DESCRIPTION

KOC1-DERIVED PEPTIDE AND VACCINE INCLUDING SAME

[Technical Field]

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 effective as cancer vaccines, methods for either or both of treating and preventing tumors using the peptide(s), and pharmaceutical compositions comprising the peptide(s).

The present application claims the benefit of Japanese patent applications filed on August 4, 2014 (Japanese Patent Application Nos. 2014-158919, 2014-158920, and 2014-158921), the entire contents of which are incorporated by reference herein.

[Background Art]

Cytotoxic T lymphocytes (CTLs) have been shown to recognize epitope peptides derived from the tumor-associated antigens (TAAs) found on the major histocompatibility complex (MHC) class I molecule, and then kill the tumor cells. Since the discovery of the melanoma antigen (MAGE) family, many other TAAs have been discovered through immunological approaches (NPL1: Boon T, Int J Cancer 1993 May 8, 54(2): 177-80; NPL2: 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.

In several of these TAAs, epitope peptides that can be recognized by CTLs are identified and their application in immunotherapy for various types of cancer is anticipated (NPL3: Harris CC, J Natl Cancer Inst 1996 Oct 16, 88(20): 1442-55; NPL4: Butterfield LH *et al.*, Cancer Res 1999 Jul 1, 59(13): 3134-42; NPL5: Vissers JL *et al.*, Cancer Res 1999 Nov 1, 59(21): 5554-9; NPL6: van der Burg SH *et al.*, J Immunol 1996 May 1, 156(9) 3308-14; NPL7: Tanaka F *et al.*, Cancer Res 1997 Oct 15, 57(20): 4465-8; NPL8: Fujie T *et al.*, Int J Cancer 1999 Jan 18, 80(2): 169-72; NPL9: Kikuchi M *et al.*, Int J Cancer 1999 May 5, 81(3): 439-66; NPL10: Oiso M *et al.*, Int J Cancer 1999 May 5, 81(3): 387-94). Until now, several clinical trials using these TAA-derived CTL epitope peptides have been reported. Unfortunately, many of these clinical trials show a low objective response rate (NPL11: Belli F *et al.*, J Clin Oncol 2002 Oct 15, 20(20): 4169-80; NPL12: Coulie PG *et al.*, Immunol Rev 2002 Oct, 188: 33-42; NPL13: Rosenberg SA *et al.*, Nat Med 2004 Sep, 10(9): 909-15). Therefore, there is still demand for identification of novel CTL epitopes that can be used in cancer immunotherapy.

KOC1 (insulin-like growth factor II mRNA binding protein 3 also described as IGF2BP3 or IMP-3; reference sequence: GeneBank Accession Number NM_006547.2 (SEQ ID

NO: 109)) is identified as a gene up-regulated in lung cancer by gene expression profile analysis using a genome-wide cDNA microarray containing 23,040 genes (NPL14: Kikuchi T *et al.*, Oncogene. 2003 Apr 10; 22(14): 2192-205; PTL1: WO2004/031413). The KOC1 expression is observed to be up-regulated specifically in tumor cells in over 90% of lung cancer patients, but it is not expressed in other normal important organs except the testis and placenta. Further, it is shown that cell proliferation in KOC1-expressing cancer cell lines is suppressed as a result of down-regulation of the KOC1 expression by RNA interference.

Recently, KOC1-derived HLA-A24-restricted CTL epitope peptides (PTL2: WO2006/090810; NPL15: Suda T *et al.*, Cancer Sci. 2007 Nov; 98(11): 1803-8) and HLA-A2-restricted CTL epitope peptides (PTL3: WO2011/067920; NPL16: Tomita Y *et al.*, Cancer Sci. 2011 Jan; 102(1): 71-8) have been identified. These peptides are effective in cancer patients having the HLA-A24 type or HLA-A2 type, but cannot be expected to have effect on cancer patients who do not have these HLA types.

[Citation List]

[Patent Literature]

[PTL 1] WO2004/031413
[PTL2] WO2006/090810
[PTL3] WO2011/067920

[Non Patent Literature]

[NPL 1] Boon T, Int J Cancer 1993 May 8, 54(2): 177-80
[NPL 2] Boon T & van der Bruggen P, J Exp Med 1996 Mar 1, 183(3): 725-9
[NPL 3] Harris CC, J Natl Cancer Inst 1996 Oct 16, 88(20): 1442-55
[NPL 4] Butterfield LH *et al.*, Cancer Res 1999 Jul 1, 59(13): 3134-42
[NPL 5] Vissers JL *et al.*, Cancer Res 1999 Nov 1, 59(21): 5554-9
[NPL 6] van der Burg SH *et al.*, J Immunol 1996 May 1, 156(9): 3308-14
[NPL 7] Tanaka F *et al.*, Cancer Res 1997 Oct 15, 57(20): 4465-8
[NPL 8] Fujie T *et al.*, Int J Cancer 1999 Jan 18, 80(2): 169-72
[NPL 9] Kikuchi M *et al.*, Int J Cancer 1999 May 5, 81(3): 459-66
[NPL 10] Oiso M *et al.*, Int J Cancer 1999 May 5, 81(3): 387-94
[NPL 11] Belli F *et al.*, J Clin Oncol 2002 Oct 15, 20(20): 4169-80
[NPL 12] Coulie PG *et al.*, Immunol Rev 2002 Oct, 188: 33-42
[NPL 13] Rosenberg SA *et al.*, Nat Med 2004 Sep, 10(9): 909-15
[NPL 14] Kikuchi T *et al.*, Oncogene. 2003 Apr 10; 22(14): 2192-205
[NPL 15] Suda T *et al.*, Cancer Sci. 2007 Nov; 98(11): 1803-8

[NPL 16] Tomita Y *et al.*, Cancer Sci. 2011 Jan; 102(1): 71-8

Summary of the Invention

The present invention relates to peptides that can induce CTLs specific to KOC1-expressing cells. When these peptides are presented on antigen-presenting cells (APCs) by the human leukocyte antigen (HLA), CTLs that show a specific cytotoxic activity against KOC1-expressing cells are induced. KOC1-derived peptides that have been identified so far to have CTL-inducing ability (CTL inducibility) are either HLA-A2-restricted or HLA-A24-restricted peptides, and cannot induce CTLs against cells that do not express these HLAs. Therefore, conventional peptides are not suitable for performing immunotherapy in subjects that do not have these HLAs. HLA-A11, HLA-A33 and HLA-A03 are alleles commonly seen in Asians (Sette A, Sidney J., Immunogenetics 1999, 50: 201-12), and HLA-A03 and HLA-A01 are alleles commonly seen in Caucasians (Cao *et al.*, Hum Immunol 2001; 62(9): 1009-30). It is desirable to administer HLA-A11-restricted peptides to HLA-A11-positive subjects, HLA-A33-restricted peptides to HLA-A33-positive subjects, HLA-A03-restricted peptides to HLA-A03-positive subjects, and HLA-A01-restricted peptides to HLA-A01-positive subjects. Hence, the present invention relates to KOC1-derived peptides with CTL-inducing ability that are restrictive to HLA-A11, HLA-A33, HLA-A03, or HLA-A01. Based on results disclosed herein, the peptides of the present invention have been proven to be epitope peptides that can induce a potent and specific immune response against cells expressing KOC1 and HLA-A11, HLA-A33, HLA-A03, or HLA-A01.

Therefore, one of the objectives of the present invention is to provide KOC1-derived peptides that can induce CTLs in an HLA-A11-, HLA-A33-, HLA-A03- or HLA-A01-restrictive manner. These peptides can be used to induce CTLs *in vitro*, *ex vivo* or *in vivo*, or can be used to administer to subjects for the purpose of inducing an immune response against KOC1-expressing cancer cells. Preferable peptides are peptides comprising the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30, 32, 61, 62, 63, 64, 67, 74,77, 52, 79, 80, 85, 27, 86, 87, 90, 92, 46, 95 and 41; more preferable peptides are nonapeptides or decapeptides; and even more preferable peptides are peptides consisting of the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30, 32, 61, 62, 63, 64, 67, 74,77, 52, 79, 80, 85, 27, 86, 87, 90, 92, 46, 95 and 41.

The peptides of the present invention encompass peptides in which one, two or more amino acid(s) is/are substituted, deleted, inserted and/or added, as long as the resultant modified peptides retain the CTL-inducing ability of the original peptide.

The present invention further provides isolated polynucleotides encoding any one of the peptides of the present invention. Similar to the peptides of the present invention, these

polynucleotides can be used for inducing APCs with CTL-inducing ability, and can be administered to subjects for inducing an immune response against KOC1-expressing cancer cells.

The present invention also provides compositions comprising one or more types of peptides of the present invention, one or more types of polynucleotides encoding one or more types of peptides of the present invention, APCs of the present invention, exosomes presenting peptides of the present invention, and/or CTLs of the present invention. The compositions of the present invention are preferably pharmaceutical compositions. The pharmaceutical compositions of the present invention can be used for treating and/or preventing cancer, as well as preventing postoperative recurrence thereof. They can also be used for inducing an immune response against cancer. When administered to a subject, a peptide of the present invention is presented on the surface of an APC, and as a result CTLs targeting the peptide are induced. Therefore, another objective of the present invention is to provide compositions for inducing CTLs, wherein the compositions comprise one or more types of peptides of the present invention, one or more types of polynucleotides encoding one or more types of peptides of the present invention, APCs of the present invention, and/or exosomes presenting peptides of the present invention.

A further objective of the present invention is to provide methods of inducing APCs having CTL-inducing ability, wherein the methods comprise a step of contacting one or more types of peptides of the present invention with an APC, or a step of introducing a polynucleotide encoding any one peptide of the present invention into an APC.

The present invention further provides a method of inducing CTLs, comprising a step of co-culturing a CD8-positive T cell with an APC that presents on its surface a complex of an HLA antigen and a peptide of the present invention, a step of co-culturing a CD8-positive T cell with an exosome that presents on its surface a complex of an HLA antigen and a peptide of the present invention, or a step of introducing into a CD8-positive T cell a vector comprising a polynucleotide encoding each subunit of a T cell receptor (TCR) capable of binding to a peptide of the present invention presented by an HLA antigen on a cell surface. The preferred HLA antigen in the present invention is HLA-A11, HLA-A33, HLA-A03 or HLA-A01.

A further objective of the present invention is to provide isolated APCs that present on their surface a complex of an HLA antigen and a peptide of the present invention. The present invention further provides isolated CTLs targeting a peptide of the present invention. These APCs and CTLs can be used in immunotherapy for KOC1-expressing cancers. In the present invention, the cancer to be subjected to immunotherapy is, for example, a cancer present in patients who have a homozygote or heterozygote of HLA-A11, HLA-A33, HLA-A03 or HLA-A01. That is, the present invention provides immunotherapy for cancers expressing KOC1 and at least one HLA antigen selected from HLA-A11, HLA-A33, HLA-A03 and HLA-A01.

Another objective of the present invention is to provide methods of inducing an immune response against cancer in a subject, wherein the methods comprise a step of administering to the subject a peptide(s) of the present invention, a polynucleotide(s) encoding the peptide(s), an APC(s) of the present invention, an exosome(s) presenting a peptide(s) of the present invention, and/or a CTL(s) of the present invention. Another objective of the present invention is to provide methods of treating and/or preventing cancer, as well as preventing postoperative recurrence thereof in a subject, wherein the methods comprise a step of administering to the subject a peptide(s) of the present invention, a polynucleotide(s) encoding the peptide(s), an APC(s) of the present invention, an exosome(s) presenting a peptide(s) of the present invention, and/or a CTL(s) of the present invention.

In addition to the above, other objects and features of the present 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 present invention and the following detailed description are of exemplified embodiments, and not restrictive of the present invention or other alternate embodiments of the present invention. In particular, while the present invention is described herein with reference to a number of specific embodiments, it will be appreciated that the description is illustrative of the present invention and is not constructed as limiting of the present 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 present 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 the Drawings

Fig. 1 consists of photos (a) to (e) showing results of an interferon (IFN)-gamma enzyme-linked immunospot (ELISPOT) assay in CTLs induced using peptides derived from KOC1. In comparison with the control, CTLs in Well #6 with KOC1-A11-9-415 (SEQ ID NO: 5) (a), Well #4 with KOC1-A11-10-414 (SEQ ID NO: 28) (b), Well #5 with KOC1-A11-10-204 (SEQ ID NO: 30) (c), and Well #8 with KOC1-A11-10-14 (SEQ ID NO: 32) (d) showed potent IFN-gamma production. In these photos, the square on the wells show that cells from the respective wells were propagated for the establishment of CTL lines. In contrast, KOC1-A11-9-258 (SEQ ID NO: 1) (e) is shown as an example of typical negative data where there was no

specific IFN-gamma production. In the figure, "+" shows IFN-gamma production against target cells pulsed with an appropriate peptide; and "-" shows IFN-gamma production against target cells that have not been pulsed with any peptides.

Fig. 2 consists of a series of line graphs (a) to (c) showing results of an IFN-gamma enzyme-linked immunosorbent assay (ELISA), confirming IFN-gamma production in CTL lines stimulated with KOC1-A11-9-415 (SEQ ID NO: 5) (a), KOC1-A11-10-204 (SEQ ID NO: 30) (b) or KOC1-A11-10-14 (SEQ ID NO: 32) (c). These results prove that the CTL lines established by stimulation with each of the peptides showed potent IFN-gamma production in comparison with the control. In the figure, "+" shows IFN-gamma production against target cells pulsed with an appropriate peptide; and "-" shows IFN-gamma production against target cells that have not been pulsed with any peptides. The R/S ratio indicates the ratio of the cell number of CTL line (Responder cells) and the cell number of target cells (Stimulator cells).

Fig. 3 consists of line graphs (a) and (b) showing IFN-gamma production in CTL clones established by limiting dilution from CTL lines stimulated with KOC1-A11-9-415 (SEQ ID NO: 5) or KOC1-A11-10-14 (SEQ ID NO: 32). These results prove that the CTL clones established by stimulation with each of the peptides showed potent IFN-gamma production in comparison with the control. In the figure, "+" shows IFN-gamma production against target cells pulsed with an appropriate peptide; and "-" shows IFN-gamma production against target cells that have not been pulsed with any peptides. The R/S ratio indicates the ratio of the cell number of CTL clone (Responder cells) and the cell number of target cells (Stimulator cells).

Fig. 4 is a line graph showing specific CTL activity against target cells expressing both KOC1 and HLA-A*1101. COS7 cells transfected with either HLA-A*1101 or the full-length KOC1 gene were prepared as the control. The CTL clone established using KOC1-A11-10-14 (SEQ ID NO: 32) demonstrated a specific CTL activity against COS7 cells transfected with both KOC1 and HLA-A*1101 (black diamond). On the other hand, a significant specific CTL activity was not shown against target cells transfected with either one of HLA-A*1101 (white triangle) and KOC1 (white circle).

Fig. 5 consists of photos (a) to (l) showing results of an IFN-gamma ELISPOT assay in CTLs induced using peptides derived from KOC1. In comparison with the control, CTLs in Well #1 with KOC1-A33-9-543 (SEQ ID NO: 61) (a), Well #2 with KOC1-A33-9-282 (SEQ ID NO: 62) (b), Well #3 with KOC1-A33-9-317 (SEQ ID NO: 63) (c), Well #8 with KOC1-A33-9-485 (SEQ ID NO: 64) (d), Well #3 with KOC1-A33-9-286 (SEQ ID NO: 67) (e), Well #8 with KOC1-A33-9-34 (SEQ ID NO: 74) (f), Well #4 with KOC1-A33-10-542 (SEQ ID NO: 77) (g), Well #3 with KOC1-A33-10-281 (SEQ ID NO: 52) (h), Well #6 with KOC1-A33-10-543 (SEQ ID NO: 79) (i), Well #1 with KOC1-A33-10-424 (SEQ ID NO: 80) (j), and Well #5 with KOC1-A33-10-285 (SEQ ID NO: 85) (k) showed potent IFN-gamma production. In these photos, the

square on the wells show that cells from the respective wells were propagated for the establishment of CTL lines. In contrast, KOC1-A33-9-517 (SEQ ID NO: 4) (l) is shown as an example of typical negative data where there was no specific IFN-gamma production. In the figure, "+" shows IFN-gamma production against target cells pulsed with an appropriate peptide; and "-" shows IFN-gamma production against target cells that have not been pulsed with any peptides.

Fig. 6 consists of a series of line graphs (a) to (f) showing results of IFN-gamma ELISA, confirming IFN-gamma production in CTL lines stimulated with KOC1-A33-9-543 (SEQ ID NO: 61) (a), KOC1-A33-9-282 (SEQ ID NO: 62) (b), KOC1-A33-9-485 (SEQ ID NO: 64) (c), KOC1-A33-9-286 (SEQ ID NO: 67) (d), KOC1-A33-10-542 (SEQ ID NO: 77) (e), or KOC1-A33-10-281 (SEQ ID NO: 52) (f). These results prove that the CTL lines established by stimulation with each of the peptides showed potent IFN-gamma production in comparison with the control. In the figure, "+" shows IFN-gamma production against target cells pulsed with an appropriate peptide; and "-" shows IFN-gamma production against target cells that have not been pulsed with any peptides. The R/S ratio indicates the ratio of the cell number of CTL line (Responder cells) and the cell number of target cells (Stimulator cells).

Fig. 7 consists of a series of line graphs (a) to (f) showing IFN-gamma production in CTL clones established by limiting dilution from CTL lines stimulated with KOC1-A33-9-543 (SEQ ID NO: 61) (a), KOC1-A33-9-282 (SEQ ID NO: 62) (b), KOC1-A33-9-485 (SEQ ID NO: 64) (c), KOC1-A33-9-286 (SEQ ID NO: 67) (d), KOC1-A33-10-542 (SEQ ID NO: 77) (e), or KOC1-A33-10-281 (SEQ ID NO: 52) (f). These results prove that the CTL clones established by stimulation with each of the peptides showed potent IFN-gamma production in comparison with the control. In the figure, "+" shows IFN-gamma production against target cells pulsed with an appropriate peptide; and "-" shows IFN-gamma production against target cells that have not been pulsed with any peptides. The R/S ratio indicates the ratio of the cell number of CTL clone (Responder cells) and the cell number of target cells (Stimulator cells).

Fig. 8 consists of a series of line graphs (a) to (c) showing specific CTL activity against target cells expressing both KOC1 and HLA-A*3303. COS7 cells transfected with either HLA-A*3303 or the full-length KOC1 gene were prepared as the control. The CTL clones established using KOC1-A33-9-485 (SEQ ID NO: 64) (a), KOC1-A33-9-286 (SEQ ID NO: 67) (b), and KOC1-A33-10-542 (SEQ ID NO: 77) (c) demonstrated a specific CTL activity against COS7 cells transfected with both KOC1 and HLA-A*3303 (black diamond). On the other hand, a significant specific CTL activity was not shown against target cells transfected with either one of HLA-A*3303 (white triangle) and KOC1 (white circle).

