cancer. The article of manufacture can include a container of any of the present pharmaceutical agents or compositions with a label. Suitable containers include bottles, vials, and test tubes. The containers can be formed from a variety of materials, such as glass or plastic. The label on the container should indicate the agent is used for treating or prevention of one or more conditions of the disease. The label can also indicate directions for administration and so on.

[0081] In addition to the container described above, a kit including a pharmaceutical agent or composition of the present invention can optionally further include a second container housing a pharmaceutically-acceptable diluent. It can further include other materials desirable from a commercial and user standpoint, including other buffers, diluents, filters, needles, syringes, and package inserts with instructions for use.

[0082] The pharmaceutical agents or compositions can, if desired, be presented in a pack or dispenser device which can contain one or more unit dosage forms containing the active ingredient. The pack can, for example, include metal or plastic foil, such as a blister pack. The pack or dispenser device can be accompanied by instructions for administration.

[0083] (1) Pharmaceutical agents or compositions containing the peptides as the active ingredient

The peptide of the present invention can be administered directly as a pharmaceutical agent or composition, or if necessary, that has been formulated by conventional formulation methods. In the latter case, in addition to the peptides of the present invention, carriers, excipients, and such that are ordinarily used for drugs can be included as appropriate without particular limitations. Examples of such carriers are sterilized water, physiological saline, phosphate buffer, culture fluid and such. Furthermore, the pharmaceutical agents or compositions can contain as necessary, stabilizers, suspensions, preservatives, surfactants and such. The pharmaceutical agents or compositions of the present invention can be used for anticancer purposes.

[0084] The peptides of the present invention can be prepared in a combination, composed of two or more of peptides of the present invention to induce CTLs in vivo. The peptide combination can take the form of a cocktail or can be conjugated to each other using standard techniques. For example, the peptides can be chemically linked or expressed as a single fusion polypeptide sequence. The peptides in the combination can be the same or different.

[0085] By administering the peptides of the present invention, the peptides are presented at a high density by the HLA antigens on APCs, then CTLs that specifically react toward the complex formed between the displayed peptide and the HLA antigen are induced.

Alternatively, APCs that present any of the peptides of the present invention on their cell surface, which may be obtained by stimulating APCs (e.g., DCs) derived from a subject with the peptides of the present invention, may be administered to the subject, and as a result, CTLs are induced in the subject and aggressiveness towards the cancer cells can be increased.

[0086] The pharmaceutical agents or compositions for the treatment and/or prevention of cancer or tumor, which include a peptide of the present invention as the active ingredient, can also include an adjuvant known to effectively establish cellular immunity. Alternatively, the pharmaceutical agents or compositions can be administered with other active ingredients or can be administered by formulation into granules. An adjuvant refers to a compound that enhances the immune response against the protein when administered together (or successively) with the protein having immunological activity. Adjuvants contemplated herein include those described in the literature (Clin Microbiol Rev 1994, 7: 277-89). Examples of suitable adjuvants include, but are not limited to, aluminum phosphate, aluminum hydroxide, alum, cholera toxin, salmonella toxin, and the like.

[0087] Furthermore, liposome formulations, granular formulations in which the peptide is bound to few-micrometers diameter beads, and formulations in which a lipid is bound to the peptide may be conveniently used.

[0088] In some embodiments, the pharmaceutical agents or compositions of the present invention may further include a component which primes CTLs. Lipids have been identified as agents capable of priming CTLs in vivo against viral antigens. For example, palmitic acid residues can be attached to the epsilon- and alpha-amino groups of a lysine residue and then linked to a peptide of the present invention. The lipidated peptide can then be administered either directly in a micelle or particle, incorporated into a liposome, or emulsified in an adjuvant. As another example of lipid priming of CTL responses, E. coli lipoproteins, such as tripalmitoyl-S-glycerylcysteinlyseryl-serine (P3CSS) can be used to prime CTLs when covalently attached to an appropriate peptide (see, e.g., Deres et al., Nature 1989, 342: 561-4).

[0089] The method of administration can be oral, intradermal, subcutaneous, intravenous injection, or such, and systemic administration or local administration to the vicinity of the targeted sites. The administration can be performed by single administration or boosted by multiple administrations. The dose of the peptides of the present invention can be adjusted appropriately according to the disease to be treated, age of the patient, weight, method of administration, and such, and is ordinarily 0.001 mg to 1000 mg, for example, 0.001 mg to 1000 mg, for example, 0.1 mg to 10 mg, and can be administered once in a few days to few months. One skilled in the art can appropriately select a suitable dose.

[0090] (2) Pharmaceutical agents or compositions containing polynucleotides as the active ingredient

The pharmaceutical agents or compositions of the present invention can also contain nucleic acids encoding the peptides disclosed herein in an expressible form. Herein, the phrase "in an expressible form" means that the polynucleotide, when introduced into a cell, will be expressed in vivo as a polypeptide that induces anti-tumor immunity. In an exemplified embodiment, the nucleic acid sequence of the polynucleotide of interest includes regulatory elements necessary for expression of the polynucleotide. The polynucleotide(s) can be equipped so to achieve stable insertion into the genome of the target cell (see, e.g., Thomas KR & Capecchi MR, Cell 1987, 51: 503-12 for a description of homologous recombination cassette vectors). See, e.g., Wolff et al., Science 1990, 247: 1465-8; U.S. Patent Nos. 5,580,859; 5,589,466; 5,804,566; 5,739,118; 5,736,524; 5,679,647; and WO 98/04720. Examples of DNA-based delivery technologies include "naked DNA", facilitated (bupivacaine, polymers, peptide-mediated) delivery, cationic lipid complexes, and particle-mediated ("gene gun") or pressure-mediated delivery (see, e.g., U.S. Patent No. 5,922,687).