Fig. 9 consists of photos (a) to (d) showing results of an IFN-gamma ELISPOT assay in CTLs induced using peptides derived from KOC1. In comparison with the control, CTLs in

Well #5 with KOC1-A03-10-120 (SEQ ID NO: 27) (a), Well #3 with KOC1-A03-10-204 (SEQ ID NO: 30) (b), and Well #5 with KOC1-A03-10-281 (SEQ ID NO: 52) (c) showed potent IFN-gamma production. In these photos, the square on the wells show that cells from the respective wells were propagated for the establishment of CTL lines. In contrast, KOC1-A03-10-414 (SEQ ID NO: 28) (d) is shown as an example of typical negative data where there was no specific IFN-gamma production. In the figure, "+" shows IFN-gamma production against target cells pulsed with an appropriate peptide; and "-" shows IFN-gamma production against target cells that have not been pulsed with any peptides.

Fig. 10 is a series of line graphs showing results of IFN-gamma ELISA, confirming IFN-gamma production in a CTL line stimulated with KOC1-A03-10-120 (SEQ ID NO: 27). These results prove that the CTL line established by stimulation with each of the peptides showed potent IFN-gamma production in comparison with the control. In the figure, "+" shows IFN-gamma production against target cells pulsed with an appropriate peptide; and "-" shows IFN-gamma production against target cells that have not been pulsed with any peptides. The R/S ratio indicates the ratio of the cell number of the CTL line (Responder cells) and the cell number of the target cells (Stimulator cells).

Fig. 11 is a line graph showing IFN-gamma production in a CTL clone established by limiting dilution from the CTL line stimulated with KOC1-A03-10-120 (SEQ ID NO: 27). These results prove that the CTL clone established by stimulation with each of the peptides showed potent IFN-gamma production in comparison with the control. In the figure, "+" shows IFN-gamma production against target cells pulsed with an appropriate peptide; and "-" shows IFN-gamma production against target cells that have not been pulsed with any peptides. The R/S ratio indicates the ratio of the cell number of the CTL clone (Responder cells) and the cell number of the target cells (Stimulator cells).

Fig. 12 is a line graph showing specific CTL activity against target cells expressing both KOC1 and HLA-A*0301. COS7 cells transfected with either HLA-A*0301 or the full-length KOC1 gene were prepared as the control. The CTL clone established using KOC1-A03-10-120 (SEQ ID NO: 27) demonstrated a specific CTL activity against COS7 cells transfected with both KOC1 and HLA-A*0301 (black diamond). On the other hand, a significant specific CTL activity was not shown against target cells transfected with either one of HLA-A*0301 (white triangle) and KOC1 (white circle).

Fig. 13 consists of photos (a) to (h) showing results of an IFN-gamma ELISPOT assay in CTLs induced using peptides derived from KOC1. In comparison with the control, CTLs in Well #2 with KOC1-A01-9-96 (SEQ ID NO: 86) (a), Well #4 with KOC1-A01-9-118 (SEQ ID NO: 87) (b), Well #3 with KOC1-A01-9-404 (SEQ ID NO: 90) (c), Well #4 with KOC1-A01-9-402 (SEQ ID NO: 92) (d), Well 7# with KOC1-A01-10-312 (SEQ ID NO: 46) (e), Well #1 with

KOC1-A01-10-402 (SEQ ID NO: 95) (f), and Well #1 with KOC1-A01-10-535 (SEQ ID NO: 41) (g) showed potent IFN-gamma production. In these photos, the square on the wells show that cells from the respective wells were propagated for establishment of CTL lines. In contrast, KOC1-A01-9-536 (SEQ ID NO: 13) (h) is shown as an example of typical negative data where there was no specific IFN-gamma production. In the figure, "+" shows IFN-gamma production against target cells pulsed with an appropriate peptide; and "-" shows IFN-gamma production against target cells that have not been pulsed with any peptides.

Fig. 14 consists of a series of line graphs (a) and (b) showing results of IFN-gamma ELISA, confirming IFN-gamma production in CTL lines stimulated with KOC1-A01-9-96 (SEQ ID NO: 86) (a) or KOC1-A01-9-118 (SEQ ID NO: 87) (b). These results prove that the CTL lines established by stimulation with each of the peptides showed potent IFN-gamma production in comparison with the control. In the figure, "+" shows IFN-gamma production against target cells pulsed with an appropriate peptide; and "-" shows IFN-gamma production against target cells that have not been pulsed with any peptides. The R/S ratio indicates the ratio of the cell number of CTL line (Responder cells) and the cell number of target cells (Stimulator cells).

Fig. 15 is a line graph showing IFN-gamma production in a CTL clone established by limiting dilution from the CTL line stimulated with KOC1-A01-9-96 (SEQ ID NO: 86). These results prove that the CTL clone established by stimulation with each of the peptides showed potent IFN-gamma production in comparison with the control. In the figure, "+" shows IFN-gamma production against target cells pulsed with an appropriate peptide; and "-" shows IFN-gamma production against target cells that have not been pulsed with any peptides. The R/S ratio indicates the ratio of the cell number of the CTL clone (Responder cells) and the cell number of the target cells (Stimulator cells).

Fig. 16 is a line graph showing specific CTL activity against target cells expressing both KOC1 and HLA-A*0101. COS7 cells transfected with either HLA-A*0101 or the full-length KOC1 gene were prepared as the control. The CTL clone established using KOC1-A01-9-96 (SEQ ID NO: 86) demonstrated a specific CTL activity against COS7 cells transfected with both KOC1 and HLA-A*0101 (black diamond). On the other hand, a significant specific CTL activity was not shown against target cells transfected with either one of HLA-A*0101 (white triangle) and KOC1 (white circle).

[Mode for Carrying out the Invention]

Description of Embodiments

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.

I. Definitions

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

The terms "isolated" and "purified" used in relation with a substance (for example, peptide, antibody, polynucleotide or such) indicate that the substance does not substantially contain at least one substance that may else be included in a natural source. Thus, an isolated or purified peptide refers to a peptide that does not substantially contain another cellular material, for example, carbohydrate, lipid and other contaminating proteins from the cell or tissue source from which the peptide is derived. When the peptide is chemically synthesized, an isolated or purified peptide refers to a peptide that does not substantially contain a precursor substance or another chemical substance. The phrase "does not substantially contain a cellular material" includes peptide preparations in which the peptide is separated from cellular components of the cells from which it is isolated or recombinantly produced. Thus, a peptide that does not substantially contain a cellular material encompasses peptide preparations that contain less than about 30%, 20%, 10%, 5%, 3%, 2% or 1% (dry weight basis) of other cellular materials. When the peptide is recombinantly produced, an isolated or purified peptide does not substantially contain culture medium, which encompasses peptide preparations that contain culture medium less than about 20%, 10%, or 5%, 3%, 2% or 1% (dry weight basis) of the volume of the peptide preparation. When the peptide is chemically synthesized, an isolated or purified peptide does not substantially contain a precursor substance or other chemical substances, which encompasses peptide preparations that contain a precursor substance or other chemical substances less than about 30%, 20%, 10%, 5%, 3%, 2% or 1% (dry weight basis) of the volume of the peptide preparation. That a particular peptide preparation is an isolated or purified peptide can be confirmed, for example, by the appearance of a single band following sodium dodecyl sulfate (SDS)-polyacrylamide gel electrophoresis and Coomassie Brillliant Blue staining or such of the gel. In a preferred embodiment, the peptides and polynucleotides of the present invention are isolated or purified.

The terms "polypeptide", "peptide" and "protein" are used interchangeably herein, and refer to polymers of amino acid residues. These terms are applied to also non-naturally

occurring amino acid polymers comprising one or more non-naturally occurring amino acid residues, in addition to naturally occurring amino acid polymers. Non-naturally occurring amino acids include amino acid analogs, amino acid mimetics, and such.

The term "amino acid" as used herein refers to naturally occurring amino acids, as well as amino acid analogs and amino acid mimetics that functions similarly 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, *etc.*). 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, and such). The phrase "amino acid mimetic" refers to chemical compounds that have different structures but similar functions to general amino acids. Amino acids can be either L-amino acids or D-amino acids, and the peptides of the present invention are preferably L-amino acid polymers.

The terms "polynucleotide" and "nucleic acid" are used interchangeably herein, and refer to a polymer of nucleotides.

The term "composition" used in the present specification is intended to encompass products that include specified ingredients in specified amounts, and any products generated directly or indirectly from combination of specified ingredients in the specified amounts. When the composition is a pharmaceutical composition, the term "composition" is intended to encompass products including active ingredient(s) and inert ingredient(s), as well as any products generated directly or indirectly from combination, complexation or aggregation of any two or more ingredients, from dissociation of one or more ingredients, or from other types of reactions or interactions of one or more ingredients. Thus, the pharmaceutical compositions of the present invention encompass any compositions made by admixing compounds or cells of the present invention with a pharmaceutically or physiologically acceptable carrier. Without being limited thereto, the terms "pharmaceutically acceptable carrier" or "physiologically acceptable carrier" used in the present specification include liquid or solid bulking agents, diluents, excipients, solvents, and encapsulation materials; and mean pharmaceutically or physiologically acceptable materials, compositions, substances or media.

Unless otherwise specified, the term "cancer" refers to a cancer that overexpresses the KOC1 gene; and examples thereof include bladder cancer, cervical cancer, cholangiocellular cancer, chronic myeloid leukemia (CML), colon cancer, rectum cancer, esophagus cancer, diffuse gastric cancer, non-small-cell lung cancer, small-cell lung cancer, lymphoma, osteosarcoma, ovarian cancer, kidney cancer, head and neck cancer, soft tissue tumor, testis

cancer and such, without being limited thereto. In an exemplary embodiment, the "cancer" is a cancer that expresses KOC1 and HLA-A11, HLA-A33, HLA-A03 and/or HLA-A01.

Unless otherwise specified, the terms "cytotoxic T lymphocyte" and "cytotoxic T cell" and "CTL" are used interchangeably herein. Unless otherwise specifically indicated, they refer to a sub-group of T lymphocytes that can recognize non-self cells (for example, tumor/cancer cells, virus-infected cells) and induce the death of such cells.

Unless otherwise specified, the term "HLA-A11" refers to the HLA-A11 type which includes subtypes such as HLA-A*1101, HLA-A*1102, HLA-A*1103, and HLA-A*1104.

Unless otherwise specified, the term "HLA-A33" refers to the HLA-A33 type which includes subtypes such as HLA-A*3303, HLA-A*3301, and HLA-A*3304.

Unless otherwise specified, the term "HLA-A03" refers to the HLA-A03 type which includes subtypes such as HLA-A*0301, HLA-A*0302, and HLA-A*0305.

Unless otherwise specified, the term "HLA-A01" refers to the HLA-A01 type which includes subtypes such as HLA-A*0101, HLA-A*0102, HLA-A*0103, and HLA-A*0104.

In the context of a subject or patient, the phrase "HLA antigen of a subject (or patient) is HLA-A11" used herein refers to that a subject or patient has the HLA-A11 antigen gene homozygously or heterozygously as the MHC (Major Histocompatibility Complex) Class I molecule, and that the HLA-A11 antigen is expressed in the cells of the subject or patient as the HLA antigen. Similarly, the phrases "HLA antigen of a subject (or patient) is HLA-A33", "HLA antigen of a subject (or patient) is HLA-A03" and "HLA antigen of a subject (or patient) is HLA-A01" used herein refer to, respectively, that a subject or patient has the HLA-A33 antigen gene homozygously or heterozygously as the MHC (Major Histocompatibility Complex) Class I molecule and that the HLA-A33 antigen is expressed as the HLA antigen in the cells of the subject or patient; that a subject or patient has the HLA-A03 antigen gene homozygously or heterozygously as the MHC (Major Histocompatibility Complex) Class I molecule and that the HLA-A03 antigen is expressed as the HLA antigen in the cells of the subject or patient; and that a subject or patient has the HLA-A01 antigen gene homozygously or heterozygously as the MHC (Major Histocompatibility Complex) Class I molecule and that the HLA-A01 antigen is expressed as the HLA antigen in the cells of the subject or patient.

As long as the methods and compositions of the present invention are useful in the context of cancer "treatment", the treatment is considered "efficacious" when it achieves clinical advantages, for example, reduction in the size, spreading or metastatic ability of cancer, retardation of cancer progression, alleviation of clinical symptoms of cancer, prolongation of survival period, suppression of postoperative recurrence in a subject. When the treatment is applied prophylactically, "efficacious" means that the treatment retards or prevents cancer

formation, or prevents or alleviates clinical symptoms of cancer. Effectiveness is determined in relation to any publicly known method for diagnosing or treating a specific tumor type.

As long as the methods and compositions of the present invention are useful in the context of cancer "prevention (prophylaxis)", the term "prevention (prophylaxis)" herein includes any work that eases the load of cancer-associated mortality or morbidity. Prevention (Prophylaxis) can be carried out at the "primary, secondary and tertiary prevention (prophylaxis) levels". Whereas the primary prevention (prophylaxis) avoids the development of a disease, prevention (prophylaxis) at the secondary and tertiary levels encompasses prevention (prophylaxis) of disease progression and appearance of symptoms, as well as workings intended to reduce adverse effects of the existing disease by restoring functions and reducing disease-associated complications. Alternately, prevention (prophylaxis) can include alleviation of severity of a specific disorder, for example, extensive preventive therapy intended to reduce tumor growth and metastasis.

In the context of the present invention, the treatment and/or prevention (prophylaxis) of cancer and/or prevention (prophylaxis) of postoperative recurrence thereof include either of the events such as inhibition of cancer cell proliferation, tumor involution or regression, induction of remission and suppression of cancer development, tumor regression, as well as reduction or inhibition of metastasis, suppression of postoperative recurrence of cancer, and prolongation of survival period. Effective treatment and/or prevention (prophylaxis) of cancer reduce mortality, improve prognosis of an individual with cancer, reduce the blood levels of tumor markers, and alleviate detectable symptoms associated with cancer. For example, alleviation or improvement of symptoms constitutes effective treatment and/or prevention (prophylaxis), and includes a condition in which the symptoms are stable or alleviated by 10%, 20%, 30% or more.

In the context of the present invention, the term "antibody" refers to immunoglobulins and fragments thereof that are specifically reactive to a designated protein or peptide thereof. An antibody can include human antibodies, primatized antibodies, chimeric antibodies, bispecific antibodies, humanized antibodies, antibodies fused to other proteins or radiolabels, and antibody fragments. Furthermore, an "antibody" herein is used in the broadest sense and specifically covers intact monoclonal antibodies, polyclonal antibodies, multispecific antibodies (*e.g.*, bispecific antibodies) formed from two or more intact antibodies, and antibody fragments so long as they exhibit the desired biological activity. An "antibody" may be antibodies of all classes (*e.g.*, IgA, IgD, IgE, IgG and IgM).

Unless otherwise specified, the technical terms and scientific terms used herein all have the same meanings as terms commonly understood by one of ordinary skill in the art to which the present invention belongs.

II. Peptides

HLA-A11 and HLA-A33 are alleles commonly seen in Asians (Sette A, Sidney J., Immunogenetics 1999, 50: 201-12), and HLA-A03 and HLA-A01 are alleles commonly seen in Caucasians (Cao *et al.*, Hum Immunol 2001; 62(9): 1009-30). Thus, an effective method of treating KOC1-expressing cancers for a great population of Asians or Caucasians can be provided by providing KOC1-derived CTL-inducing peptides restricted to HLA-A11, HLA-A33, HLA-A03, or HLA-A01. Thus, the present invention provides KOC1-derived peptides that are capable of inducing CTLs in an HLA-A11-, HLA-A33-, HLA-A03-, or HLA-A01-restrictive manner.

The peptides of the present invention are KOC1-derived peptides that are capable of inducing CTLs in an HLA-A11-, HLA-A33-, HLA-A03-, or HLA-A01-restrictive manner. Peptides capable of inducing CTLs in an HLA-A11-restrictive manner include peptides having the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32. Similarly, peptides capable of inducing CTLs in an HLA-A33-restrictive manner include peptides having the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80 and 85. Similarly, peptides capable of inducing CTLs in an HLA-A03-restrictive manner include peptides having the amino acid sequence selected from among SEQ ID NOs: 27, 30 and 52. Similarly, peptides capable of inducing CTLs in an HLA-A01-restrictive manner include peptides having the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95, and 41.

CTLs having a cytotoxic activity specific to these peptides can be established by *in vitro* stimulation of T cells by dendritic cells (DCs) pulsed with these peptides. The established CTLs show a specific cytotoxic activity against target cells pulsed with each of the peptides.

The KOC1 gene is overexpressed in cancer cells such as cancer cells in, for example, bladder cancer, cervical cancer, cholangiocellular cancer, chronic myeloid leukemia (CML), colon cancer, rectum cancer, esophagus cancer, diffuse gastric cancer, non-small-cell lung cancer, small-cell lung cancer, lymphoma, osteosarcoma, ovarian cancer, kidney cancer, head and neck cancer, soft tissue tumor, testis cancer and such, but is not expressed in most normal organs. It is thus an excellent target for immunotherapy. Therefore, the peptides of the present invention can be suitably used for cancer immunotherapy. A preferred peptide is a nonapeptide (a peptide consisting of 9 amino acid residues) or a decapeptide (a peptide consisting of 10 amino acid residues), and it is more preferably a peptide consisting of the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30, 32, 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, 85, 27, 86, 87, 90, 92, 46, 95, and 41. For example, a peptide having the amino acid sequence of SEQ ID NO: 32 is suitable for induction of CTLs that show a specific cytotoxic activity against cells expressing HLA-A11 and KOC1, and can be suitably used for cancer immunotherapy for HLA-A11-

positive patients. Furthermore, for example, a peptide having the amino acid sequence selected from among SEQ ID NOs: 64, 67 and 77 is suitable for induction of CTLs that show a specific cytotoxic activity against cells expressing HLA-A33 and KOC1, and can be suitably used for cancer immunotherapy for HLA-A33-positive patients. In addition, for example, a peptide having the amino acid sequence of SEQ ID NO: 27 is suitable for induction of CTLs that show a specific cytotoxic activity against cells expressing HLA-A03 and KOC1, and can be suitably used for cancer immunotherapy for HLA-A03-positive patients. Additionally, for example, a peptide having the amino acid sequence of SEQ ID NO: 86 is suitable for induction of CTLs that show a specific cytotoxic activity against cells expressing HLA-A01 and KOC1, and can be suitably used for cancer immunotherapy for HLA-A01-positive patients. In a more preferred embodiment, the peptide of the present invention is a peptide consisting of the amino acid sequence selected from among SEQ ID NOs: 32, 64, 67, 77, 27, and 86.

For the peptides of the present invention, an additional amino acid residue(s) can be made to adjoin the amino acid sequence of the peptide of the present invention, as long as the resultant peptides retain the CTL-inducing ability of the original peptide. The additional amino acid residue(s) may be composed of any types of amino acid(s), as long as they do not impair the CTL-inducing ability of the original peptide. Therefore, the peptides of the present invention encompass peptides having CTL-inducing ability, comprising the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30, 32, 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, 85, 27, 86, 87, 90, 92, 46, 95, and 41. Such peptides are, for example, less than about 40 amino acids, in many cases less than about 20 amino acids, and usually less than about 15 amino acids. Therefore, if the original peptide is a nonapeptide, the peptide of the present invention encompasses peptides that are 10 amino-acid long or 11-40 amino-acid long, which are produced by adjoining additional amino acid(s) to the peptide. Furthermore, if the original peptide is a decapeptide, the peptide of the present invention encompasses peptides that are 11-40 amino-acid long, which are produced by adjoining additional amino acid(s) to the peptide. Such a peptide can be, for example, a peptide that is 11-20 amino-acid long or a peptide that is 11-15 amino-acid long. A preferred example of an additional amino acid residue(s) is an amino acid residue(s) adjacent to the amino acid sequence of the peptide of the present invention in the full-length amino acid sequence of KOC1 (for example, SEQ ID NO: 110). Therefore, the peptides of the present invention encompass peptides comprising the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30, 32, 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, 85, 27, 86, 87, 90, 92, 46, 95, and 41, and wherein the peptides are peptide fragments of KOC1 and have CTL-inducing ability.

In general, modifications of one, two or more amino acids in a certain peptide do not affect the functions of the peptide, or in some cases even enhance the desired functions of the original peptide. In fact, modified peptides (*i.e.*, peptides composed of the amino acid sequence

in which one, two or several amino acid residues are modified (*i.e.*, substituted, deleted, inserted, and/or added) compared to the original reference sequence) are 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 can be peptides comprising the amino acid sequence in which one, two or several amino acids are substituted, deleted, inserted and/or added to the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30, 32, 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, 85, 27, 86, 87, 90, 92, 46, 95, and 41 and having CTL-inducing ability.

On skilled in the art can recognize that individual substitutions to an amino acid sequence that 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(s). Those are frequently referred to as "conservative substitutions" or "conservative modifications"; and modification of a protein by "conservative substitution" or "conservative modification" may result in a modified protein that has similar functions as the original protein. Tables of conservative substitutions presenting functionally similar amino acids are well known in the art. Examples of amino acid side chain characteristics that functionally resemble include, for example, 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 accepted in the art as conservative substitutions for one another:

1) Alanine (A), Glycine (G);
2) Aspartic acid (D), Glutamic acid (E);
3) Asparagine (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).

Such conservatively modified peptides are also encompassed in 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-inducing ability

of the original peptide. Furthermore, modified peptides do not exclude CTL inducible peptides derived from polymorphic variants, interspecies homologues, and alleles of KOC1.

So long as a peptide retains the CTL-inducing ability of an original peptide, one can modify (*i.e.*, substitute, delete, insert and/or add) 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, 4 or 3 or fewer. The percentage of amino acids to be modified is preferably 20% or less, more preferably 15% or less, even more preferably 10% or less or 1 to 5%.

When used in the context of immunotherapy, peptides of the present invention are presented on the surface of a cell or exosome, preferably as a complex with an HLA antigen. Therefore, it is preferable that the peptides of the present invention possess high binding affinity to the HLA antigen. To that end, the peptides can be modified by substitution, deletion, insertion, and/or addition of the amino acid residues to yield a modified peptide having improved binding affinity. Since the regularity of the sequences of peptides displayed by binding to HLA antigens is already known (Falk, *et al.*, Immunogenetics 1994 40 232-41; Chujoh, *et al.*, Tissue Antigens 1998: 52: 501-9; Takiguchi, *et al.*, Tissue Antigens 2000: 55: 296-302.), modifications based on such regularity can be introduced into the peptides of the present invention.

For example, in peptides having binding affinity for HLA Class I, the second amino acid from the N terminus and the C-terminal amino acid are generally anchor residues involved in the binding to HLA Class I (Rammensee HG, *et al.*, Immunogenetics. 1995; 41(4): 178-228.). For example, for HLA-A11, threonine, valine, isoleucine, leucine, phenylalanine, and tyrosine for the second amino acid from the N terminus, and lysine and arginine for the C-terminal amino acid are known as anchor residues with high binding affinity for HLA-A11 (Falk, *et al.*, Immunogenetics 1994, 40: 232-41; Chujoh, *et al.*, Tissue Antigens 1998: 52: 501-9). Further, in HLA-A11, there is auxiliary anchor residues at positions 3 and 7 from the N terminus; and it is known that leucine, phenylalanine, tyrosine, isoleucine, and alanine are preferred as the third amino acid from the N terminus, and that leucine, isoleucine, tyrosine, valine and phenylalanine are preferred as the seventh amino acid from the N terminus (Falk, *et al.*, Immunogenetics 1994, 40: 232-41; Chujoh, *et al.*, Tissue Antigens 1998: 52: 501-9). Thus, to maintain or enhance the HLA-A11-binding affinity, there is a possibility that it is desirable to substitute the second amino acid from the N terminus with threonine, valine, isoleucine, leucine, phenylalanine, or tyrosine, and/or to substitute the C-terminal amino acid with lysine or arginine. Further, there is a possibility that it is also desirable to substitute the third amino acid from the N terminus with leucine, phenylalanine, tyrosine, isoleucine, or alanine, and/or to substitute the seventh amino acid from the N terminus with leucine, isoleucine, tyrosine, valine or phenylalanine. Thus, peptides with CTL-inducing ability, comprising an amino acid sequence in which, in the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32, the second amino acid from

the N terminus is substituted with threonine, valine, isoleucine, leucine, phenylalanine, or tyrosine; the third amino acid from the N terminus is substituted with leucine, phenylalanine, tyrosine, isoleucine, or alanine; the seventh amino acid from the N terminus is substituted with leucine, isoleucine, tyrosine, valine or phenylalanine; and/or the C-terminal amino acid is substituted with lysine or arginine are encompassed by the peptides of the present invention. In a preferred embodiment, the peptide of the present invention can be a peptide having CTL-inducing ability that consists of an amino acid sequence in which, in the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32, the second amino acid from the N terminus is substituted with threonine, valine, isoleucine, leucine, phenylalanine, or tyrosine; the third amino acid from the N terminus is substituted with leucine, phenylalanine, tyrosine, isoleucine, or alanine; the seventh amino acid from the N terminus is substituted with leucine, isoleucine, tyrosine, valine or phenylalanine; and/or the C-terminal amino acid is substituted with lysine or arginine. That is, the peptides of the present invention encompass peptides having CTL-inducing ability, which comprise an amino acid sequence in which one or more substitutions selected from (a) to (d) below are introduced into the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32:

(a) the second amino acid from the N terminus is substituted with threonine, valine, isoleucine, leucine, phenylalanine, or tyrosine;

(b) the third amino acid from the N terminus is substituted with leucine, phenylalanine, tyrosine, isoleucine, or alanine;

(c) the seventh amino acid from the N terminus is substituted with leucine, isoleucine, tyrosine, valine or phenylalanine; and

(d) the C-terminal amino acid is substituted with lysine or arginine.

In a preferred embodiment, the peptide of the present invention may be a peptide having CTL-inducing ability that consists of an amino acid sequence in which one or more substitutions selected from (a) to (d) above are introduced into the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32. In the present invention, the preferred number of substitutions is 1, 2, 3 or 4 substitutions selected from (a) to (d) above.

The peptide of the present invention may be a peptide having CTL-inducing ability, which comprises an amino acid sequence in which, in the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30, and 32, the second amino acid from the N terminus is substituted with threonine, valine, isoleucine, leucine, phenylalanine, or tyrosine, and/or the C-terminal amino acid is substituted with lysine or arginine. Preferably, the peptide of the present invention may be a peptide having CTL-inducing ability, which consists of an amino acid sequence in which, in the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32, the second amino acid from the N terminus is substituted with threonine, valine, isoleucine, leucine,

phenylalanine, or tyrosine, and/or the C-terminal amino acid is substituted with lysine or arginine. That is, the peptide of the present invention may be a peptide having CTL-inducing ability, which comprises an amino acid sequence in which one or more substitutions selected from (a) and (b) below are introduced into the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32:

(a) the second amino acid from the N terminus is substituted with threonine, valine, isoleucine, leucine, phenylalanine, or tyrosine; and

(b) the C-terminal amino acid is substituted with lysine or arginine.

In a preferred embodiment, the peptide of the present invention may be a peptide having CTL-inducing ability, which consists of an amino acid sequence in which one or more substitutions selected from (a) to (b) above are introduced into the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32. In a more preferred embodiment, the second amino acid from the N terminus is substituted with threonine, valine, isoleucine, or leucine.

In HLA-A33, phenylalanine, tyrosine, alanine, isoleucine, leucine, and valine for the second amino acid from the N terminus, and lysine and arginine for the C-terminal amino acid are known as anchor residues with high binding affinity for HLA-A33 (Falk, *et al.*, Immunogenetics 1994, 40: 232-41; Takiguchi, *et al.*, Tissue Antigens 2000, 55: 296-302). Further, in HLA-A33, the first amino acid residue from the N terminus is also known to function as an anchor residue, and it is known that aspartic acid and glutamic acid is preferred as the first amino acid from the N terminus (Falk, *et al.*, Immunogenetics 1994, 40: 232-41; Takiguchi, *et al.*, Tissue Antigens 2000: 55: 296-302). Thus, to maintain or enhance the HLA-A33-binding affinity, there is a possibility that it is desirable to substitute the first amino acid from the N terminus with aspartic acid or glutamic acid, the second amino acid from the N terminus with phenylalanine, tyrosine, alanine, isoleucine, leucine, or valine, and/or the C-terminal amino acid with lysine or arginine. Therefore, peptides having CTL-inducing ability, which comprise an amino acid sequence in which, in the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, and 85, the first amino acid from the N terminus is substituted with aspartic acid or glutamic acid, the second amino acid from the N terminus is substituted with phenylalanine, tyrosine, alanine, isoleucine, leucine, or valine, and/or the C-terminal amino acid is substituted with lysine or arginine are encompassed by the peptides of the present invention. In a preferred embodiment, the peptide of the present invention may be a peptide having CTL-inducing ability, which consists of an amino acid sequence in which, in the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, and 85, the first amino acid from the N terminus is substituted with aspartic acid or glutamic acid, the second amino acid from the N terminus is substituted with phenylalanine, tyrosine, alanine, isoleucine, leucine, or valine, and/or the C-terminal amino acid is substituted with lysine or

arginine. That is, the peptides of the present invention encompass a peptide having CTL-inducing ability, which comprises an amino acid sequence in which one or more substitutions selected from (a) to (c) below are introduced into the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, and 85:

(a) the first amino acid from the N terminus is substituted with aspartic acid or glutamic acid;

(b) the second amino acid from the N terminus is substituted with phenylalanine, tyrosine, alanine, isoleucine, leucine, or valine; and

(c) the C-terminal amino acid is substituted with arginine or lysine.

In a preferred embodiment, the peptide of the present invention may be a peptide having CTL-inducing ability, which consists of an amino acid sequence in which one or more substitutions selected from (a) to (c) above are introduced into the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, and 85. In the present invention, the preferred number of substitutions is 1, 2 or 3 substitutions selected from (a) to (c) above.

Furthermore, the peptide of the present invention can be a peptide having CTL-inducing ability, which comprises an amino acid sequence in which, in the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, and 85, the second amino acid from the N terminus is substituted with phenylalanine, tyrosine, alanine, isoleucine, leucine, or valine, and/or the C-terminal amino acid is substituted with arginine or lysine. Preferably, the peptide of the present invention can be a peptide having CTL-inducing ability, which consists of an amino acid sequence in which, in the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, and 85, the second amino acid from the N terminus is substituted with phenylalanine, tyrosine, alanine, isoleucine, leucine, or valine, and/or the C-terminal amino acid is substituted with arginine or lysine. That is, the peptide of the present invention can be a peptide having CTL-inducing ability, which comprises an amino acid sequence in which one or more substitutions selected from (a) and (b) below are introduced into the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, and 85:

(a) the second amino acid from the N terminus is substituted with phenylalanine, tyrosine, alanine, isoleucine, leucine, or valine; and

(b) the C-terminal amino acid is substituted with arginine or lysine.

In a preferred embodiment, the peptide of the present invention may be a peptide having CTL-inducing ability, which consists of an amino acid sequence in which one or more substitutions selected from (a) and (b) above are introduced into the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, and 85. In a more

preferred embodiment, the second amino acid from the N terminus is substituted with phenylalanine or tyrosine.

In HLA-A03, leucine, methionine, valine, alanine, isoleucine, serine, and threonine for the second amino acid from the N terminus, and arginine, lysine, tyrosine, and phenylalanine for the C-terminal amino acid are known as anchor residues with high binding affinity for HLA-A03 (Kubo RT. *et al.*, J Immunol. 1994 Apr 15; 152(8): 3913-24; Sidney J *et al.*, Hum Immunol. 1996 Feb; 45(2): 79-93; Gambacorti-Passerini C *et al.*, Clin Cancer Res. 1997 May; 3(5): 675-83). Thus, to maintain or enhance the HLA-A03-binding affinity, there is a possibility that it is preferable to substitute the second amino acid from the N terminus with leucine, methionine, valine, alanine, isoleucine, serine or threonine, and/or the C-terminal amino acid with arginine, lysine, tyrosine or phenylalanine. Therefore, peptides having CTL-inducing ability, which comprise an amino acid sequence in which, in the amino acid sequence selected from among SEQ ID NOs: 27, 30, and 52, the second amino acid from the N terminus is substituted with leucine, methionine, valine, alanine, isoleucine, serine or threonine, and/or the C-terminal amino acid is substituted with arginine, lysine, tyrosine or phenylalanine are encompassed by the peptides of the present invention. In a preferred embodiment, the peptides of the present invention may be a peptide having CTL-inducing ability, which consists of an amino acid sequence in which, in the amino acid sequence selected from among SEQ ID NOs: 27, 30, and 52, the second amino acid from the N terminus is substituted with leucine, methionine, valine, alanine, isoleucine, serine or threonine, and/or the C-terminal amino acid is substituted with arginine, lysine, tyrosine or phenylalanine. That is, the peptides of the present invention encompass a peptide having CTL-inducing ability, which comprises an amino acid sequence in which one or more substitutions selected from (a) and (b) below are introduced into the amino acid sequence selected from among SEQ ID NOs: 27, 30, and 52:

(a) the second amino acid from the N terminus is substituted with leucine, methionine, valine, alanine, isoleucine, serine or threonine; and

(b) the C-terminal amino acid is substituted with arginine, lysine, tyrosine or phenylalanine.

In a preferred embodiment, the peptide of the present invention may be a peptide having CTL-inducing ability, which consists of an amino acid sequence in which one or more substitutions selected from (a) and (b) above are introduced into the amino acid sequence selected from among SEQ ID NOs: 27, 30, and 52. In a more preferred embodiment, the second amino acid from the N terminus is substituted with leucine, methionine or valine. In the present invention, the preferred number of substitutions is 1 or 2 substitutions selected from (a) and (b) above.

In HLA-A01, aspartic acid and glutamic acid for the third amino acid from the N terminus, and tyrosine for the C-terminal amino acid are known as anchor residues with high

binding affinity for HLA-A01. Further, it is known that there are auxiliary anchor residues at position 2 from the N terminus for HLA-A01 and that threonine and serine are preferred as the second amino acid from the N terminus (Kubo, R.T Journal of Immunology 1994, 152: 3913; Gambacorti-Passerini, C. Clinical Cancer Research 1997, 3: 675-83; Falk, K. Immunogenetics 1994, 40: 238-41). Thus, to maintain or enhance the HLA-A01-binding affinity, there is a possibility that it is desirable to substitute the third amino acid from the N terminus with aspartic acid or glutamic acid, and/or the C-terminal amino acid with tyrosine. Another possibility is that it is desirable to substitute the second amino acid from the N terminus with threonine or serine. Therefore, peptides having CTL-inducing ability, which comprise an amino acid sequence in which, in the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41, the second amino acid from the N terminus is substituted with threonine or serine, the third amino acid from the N terminus is substituted with aspartic acid or glutamic acid, and/or the C-terminal amino acid is substituted with tyrosine are encompassed by the peptides of the present invention. In a preferred embodiment, the peptide of the present invention may be a peptide having CTL-inducing ability, which consists of an amino acid sequence in which, in the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41, the second amino acid from the N terminus is substituted with threonine or serine, the third amino acid from the N terminus is substituted with aspartic acid or glutamic acid, and/or the C-terminal amino acid is substituted with tyrosine. That is, the peptides of the present invention encompass a peptide having CTL-inducing ability, which comprises an amino acid sequence in which one or more substitutions selected from (a) to (c) below are introduced into the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41:

(a) the second amino acid from the N terminus is substituted with threonine or serine;

(b) the third amino acid from the N terminus is substituted with aspartic acid or glutamic acid; and

(c) the C-terminal amino acid is substituted with tyrosine.

In a preferred embodiment, the peptide of the present invention can be a peptide having CTL-inducing ability, which consists of an amino acid sequence in which one or more substitutions selected from (a) to (c) above are introduced into the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41. In the present invention, the preferred number of substitutions is 1, 2 or 3 substitutions selected from (a) to (c) above.

Furthermore, the peptide of the present invention may be a peptide having CTL-inducing ability, which comprises an amino acid sequence in which, in the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41, the third amino acid from the N terminus is substituted with aspartic acid or glutamic acid, and/or the C-terminal amino acid is substituted with tyrosine. Preferably, the peptide of the present invention may be a peptide

having CTL-inducing ability, which consists of an amino acid sequence in which, in the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41, the third amino acid from the N terminus is substituted with aspartic acid or glutamic acid, and/or the C-terminal amino acid is substituted with tyrosine. That is, the peptide of the present invention can be a peptide having CTL-inducing ability, which comprises an amino acid sequence in which one or more substitutions selected from (a) and (b) below are introduced into the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41:

(a) the third amino acid from the N terminus is substituted with aspartic acid or glutamic acid; and

(b) the C-terminal amino acid is substituted with tyrosine.

In a preferred embodiment, the peptide of the present invention may be a peptide having CTL-inducing ability, which consists of an amino acid sequence in which one or more substitutions selected from (a) to (b) above are introduced into the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41.

Substitution(s) may be introduced into amino acid(s) not only at the anchor site(s), but also at a position(s) of potential T cell receptor (TCR) recognition site(s) of the peptides. Several research studies have demonstrated that a peptide that has amino acid substitutions, such as CAP1, $p53_{(264-272)}$, Her-2/$neu_{(369-377)}$ or $gp100_{(209-217)}$, may have equal to or better activity than that of the original peptide (Zaremba *et al.* Cancer Res. 57, 4570-7, 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, 307-14).

The present invention also contemplates that one, two or several amino acids can be added to the N terminus and/or C terminus of the peptides of the present invention (for example, peptides consisting of the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30, 32, 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, 85, 27, 86, 87, 90, 92, 46, 95 and 41). Such modified peptides that retain CTL-inducing ability are also included in the present invention. For example, when a peptide in which one, two or several amino acids are added to the N terminus and/or C terminus of a peptide consisting of the amino acid sequence selected from among SEQ ID NOs: 32, 64, 67, 77, 27 and 86 is contacted with an APC(s), it is incorporated into the APC(s) and processed to become a peptide consisting of the amino acid sequence selected from among SEQ ID NOs: 32, 64, 67, 77, 27 and 86. It can then induce CTLs through presentation on the cell surface of an APC *via* the antigen presentation pathway. More specifically, peptides of the present invention can be peptides in which one, two or several amino acids are added to either or both of the N terminus and C terminus.