[0091] The peptides of the present invention can also be expressed by viral or bacterial vectors. Examples of expression vectors include attenuated viral hosts, such as vaccinia or fowlpox. This approach involves the use of vaccinia virus, e.g., as a vector to express nucleotide sequences that encode the peptide. Upon introduction into a host, the recombinant vaccinia virus expresses the immunogenic peptide, and thereby elicits an immune response. Vaccinia vectors and methods useful in immunization protocols are described in, e.g., U.S. Patent No. 4,722,848. Another vector is BCG (Bacille Calmette Guerin). BCG vectors are described in Stover et al., Nature 1991, 351: 456-60. A wide variety of other vectors useful for therapeutic administration or immunization e.g., adeno and adeno-associated virus vectors, retroviral vectors, Salmonella typhi vectors, detoxified anthrax toxin vectors, and the like, will be apparent. See, e.g., Shata et al., Mol Med Today 2000, 6: 66-71; Shedlock et al., J Leukoc Biol 2000, 68: 793-806; Hipp et al., In Vivo 2000, 14: 571-85.

[0092] Delivery of a polynucleotide into a subject can be either direct, in which case the subject is directly exposed to a polynucleotide-carrying vector, or indirect, in which case, cells are first transformed with the polynucleotide of interest in vitro, then the cells are transplanted into the subject. These two approaches are known, respectively, as in vivo and ex vivo gene therapies.

[0093] For general reviews of the methods of gene therapy, see Goldspiel et al., Clinical Pharmacy 1993, 12: 488-505; Wu and Wu, Biotherapy 1991, 3: 87-95; Tolstoshev, Ann Rev Pharmacol Toxicol 1993, 33: 573-96; Mulligan, Science 1993, 260: 926-32; Morgan & Anderson, Ann Rev Biochem 1993, 62: 191-217; Trends in Biotechnology

1993, 11(5): 155-215). Methods commonly known in the art of recombinant DNA technology which can also be used for the present invention are described in eds. Ausubel et al., Current Protocols in Molecular Biology, John Wiley & Sons, NY, 1993; and Krieger, Gene Transfer and Expression, A Laboratory Manual, Stockton Press, NY, 1990.

[0094] The method of administration can be oral, intradermal, subcutaneous, intravenous injection, or such, and systemic administration or local administration to the vicinity of the targeted sites finds use. The administration can be performed by single administration or boosted by multiple administrations. The dose of the polynucleotide in the suitable carrier or cells transformed with the polynucleotide encoding the peptides of the present invention can be adjusted appropriately according to the disease to be treated, age of the patient, weight, method of administration, and such, and is ordinarily 0.001 mg to 1000 mg, for example, 0.001 mg to 1000 mg, for example, 0.1 mg to 10 mg, and can be administered once every a few days to once every few months. One skilled in the art can appropriately select the suitable dose.

[0095] IX. Methods using the peptides, exosomes, APCs and CTLs

The peptides of the present invention and polynucleotides encoding such peptides can be used for inducing APCs and CTLs. The exosomes and APCs of the present invention can be also used for inducing CTLs. The peptides, polynucleotides, exosomes and APCs can be used in combination with any other compounds so long as the compounds do not inhibit their CTL inducibility. Thus, any of the aforementioned pharmaceutical agents or compositions of the present invention can be used for inducing CTLs, and in addition thereto, those including the peptides and polynucleotides can be also be used for inducing APCs as discussed below.

[0096] (1) Method of inducing antigen-presenting cells (APCs)

The present invention provides methods of inducing APCs using the peptides of the present invention or polynulceotides encoding the peptides. The induction of APCs can be performed as described above in section "VI. Antigen-presenting cells". The present invention also provides a method for inducing APCs having a high level of CTL inducibility, the induction of which has been also mentioned under the item of "VI. Antigen-presenting cells", supra.

[0097] (2) Method of inducing CTLs

Furthermore, the present invention provides methods for inducing CTLs using the peptides of the present invention, polynucleotides encoding the peptides, exosomes or APCs presenting the peptides. The present invention also provides methods for inducing CTLs using a polynucleotide encoding a polypeptide that is capable of forming a T cell receptor (TCR) subunit recognizing a complex of the peptides of the present invention and HLA antigens. Preferably, the methods for inducing CTLs

comprise at least one step selected from the group consisting of:

a: contacting a CD8-positive T cell with an antigen-presenting cell and/or an exosome that presents on its surface a complex of an HLA antigen and the peptide of the present invention, and

b: introducing a polynucleotide encoding a polypeptide that is capable of forming a TCR subunit recognizing a complex of the peptide of the present invention and an HLA antigen into a CD8 positive T cell.

[0098] When the peptides of the present invention are administered to a subject, CTLs are induced in the body of the subject, and the strength of the immune response targeting the cancer cells is enhanced. Alternatively, the peptides and polynucleotides encoding the peptides can be used for an ex vivo therapeutic method, in which subject-derived APCs and CD8 -positive cells, or peripheral blood mononuclear leukocytes are contacted (stimulated) with the peptides of the present invention in vitro, and after inducing CTLs, the activated CTL cells are returned to the subject. For example, the method can include the steps of:

a: collecting APCs from subject:,

b: contacting with the APCs of step a, with the peptide:,

c: mixing the APCs of step b with CD^{8+} T cells, and co-culturing for inducing CTLs: and

d: collecting CD^{8+} T cells from the co-culture of step c.

[0099] Alternatively, according to the present invention, use of the peptides of the present invention for manufacturing a pharmaceutical agent or composition inducing CTLs is provided. In addition, the present invention provides a method or process for manufacturing a pharmaceutical agent or composition inducing CTLs, wherein the method comprises the step for admixing or formulating the peptide of the present invention with a pharmaceutically acceptable carrier. Further, the present invention also provides the peptide of the present invention for inducing CTLs.

[0100] The CD^{8+} T cells having cytotoxic activity obtained by step d can be administered to the subject as a vaccine. The APCs to be mixed with the CD^{8+} T cells in above step c can also be prepared by transferring genes coding for the present peptides into the APCs as detailed above in section "VI. Antigen-presenting cells"; but are not limited thereto. Accordingly, any APCs or exosomes which effectively presents the present peptides to the T cells can be used for the present method.

[0101] The following examples are presented to illustrate the present invention and to assist one of ordinary skill in making and using the same. The examples are not intended in any way to otherwise limit the scope of the invention.

Examples

[0102] Materials and Methods

Cell lines

A24 lymphoblastoid cell line (A24LCL) cells were established by transformation with Epstein-bar virus into HLA-A24 positive human B lymphocyte.

[0103] Candidate selection of peptides derived from CDCA1

9-mer and 10-mer peptides derived from CDCA1 that bind to HLA-A*2402 were predicted using binding prediction software "BIMAS" (http://www-bimas.cit.nih.gov/molbio/hla_bind), which algorithms had been described by Parker KC et al.(J Immunol 1994, 152(1): 163-75) and Kuzushima K et al.(Blood 2001, 98(6): 1872-81). These peptides were synthesized by American Peptide Company Inc. (Sunnyvale, CA) according to a standard solid phase synthesis method and purified by reversed phase high performance liquid chromatography (HPLC). The purity (>90%) and the identity of the peptides were determined by analytical HPLC and mass spectrometry analysis, respectively. Peptides were dissolved in dimethyl-sulfoxide (DMSO) at 20 mg/ml and stored at -80 degrees C.

[0104] In vitro CTL Induction

Monocyte-derived dendritic cells (DCs) were used as antigen-presenting cells (APCs) to induce cytotoxic T lymphocyte (CTL) responses against peptides presented on human leukocyte antigen (HLA). DCs were generated in vitro as described elsewhere (Nakahara S et al., Cancer Res 2003 Jul 15, 63(14): 4112-8). Specifically, peripheral blood mononuclear cells (PBMCs) isolated from a normal volunteer (HLA-A*2402 positive) by Ficoll-Plaque (Pharmacia) solution were separated by adherence to a plastic tissue culture dish (Becton Dickinson) so as to enrich them as the monocyte fraction. The monocyte-enriched population was cultured in the presence of 1000 U/ml of granulocyte-macrophage colony-stimulating factor (GM-CSF) (R&D System) and 1000 U/ml of interleukin (IL)-4 (R&D System) in AIM-V Medium (Invitrogen) containing 2% heat-inactivated autologous serum (AS). After 7 days of culture, the cytokine-induced DCs were pulsed with 20 micro g/ml of each of the synthesized peptides in the presence of 3 micro g/ml of beta 2-microglobulin for 3 hr at 37 degrees C in AIM-V Medium. The generated cells appeared to express DC-associated molecules, such as CD80, CD83, CD86 and HLA class II, on their cell surfaces (data not shown). These peptide-pulsed DCs were then inactivated by Mitomycin C (MMC) (30 micro g/ml for 30 min) and mixed at a 1:20 ratio with autologous CD8+ T cells, obtained by positive selection with CD8 Positive Isolation Kit (Dynal). These cultures were set up in 48-well plates (Corning); each well contained 1.5 x 10^4 peptide-pulsed DCs, 3 x 10^5 CD8+ T cells and 10 ng/ml of IL-7 (R&D System) in 0.5 ml of AIM-V/2% AS medium. Three days later, these cultures were supplemented with IL-2 (CHIRON) to a final concentration of 20 IU/ml. On day 7 and 14, the T cells were

further stimulated with the autologous peptide-pulsed DCs. The DCs were prepared each time by the same way described above. CTL was tested against peptide-pulsed A24LCL cells after the 3rd round of peptide stimulation on day 21 (Tanaka H et al., Br J Cancer 2001 Jan 5, 84(1): 94-9; Umano Y et al., Br J Cancer 2001 Apr 20, 84(8): 1052-7; Uchida N et al., Clin Cancer Res 2004 Dec 15, 10(24): 8577-86; Suda T et al., Cancer Sci 2006 May, 97(5): 411-9; Watanabe T et al., Cancer Sci 2005 Aug, 96(8): 498-506).