However, when the amino acid sequence of a peptide 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 perform homology searches using available databases to avoid situations in which the amino acid sequence of the peptide matches the amino acid sequence of another protein. When it becomes clear from the homology searches that no peptide exists with as few as 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-inducing ability without danger of such side effects.

Peptides in which one, two or several amino acids of a peptide of the present invention are modified are predicted to be able to retain CTL-inducing ability of the original peptide; however, it is preferable to verify the CTL-inducing ability of the modified peptides. Herein, the "peptide having CTL-inducing ability (CTL inducibility)" refers to a peptide that induces CTLs through APCs stimulated with the peptide. "CTL induction" includes induction of differentiation into CTLs, induction of CTL activation, induction of CTL proliferation, induction of CTL's cytotoxic activity, induction of CTL-mediated dissolution of target cells, and induction of increase of IFN-gamma production of CTLs.

The CTL-inducing ability can be confirmed by inducing and stimulating APCs that retain an HLA antigen (for example, B lymphocytes, macrophages, and dendritic cells) with a peptide, and mixing it with CD8-positive T cells; and then measuring IFN-gamma released by CTLs against the target cells. For the APCs, human peripheral blood mononuclear leukocyte-derived dendritic cells can be preferably used. As a reaction system, transgenic animals generated to express an HLA antigen can be used. Alternatively, for example, the target cells may be radio-labelled with ^{51}Cr or such, and the cytotoxic activity of the peptide-induced CTLs may be calculated from the radioactivity emitted from the target cells. Alternatively, in the presence of peptide-stimulated APCs, it is possible to evaluate the CTL-inducing ability by measuring the IFN-gamma produced and released by CTLs, and visualizing the inhibition zone on the media using anti-IFN-gamma monoclonal antibodies.

In addition to the modifications above, the peptides of the present invention can be linked to other peptides as long as the resultant linked peptide retains the CTL-inducing ability. An example of an appropriate peptide to be linked with the peptides of the present invention includes a TAA-derived CTL-inducing peptide. Further, the peptides of the present invention can also be linked with each other. Suitable linkers for use in linking peptides are known in the art, and for example, linkers such as AAY (P. M. Daftarian *et al.*, J Trans Med 2007, 5:26), AAA, NKRK (SEQ ID NO: 111) (R. P. M. Sutmuller *et al.*, J Immunol. 2000, 165: 7308-15), or K (S. Ota *et al.*, Can Res. 62, 1471-6, K. S. Kawamura *et al.*, J Immunol. 2002, 168: 5709-15) can be

used. Peptides can be linked in various arrangements (for example, catenulate, repeated, *etc.*), and one can also link three or more peptides.

The peptides of the present invention can also be linked to other substances as long as the resultant linked peptide retains the CTL-inducing ability. Examples of an appropriate substance to be linked with a peptide of the present invention include, for example, a peptide, a lipid, a sugar or sugar chain, an acetyl group, and a naturally-occurring or synthetic polymer. The peptides of the present invention can be modified by glycosylation, side-chain oxidation, phosphorylation or such, as long as their CTL-inducing ability is not impaired. One can also perform such types of modifications to confer additional functions (for example, targeting function and delivery function) or to stabilize the peptide.

For example, to increase the *in vivo* stability of a peptide, it is known in the art to introduce D-amino acids, amino acid mimetics or non-naturally occurring amino acids, and this concept may also be applied to peptides of the present invention. Peptide stability can be assayed by several methods. For example, stability can be tested by using a peptidase as well as various biological media such as human plasma and serum (see, *e.g.*, Verhoef *et al.*, Eur J Drug Metab Pharmacokin 1986, 11: 291-302).

Further, as stated above, among the modified peptides in which one, two, or several amino acid residues have been substituted, deleted, inserted and/or added, those having the same or higher activity as compared to original peptides can be screened for or selected. Thus, the present invention also provides methods of screening for or selecting modified peptides that have the same or higher activity than that of the original peptide. Specifically, the present invention provides a method of screening for a peptide having CTL-inducing ability, wherein the method comprises the steps of:

(a) generating candidate sequences consisting of an amino acid sequence in which one, two, or several amino acid residues are substituted, deleted, inserted and/or added to the original amino acid sequence consisting of the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30, 32, 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, 85, 27, 86, 87, 90, 92, 46, 95 and 41;

(b) selecting from among the candidate sequences generated in (a), a candidate sequence that does not have a significant homology (sequence identity) with any known human gene product other than KOC1;

(c) contacting a peptide consisting of the candidate sequence selected in (b) with APCs;

(d) contacting the APCs of (c) with CD8-positive T cells; and

(e) selecting a peptide that has an equal to or higher CTL-inducing ability than that of a peptide consisting of the original amino acid sequence.

Herein, the peptide of the present invention is also described as a "KOC1 peptide(s)" or a "KOC1 polypeptide(s)".

III. Preparation of peptides of the present invention

Well known techniques can be used to prepare peptides of the present invention. For example, recombinant DNA technology or chemical synthesis can be used to prepare peptides of the present invention. Peptides of the present invention can be synthesized individually, or as longer polypeptides including two or more peptides. Peptides of the present invention can be isolated from host cells or synthesis reaction products after they are produced in the host cells using recombinant DNA technology or after they are chemically synthesized. That is, peptides of the present invention can be purified or isolated so as not to substantially contain other host-cell proteins and fragments thereof, or any other chemical substances.

The peptides of the present invention may contain modifications, such as glycosylation, side chain oxidation, or phosphorylation provided such modifications do not destroy the biological activity of the original peptide. Other illustrative modifications include incorporation of D-amino acids or other amino acid mimetics that may be used, for example, to increase the serum half life of the peptides.

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 to the synthesis include the methods described in the documents below:

(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" (in Japanese), Continued 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.

Alternatively, the peptides of the present invention can be obtained adapting any known genetic engineering methods for producing peptides (*e.g.*, Morrison J, J Bacteriology 1977, 132: 349-51; Clark-Curtiss & Curtiss, Methods in Enzymology (Wu *et al.*) 1983, 101: 347-62). For example, first, a suitable vector harboring a polynucleotide encoding the peptide of the present invention 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 the present invention. The peptide of the present invention can also be produced *in vitro* using an *in vitro* translation system.

IV. Polynucleotides

The present invention also provides a polynucleotide which encodes any of the peptides of the present invention. These include polynucleotides derived from the naturally occurring KOC1 gene (*e.g.*, GenBank Accession No. NM_006547 (SEQ ID NO: 109)) 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 above 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.

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.

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 (*e.g.*, 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.

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.

V. Exosomes

The present invention further provides intracellular vesicles, referred to as exosomes, that present complexes formed between the peptides of the present invention and HLA antigens on their surface. Exosomes can be prepared, for example, using the methods detailed in JPH11-510507 and WO99/03499, and can be prepared using APCs obtained from patients who are subject to treatment and/or prevention (prophylaxis). The exosomes of the present invention can be inoculated as vaccines, in a fashion similar to the peptides of the present invention.

The type of the HLA antigens included in the above-described complexes must match that of the subject in need of treatment and/or prevention (prophylaxis). For example, in Asian populations, HLA-A11 (for example, HLA-A*1101) and HLA-A33 (for example, HLA-A*3303) are alleles widely and generally seen in Asian populations, and these HLA antigen types are considered to be suitable for treatment in Asian patients. Further, HLA-A03 (for example, HLA-A*0301) and HLA-A01 (for example, HLA-A*0101) are alleles widely and generally seen in Caucasian populations, and these HLA antigen types are considered to be suitable for treatment in Caucasian patients. Typically in clinical practice, it is possible to select an appropriate peptide that has a high level of binding affinity for a specific HLA antigen or that has CTL-inducing ability by antigen presentation mediated by a specific HLA antigen, by studying in advance the HLA antigen type of the patient in need of treatment.

The exosomes of the present invention present on their surface a complex of a peptide of the present invention and HLA-A11, HLA-A33, HLA-A03 or HLA-A01. When the HLA that forms a complex with a peptide of the present invention is HLA-A11, the peptide of the present invention is preferably a peptide having the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32 or a modified peptide thereof, and more preferably a peptide consisting of the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32 or a modified peptide thereof. Further, when the HLA that forms a complex with a peptide of the present invention is HLA-A33, the peptide of the present invention is preferably a peptide having the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80 and 85 or a modified peptide thereof, and more preferably a peptide consisting of the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80 and 85 or a

modified peptide thereof. Further, when the HLA that forms a complex with a peptide of the present invention is HLA-A03, the peptide of the present invention is preferably a peptide having the amino acid sequence selected from among SEQ ID NOs: 27, 30 and 52 or a modified peptide thereof, and more preferably a peptide consisting of the amino acid sequence selected from among SEQ ID NOs: 27, 30 and 52 or a modified peptide thereof. Further, when the HLA that forms a complex with a peptide of the present invention is HLA-A01, the peptide of the present invention is preferably a peptide having the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41 or a modified peptide thereof, and more preferably a peptide consisting of the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41 or a modified peptide thereof.

VI. Antigen-presenting cells (APCs)

The present invention further provides APCs that present on their surface complexes formed between HLA antigens and peptides of the present invention. Alternatively, the present invention provides APCs having on their cell surface complexes formed between HLA antigens and peptides of the present invention. The APCs of the present invention can be isolated APCs. When used in the context of cells (APCs, CTLs, *etc.*), the term "isolated" means that the cells are separated from another type of cells. The APCs of the present invention may be APCs induced from APCs derived from the patient to be subjected to treatment and/or prevention (prophylaxis), and can be administered as a vaccine by themselves or in combination with other drugs including a peptide(s), an exosome(s) or a CTL(s) of the present invention.

The APCs of the present invention are not limited to specific types of cells, and include cells known to present proteinaceous antigens on their cell surface so as to be recognized by lymphocytes, for example, dendritic cells (DCs), Langerhans cells, macrophages, B cells, and activated T cells. Since DC is a representative APC that has the strongest CTL-inducing activity among APCs, DCs can be preferably used as the APCs of the present invention. In the present invention, the preferable DC is an isolated DC derived from human. Further, it is not necessary for the APCs of the present invention to be homogeneous, and they can be mixtures of multiple types of cells having an antigen-presenting function and can be mixtures of APCs each of which presents different types of the peptides of the present invention.

For example, APCs of the present invention can be obtained by isolating DCs from peripheral blood mononuclear cells and then stimulating them *in vitro* with the peptides of the present invention. When the peptide of the present invention is administered to a subject, APCs presenting the peptide of the present invention are induced in the body of the subject. Therefore, after the peptides of the present invention are administered to a subject, the APCs of the present invention can be obtained by collecting APCs from the subject. Alternatively, the APCs of the

present invention can be obtained by contacting APCs collected from a subject with a peptide of the present invention.

In order to induce an immune response against KOC1-expressing cancer cells in a subject, the APCs of the present invention can be administered to the subject by themselves or in combination with other drugs including peptide(s), exosome(s) or CTL(s) of the present invention. For example, the *ex vivo* administration can comprise the following steps of:

(a) collecting APCs from a first subject;

(b) contacting the APCs of step (a) with a peptide; and

(c) administering the APCs of step (b) to a second subject.

The first subject and the second subject may be the same individual, or may be different individuals. When the first subject and the second subject are different individuals, it is preferable that the HLAs of the first subject and the second subject are of the same type. The APC obtained in step (b) above can be a vaccine for cancer treatment and/or prevention (prophylaxis).

The APCs of the present invention obtained by a method such as described above have CTL-inducing ability. The term "CTL-inducing ability (CTL inducibility)" used in the context of an APC(s) refers to the ability of the APC to be able to induce a CTL(s) when placed in contact with a CD8-positive T cell(s). Further, the "CTL-inducing ability (CTL inducibility)" includes the ability of an APC to induce CTL activation, the ability of an APC to induce CTL proliferation, the ability of an APC to facilitate CTL-mediated dissolution of target cells, and the ability of an APC to increase CTL-mediated IFN-gamma production. The CTL(s) induced by the APC of the present invention is a CTL(s) specific to KOC1 and demonstrates a specific cytotoxic activity against KOC1-expressing cells.

In addition to the above-described methods, the APCs of the present invention can be prepared by introducing a polynucleotide encoding a peptide of the present invention into APCs *in vitro*. The polynucleotide to be introduced can be in the form of DNA or RNA. The method of introduction is not particularly limited, and examples thereof include various methods conventionally performed in the art such as lipofection, electroporation and the calcium phosphate method. More specifically, methods described in Cancer Res 1996, 56: 5672-7; J Immunol 1998, 161: 5607-13; J Exp Med 1996, 184: 465-72, and JP2000-509281 can be used. By introducing a polynucleotide encoding a peptide of the present invention into an APC, the polynucleotide is transcribed and translated in the cell, and then the produced peptide is processed by MHC Class I and proceeds through a presentation pathway to present the peptide of the present invention on the cell surface of the APC.

In a preferred embodiment, the APC of the present invention presents on its cell surface a complex formed between a peptide of the present invention and HLA-A11 (more preferably

HLA-A*1101), HLA-A33 (more preferably HLA-A*3303), HLA-A03 (more preferably HLA-A*0301) or HLA-A01 (more preferably HLA-A*0101). When the HLA that forms a complex with a peptide of the present invention is HLA-A11, the peptide of the present invention is preferably a peptide having the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32 or a modified peptide thereof, and more preferably a peptide consisting of the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32. When the HLA that forms a complex with a peptide of the present invention is HLA-A33, the peptide of the present invention is preferably a peptide having the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80 and 85 or a modified peptide thereof, and more preferably a peptide consisting of the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80 and 85. When the HLA that forms a complex with a peptide of the present invention is HLA-A03, the peptide of the present invention is preferably a peptide having the amino acid sequence selected from among SEQ ID NOs: 27, 30 and 52 or a modified peptide thereof, and more preferably a peptide consisting of the amino acid sequence selected from among SEQ ID NOs: 27, 30 and 52. When the HLA that forms a complex with a peptide of the present invention is HLA-A01, the peptide of the present invention is preferably a peptide having the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41 or a modified peptide thereof, and more preferably a peptide consisting of the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41.

The APC(s) of the present invention is preferably an APC(s) induced by a method comprising a step described (a) or (b) below:

(a) contacting an APC(s) expressing at least one HLA selected from among HLA-A11 (more preferably HLA-A*1101), HLA-A33 (more preferably HLA-A*3303), HLA-A03 (more preferably HLA-A*0301) and HLA-A01 (more preferably HLA-A*0101) with a peptide of the present invention; or

(b) introducing a polynucleotide encoding a peptide of the present invention into an APC(s) expressing at least one HLA selected from among HLA-A11 (more preferably HLA-A*1101), HLA-A33 (more preferably HLA-A*3303), HLA-A03 (more preferably HLA-A*0301) and HLA-A01 (more preferably HLA-A*0101).

The peptide of the present invention to be contacted with the HLA-A11-expressing APC(s) is preferably a peptide having the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32 or a modified peptide thereof, and more preferably a peptide consisting of the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32.

The peptide of the present invention to be contacted with the HLA-A33-expressing APC(s) is preferably a peptide having the amino sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80 and 85 or a modified peptide thereof, and more preferably a

peptide consisting of the amino sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80 and 85.

The peptide of the present invention to be contacted with the HLA-A03-expressing APC(s) is preferably a peptide having the amino acid sequence selected from among SEQ ID NOs: 27, 30 and 52 or a modified peptide thereof, and more preferably a peptide consisting of the amino acid sequence selected from among SEQ ID NOs: 27, 30 and 52.

The peptide of the present invention to be contacted with the HLA-A01-expressing APC(s) is preferably a peptide having the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41 or a modified peptide thereof, and more preferably a peptide consisting of the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41.

The present invention provides use of a peptide of the present invention for the manufacture of a pharmaceutical composition that induces an APC(s) having CTL-inducing ability. In addition, the present invention provides a method or process of manufacturing a pharmaceutical composition that induces an APC(s) having CTL-inducing ability. Further, the present invention provides a peptide of the present invention for inducing an APC(s) having CTL-inducing ability.

VII. Cytotoxic T lymphocytes (CTLs)

The CTL induced by a peptide of the present invention can be used as a vaccine in a similar manner to the peptide of the present invention for enhancing an immune response targeting KOC1-expressing cell *in vivo*. Thus, the present invention provides CTLs that are induced or activated by a peptide of the present invention. The CTLs of the present invention are CTLs that target a peptide of the present invention, and are capable of binding to a complex of a peptide of the present invention and an HLA antigen. Binding of a CTL to the complex is mediated *via* a T cell receptor (TCR) present on the cell surface of the CTL. The CTLs of the present invention can be isolated CTLs. The preferable CTLs are isolated CTLs of human origin. The CTLs of the present invention do not have to be homogeneous, and can be mixtures of CTLs each of which targets different types of peptides of the present invention.

The CTLs of the present invention can be obtained by (1) administering a peptide of the present invention to a subject, (2) stimulating APCs and CD8-positive T cells, or peripheral blood mononuclear cells (PBMCs) derived from a subject with a peptide of the present invention *in vitro*, (3) contacting *in vitro* CD8-positive T cells or PBMCs with APCs or exosomes that present on their surface a complex of an HLA antigen and a peptide of the present invention, or (4) introducing into CD8-positive T cells a vector comprising a polynucleotide encoding each subunit of a T cell receptor (TCR) capable of binding to a peptide of the present invention

presented on cell surface *via* an HLA antigen. The exosomes and APCs used in the method of (2) or (3) above can be prepared by methods described in the "V. Exosomes" and "VI. Antigen-presenting cells (APCs)" sections, respectively, and the details of the method of (4) above will be described in the "VIII. T cell receptor (TCR)" section.

The CTLs of the present invention can be administered by themselves to patients who are subject to treatment and/or prevention (prophylaxis), or in combination with other drugs including peptide(s), APC(s) or exosome(s) of the present invention for the purpose of regulating effects. Further, the CTLs of the present invention can be CTLs induced from CD8-positve T cells derived from the patients who are subject to administration of the CTLs. The CTLs of the present invention act specifically on target cells that present the peptides of the present invention, for example, the same peptides used to induce the CTLs of the present invention. The target cells may be cells that endogenously express KOC1, such as cancer cells, or cells transfected with the KOC1 gene. Cells that present a peptide of the present invention on their cell surface due to stimulation by the peptide can become a target of attack by the CTLs of the present invention. The cells targeted by the CTLs of the present invention are preferably cells that are positive for at least one of HLA-A11 (more preferably HLA-A*1101), HLA-A33 (more preferably HLA-A*3303), HLA-A03 (more preferably HLA-A*0301), and HLA-A01 (more preferably HLA-A*0101).

In a preferred embodiment, the CTLs of the present invention target specifically cells that express both KOC1 and at least one HLA selected from among HLA-A11 (more preferably HLA-A*1101), HLA-A33 (more preferably HLA-A*3303), HLA-A03 (more preferably HLA-A*0301), and HLA-A01 (more preferably HLA-A*0101). In the present invention, the cells targeted by the CTLs can be cells that have any of the alleles of HLA-A11, HLA-A33, HLA-A03, and HLA-A01 homozygously or heterozygously.