[0105] CTL Expansion Procedure

CTLs were expanded in culture using the method similar to the one described by Riddell et al. (Walter EA et al., N Engl J Med 1995 Oct 19, 333(16): 1038-44; Riddell SR et al., Nat Med 1996 Feb, 2(2): 216-23). A total of 5 x 10^4 CTLs were suspended in 25 ml of AIM-V/5% AS medium with 2 kinds of human B-lymphoblastoid cell lines, inactivated by MMC, in the presence of 40 ng/ml of anti-CD3 monoclonal antibody (Pharmingen). One day after initiating the cultures, 120 IU/ml of IL-2 were added to the cultures. The cultures were fed with fresh AIM-V/5% AS medium containing 30 IU/ml of IL-2 on days 5, 8 and 11 (Tanaka H et al., Br J Cancer 2001 Jan 5, 84(1): 94-9; Umano Y et al., Br J Cancer 2001 Apr 20, 84(8): 1052-7; Uchida N et al., Clin Cancer Res 2004 Dec 15, 10(24): 8577-86; Suda T et al., Cancer Sci 2006 May, 97(5): 411-9; Watanabe T et al., Cancer Sci 2005 Aug, 96(8): 498-506).

[0106] Establishment of CTL clones

The dilutions were made to have 0.3, 1, and 3 CTLs/ well in 96 round-bottomed micro titer plate (Nalge Nunc International). CTLs were cultured with 1 x 10^4 cells/ well of 2 kinds of human B-lymphoblastoid cell lines, 30ng/ml of anti-CD3 antibody, and 125 U/ml of IL-2 in a total of 150 micro l/ well of AIM-V Medium containing 5%AS. 50 micro l / well of IL-2 were added to the medium 10 days later so to reach a final concentration of 125 U/ml IL-2. CTL activity was tested on the 14th day, and CTL clones were expanded using the same method as described above (Uchida N et al., Clin Cancer Res 2004 Dec 15, 10(24): 8577-86; Suda T et al., Cancer Sci 2006 May, 97(5): 411-9; Watanabe T et al., Cancer Sci 2005 Aug, 96(8): 498-506).

[0107] Specific CTL activity

To examine specific CTL activity, interferon (IFN)-gamma enzyme-linked immunospot (ELISPOT) assay and IFN-gamma enzyme-linked immunosorbent assay (ELISA) were performed. Specifically, peptide-pulsed A24LCL (1 x 10^4/well) was prepared as stimulator cells. Cultured cells in 48 wells were used as responder cells. IFN-gamma ELISPOT assay and IFN-gamma ELISA assay were performed under manufacture procedure.

[0108] Establishment of the cells forcibly expressing either or both of the target gene and HLA-A24

The cDNA encoding an open reading frame of target genes or HLA-A24 was amplified by PCR. The PCR-amplified product was cloned into pCAGGS vector. The plasmids were transfected into COS7, which is the target genes and HLA-A24-null cell line, using lipofectamine 2000 (Invitrogen) according to the manufacturer's recommended procedures. After 2days from transfection, the transfected cells were harvested with versene (Invitrogen) and used as the target cells (5 x 10^4 cells/ well) for CTL activity assay.

[0109] Results

Prediction of HLA-A24 binding peptides derived from CDCA1

Table 1 shows the HLA-A*2402 binding peptides of CDCA1 in order of highest binding affinity. A total of 40 peptides having potential HLA-A24 binding ability were selected and examined to determine the epitope peptides.

[0110]

[Table 1]

HLA-A24 binding peptides derived from CDCA1

Start position	Amino acid sequence	Binding score	SEQ ID NO.
36	LYPNPKPEVL	300	1
74	MYPHLMEGFL	300	2
119	RFLSGIINFI	25.2	3
335	KTEENSFKRL	17.28	4
432	KYHDGIEKAA	16.8	5
181	KQLSDGIQEL	15.84	6
64	FYMMPVNSEV	11.55	7
295	LYQKKIQDLS	10.5	8
309	KLASILKESL	9.6	9
146	KSSADKMQQL	9.6	10
48	IYMRALQIVY	9	11
185	DGIQELQQSL	8.64	12
231	VSLKEIQESL	8.4	13
5	SFPRYNVAEI	8.25	14
394	INQEIQKIKL	7.92	15
322	DQIESDESEL	7.92	16
87	NLVTHLDSFL	7.2	17
368	QYKRTVIEDC	7	18
295	LYQKKIQDL	360	19
278	IYGDSVDCL	240	20
74	MYPHLMEGF	180	21
8	RYNVAEIVI	150	22
56	VYGIRLEHF	100	23
422	IFLNLKTAL	36	24
119	RFLSGIINF	30	25
144	QYKSSADKM	27.5	26
418	KSQEIFLNL	24.192	27
197	DFHQKTIVL	20	28
275	KYEIYGDSV	15	29
432	KYHDGIEKA	13.2	30
387	VYERVTTIN	10.5	31
186	GIQELQQSL	10.368	32
48	IYMRALQIV	9	33

Start position indicates the number of amino acid residue from the N-terminal of CDCA1.

Binding score is derived from "BIMAS".

[0111] CTL induction with the predicted peptides from CDCA1 restricted with HLA-A*2402 and establishment for CTL lines stimulated with CDCA1 derived peptides

CTLs for those peptides derived from CDCA1 were generated according to the

protocols as described in "Materials and Methods". Peptide specific CTL activity was determined by IFN-gamma ELISPOT assay (Figure 1a-f). It showed that CDCA1-A24-10-119 (SEQ ID NO: 3), CDCA1-A24-10-335 (SEQ ID NO: 4), CDCA1-A24-10-48 (SEQ ID NO: 11), CDCA1-A24-10-5 (SEQ ID NO: 14), CDCA1-A24-9-8 (SEQ ID NO: 22) and CDCA1-A24-9-56 (SEQ ID NO: 23) demonstrated potent IFN-gamma production as compared to the control wells. Furthermore, the cells in the positive well number #8 stimulated with CDCA1-A24-10-119 (SEQ ID NO: 3), #1 with CDCA1-A24-10-335 (SEQ ID NO: 4), #1 with CDCA1-A24-10-48 (SEQ ID NO: 11), #4 with CDCA1-A24-10-5 (SEQ ID NO: 14), #2 with CDCA1-A24-9-8 (SEQ ID NO: 22) and #2 with CDCA1-A24-9-56 (SEQ ID NO: 23) were expanded and established CTL lines. CTL activity of those CTL lines was determined by IFN-gamma ELISA assay (Figure 2a-f). It showed that all CTL lines demonstrated potent IFN-gamma production against the target cells pulsed with corresponding peptide as compared to target cells without peptide pulse. On the other hand, no CTL lines could be established by stimulation with other peptides, despite the peptides had possible binding activity with HLA-A*2402. For example, typical negative data of CTL response stimulated with CDCA1-A24-10-74 (SEQ ID NO: 2) was shown in Figure 1g and Figure 2g. The results herein indicate that six peptides derived from CDCA1 have ability to induce potent CTL lines.

[0112] Establishment of CTL clones against CDCA1 specific peptides

CTL clones were established by limiting dilution from CTL lines as described in "Materials and Methods", and IFN-gamma production from CTL clones against target cells pulsed peptide were determined by IFN-gamma ELISA assay. Potent IFN-gamma productions were determined from CTL clones stimulated with SEQ ID NO: 23 in Figure 3.

[0113] Specific CTL activity against target cells exogenously expressing CDCA1 and HLA-A*2402

The established CTL lines raised against these peptides were examined for their ability to recognize target cells that exogenously express CDCA1 and HLA-A*2402 molecule. Specific CTL activity against COS7 cells which transfected with both the full length of CDCA1 and HLA-A*2402 molecule gene (a specific model for the target cells that exogenously express CDCA1 and HLA-A*2402 gene) was tested using the CTL lines raised by corresponding peptide as the effecter cells. COS7 cells transfected with either full length of CDCA1 genes or HLA-A* 2402 were prepared as control. In Figure 4, the CTLs stimulated with SEQ ID NO: 23 showed potent CTL activity against COS7 cells expressing both CDCA1 and HLA-A* 2402. On the other hand, no significant specific CTL activity was detected against the controls. Thus, these data clearly demonstrate that the peptide having the amino acid sequence of SEQ ID NO:

23 is naturally presented on the target cells with HLA-A*2402 molecule and is recognized by the CTLs. The results indicate that this peptide derived from CDCA1 may be applicable for cancer immunotherapy, particularly as a cancer vaccine for patients with CDCA1 expressing tumors.

[0114] Homology analysis of antigen peptides

The CTLs stimulated with CDCA1-A24-10-119 (SEQ ID NO: 3), CDCA1-A24-10-335 (SEQ ID NO: 4), CDCA1-A24-10-48 (SEQ ID NO: 11), CDCA1-A24-10-5 (SEQ ID NO: 14), CDCA1-A24-9-8 (SEQ ID NO: 22) and CDCA1-A24-9-56 (SEQ ID NO: 23)showed significant and specific CTL activity. This result may be due to the fact that the sequences of CDCA1-A24-10-119 (SEQ ID NO: 3), CDCA1-A24-10-335 (SEQ ID NO: 4), CDCA1-A24-10-48 (SEQ ID NO: 11), CDCA1-A24-10-5 (SEQ ID NO: 14), CDCA1-A24-9-8 (SEQ ID NO: 22) and CDCA1-A24-9-56 (SEQ ID NO: 23) are homologous to peptides derived from other molecules that are known to sensitize the human immune system. To exclude this possibility, homology analyses were performed for these peptide sequences using as queries the BLAST algorithm (http://www.ncbi.nlm.nih.gov/blast/blast.cgi) which revealed no sequences with significant homology. The results of homology analyses indicate that the sequences of CDCA1-A24-10-119 (SEQ ID NO: 3), CDCA1-A24-10-335 (SEQ ID NO: 4), CDCA1-A24-10-48 (SEQ ID NO: 11), CDCA1-A24-10-5 (SEQ ID NO: 14), CDCA1-A24-9-8 (SEQ ID NO: 22) and CDCA1-A24-9-56 (SEQ ID NO: 23) are unique and thus, there is little possibility that these molecules raise unintended immunologic responses to some unrelated molecules.