Herein, that the CTL "targets" cells refers to CTL recognition of cells that present on their cell surface a complex of HLA and a peptide of the present invention and demonstration of a cytotoxic activity against the cells. Further, "specifically target" refers to that the CTLs demonstrate a cytotoxic activity against those cells, but do not show a damaging activity to other cells. The expression "recognize cells" used in the context of CTLs refers to binding to a complex of HLA and a peptide of the present invention presented on cell surface *via* its TCR, and demonstrating a specific cytotoxic activity against the cell. Therefore, the CTLs of the present invention are preferably CTLs that can bind *via* TCR to a complex formed between a peptide of the present invention and HLA-A11 (more preferably HLA-A*1101), HLA-A33 (more preferably HLA-A*3303), HLA-A03 (more preferably HLA-A*0301) or HLA-A01 (more preferably HLA-A*0101) presented on cell surface.

Furthermore, the CTLs of the present invention are preferably CTLs induced by a method comprising a step described in (a) or (b) below:

(a) contacting *in vitro* CD8-positive T cells with APCs or exosomes that present on their surface a complex of a peptide of the present invention and HLA-A11 (more preferably HLA-A*1101), HLA-A33 (more preferably HLA-A*3303), HLA-A03 (more preferably HLA-A*0301) or HLA-A01 (more preferably HLA-A*0101); or

(b) introducing into CD8-positive T cells a polynucleotide encoding each subunit of a TCR capable of binding to a peptide of the present invention presented on cell surface by HLA-A11 (more preferably HLA-A*1101), HLA-A33 (more preferably HLA-A*3303), HLA-A03 (more preferably HLA-A*0301) or HLA-A01 (more preferably HLA-A*0101).

VIII. T cell receptors (TCRs)

The present invention also provides compositions comprising a polynucleotide encoding each subunit of a TCR capable of binding to a peptide of the present invention presented on cell surface by an HLA antigen, and methods of using the same. The polynucleotide confers CD8-positive T cells with specificity against KOC1-expressing cancer cells through expression of a TCR capable of binding to a peptide of the present invention presented on cell surface by an HLA antigen. Polynucleotides encoding an alpha chain(s) and a beta chain(s) can be identified as the TCR subunit of the CTL induced by a peptide of the present invention by using known methods in the art (WO2007/032255 and Morgan *et al.*, J Immunol, 171, 3288 (2003)). For example, PCR methods are preferred for TCR analysis. Without being limited thereto, PCR primers for analysis may be, for example, a primer set(s) for amplification by combining the 5' side primer and the 3' side primer(s) below:

5' side primer:

5'-R Primer (5'-gtctaccaggcattcgcttcat-3') (SEQ ID NO: 105)

3' side primers:

TCR-alpha-chain C-region-specific

3-TRa-C Primer (5'-tcagctggaccacagccgcagcgt-3') (SEQ ID NO: 106)

TCR-beta-chain C1-region-specific

3-TRb-C1 Primer (5'-tcagaaatcctttctcttgac-3') (SEQ ID NO: 107) or

TCR-beta-chain C2-region-specific

3-TR-beta-C2 Primer (5'-ctagcctctggaatcctttctctt-3') (SEQ ID NO: 108)

The TCRs formed by introducing the identified polynucleotides into CD8-positive T cells can bind with high binding affinity to the target cells that present a peptide of the present invention, and mediates efficient killing of the target cells presenting a peptide of the present invention *in vivo* and *in vitro*.

A polynucleotide encoding each TCR subunit can be incorporated into an appropriate vector, for example, retrovirus vector. These vectors are well known in the art. The polynucleotide or a vector comprising thereof in an expressible form can be introduced into a CD8-positive T cell, for example, a CD8-positive T cell derived from a patient. The present invention provides off-the-shelf compositions that allow rapid and easy production of modified T cells that have superior cancer cell-killing properties by rapid modification of the patient's own T cells (or T cells derived from another subject).

Herein, a specific TCR is a TCR that can confer a specific cytotoxic activity against target cells by specifically recognizing a complex of a peptide of the present invention and an HLA antigen presented on the surface of the target cell when the TCR is present on the surface of a CD8-positive T cell. Specific recognition of the above-described complex can be confirmed by any known method, and preferable examples thereof include HLA multimer staining analysis using HLA molecules and peptides of the present invention and ELISPOT assay methods. Specific TCR-mediated recognition of target cell by T cell introduced with the above-described polynucleotide and signal transduction in the cell can be confirmed by carrying out an ELISPOT assay. When the above-described TCR is present on the surface of a CD8-positive T cell, whether the TCR can confer a target cell-specific cytotoxic activity against the CD8-positive T cell can also be confirmed by known methods. Preferable methods include, for example, measuring the cytotoxic activity against target cells by a chrome release assay method or such.

The present invention provides, in the context of HLA-A11, CTLs prepared by transforming CD8-positive T cells with a polynucleotide encoding each subunit of TCR that binds to, for example, a peptide having the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32.

The present invention provides, in the context of HLA-A33, CTLs prepared by transforming CD8-positive T cells with a polynucleotide encoding each subunit of TCR that binds to, for example, a peptide having the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80 and 85.

The present invention provides, in the context of HLA-A03, CTLs prepared by transforming CD8-positive T cells with a polynucleotide encoding each subunit of TCR that binds to, for example, a peptide having the amino acid sequence selected from among SEQ ID NOs: 27, 30 and 52.

The present invention provides, in the context of HLA-A01, CTLs prepared by transforming CD8-positive T cells with a polynucleotide encoding each subunit of TCR that binds to, for example, a peptide having the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41.

The transformed CTLs are capable of homing *in vivo* and may be propagated by a well-known *in vitro* culturing method (for example, Kawakami *et al.*, J Immunol., 142, 3452-61 (1989)). The CTLs of the present invention can be used to form an immunogenic composition useful for disease treatment or prevention (prophylaxis) in a patient in need of treatment or prevention (prophylaxis) (the contents are incorporated herein for reference WO2006/031221).

IX. Pharmaceutical compositions

The present invention further provides compositions or pharmaceutical compositions, comprising at least one active ingredient selected from below:

(a) a peptide of the present invention;
(b) a polynucleotide encoding a peptide of the present invention in an expressible form;
(c) an APC of the present invention;
(d) an exosome of the present invention; and
(e) a CTL of the present invention.

The pharmaceutical compositions of the present invention can comprise as needed a carrier(s), an excipient(s) or such commonly used in pharmaceuticals without particular limitations, in addition to the active ingredient(s) described above. An example of a carrier that can be used in a pharmaceutical composition of the present invention includes sterilized water, physiological saline, phosphate buffer, culture fluid and such. Therefore, the present invention also provides pharmaceutical compositions, comprising at least one active ingredient selected from (a) to (e) below and a pharmaceutically acceptable carrier:

(a) a peptide of the present invention;
(b) a polynucleotide encoding a peptide of the present invention in an expressible form;
(c) an APC of the present invention;
(d) an exosome of the present invention; and
(e) a CTL of the present invention.

Further, the pharmaceutical compositions of the present invention can comprise, as needed, stabilizers, suspensions, preservatives, surfactants, solubilizing agents, pH adjusters, aggregation inhibitors and such.

The KOC1 expression significantly up-regulates in cancer cells compared with normal tissues. Thus, a peptide of the present invention or a polynucleotide encoding the peptide can be used to treat and/or prevent cancer, and/or prevent postoperative recurrence thereof. Therefore, the present invention provides pharmaceutical compositions for treating and/or preventing cancer, and/or preventing postoperative recurrence thereof, comprising one or more types of peptides or polynucleotides of the present invention as an active ingredient. Alternatively, the peptides of the present invention can be made to be presented on the surface of exosomes or APCs for use as

pharmaceutical compositions. In addition, CTLs of the present invention targeting any one of the peptides of the present invention can also be used as an active ingredient of the pharmaceutical compositions of the present invention. The pharmaceutical compositions of the present invention may comprise a therapeutically effective amount or a pharmaceutically effective amount of the above-described active ingredient.

The pharmaceutical compositions of the present invention may also be used as a vaccine. In the context of the present invention, the term "vaccine" (also called "immunogenic composition") refers to a composition that has a function of inducing an immune response that leads to antitumor action when inoculated into an animal. Thus, a pharmaceutical composition of the present invention can be used to induce an immune response that leads to antitumor action. The immune response induced by a peptide, a polypeptide, an APC, a CTL and a pharmaceutical composition of the present invention is not particularly limited as long as it is an immune response that leads to antitumor action, and examples include induction of cancer cell-specific CTLs and induction of cancer cell-specific cytotoxic activity.

The pharmaceutical compositions of the present invention can be used to treat and/or prevent cancer, and/or prevent postoperative recurrence thereof in human subjects or patients. The pharmaceutical compositions of the present invention can be used preferably to a subject positive for at least one HLA selected from among HLA-A11, HLA-A33, HLA-A03 and HLA-A01. Further, the pharmaceutical compositions of the present invention can be used preferably to treat and/or prevent cancers expressing KOC1 and at least one HLA selected from among HLA-A11, HLA-A33, HLA-A03 and HLA-A01, and/or prevent postoperative recurrence thereof.

In another embodiment, the present invention provides use of an active ingredient selected from below in the manufacture of a pharmaceutical composition for treating or preventing cancer:

(a) a peptide of the present invention;
(b) a polynucleotide encoding a peptide of the present invention in an expressible form;
(c) an APC that presents a peptide of the present invention on its surface;
(d) an exosome that presents a peptide of the present invention on its surface; and
(e) a CTL of the present invention.

Alternatively, the present invention further provides an active ingredient selected from below for use in treating or preventing cancer:

(a) a peptide of the present invention;
(b) a polynucleotide encoding a peptide of the present invention in an expressible form;
(c) an APC that presents a peptide of the present invention on its surface;
(d) an exosome that presents a peptide of the present invention on its surface; and
(e) a CTL of the present invention.

Alternatively, the present invention further provides a method or process for manufacturing a pharmaceutical composition for treating or preventing cancer, wherein the method or process comprises a step of formulating at least one active ingredient selected from below with a pharmaceutically or physiologically acceptable carrier:

(a) a peptide of the present invention;

(b) a polynucleotide encoding a peptide of the present invention in an expressible form;

(c) an APC that presents a peptide of the present invention on its surface;

(d) an exosome that presents a peptide of the present invention on its surface; and

(e) a CTL of the present invention.

In another embodiment, the present invention further provides a method or process for manufacturing a pharmaceutical composition for treating or preventing cancer, wherein the method or process comprises a step of mixing an active ingredient selected from below with a pharmaceutically or physiologically acceptable carrier:

(a) a peptide of the present invention;

(b) a polynucleotide encoding a peptide of the present invention in an expressible form;

(c) an APC that presents a peptide of the present invention on its surface;

(d) an exosome that presents a peptide of the present invention on its surface; and

(e) a CTL of the present invention.

In another embodiment, the present invention further provides a method for treating or preventing cancer, which comprises a step of administering to a subject at least one active ingredient selected from below:

(a) a peptide of the present invention;

(b) a polynucleotide encoding a peptide of the present invention in an expressible form;

(c) an APC that presents a peptide of the present invention on its surface;

(d) an exosome that presents a peptide of the present invention on its surface; and

(e) a CTL of the present invention.

In the present invention, peptides having the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32 are identified as HLA-A11-restricted epitope peptides that can induce a potent and specific immune response. Therefore, pharmaceutical compositions of the present invention comprising at least one peptide having the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32 are suitable particularly for administration to a subject having HLA-A11 (for example, HLA-A*1101) as an HLA antigen. The same applies to pharmaceutical compositions comprising a polynucleotide encoding any of these peptides (*i.e.*, polynucleotides of the present invention), an APC or exosome that presents these peptides (*i.e.*, APCs or exosomes of the present invention), or a CTL targeting these peptides (*i.e.*, CTLs of the present invention). That is, pharmaceutical compositions comprising an active ingredient in

association with a peptide having the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32 are suitable for administration to subjects having HLA-A11 (*i.e.*, HLA-A11-positive subjects). In a more preferred embodiment, the pharmaceutical composition of the present invention is a pharmaceutical composition that comprises a peptide having the amino acid sequence of SEQ ID NO: 32.

Similarly, in the present invention, peptides having the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80 and 85 are identified as HLA-A33-restricted epitope peptides that can induce a potent and specific immune response. Therefore, pharmaceutical compositions of the present invention comprising at least one peptide having the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80 and 85 are suitable particularly for administration to a subject having HLA-A33 (for example, HLA-A*3303) as an HLA antigen. The same applies to pharmaceutical compositions comprising a polynucleotide encoding any of these peptides (*i.e.*, polynucleotides of the present invention), an APC or exosome that presents these peptides (*i.e.*, APCs or exosomes of the present invention), or a CTL targeting these peptides (*i.e.*, CTLs of the present invention). That is, pharmaceutical compositions comprising an active ingredient in association with a peptide having the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80 and 85 are suitable for administration to subjects having HLA-A33 (*i.e.*, HLA-A33-positive subjects). In a more preferred embodiment, the pharmaceutical composition of the present invention is a pharmaceutical composition that comprises at least one peptide having the amino acid sequence selected from among SEQ ID NOs: 64, 67, and 77.

Similarly, in the present invention, peptides having the amino acid sequence selected from among SEQ ID NOs: 27, 30 and 52 are identified as HLA-A03-restricted epitope peptides that can induce a potent and specific immune response. Therefore, pharmaceutical compositions of the present invention comprising at least one peptide having the amino acid sequence selected from among SEQ ID NOs: 27, 30 and 52 are suitable particularly for administration to a subject having HLA-A03 (for example, HLA-A*0301) as an HLA antigen. The same applies to pharmaceutical compositions comprising a polynucleotide encoding any of these peptides (*i.e.*, polynucleotides of the present invention), an APC or exosome that presents these peptides (*i.e.*, APCs or exosomes of the present invention), or a CTL targeting these peptides (*i.e.*, CTLs of the present invention). That is, pharmaceutical compositions comprising an active ingredient in association with a peptide having the amino acid sequence selected from among SEQ ID NOs: 27, 30 and 52 are suitable for administration to subjects having HLA-A03 (*i.e.*, HLA-A03-positive subjects). In a more preferred embodiment, the pharmaceutical composition of the present invention is a pharmaceutical composition that comprises a peptide having the amino acid sequence of SEQ ID NO: 27.

Similarly, in the present invention, peptides having the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41 are identified as HLA-A01-restricted epitope peptides that can induce a potent and specific immune response. Therefore, pharmaceutical compositions of the present invention comprising at least one peptide having the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41 are suitable particularly for administration to a subject having HLA-A01 (for example, HLA-A*0101) as an HLA antigen. The same applies to pharmaceutical compositions comprising a polynucleotide encoding any of these peptides (*i.e.*, polynucleotides of the present invention), an APC or exosome that presents these peptides (*i.e.*, APCs or exosomes of the present invention), or a CTL targeting these peptides (*i.e.*, CTLs of the present invention). That is, pharmaceutical compositions comprising an active ingredient in association with a peptide having the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41 are suitable for administration to subjects having HLA-A01 (*i.e.*, HLA-A01-positive subjects). In a more preferred embodiment, the pharmaceutical composition of the present invention is a pharmaceutical composition that comprises a peptide having the amino acid sequence of SEQ ID NO: 86.

Cancers to be treated and/or prevented by pharmaceutical compositions of the present invention are not particularly limited as long as they are cancers that express KOC1, and include bladder cancer, cervical cancer, cholangiocellular cancer, chronic myeloid leukemia (CML), colon cancer, rectum cancer, esophagus cancer, diffuse gastric cancer, non-small-cell lung cancer, small-cell lung cancer, lymphoma, osteosarcoma, ovarian cancer, kidney cancer, head and neck cancer, soft tissue tumor, testis cancer and such. It is preferable to use the pharmaceutical composition of the present invention in subjects that homozygously or heterozygously have an HLA allele selected from among HLA-A11, HLA-A33, HLA-A03 and HLA-A01.

In addition to the active ingredients described above, the pharmaceutical compositions of the present invention can comprise the other peptides that have the ability to induce CTLs against cancer cells (for example, the other TAA-derived CTL-inducing peptides), the other polynucleotides encoding the other peptides, the other cells that present the other peptides, or such.

The pharmaceutical compositions of the present invention may also optionally comprise the other therapeutic substances as an active ingredient, as long as they do not inhibit the anti-tumor effects of the above-described active ingredients such as peptides of the present invention. For example, the pharmaceutical compositions of the present invention may optionally comprise anti-inflammatory compositions, analgesics, chemotherapeutics and the like. In addition to including the other therapeutic substances to a pharmaceutical composition of the present invention itself, one can also administer the pharmaceutical composition of the present invention

sequentially or concurrently with one or more other pharmaceutical compositions. The dose of the pharmaceutical composition of the present invention and the other pharmaceutical compositions depend on, for example, the type of pharmaceutical composition used and the disease being treated, as well as the scheduling and routes of administration.

It should be understood that in consideration of the formulation type, the pharmaceutical composition of the present invention may include other components conventional in the art, in addition to the ingredients specifically mentioned herein.

The present invention also provides articles of manufacture or kits that comprise a pharmaceutical composition of the present invention. The articles of manufacture or kits of the present invention can include a container that houses the pharmaceutical composition of the present invention. An example of an appropriate container includes a bottle, a vial or a test tube, but is not limited thereto. The container may be formed of various materials such as glass or plastic. A label may be attached to the container, and the disease or disease state to which the pharmaceutical composition of the present invention should be used may be described in the label. The label may also indicate directions for administration and such.

The articles of manufacture or kits of the present invention may further comprise a second container that houses pharmaceutically acceptable diluents optionally, in addition to the container that houses the pharmaceutical composition of the present invention. The articles of manufacture or kits of the present invention may further comprise the other materials desirable from a commercial standpoint and the user's perspective, such as the other buffers, diluents, filters, injection needles, syringes, package inserts with instructions for use.

As needed, the pharmaceutical composition of the present invention can be provided in a pack or dispenser device that can contain one or more units of dosage forms containing active ingredients. The pack can include, for example, a metallic foil or a plastic foil such as a blister pack. Instructions for administration can be attached to the pack or dispenser device.

(1) Pharmaceutical compositions comprising peptide(s) as an active ingredient

The pharmaceutical composition comprising a peptide of the present invention can be formulated by conventional formulation methods as needed. The pharmaceutical compositions of the present invention may comprise as needed in addition to the peptide of the present invention, carriers, excipients and such commonly used in pharmaceuticals without particular limitations. Examples of carriers that can be used in pharmaceutical compositions of the present invention include sterilized water (for example, water for injection), physiological saline, phosphate buffer, phosphate buffered saline, Tris buffered saline, 0.3% glycine, culture fluid, and such. Further, the pharmaceutical compositions of the present invention may comprise as needed stabilizers, suspensions, preservatives, surfactants, solubilizing agents, pH adjusters,

aggregation inhibitors, and such. The pharmaceutical compositions of the present invention can induce specific immunity against KOC1-expressing cancer cells, and thus can be applied for the purpose of cancer treatment or prevention (prophylaxis).