[0115] In conclusion, novel HLA-A24 epitope peptides derived from CDCA1 were identified and demonstrated to be applicable for cancer immunotherapy.

Industrial Applicability

[0116] The present invention describes new TAAs, particularly those derived from CDCA1 which induce potent and specific anti-tumor immune responses and have applicability to a wide array of cancer types. Such TAAs warrant further development as peptide vaccines against diseases associated with CDCA1, e.g. cancers, more particularly, testicular tumor, pancreatic cancer, bladder cancer, non-small cell lung cancer, small cell lung cancer and esophageal cancer.

[0117] While the invention is herein described in detail and with reference to specific embodiments thereof, it is to be understood that the foregoing description is exemplary and explanatory in nature and is intended to illustrate the invention and its preferred embodiments. Through routine experimentation, one skilled in the art will readily recognize that various changes and modifications can be made therein without departing from the spirit and scope of the invention, the metes and bounds of which are

defined by the appended claims.

Claims

[Claim 1] An isolated peptide having cytotoxic T lymphocyte (CTL) inducibility, wherein the peptide comprises the amino acid sequence of SEQ ID NO: 35 or fragment thereof.

[Claim 2] The isolated peptide of claim 1, wherein the peptide is nonapeptide or decapeptide.

[Claim 3] The isolated peptide of claim 1 or 2, wherein the peptide comprises an amino acid sequence selected from the group consisting of:
(a) SEQ ID NO: 3, 4, 11, 14, 22 and 23; and
(b) SEQ ID NO: 3, 4, 11, 14, 22 and 23, wherein 1, 2, or several amino acids are substituted, inserted, deleted or added.

[Claim 4] The isolated peptide of claim 1 to 3 having one or both of the following characteristics:
(a) the second amino acid from the N-terminus of the amino acid sequence of said SEQ ID NOs is or is modified to be an amino acid selected from the group consisting of phenylalanine, tyrosine, methionine and tryptophan, and
(b) the C-terminal amino acid of the amino acid sequence of said SEQ ID NOs is or is modified to be selected from the group consisting of phenylalanine, leucine, isoleucine, tryptophan and methionine.

[Claim 5] An isolated polynucleotide encoding a peptide of any one of claims 1 to 4.

[Claim 6] A method for inducing an antigen-presenting cell with high CTL inducibility by using a peptide as set forth in any one of claims 1 to 4, and/or a polynucleotide as set forth in claim 5.

[Claim 7] The method of claim 6, wherein said method comprises one or both of the following steps:
(a) contacting an antigen-presenting cell with a peptide as set forth in any one of claims 1 to 4, and
(b) introducing a polynucleotide as set forth in claim 5 into an antigen-presenting cell.

[Claim 8] An isolated antigen-presenting cell that presents a peptide of any one as set forth in claims 1 to 4 on its surface.

[Claim 9] The antigen-presenting cell of claim 8, wherein said cell is induced by the method of claim 6 or 7.

[Claim 10] A method for inducing a CTL by using:
(a) a peptide as set forth in any one of claims 1 to 4;

(b) a polynucleotide as set forth in claim 5;
(c) an antigen-presenting cell and/or an exosome that presents a peptide of any one as set forth in claims 1 to 4 on its surface;
(d) a polynucleotide encoding a polypeptide that is capable of forming a T cell receptor (TCR) subunit recognizing a complex of a peptide as set forth in any one of claim 1 to 4 and an HLA antigen; or
(e) combinations thereof.

[Claim 11] The method of claim 10, wherein said method comprises at least one step selected from the group consisting of:
(a) contacting a CD8-positive T cell with an antigen-presenting cell and/or an exosome that presents a peptide as set forth in any one of claims 1 to 4 on its surface, and
(b) introducing a polynucleotide encoding a polypeptide that is capable of forming a T cell receptor (TCR) subunit recognizing a complex of a peptide as set forth in any one of claim 1 to 4 and an HLA antigen into a CD8-positive T cell.

[Claim 12] An agent for inducing a CTL, wherein said agent comprises an active ingredient selected from the group consisting of:
(a) a peptide as set forth in any one of claims 1 to 4;
(b) a polynucleotide as set forth in claim 5;
(c) an antigen-presenting cell and/or an exosome that presents a peptide as set forth in any one of claims 1 to 4 on its surface; and
(d) combinations thereof.

[Claim 13] An isolated CTL which targets any one of the peptides of claims 1 to 4.

[Claim 14] An isolated CTL that is induced by using the method of claims 10 or 11.

[Claim 15] A pharmaceutical agent comprising an active ingredient selected from the group consisting of:
(a) at least one peptide as set forth in any one of claims 1 to 4;
(b) at least one polynucleotide as set forth in claim 5;
(c) an antigen-presenting cell and/or an exosome that presents at least one peptide as set forth in any one of claims 1 to 4 on its surface;
(d) a CTL as set fort in claim 13 or 14; and
(e) combinations thereof,
in combination with a pharmacologically acceptable carrier formulated for a purpose selected from the group consisting of:
(i) treatment of a cancer;
(ii) prophylaxis of a cancer;

(iii) prevention of postoperative recurrence of a cancer; and
(iv) combinations thereof.

[Claim 16] A method of inducing an immune response against cancer in a subject, said method comprising the step of administering to said subject:
(a) a peptide as set forth in any one of claims 1 to 4;
(b) a polynucleotide as set forth in claim 5;
(c) an antigen-presenting cell and/or an exosome that presents a peptide as set forth in any one of claims 1 to 4 on its surface;
(d) a CTL as set fort in claim 13 or 14; or
(e) combinations thereof.

[Claim 17] A vaccine for inducing anti tumor immunity in a subject, said vaccine comprising an active ingredient selected from the group consisting of:
(a) a peptide as set forth in any one of claims 1 to 4;
(b) a polynucleotide as set forth in claim 5;
(c) an antigen-presenting cell and/or an exosome that presents a peptide as set forth in any one of claims 1 to 4 on its surface;
(d) a CTL as set fort in claim 13 or 14; and
(e) combinations thereof.

[Claim 18] The pharmaceutical agent of claim 15 or the vaccine of claim 17, which is formulated for the administration to a subject whose HLA antigen is HLA-A24.

[Claim 19] The method of claim 16, wherein the HLA antigen of the subject is HLA-A24.

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caa       732
His Phe Arg Glu Ala Cys Arg Glu Thr Tyr Met Glu Phe Leu Trp
Gln
    130                 135                 140

tat aaa tcc tct gcg gac aaa atg caa cag tta aac gcc gca cac
cag       780
Tyr Lys Ser Ser Ala Asp Lys Met Gln Gln Leu Asn Ala Ala His
Gln
145                 150                 155
160

gag gca tta atg aaa ctg gag aga ctt gat tct gtt cca gtt gaa
gag       828
Glu Ala Leu Met Lys Leu Glu Arg Leu Asp Ser Val Pro Val Glu
Glu
                165                 170                 175

caa gaa gag ttc aag cag ctt tca gat gga att cag gag cta caa
caa       876
Gln Glu Glu Phe Lys Gln Leu Ser Asp Gly Ile Gln Glu Leu Gln
Gln
            180                 185                 190
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tca cta aat cag gat ttt cat caa aaa acg ata gtg ctg caa gag
gga      924
Ser Leu Asn Gln Asp Phe His Gln Lys Thr Ile Val Leu Gln Glu
Gly
        195                 200                 205


aat tcc caa aag aag tca aat att tca gag aaa acc aag cgt ttg
aat      972
Asn Ser Gln Lys Lys Ser Asn Ile Ser Glu Lys Thr Lys Arg Leu
Asn
    210                 215                 220


gaa cta aaa ttg tcg gtg gtt tct ttg aaa gaa ata caa gag agt
ttg     1020
Glu Leu Lys Leu Ser Val Val Ser Leu Lys Glu Ile Gln Glu Ser
Leu
225                 230                 235
240

aaa aca aaa att gtg gat tct cca gag aag tta aag aat tat aaa
gaa     1068
Lys Thr Lys Ile Val Asp Ser Pro Glu Lys Leu Lys Asn Tyr Lys
Glu
                245                 250                 255


aaa atg aaa gat acg gtc cag aag ctt aaa aat gcc aga caa gaa
gtg     1116
Lys Met Lys Asp Thr Val Gln Lys Leu Lys Asn Ala Arg Gln Glu
Val
            260                 265                 270


gtg gag aaa tat gaa atc tat gga gac tca gtt gac tgc ctg cct
tca     1164
Val Glu Lys Tyr Glu Ile Tyr Gly Asp Ser Val Asp Cys Leu Pro
Ser
        275                 280                 285


tgt cag ttg gaa gtg cag tta tat caa aag aaa ata cag gac ctt
tca     1212
Cys Gln Leu Glu Val Gln Leu Tyr Gln Lys Lys Ile Gln Asp Leu
Ser
    290                 295                 300


gat aat agg gaa aaa tta gcc agt atc tta aag gag agc ctg aac
ttg     1260
Asp Asn Arg Glu Lys Leu Ala Ser Ile Leu Lys Glu Ser Leu Asn
Leu
305                 310                 315
320

gag gac caa att gag agt gat gag tca gaa ctg aag aaa ttg aag
act     1308
Glu Asp Gln Ile Glu Ser Asp Glu Ser Glu Leu Lys Lys Leu Lys
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Thr
                325                 330                 335

gaa gaa aat tcg ttc aaa aga ctg atg att gtg aag aag gaa aaa
ctt     1356
Glu Glu Asn Ser Phe Lys Arg Leu Met Ile Val Lys Lys Glu Lys
Leu
            340                 345                 350

gcc aca gca caa ttc aaa ata aat aag aag cat gaa gat gtt aag
caa     1404
Ala Thr Ala Gln Phe Lys Ile Asn Lys Lys His Glu Asp Val Lys
Gln
        355                 360                 365

tac aaa cgc aca gta att gag gat tgc aat aaa gtt caa gaa aaa
aga     1452
Tyr Lys Arg Thr Val Ile Glu Asp Cys Asn Lys Val Gln Glu Lys
Arg
    370                 375                 380

ggt gct gtc tat gaa cga gta acc aca att aat caa gaa atc caa
aaa     1500
Gly Ala Val Tyr Glu Arg Val Thr Thr Ile Asn Gln Glu Ile Gln
Lys
385                 390                 395
400