For example, the pharmaceutical compositions of the present invention can be prepared by dissolving in pharmaceutically or physiologically acceptable water-soluble carriers such as sterilized water (for example, water for injection), physiological saline, phosphate buffer, phosphate buffered saline, and Tris buffered saline and adding, as needed, stabilizers, suspensions, preservatives, surfactants, solubilizing agents, pH adjusters, aggregation inhibitors and such, and then sterilizing the peptide solution. The method of sterilizing a peptide solution is not particularly limited, and is preferably carried out by filtration sterilization. Filtration sterilization can be performed using, for example, a filtration sterilization filter of 0.22 micro-m or less in pore diameter. The filtration-sterilized peptide solution can be administered to a subject, for example, as an injection, without being limited thereto. The pharmaceutical compositions of the present invention may be prepared as a freeze-dried formulation by freeze-drying the above-described peptide solution. The freeze-dried formulation can be prepared by filling the peptide solution prepared as described above into an appropriate container such as an ampule, a vial or a plastic container, followed by freeze drying and encapsulation into the container with a wash-sterilized rubber plug or such after pressure recovery. The freeze-dried formulation can be administered to a subject after it is re-dissolved in pharmaceutically or physiologically acceptable water-soluble carriers such as sterilized water (for example, water for injection), physiological saline, phosphate buffer, phosphate buffered saline, Tris buffered saline and such before administration. Preferred examples of pharmaceutical compositions of the present invention include injections of such a filtration-sterilized peptide solution, and freeze-dried formulations that result from freeze-drying the peptide solution. The present invention further encompasses kits comprising such a freeze-dried formulation and re-dissolving solution. The present invention also encompasses kits comprising a container that houses the freeze-dried formulation, which is a pharmaceutical composition of the present invention, and a container that houses a re-dissolving solution thereof.

The pharmaceutical compositions of the present invention can comprise a combination of two or more types of the peptides of the present invention. The combination of peptides can take a cocktail form of mixed peptides, or can be conjugated with each other using standard techniques. For example, peptides can be chemically linked or expressed as single fusion polypeptide sequences. By administering a peptide of the present invention, the peptide is presented on APCs by an HLA antigen at a high density, and then subsequently CTLs that react specifically to a complex formed between the presented peptide and the HLA antigen are induced. Alternatively, APCs (for example, DCs) are removed from a subject, and subsequently

stimulated with peptides of the present invention to obtain APCs that present any of the peptides of the present invention on their cell surface. These APCs are re-administered to a subject to induce CTLs in the subject, and as a result, the aggressiveness towards KOC1-expressing cancer cells can be increased.

The pharmaceutical compositions of the present invention may also comprise an adjuvant known for effectively establishing cellular immunity. An adjuvant refers to a compound that enhances the immune response against an antigen that has immunological activity when administered together (or successively) with the antigen. Known adjuvants described in literatures, for example, Clin Microbiol Rev 1994, 7: 277-89, can be used. Examples of a suitable adjuvant include aluminum salts (aluminum phosphate, aluminum hydroxide, aluminum oxyhydroxide and such), alum, cholera toxin, Salmonella toxin, Incomplete Freund's adjuvant (IFA), Complete Freund's adjuvant (CFA), ISCOMatrix, GM-CSF and other immunostimulatory cytokines, oligodeoxynucleotide containing the CpG motif (CpG7909 and such), oil-in-water emulsions, Saponin or its derivatives (QS21 and such), lipopolysaccharide such as Lipid A or its derivatives (MPL, RC529, GLA, E6020 and such), lipopeptides, lactoferrin, flagellin, double-stranded RNA or its derivatives (poli IC and such), bacterial DNA, imidazoquinolines (Imiquimod, R848 and such), C-type lectin ligand (trehalose-6,6'-dibehenate (TDB) and such), CD1d ligand (alpha-galactosylceramide and such), squalene emulsions (MF59, AS03, AF03 and such), PLGA, and such, without being limited thereto. The adjuvant may be contained in another container separate from the pharmaceutical composition comprising a peptide of the present invention in the kits comprising the pharmaceutical composition of the present invention. In this case, the adjuvant and the pharmaceutical composition may be administered to a subject in succession, or mixed together immediately before administration to a subject. Such kits comprising a pharmaceutical composition comprising a peptide of the present invention and an adjuvant are also provided by the present invention. When the pharmaceutical composition of the present invention is a freeze-dried formulation, the kit can further comprise a re-dissolving solution. Further, the present invention provides kits comprising a container that houses a pharmaceutical composition of the present invention and a container that stores an adjuvant. The kit can further comprise as needed a container that stores the re-dissolving solution.

When an oil adjuvant is used as an adjuvant, the pharmaceutical composition of the present invention may be prepared as an emulsion. Emulsions can be prepared, for example, by mixing and stirring the peptide solution prepared as described above and an oil adjuvant. The peptide solution may be one that has been re-dissolved after freeze-drying. The emulsion may be either of the W/O-type emulsion and O/W-type emulsion, and the W/O-type emulsion is preferred for obtaining a high immune response-enhancing effect. IFA can be preferably used as

an oil adjuvant, without being limited thereto. Preparation of an emulsion can be carried out immediately before administration to a subject, and in this case, the pharmaceutical composition of the present invention may be provided as a kit comprising the peptide solution of the present invention and an oil adjuvant. When the pharmaceutical composition of the present invention is a freeze-dried formulation, the kit can further comprise a re-dissolving solution.

Further, the pharmaceutical composition of the present invention may be a liposome formulation within which a peptide of the present invention is encapsulated, a granular formulation in which a peptide is bound to beads with several micrometers in diameter, or a formulation in which a lipid is bound to a peptide.

In another embodiment of the present invention, the peptide of the present invention may also be administered in the form of a pharmaceutically acceptable salt. Preferred examples of salts include salts with alkali metals (lithium, potassium, sodium and such), salts with alkaline-earth metals (calcium, magnesium and such), salts with other metals (copper, iron, zinc, manganese and such), salts with organic bases, salts with amines, salts with organic acids (acetic acid, formic acid, propionic acid, fumaric acid, maleic acid, succinic acid, tartaric acid, citric acid, malic acid, oxalic acid, benzoic acid, methanesulfonic acid and such), and salts with inorganic acids (hydrochloric acid, phosphoric acid, hydrobromic acid, sulfuric acid, nitric acid and such). The phrase "pharmaceutically acceptable salt" used herein refers to a salt that retains the biological, physiological, pharmacological and pharmaceutical efficacy and property of the compound. Therefore, pharmaceutical compositions comprising a pharmaceutically acceptable salt of a peptide of the present invention are also encompassed by the present invention. Further, the "peptide of the present invention" also encompasses, in addition to the free peptide, pharmaceutically acceptable salts thereof.

In some embodiments, the pharmaceutical compositions of the present invention may further include a component which primes CTLs. Lipids have been identified as substances 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-glycerylcysteinyl-seryl-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).

Examples of suitable methods for administering the peptides or pharmaceutical compositions of the present invention include oral, epidermal, subcutaneous, intramuscular, intraosseous, peritoneal, and intravenous injections, as well as systemic administration or local administration to the vicinity of the targeted sites, but are not limited thereto. A preferred

administration method includes subcutaneous injection to the vicinity of lymph nodes such as the armpit or groin. The administration can be performed by single administration or boosted by multiple administrations. The peptides of the present invention can be administered to a subject in a therapeutically or pharmaceutically effective amount for treating cancer or in a therapeutically or pharmaceutically effective amount for inducing immunity (more specifically CTLs) against KOC1-expressing cancer cells. The dose of the peptides of the present invention can be appropriately adjusted according to the disease to be treated, the patient's age and weight, the method of administration and such. For each of the peptides of the present invention, the dose is usually 0.001 mg - 1000 mg, for example, 0.01 mg - 100 mg, for example, 0.1 mg - 30 mg, for example, 0.1 mg - 10 mg, for example, 0.5 mg - 5 mg. The dosing interval can be once every several days to several months, and for example, the dosing can be done in a once-per-week interval. A skilled artisan can appropriately select a suitable dose (dosage).

In a preferred embodiment, the pharmaceutical compositions of the present invention comprise a therapeutically effective amount of a peptide of the present invention and a pharmaceutically or physiologically acceptable carrier. In another embodiment, the pharmaceutical compositions of the present invention comprise a therapeutically effective amount of a peptide of the present invention, a pharmaceutically or physiologically acceptable carrier, and an adjuvant. The pharmaceutical compositions of the present invention can comprise 0.001 mg - 1000 mg, preferably 0.01 mg - 100 mg, more preferably 0.1 mg - 30 mg, even more preferably 0.1 mg - 10 mg, for example, 0.5 mg - 5 mg of a peptide of the present invention. When a pharmaceutical composition of the present invention is an injection, it can comprise a peptide of the present invention at a concentration of 0.001 mg/ml - 1000 mg/ml, preferably 0.01 mg/ml - 100 mg/ml, more preferably 0.1 mg/ml - 30 mg/ml, even more preferably 0.1 mg/ml - 10 mg/ml, for example, 0.5 mg/ml - 5 mg/ml. In this case, for example, 0.1 to 5 ml, preferably 0.5 ml to 2 ml of the pharmaceutical composition of the present invention can be administered to a subject by injection.

Further, the present invention provides methods of treating and/or preventing cancer and/or preventing postoperative recurrence thereof, which comprise administering to a subject a therapeutically effective amount of a peptide of the present invention or a pharmaceutical composition of the present invention. As described above, the peptides of the present invention can be administered to a subject in a single dose of usually 0.001 mg - 1000 mg, for example, 0.01 mg - 100 mg, for example, 0.1 mg - 30 mg, for example, 0.1 mg - 10 mg, or for example, 0.5 mg - 5 mg. In a preferred embodiment, the peptides of the present invention are administered to a subject together with an adjuvant. Further, the dosing interval can be once every several days to several months, preferably once every several days to every month, for

example, once every week or once every two weeks.

(2) Pharmaceutical compositions containing polynucleotides as the active ingredient

The pharmaceutical compositions of the present invention can also contain polynucleotides encoding the peptides of the present invention in an expressible form. Herein, the phrase "in an expressible form" means that the polynucleotide, when introduced into a cell, will be expressed as a peptide of the present invention. In an exemplified embodiment, the sequence of the polynucleotide of the present invention includes regulatory elements necessary for expression of the peptide of the present invention. The polynucleotide(s) of the present invention can be equipped with a sequence necessary 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; US Patent Nos. 5,580,859, 5,589,466, 5,804,566, 5,739,118, 5,736,524, 5,679,647; and WO98/04720. 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).

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. For example, as a vector to express the peptide of the present invention, vaccinia virus can be used. 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.

Delivery of a polynucleotide of the present invention into a patient can be either direct, in which case the patient can be directly exposed to a vector harboring the polynucleotide of the present invention, or indirect, in which case, cells are first transformed with the vector harboring the polynucleotide of the present invention *in vitro*, then the cells are transplanted into the patient. These two approaches are known, respectively, as *in vivo* and *ex vivo* gene therapies.

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 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.

Similar to peptide administration, administration of polynucleotides may be performed by oral, intradermal, subcutaneous, intravenous, intramuscular, intraosseous and/or peritoneal injection, and such. Polynucleotide administration can be a systemic administration or a local administration to the vicinity of the targeted sites. The administration can be performed by single administration or boosted by multiple administrations. The polynucleotides of the present invention can be administered to a subject in a therapeutically or pharmaceutically effective dose for inducing immunity (more specifically CTLs) against KOC1-expressing cancer cells, or in a therapeutically or pharmaceutically effective dose for treating cancer. The dose of a polynucleotide in a suitable carrier or the dose of a polynucleotide in cells transformed with a polynucleotide encoding a peptide of the present invention can be appropriately adjusted according to the disease to be treated, the patient's age and weight, the method of administration and such, and this may be usually 0.001 mg - 1000 mg, for example, 0.01 mg - 100 mg, for example, 0.1 mg - 30 mg, for example, 0.1 mg - 10 mg, or for example, 0.5 mg - 5 mg. The dosing interval can be once every several days to several months, and for example, the dosing can be done in a once-per-week interval. A skilled artisan can appropriately select a suitable dose (dosage).

X. Methods of using peptides, exosomes, APCs and CTLs

The peptides and polynucleotides of the present invention can be used to induce APCs and CTLs. CTLs can also be induced using the exosomes and APCs of the present invention. The peptides, polynucleotides, exosomes, and APCs can be used in combination with any other compound(s) as long as their CTL-inducing ability is not inhibited. Therefore, CTLs of the present invention can be induced using a pharmaceutical composition comprising any of the peptides, polynucleotides, APCs and exosomes of the present invention. Further, APCs of the present invention can be induced using a pharmaceutical composition comprising a peptide or polynucleotide of the present invention.

(1) Methods of inducing APCs

The present invention provides methods of inducing APCs having CTL-inducing ability, using a peptide(s) or polynucleotide(s) of the present invention.

The methods of the present invention comprise a step of contacting an APC with a peptide of the present invention *in vitro*, *ex vivo*, or *in vivo*. For example, a method of contacting APCs with the peptide *ex vivo* may comprise the steps below:

(a) collecting APCs from a subject; and

(b) contacting the APCs of step (a) with a peptide of the present invention.

The above-described APCs are not limited to a particular type of cell, and cells known to present a proteinaceous antigen on their cell surface to be recognized by lymphocytes, for example, DCs, Langerhans cells, macrophages, B cells, and activated T cells can be used. DCs have the most potent CTL-inducing ability among APCs, and thus it is preferable to use DCs. Any peptides of the present invention can be used by themselves or in combination with other peptides of the present invention. Further, peptides of the present invention can be used in combination with other CTL-inducing peptides (for example, other TAA-derived CTL-inducing peptides).

Meanwhile, when a peptide of the present invention is administered to a subject, APCs are contacted with the peptide *in vivo*, and as a result, APCs having a high CTL-inducing ability are induced in the body of the subject. Therefore, the methods of the present invention may comprise a step of administering a peptide of the present invention to a subject. Similarly, when a polynucleotide of the present invention is administered to a subject in an expressible form, a peptide of the present invention is expressed *in vivo*, the expressed peptide is contacted with APCs *in vivo*, and as a result APCs having a high CTL-inducing ability are induced in the body of the subject. Therefore, the present invention may also comprise a step of administering a polynucleotide of the present invention to a subject.

In order to induce APCs having CTL-inducing ability, the present invention may comprise a step of introducing a polynucleotide of the present invention into APCs. For example, the method may comprise the steps below:

(a) collecting APCs from a subject; and

(b) introducing a polynucleotide encoding a peptide of the present invention into the APCs of step (a).

Step (b) can be performed as described in the above "VI. Antigen-presenting cells (APCs)" section.

Thus, in one embodiment, the present invention provides a method of inducing APCs having CTL-inducing ability, which comprises the step (a) or (b) below:

(a) contacting APCs with a peptide of the present invention; and

(b) introducing a polynucleotide encoding a peptide of the present invention into APCs.

Furthermore, the present invention provides a method of preparing APCs having CTL-inducing ability, which comprises the step (a) or (b) below:

(a) contacting APCs with a peptide of the present invention; or

(b) introducing a polynucleotide encoding a peptide of the present invention into APCs.

The above-described methods can be performed *in vitro*, *ex vivo*, or *in vivo*, and it is preferable to perform them *in vitro* or *ex vivo*. APCs used in the above-described methods may be derived from a subject scheduled for administration of the induced APCs, or they may be derived from a different subject. When APCs derived from a subject (donor) different from the subject scheduled for administration are used, the subject of administration and the donor must have the identical HLA type. In the methods of the present invention, when a peptide having the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32 or a modified peptide thereof is used as a peptide of the present invention, the HLA type is preferably HLA-A11 (more preferably HLA-A*1101) in both the subject of administration and the donor. Alternatively, APCs used in the above-described methods are preferably APCs that express HLA-A11 (more preferably HLA-A*1101). Similarly, when a peptide having the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80 and 85 or a modified peptide thereof is used as a peptide of the present invention, the HLA is preferably HLA-A33 (more preferably HLA-A*3303) in both the subject of administration and the donor. Alternatively, APCs used in the above-described methods are preferably APCs that express HLA-A33 (more preferably HLA-A*3303). Similarly, when a peptide having the amino acid sequence selected from among SEQ ID NOs: 27, 30 and 52 or a modified peptide thereof is used as a peptide of the present invention, the HLA type is preferably HLA-A03 (more preferably HLA-A*0301) in both the subject of administration and the donor. Alternatively, APCs used in the above-described methods are preferably APCs that express HLA-A03 (more preferably HLA-A*0301). Similarly, when a peptide comprising the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41 or a modified peptide thereof is used as a peptide of the present invention, the HLA type is preferably HLA-A01 (more preferably HLA-A*0101) in both the subject of administration and the donor. Alternatively, APCs used in the above-described methods are preferably APCs that express HLA-A01 (more preferably HLA-A*0101). The APCs can be prepared using known methods from PBMCs after PBMCs are separated from blood collected from a donor by a specific gravity centrifugal method or such.

In another embodiment, the present invention also provides pharmaceutical compositions that comprise a peptide of the present invention or a polynucleotide encoding the peptide for inducing an APC(s) having CTL-inducing ability.

Alternatively, the present invention further provides use of a peptide of the present invention or a polynucleotide encoding the peptide in the manufacture of a pharmaceutical composition for inducing an APC(s) having CTL-inducing ability.

Alternatively, the present invention further provides peptides of the present invention or polynucleotides encoding the peptides for use in the induction of an APC(s) having CTL-inducing ability.

Alternatively, the present invention further provides methods or processes of manufacturing a pharmaceutical composition for inducing an APC(s), wherein the method or process comprises a step of formulating a peptide of the present invention or a polynucleotide encoding the peptide with a pharmaceutically or physiologically acceptable carrier.

In another embodiment, the present invention further provides methods or processes of manufacturing a pharmaceutical composition for inducing an APC(s) having CTL-inducing ability, wherein the method or process comprises a step of mixing a peptide of the present invention or a polynucleotide encoding the peptide with a pharmaceutically or physiologically acceptable carrier.

APCs induced by the methods of the present invention can induce CTLs specific to KOC1 (*i.e.*, CTLs of the present invention).

(2) Methods of inducing CTLs

The present invention also provides methods of inducing CTLs using peptides, polynucleotides, exosomes or APCs of the present invention. The present invention further provides methods of inducing CTLs using one or more polynucleotides encoding a polypeptide(s) that can form a T cell receptor (TCR) (*i.e.*, TCR subunit) capable of recognizing a complex of a peptide of present invention and an HLA antigen. Preferably, the methods of inducing CTLs comprise at least one steps selected from below:

(a) contacting CD8-positive T cells with antigen-presenting cells that present on their surface a complex of an HLA antigen and a peptide of present invention;

(b) contacting CD8-positive T cells with exosomes that present on its surface a complex of an HLA antigen and a peptide of present invention; and

(c) introducing into CD8-positive T cells one or more polynucleotides encoding a polypeptide(s) that can form a TCR capable of recognizing a complex of a peptide of present invention and an HLA antigen.

When a peptide(s), a polynucleotide(s), an exosome(s) or an APC(s) of the present invention is administered to a subject, CTLs are induced in the body of the subject and the strength of the immune response targeting KOC1-expressing cancer cells is enhanced. Therefore, the methods of the present invention may comprise a step of administering a peptide(s), a polynucleotide(s), an APC(s) or an exosome(s) of the present invention to a subject.