att aaa ctt gga att caa caa cta aaa gat gct gct gaa agg gag
aaa     1548
Ile Lys Leu Gly Ile Gln Gln Leu Lys Asp Ala Ala Glu Arg Glu
Lys
                405                 410                 415

ctg aag tcc cag gaa ata ttt cta aac ttg aaa act gct ttg gag
aaa     1596
Leu Lys Ser Gln Glu Ile Phe Leu Asn Leu Lys Thr Ala Leu Glu
Lys
            420                 425                 430

tac cac gac ggt att gaa aag gca gca gag gac tcc tat gct aag
ata     1644
Tyr His Asp Gly Ile Glu Lys Ala Ala Glu Asp Ser Tyr Ala Lys
Ile
        435                 440                 445

gat gag aag aca gct gaa ctg aag agg aag atg ttc aaa atg tca
acc     1692
Asp Glu Lys Thr Ala Glu Leu Lys Arg Lys Met Phe Lys Met Ser
Thr
    450                 455                 460
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tga ttaacaaaat tacatgtctt tttgtaaatg gcttgccatc ttttaatttt
1745

ctatttagaa agaaaagttg aagcgaatgg aagtatcaga agtaccaaat
aatgttggct 1805

tcatcagttt ttatacactc tcataagtag ttaataagat gaatttaatg
taggctttta 1865

ttaatttata attaaaataa cttgtgcagc tattcatgtc tctactctgc
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1980

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<400> 35

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Ile
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His Ile Arg Asn Lys Ile Leu Thr Gly Ala Asp Gly Lys Asn Leu
Thr
20 25 30

Lys Asn Asp Leu Tyr Pro Asn Pro Lys Pro Glu Val Leu His Met
Ile
35 40 45

Tyr Met Arg Ala Leu Gln Ile Val Tyr Gly Ile Arg Leu Glu His
Phe
50 55 60

Tyr Met Met Pro Val Asn Ser Glu Val Met Tyr Pro His Leu Met
Glu
65 70 75 80

Gly Phe Leu Pro Phe Ser Asn Leu Val Thr His Leu Asp Ser Phe
Leu
85 90 95

```
Pro Ile Cys Arg Val Asn Asp Phe Glu Thr Ala Asp Ile Leu Cys
Pro
            100                 105                 110

Lys Ala Lys Arg Thr Ser Arg Phe Leu Ser Gly Ile Ile Asn Phe
Ile
        115                 120                 125

His Phe Arg Glu Ala Cys Arg Glu Thr Tyr Met Glu Phe Leu Trp
Gln
    130                 135                 140

Tyr Lys Ser Ser Ala Asp Lys Met Gln Gln Leu Asn Ala Ala His
Gln
145                 150                 155
160

Glu Ala Leu Met Lys Leu Glu Arg Leu Asp Ser Val Pro Val Glu
Glu
                165                 170                 175

Gln Glu Glu Phe Lys Gln Leu Ser Asp Gly Ile Gln Glu Leu Gln
Gln
            180                 185                 190

Ser Leu Asn Gln Asp Phe His Gln Lys Thr Ile Val Leu Gln Glu
Gly
        195                 200                 205

Asn Ser Gln Lys Lys Ser Asn Ile Ser Glu Lys Thr Lys Arg Leu
Asn
    210                 215                 220

Glu Leu Lys Leu Ser Val Val Ser Leu Lys Glu Ile Gln Glu Ser
Leu
225                 230                 235
240

Lys Thr Lys Ile Val Asp Ser Pro Glu Lys Leu Lys Asn Tyr Lys
Glu
                245                 250                 255
```

Lys Met Lys Asp Thr Val Gln Lys Leu Lys Asn Ala Arg Gln Glu Val
260 265 270

Val Glu Lys Tyr Glu Ile Tyr Gly Asp Ser Val Asp Cys Leu Pro Ser
275 280 285

Cys Gln Leu Glu Val Gln Leu Tyr Gln Lys Lys Ile Gln Asp Leu Ser
290 295 300

Asp Asn Arg Glu Lys Leu Ala Ser Ile Leu Lys Glu Ser Leu Asn Leu
305 310 315 320

Glu Asp Gln Ile Glu Ser Asp Glu Ser Glu Leu Lys Lys Leu Lys Thr
325 330 335

Glu Glu Asn Ser Phe Lys Arg Leu Met Ile Val Lys Lys Glu Lys Leu
340 345 350

Ala Thr Ala Gln Phe Lys Ile Asn Lys Lys His Glu Asp Val Lys Gln
355 360 365

Tyr Lys Arg Thr Val Ile Glu Asp Cys Asn Lys Val Gln Glu Lys Arg
370 375 380

Gly Ala Val Tyr Glu Arg Val Thr Thr Ile Asn Gln Glu Ile Gln Lys
385 390 395 400

Ile Lys Leu Gly Ile Gln Gln Leu Lys Asp Ala Ala Glu Arg Glu Lys
405 410 415

Leu Lys Ser Gln Glu Ile Phe Leu Asn Leu Lys Thr Ala Leu Glu Lys
420 425 430

Tyr His Asp Gly Ile Glu Lys Ala Ala Glu Asp Ser Tyr Ala Lys Ile
435 440 445

Asp Glu Lys Thr Ala Glu Leu Lys Arg Lys Met Phe Lys Met Ser Thr
450 455 460