Alternatively, CTLs can be induced by using them *in vitro* or *ex vivo*. For example, the methods of the present invention may include the following steps:

(a) collecting APCs from a subject;
(b) contacting the APCs of step (a) with a peptide of the present invention; and
(c) co-culturing the APCs of step (b) with CD8-positive T cells.

The induced CTLs may be returned to the subject afterwards.

The APCs to be co-cultured with the CD8-positive T cells in step (c) above can also be prepared by introducing into APCs a polynucleotide encoding a peptide of the present invention as described above in the "VI. Antigen-presenting cells (APCs)" section. However, the APCs to be used in the methods of the present invention are not limited thereto, and any APCs that present on their surface a complex of an HLA antigen and a peptide of the present invention can be used.

In the methods of the present invention, instead of such APCs, exosomes that present on their surface a complex of an HLA antigen and a peptide of the present invention can also be used. That is, the methods of the present invention can comprise a step of co-culturing with exosomes that present on their surface a complex of an HLA antigen and a peptide of the present invention. Such exosomes can be prepared by the above-described methods in the "V. Exosomes" section.

Further, CTLs can also be induced by introducing into a CD8-positive T cell a vector comprising a polynucleotide encoding each subunit of a TCR capable of binding to a peptide of the present invention presented by an HLA antigen on the cell surface. Such transformation can be carried out as described above in the "VIII. T cell receptors (TCRs)" section.

Accordingly, in one embodiment, the present invention provides methods of inducing CTLs, comprising a step selected from below:

(a) co-culturing CD8-positive T cells with APCs that present on their surface a complex of an HLA antigen and a peptide of present invention;
(b) co-culturing CD8-positive T cells with exosomes that present on their surface a complex of an HLA antigen and a peptide of present invention; and
(c) introducing into CD8-positive T cells, a vector comprising a polynucleotide encoding each subunit of a TCR capable of binding to a peptide of the present invention presented by an HLA antigen on a cell surface.

The above-described methods can be performed *in vitro*, *ex vivo*, or *in vivo*, and it is preferable to perform them *in vitro* or *ex vivo*. APCs or exosomes and CD8-positive T cells used in the above-described methods may be derived from a subject scheduled for administration of the induced CTLs, or they may be derived from a different subject. When APCs or exosomes and CD8-positive T cells derived from a subject (donor) different from the subject scheduled for administration are used, the subject of administration and the donor must have the identical HLA type. For example, when a peptide having the amino acid sequence selected from among SEQ

ID NOs: 5, 28, 30 and 32 or a modified peptide thereof is used as peptides of the present invention, the HLA type in both the subject of administration and the donor is preferably HLA-A11 (more preferably HLA-A*1101). Alternatively, APCs or exosomes used in the above-described methods are preferably APCs or exosomes that present on their surface a complex of HLA-A11 (more preferably HLA-A*1101) and a peptide of the present invention (a peptide having the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32 or a modified peptide thereof). In this case, the induced CTLs show a specific cytotoxic activity against cells that present a complex of HLA-A11 and a peptide of the present invention (for example, KOC1-expressing HLA-A11-positive cells). Alternatively, for example, when a peptide having the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80 and 85 or a modified peptide thereof is used as peptides of the present invention, the HLA in the subject of administration and the donor is preferably both HLA-A33 (more preferably HLA-A*3303). Alternatively, APCs or exosomes used in the above-described methods are preferably APCs or exosomes that present on their surface a complex of HLA-A33 (more preferably HLA-A*3303) and a peptide of the present invention (a peptide having the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80 and 85 or a modified peptide thereof). In this case, the induced CTLs show a specific cytotoxic activity against cells that present a complex of HLA-A33 and a peptide of the present invention (for example, KOC1-expressing HLA-A33-positive cells). Alternatively, for example, when a peptide having the amino acid sequence selected from among SEQ ID NOs: 27, 30 and 52 or a modified peptide thereof is used as peptides of the present invention, the HLA type in both the subject of administration and the donor is preferably HLA-A03 (more preferably HLA-A*0301). Alternatively, APCs or exosomes used in the above-described methods are preferably APCs or exosomes that present on their surface a complex of HLA-A03 (more preferably HLA-A*0301) and a peptide of the present invention (a peptide having the amino acid sequence selected from among SEQ ID NOs: 27, 30 and 52 or a modified peptide thereof). In this case, the induced CTLs show a specific cytotoxic activity against cells that present a complex of HLA-A03 and a peptide of the present invention (for example, KOC1-expressing HLA-A03-positive cells). Alternatively, for example, when a peptide having the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41 or a modified peptide thereof is used as peptides of the present invention, the HLA type in both the subject of administration and the donor is preferably HLA-A01 (more preferably HLA-A*0101). Alternatively, APCs or exosomes used in the above-described methods are preferably APCs or exosomes that present on their surface a complex of HLA-A01 (more preferably HLA-A*0101) and a peptide of the present invention (a peptide having the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41 or a modified peptide thereof). In this case, the induced CTLs show a specific

cytotoxic activity against cells that present a complex of HLA-A01 and a peptide of the present invention (for example, KOC1-expressing HLA-A01-positive cells).

In another embodiment, the present invention also provides compositions or pharmaceutical compositions for inducing CTLs, comprising at least one active ingredient selected from below:

(a) a peptide of the present invention;
(b) a polynucleotide encoding a peptide of the present invention in an expressible form;
(c) an APC that presents on its surface a peptide of the present invention; and
(d) an exosome that presents on its surface a peptide of the present invention.

In another embodiment, the present invention also provides use of an active ingredient selected from below in the manufacture of compositions or pharmaceutical compositions for inducing CTLs:

(a) a peptide of the present invention;
(b) a polynucleotide encoding a peptide of the present invention in an expressible form;
(c) an APC that presents on its surface a peptide of the present invention; and
(d) an exosome that presents on its surface a peptide of the present invention.

Alternatively, the present invention further provides an active ingredient selected from below for use in inducing CTLs:

(a) a peptide of the present invention;
(b) a polynucleotide encoding a peptide of the present invention in an expressible form;
(c) an APC that presents on its surface a peptide of the present invention; and
(d) an exosome that presents on its surface a peptide of the present invention.

Alternatively, the present invention further provides a method or process for manufacturing a composition or pharmaceutical composition for inducing CTLs, which is a method or process that comprises a step of formulating an active ingredient selected from below with a pharmaceutically or physiologically acceptable carrier:

(a) a peptide of the present invention;
(b) a polynucleotide encoding a peptide of the present invention in an expressible form;
(c) an APC that presents on its surface a peptide of the present invention; and
(d) an exosome that presents on its surface a peptide of the present invention.

In another embodiment, the present invention further provides a method or process for manufacturing a composition or pharmaceutical composition for inducing CTLs, which is a method or process that comprises a step of mixing an active ingredient selected from below with a pharmaceutically or physiologically acceptable carrier:

(a) a peptide of the present invention;
(b) a polynucleotide encoding a peptide of the present invention in an expressible form;

(c) an APC that presents on its surface a peptide of the present invention; and
(d) an exosome that presents on its surface a peptide of the present invention.

XI. Methods of inducing an immune response

The present invention further provides methods of inducing an immune response against KOC1-expressing cancers. Applicable cancers include bladder cancer, cervical cancer, cholangiocellular cancer, chronic myeloid leukemia (CML), colon cancer, rectum cancer, esophagus cancer, diffuse gastric cancer, non-small-cell lung cancer, small-cell lung cancer, lymphoma, osteosarcoma, ovarian cancer, kidney cancer, head and neck cancer, soft tissue tumor, testis cancer and such, but are not limited thereto. It is preferable that the cancer expresses at least one HLA selected from among HLA-A11, HLA-A33, HLA-A03 and HLA-A01.

The present invention further provides methods of inducing an immune response against KOC1-expressing cancer cells. KOC1 is recognized to be overexpressed in various types of cancers described above. Thus, when an immune response against KOC1-expressing cancer cells is induced, proliferation of the cancer cells is inhibited as a result. Accordingly, the present invention further provides methods of inhibiting proliferation of KOC1-expressing cancer cells. The methods of the present invention are suitable, in particular, for inhibiting proliferation of cancer cells expressing KOC1 and at least one HLA selected from among HLA-A11, HLA-A33, HLA-A03 and HLA-A01.

The methods of the present invention may comprise a step of administering a composition comprising any of the peptides of the present invention or a polynucleotide(s) encoding the peptide(s). The methods of the present invention also contemplate administration of APCs or exosomes presenting any of the peptides of the present invention. The details can be referred to the “IX. Pharmaceutical compositions” section, particularly portions describing regarding use of the pharmaceutical compositions of the present invention as vaccines. In addition, exosomes and APCs that can be used in the methods of the present invention for inducing an immune response are described in detail in “V. Exosomes”, “VI. Antigen-presenting cells (APCs)” and in Items (1) and (2) of “X. Methods of using peptides, exosomes, APCs and CTLs” described above.

In another embodiment, the present invention provides pharmaceutical compositions or vaccines for inducing an immune response against KOC1-expressing cancers, wherein the pharmaceutical composition or vaccine comprises an active ingredient selected from below:
(a) a peptide of the present invention;
(b) a polynucleotide encoding a peptide of the present invention in an expressible form;
(c) an APC that presents on its surface a peptide of the present invention;
(d) an exosome that presents on its surface a peptide of the present invention; and

(e) a CTL of the present invention.

Alternatively, the present invention also provides pharmaceutical compositions or vaccines for inducing an immune response against KOC1-expressing cancer cells, wherein the pharmaceutical composition or vaccine comprises an active ingredient selected from below:

(a) a peptide of the present invention;

(b) a polynucleotide encoding a peptide of the present invention in an expressible form;

(c) an APC that presents on its surface a peptide of the present invention;

(d) an exosome that presents on its surface a peptide of the present invention; and

(e) a CTL of the present invention.

Alternatively, the present invention further provides pharmaceutical compositions or vaccines for inhibiting proliferation of KOC1-expressing cancer cells, wherein the pharmaceutical composition or vaccine comprises an active ingredient selected from below:

(a) a peptide of the present invention;

(b) a polynucleotide encoding a peptide of the present invention in an expressible form;

(c) an APC that presents on its surface a peptide of the present invention;

(d) an exosome that presents on its surface a peptide of the present invention; and

(e) a CTL of the present invention.

In another embodiment, the present invention provides use of an active ingredient selected from below in the manufacture of pharmaceutical compositions or vaccines for inducing an immune response against KOC1-expressing cancers:

(a) a peptide of the present invention;

(b) a polynucleotide encoding a peptide of the present invention in an expressible form;

(c) an APC that presents on its surface a peptide of the present invention;

(d) an exosome that presents on its surface a peptide of the present invention; and

(e) a CTL of the present invention.

Alternatively, the present invention also provides use of an active ingredient selected from below in the manufacture of pharmaceutical compositions or vaccines for inducing an immune response against KOC1-expressing cancer cells:

(a) a peptide of the present invention;

(b) a polynucleotide encoding a peptide of the present invention in an expressible form;

(c) an APC that presents on its surface a peptide of the present invention;

(d) an exosome that presents on its surface a peptide of the present invention; and

(e) a CTL of the present invention.

Alternatively, the present invention further provides use of an active ingredient selected from below in the manufacture of pharmaceutical compositions or vaccines for inhibiting proliferation of KOC1-expressing cancer cells:

(a) a peptide of the present invention;
(b) a polynucleotide encoding a peptide of the present invention in an expressible form;
(c) an APC that presents on its surface a peptide of the present invention;
(d) an exosome that presents on its surface a peptide of the present invention; and
(e) a CTL of the present invention.

The present invention further provides methods or processes for manufacturing pharmaceutical compositions that induce an immune response against KOC1-expressing cancers, which is a method that may comprise a step of mixing or formulating a peptide or polynucleotide of the present invention with a pharmaceutically acceptable carrier.

Alternatively, the present invention provides methods for inhibiting proliferation of KOC1-expressing cancer cells or methods of inducing an immune response against KOC1-expressing cancers, which comprises a step of administering to a subject vaccines or pharmaceutical compositions comprising an active ingredient selected from below:

(a) a peptide of the present invention;
(b) a polynucleotide encoding a peptide of the present invention in an expressible form;
(c) an APC that presents a peptide of the present invention on its surface;
(d) an exosome that presents a peptide of the present invention on its surface; and
(e) a CTL of the present invention.

In the context of the present invention, KOC1-expressing cancers can be treated by administering a peptide, a polypeptide, an APC, an exosome and/or a CTL of the present invention. Alternatively, an immune response against KOC1-expressing cancers can be induced by administering a peptide, a polypeptide, an APC, an exosome and/or a CTL of the present invention. Examples of such cancers include bladder cancer, cervical cancer, cholangiocellular cancer, chronic myeloid leukemia (CML), colon cancer, rectum cancer, esophagus cancer, diffuse gastric cancer, non-small-cell lung cancer, small-cell lung cancer, lymphoma, osteosarcoma, ovarian cancer, kidney cancer, head and neck cancer, soft tissue tumor, testis cancer and such, but are not limited thereto. Further, an immune response against KOC1-expressing cancer cells can be induced by administering a peptide, a polypeptide, an APC, an exosome and/or a CTL of the present invention. Therefore, before administering a vaccine or pharmaceutical composition comprising an active ingredient described above, it is preferable to confirm whether the level of KOC1 expression at a diseased site in the subject to be treated is augmented or not.

Thus, in one embodiment, the present invention provides a method of treating a KOC1-expressing cancer in a patient in need of the cancer treatment, wherein the method comprises the steps below:

(i) measuring the level of KOC1 expression in a biological sample collected from the diseased site of a subject with cancer;

(ii) identifying a subject with KOC1-expressing cancer based on the KOC1 expression level measured in (i); and

(iii) administering to the subject with KOC1-expressing cancer at least one ingredient selected from the group consisting of (a) to (e) above.

Alternatively, the present invention further provides vaccines and pharmaceutical compositions comprising at least one active ingredient selected from the group consisting of (a) to (e) above for administration to a subject with KOC1-expressing cancer. The present invention further provides a method of identifying or selecting a subject to be treated with at least one active ingredient selected from the group consisting of (a) to (e) above, wherein the method comprises the steps below:

(i) measuring the level of KOC1 expression in a biological sample collected from the diseased site of a subject with cancer;

(ii) identifying a subject with KOC1-expressing cancer based on the KOC1 expression level measured in (i); and

(iii) identifying or selecting the subject identified in (ii) as a subject who may be treated with at least one active ingredient selected from the group consisting of (a) to (e) above.

Biological samples collected from a subject for measuring the KOC1 expression level in the above-described methods are not particularly limited, and for example, tissue samples containing cancer cells collected by biopsy or such can be preferably used. The KOC1 expression level in a biological sample can be measured by known methods, and for example, methods that detect transcription products of the KOC1 gene by probes or PCR methods (for example, cDNA microarray method, Northern blot method, RT-PCR method or such), methods that detect translation products of the KOC1 gene by antibodies or such (for example, Western blot method, immunostaining method or such), and such can be used. Further, biological samples may be blood samples, and in this case, the blood level of an antibody against KOC1 is measured, and the KOC1 expression level at a diseased site may be assessed based on the blood level. The blood level of an antibody against KOC1 or a fragment thereof can be measured using known methods, and for example, enzyme immunoassay (EIA), enzyme-linked immunosorbent assay (ELISA), radioimmunoassay (RIA) and such using the KOC1 protein or a peptide of the present invention as an antigen can be used.

Normally, in tissues and cells that do not express KOC1, there is almost no detection of KOC1 transcription products and translation products. Thus, when a transcription product or a translation product of KOC1 is detected in cancer cells or a tissue sample containing cancer cells collected from a subject, one can determine that the subject's cancer expresses KOC1. In blood

samples of a subject that does not have KOC1-expressing cancer, there is almost no detection of antibodies against KOC1 or fragments thereof. Thus, when antibodies against KOC1 or fragments thereof are detected in a blood sample collected from a subject, one can determine that the subject's cancer expresses KOC1. Whether a subject's cancer expresses KOC1 or not may also be determined by comparison with the measurement results of the same type of biological material collected from a non-cancerous site of the subject or the same type of biological material collected from a subject who does not have cancer (normal control sample). That is, in comparison with the level of the target of measurement in a normal control sample (normal control level), when the level in the biological sample of the test subject is elevated, the subject's cancer is assessed to be expressing KOC1. For example, when the amount of the target of measurement detected is increased by at least 10% or higher in comparison with the normal control level, the subject's cancer may be assessed to be expressing KOC1. It is desirable that the amount of the target of measurement detected is increased by preferably 25% or higher, and more preferably 50% or higher than the normal control level. Further, the amount of a transcription product or a translation product of KOC1 detected may be evaluated by normalizing against the detected amount of a known housekeeping gene such as beta-Actin, glyceraldehyde-3-phosphate dehydrogenase, or ribosomal protein P1.

In a preferred embodiment, it is preferable to confirm the HLA type of the subject before administering at least one active ingredient selected from the group consisting of (a) to (e) above. For example, for the subjects to be administered with an active ingredient in association with a peptide having the amino acid sequence selected from among SEQ ID NOs: 5, 28, 30 and 32, it is preferable to select HLA-A11-positive subjects. For the subjects to be administered with an active ingredient in association with a peptide having the amino acid sequence selected from among SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80 and 85, it is preferable to select HLA-A33-positive subjects. For the subjects to be administered with an active ingredient in association with a peptide having the amino acid sequence selected from among SEQ ID NOs: 27, 30 and 52, it is preferable to select HLA-A03-positive subjects. For the subjects to be administered with an active ingredient in association with a peptide having the amino acid sequence selected from among SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41, it is preferable to select HLA-A01-positive subjects.

The present invention further provides complexes of a peptide of the present invention and HLA. The complexes of the present invention described above may be monomers or multimers. When a complex of the present invention is a multimer, the number of polymerization is not particularly limited, and it can be a multimer of any number of polymerization. Examples include a tetramer, pentamer, hexamer and such, but are not limited thereto. The multimers of the present invention also encompass dextramers (WO2002/072631)

and streptamers (Knabel M *et al.*, Nat Med. 2002 Jun; 8(6): 631-7.). Complexes of a peptide of the present invention and HLA can be prepared according to known methods (for example, Altman JD *et al.*, Science.1996, 274(5284): 94-6; WO2002/072631; WO2009/003492; Knabel M *et al.*, Nat Med. 2002 Jun; 8(6): 631-7, and such). The complexes of the present invention, for example, can be used in the quantification of CTLs specific to a peptide of the present invention. For example, a blood sample is collected from a subject administered with a pharmaceutical composition of the present invention, and CD4-negative cells are prepared after separation of PBMCs and contacted with a fluorescent dye-conjugated complex of the present invention. Then, the percentage of CTLs specific to a peptide of the present invention can be measured by flow cytometry analysis. For example, immune response-inducing effects by a pharmaceutical composition of the present invention can be monitored by measuring the specific CTLs against a peptide of the present invention before, during and/or after administration of the pharmaceutical composition of the present invention.

XII. Antibodies

The present invention further provides antibodies that bind to the peptide of the present invention. Preferable antibodies bind specifically to a peptide of the present invention, but do not bind (or weakly bind) to one that is not the peptide of the present invention. In another embodiment, such an antibody may include an antibody that recognizes a peptide in the context of HLA molecules, *i.e.*, an antibody that binds to a peptide-MHC complex. The binding specificity of an antibody can be confirmed by inhibition assay. That is, if the binding between an antibody to be analyzed and a full-length KOC1 polypeptide is inhibited in the presence of a peptide of the present invention, this antibody is shown to specifically bind to the peptide of the present invention. Antibodies against peptides of the present invention can be used in assays of disease diagnosis and prognosis, as well as subject selection for administration of the pharmaceutical compositions of the present invention and monitoring of the pharmaceutical compositions of the present invention.

The present invention also provides various immunological assays for detecting and/or quantifying peptides of the present invention or fragments thereof. Such immunological assays include radioimmunoassay, immunochromatography, enzyme-linked immunosorbent assay (ELISA), enzyme-linked immunofluorescence assay (ELIFA) and such, without being limited thereto, and are performed within the scope of the various immunological assay formats well known in the art.

The antibodies of the present invention can be used in immunological imaging methods that can detect KOC1-epxressing cancers, and examples thereof include radioactive scintigraphic imaging using a labelled antibody of the present invention, without being limited thereto. Such

assay methods are used clinically in the detection, monitoring, and prognosis of KOC1-expressing cancers; and examples of such cancer include bladder cancer, cervical cancer, cholangiocellular cancer, chronic myeloid leukemia (CML), colon cancer, rectum cancer, esophagus cancer, diffuse gastric cancer, non-small-cell lung cancer, small-cell lung cancer, lymphoma, osteosarcoma, ovarian cancer, kidney cancer, head and neck cancer, soft tissue tumor, testis cancer and such, without being limited thereto.

The antibodies of the present invention can be used in any arbitrary form such as monoclonal antibodies or polyclonal antibodies, and may further include anti-sera obtained by immunizing an animal such as a rabbit with a peptide of the present invention, all classes of polyclonal antibodies and monoclonal antibodies, human antibodies, as well as chimeric antibodies and humanized antibodies generated through gene recombination.

The peptide of the present invention or a fragment thereof used as an antigen for obtaining antibodies can be obtained by chemical synthesis or genetic engineering techniques based on the amino acid sequences disclosed herein.

The peptide used as an immunizing antigen may be a peptide of the present invention or a fragment of a peptide of the present invention. Further, the peptide may be bound to or conjugated with a carrier for increasing immunogenicity. Keyhole limpet hemocyanin (KLH) is well-known as a carrier. Methods for binding KLH to a peptide are also well known in the art.

Any mammal can be immunized with an antigen described above, and it is preferable to consider the compatibility with the parent cell used in cell fusion when generating a monoclonal antibody. Generally, animals of the order Rodentia, Lagomorpha or Primate can be used. Animals of the order Rodentia include, for example, mice, rats and hamsters. Animals of the order Lagomorpha include, for example, rabbits. Animals of the order Primate include, for example, Catarrhini monkeys (old world monkeys) such as cynomolgus monkey (*Macaca fascicularis*), rhesus monkeys, hamadryas, and chimpanzee.

Methods of immunizing animals with an antigen are known in the art. Intraperitoneal injection and subcutaneous injection of an antigen are standard methods for immunizing mammals. More specifically, an antigen is diluted and suspended in an appropriate amount of phosphate buffered saline (PBS), physiological saline, or such. As needed, an antigen suspension solution can be administered to mammals after being mixed with an appropriate amount of a standard adjuvant such as Freund's complete adjuvant and emulsified. Then, it is preferable to administer the antigen mixed with an appropriate amount of a Freund's incomplete adjuvant several times every 4 to 21 days. A suitable carrier may be used for immunization. After the above immunization, the serum can be examined by standard method with respect to increase in the quantity of the desired antibody.

Polyclonal antibodies against a peptide of the present invention can be prepared by collecting blood from mammals that have been confirmed with an increase in the serum level of the desired antibody after immunization, and separating the serum from blood by any conventional method. A polyclonal antibody may be a polyclonal antibody-containing serum, or a polyclonal antibody-containing fraction may be isolated from the serum. Immunoglobulin G or M can be prepared from fractions that recognize only a peptide of the present invention by, for example, using an affinity column conjugated with the peptide of the present invention, and then further purifying the fractions using a protein A or protein G column.

In order to prepare monoclonal antibodies, upon confirming an increase in the serum level of the desired antibody after immunization, immune cells are collected from the mammals and subjected to cell fusion. Immune cells used for cell fusion may be preferably obtained from the spleen. For the other parent cells fused with the above immune cells, for example, a mammalian myeloma cell, preferably a myeloma cell that has acquired a property for drug selection of fusion cells can be used.

The above immune cells can be fused with myeloma cells by following known methods, for example, the method of Milstein *et al.* (Galfre and Milstein, Methods Enzymol 73: 3-46 (1981)).

Hybridomas obtained by cell fusion can be selected by culturing them in a standard selection medium such as the HAT medium (a medium containing hypoxanthine, aminopterin and thymidine). Cell culturing is continued in the HAT medium for a sufficient period of time (for example, several days to several weeks) to allow death of all other cells (non-fused cells) besides the desired hybridomas. Then, hybridoma cells producing the desired antibody can be screened and cloned by performing a standard limiting dilution.

In addition to the above methods of immunizing a non-human animal with an antigen for hybridoma preparation, human lymphocytes such as EB virus-infected lymphocytes can be immunized *in vitro* with a peptide, cells expressing the peptide, or lysates thereof. Then, the immunized lymphocytes can be fused with immortalized human-derived myeloma cells such as U266 to obtain hybridomas producing a desired human antibody capable of binding to the peptide (JPS63-17688).

Next, the obtained hybridoma is transplanted into the abdominal cavity of a mouse, and the ascites is extracted. The obtained monoclonal antibody can be purified by, for example, ammonium sulfate precipitation, protein A or protein G column, DEAE ion-exchange chromatography, or affinity column conjugated with the peptide of the present invention.

Alternatively, antibody-producing immune cells such as the immunized lymphocytes can be immortalized by a cancer gene and used for the preparation of monoclonal antibodies.

The monoclonal antibodies obtained as such can also be prepared by recombination using genetic engineering techniques (see, *e.g.*, Borrebaeck and Larrick, Therapeutic Monoclonal Antibodies published in United Kingdom by MacMillan Publishers LTD (1990)). For example, an antibody-encoding DNA can be cloned from immune cells such as antibody-producing hybridoma or immunized lymphocytes and inserted into a suitable vector, and then this is introduced into host cells to prepare a recombinant antibody. The present invention also provides recombinant antibodies prepared as described above.

Further, the antibodies of the present invention may be antibody fragments or modified antibodies, as long as they bind to the peptides of the present invention. For example, it is desirable that the antibody fragment contains an antigen-binding site(s) of the antibodies. Specifically, the antibody fragments may be Fab, $F(ab')_2$, Fv, or a single chain Fv(scFv) in which Fv fragments derived from an H chain and an L chain are linked with a suitable linker (Huston *et al.*, Proc Natl Acad Sci USA 85: 5879-83 (1988)). More specifically, antibody fragments may be generated by treating an antibody with an enzyme such as papain or pepsin. Alternatively, a gene encoding an antibody fragment may be constructed, inserted into an expression vector, and expressed in an appropriate host cell (see, *e.g.*, Co *et al.*, J Immunol 152: 2968-76 (1994); Better and Horwitz, Methods Enzymol 178: 476-96 (1989); Pluckthun and Skerra, Methods Enzymol 178: 497-515 (1989); Lamoyi, Methods Enzymol 121: 652-63 (1986); Rousseaux *et al.*, Methods Enzymol 121: 663-9 (1986); Bird and Walker, Trends Biotechnol 9: 132-7 (1991)).

Antibodies may be modified by conjugation with various molecules such as polyethyleneglycol (PEG). The present invention provides such modified antibodies. Modified antibodies can be obtained by chemically modifying the antibodies. These modification methods are conventional in the art.

Alternatively, the antibodies of the present invention can be obtained as chimeric antibodies of a non-human antibody-derived variable region and a human antibody-derived constant region, or as humanized antibodies comprising a non-human antibody-derived complementarity determining region (CDR) and a human antibody-derived framework region (FR) and constant region. Such antibodies can be prepared according to known techniques. Humanization can be carried out by substituting a human antibody sequence(s) with a corresponding non-human antibody CDR sequence(s) (see, *e.g.*, Verhoeyen *et al.*, Science 239: 1534-6 (1988)). Thus, such humanized antibodies are chimeric antibodies in which the substantially less than an intact human variable domain has been substituted with a corresponding sequence from a non-human species.

Intact human antibodies comprising a human variable region in addition to the human framework and constant regions can also be used. Such antibodies can be generated using various techniques known in the art. For example, *in vitro* methods include use of recombinant

libraries of human antibody fragments presented on bacteriophages (for example, Hoogenboom & Winter, J. Mol. Biol. 227: 381 (1991)). Similarly, human antibodies can also be generated by introducing human immunoglobulin gene loci into transgenic animals, for example, mice, in which the endogenous immunoglobulin genes have been partially or completely inactivated. This approach is described in, for example, US Patent Nos. 6,150,584, 5,545,807, 5,545,806, 5,569,825, 5,625,126, 5,633,425 and 5,661,016.

Antibodies obtained as described above may be purified to homogeneity. For example, antibody separation and purification can be performed according to separation methods and purification methods used for general proteins. For example, an antibody can be separated and isolated by appropriately selecting and combining use of column chromatographies such as affinity chromatography, filter, ultrafiltration, salting-out, dialysis, SDS-polyacrylamide gel electrophoresis and isoelectric focusing electrophoresis (Antibodies: A Laboratory Manual. Ed Harlow and David Lane, Cold Spring Harbor Laboratory (1988)), but are not limited thereto. Protein A column and protein G column can be used as the affinity column. Exemplary protein A columns to be used include, for example, Hyper D, POROS and Sepharose F.F. (Pharmacia).

Besides affinity chromatography, exemplary chromatography includes, for example, ion-exchange chromatography, hydrophobic chromatography, gel filtration, reversed-phase chromatography, adsorption chromatography and such (Strategies for Protein Purification and Characterization: A Laboratory Course Manual. Ed Daniel R. Marshak *et al.*, Cold Spring Harbor Laboratory Press (1996)). The chromatography procedures can be carried out by liquid-phase chromatography such as HPLC and FPLC.

The antigen-binding activity of an antibody of the present invention can be measured, for example, by using absorbance measurement, enzyme-linked immunosorbent assay (ELISA), enzyme immunoassay (EIA), radioimmunoassay (RIA), and/or immunofluorescence (IF). In the case of ELISA, an antibody of the present invention is immobilized onto a plate, a peptide of the present invention is applied to the plate, and then a sample containing the desired antibody, such as culture supernatant of antibody-producing cells or purified antibodies, is applied. Next, a secondary antibody that recognizes the primary antibody and is labelled with an enzyme such as alkaline phosphatase is applied and the plate is incubated. Then, after washing, an enzyme substrate such as *p*-nitrophenyl phosphate is applied to the plate, and the antigen-binding activity of the sample is evaluated by measuring absorbance. To assess the binding activity of an antibody, peptide fragments such as C-terminal or N-terminal fragments may be used as an antigen. BIAcore (Pharmacia) may be used to evaluate the activity of an antibody of the present invention.

It is possible to detect or measure a peptide of the present invention using the above methods, by exposing an antibody of the present invention to a sample assumed to contain the

peptide of the present invention, and detecting or measuring an immune complex formed between the antibody and the peptide.

For example, an antibody of the present invention can be used to detect a peptide of the present invention present in the blood sample (for example, serum sample) of a subject. Alternatively, an antibody of the present invention present in the blood sample (for example, serum sample) of a subject can also be detected using a peptide of the present invention. The result of measuring a peptide of the present invention or an antibody of the present invention in the blood sample of a subject can be utilized to the subject selection for administration of the pharmaceutical compositions of the present invention or monitoring of the efficacy of the pharmaceutical compositions of the present invention. In addition, it has been reported that patients having an antibody against a peptide administered as vaccine may have high responsiveness to the vaccine. Therefore, the peptide of the present invention can be utilized as an immunoassay antigen for selecting a patient with high responsiveness when the peptide is administered as a vaccine using an antibody of the patient as an index.

XIII. Vectors and host cells

The present invention provides vectors comprising a polynucleotide encoding a peptide of the present invention and host cells introduced with the vectors. A vector of the present invention may be used to keep a polynucleotide of the present invention in a host cell, to express a peptide of the present invention in a host cell, or to administer a polynucleotide of the present invention for gene therapy.

When *E. coli* is a host cell and a vector is amplified and produced in a large amount in *E. coli* (for example, JM109, DH5-alpha, HB101 or XL1-Blue), the vector needs to have a "replication origin" for amplification in *E. coli* and a marker gene for selection of transformed *E. coli* (for example, a drug resistance gene selected by a drug such as ampicillin, tetracycline, kanamycin, chloramphenicol). For example, the M13-series vectors, pUC-series vectors, pBR322, pBluescript, pCR-Script and such can be used. In addition, pGEM-T, pDIRECT and pT7 can be used for cloning as well as the above vectors. When a vector is used in the production of a peptide of the present invention, an expression vector can be used. For example, an expression vector for expression in *E. coli* needs to have the above features for amplification in *E. coli*. When *E. coli* such as JM109, DH5-alpha, HB101 or XL1-Blue are used as a host cell, the vector needs to have a promoter, for example, lacZ promoter (Ward *et al.*, Nature 341: 544-6 (1989); FASEB J 6: 2422-7 (1989)), araB promoter (Better *et al.*, Science 240: 1041-3 (1988)), T7 promoter or the like, that can efficiently express the desired gene in *E. coli*. In that respect, pGEX-5X-1 (Pharmacia), "QIAexpress system" (Qiagen), pEGFP and pET (in this case, the host is preferably BL21 which expresses T7 RNA polymerase), for example, can be used instead of

the above vectors. Additionally, the vector may contain a signal sequence for peptide secretion. An exemplary signal sequence that directs the peptide to be secreted to the periplasm of the *E. coli* is the pelB signal sequence (Lei *et al.*, J Bacteriol 169: 4379 (1987)). Means for introducing the vectors into the target host cells include, for example, the calcium chloride method and the electroporation method.

In addition to *E. coli*, for example, expression vectors derived from mammals (for example, pcDNA3 (Invitrogen) and pEGF-BOS (Nucleic Acids Res 18(17): 5322 (1990)), pEF, pCDM8), expression vectors derived from insect cells (for example, "Bac-to-BAC baculovirus expression system" (GIBCO BRL), pBacPAK8), expression vectors derived from plants (*e.g.*, pMH1, pMH2), expression vectors derived from animal viruses (*e.g.*, pHSV, pMV, pAdexLcw), expression vectors derived from retroviruses (*e.g.*, pZIpneo), expression vectors derived from yeast (*e.g.*, "Pichia Expression Kit" (Invitrogen), pNV11, SP-Q01) and expression vectors derived from Bacillus subtilis (*e.g.*, pPL608, pKTH50) can be used for producing the polypeptide of the present invention.

In order to express the vector in animal cells such as CHO, COS or NIH3T3 cells, the vector needs to carry a promoter necessary for expression in such cells, for example, the SV40 promoter (Mulligan *et al.*, Nature 277: 108 (1979)), the MMLV-LTR promoter, the EF1-alpha promoter (Mizushima *et al.*, Nucleic Acids Res 18: 5322 (1990)), the CMV promoter and the like, and preferably a marker gene for selecting transformants (for example, a drug resistance gene selected by a drug (*e.g.*, neomycin, G418)). Examples of known vectors with these characteristics include, for example, pMAM, pDR2, pBK-RSV, pBK-CMV, pOPRSV and pOP13.

The embodiments of the present invention are exemplified below based on the above explanation; however, the present invention is not limited to these embodiments.

[1] A peptide of less than 15 amino acids having cytotoxic T cell (CTL)-inducing ability, which comprises the amino acid sequence selected from the group of:

(a) the amino acid sequence selected from the group consisting of SEQ ID NOs: 5, 28, 30, 32, 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, 85, 27, 86, 87, 90, 92, 46, 95 and 41; and

(b) the amino acid sequence in which one, two or several amino acids are substituted, deleted, inserted and/or added to the amino acid sequence selected from the group consisting of SEQ ID NOs: 5, 28, 30, 32, 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, 85, 27, 86, 87, 90, 92, 46, 95 and 41.

[2] The peptide of [1], which is selected from the group consisting of (i) to (iv) below:

(i) a peptide comprising the amino acid sequence in which one or more substitution(s) selected from the group consisting of (a) to (d) below is introduced into the amino acid sequence selected from the group consisting of SEQ ID NOs: 5, 28, 30 and 32:

(a) the second amino acid from the N terminus is substituted with an amino acid selected from the group consisting of threonine, valine, isoleucine, leucine, phenylalanine and tyrosine;

(b) the third amino acid from the N terminus is substituted with an amino acid selected from the group consisting of leucine, phenylalanine, tyrosine, isoleucine and alanine;

(c) the seventh amino acid from the N terminus is substituted with an amino acid selected from the group consisting of leucine, isoleucine, tyrosine, valine and phenylalanine; and

(d) the C-terminal amino acid is substituted with an amino acid selected from the group consisting of lysine and arginine;

(ii) a peptide comprising the amino acid sequence in which one or more substitution(s) selected from the group consisting of (a) to (c) below is introduced into the amino acid sequence selected from the group consisting of SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80 and 85:

(a) the first amino acid from the N terminus is substituted with an amino acid selected from the group consisting of aspartic acid and glutamic acid;

(b) the second amino acid from the N terminus is substituted with an amino acid selected from the group consisting of phenylalanine, tyrosine, alanine, isoleucine, leucine and valine; and

(c) the C-terminal amino acid is substituted with an amino acid selected from the group consisting of arginine and lysine;

(iii) a peptide comprising the amino acid sequence in which one or more substitution(s) selected from the group consisting of (a) to (b) below is introduced into the amino acid sequence selected from the group consisting of SEQ ID NOs: 27, 30 and 52:

(a) the second amino acid from the N terminus is substituted with an amino acid selected from the group consisting of leucine, methionine, valine, alanine, isoleucine, serine and threonine; and

(b) the C-terminal amino acid is substituted with an amino acid selected from the group consisting of arginine, lysine, tyrosine and phenylalanine; and

(iv) a peptide comprising the amino acid sequence in which one or more substitution(s) selected from the group consisting of (a) to (c) below is introduced into the amino acid sequence selected from the group consisting of SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41:

(a) the second amino acid from the N terminus is substituted with an amino acid selected from the group consisting of threonine and serine;

(b) the third amino acid from the N terminus is substituted with an amino acid selected from the group consisting of aspartic acid and glutamic acid; and

(c) the C-terminal amino acid is substituted with tyrosine.

[3] The peptide of [1], which consists of the amino acid sequence selected from the group consisting of SEQ ID NOs: 5, 28, 30, 32, 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, 85, 27, 86, 87, 90, 92, 46, 95 and 41.

[4] A polynucleotide, which encodes the peptide of any one of [1] to [3].

[5] A composition comprising a pharmaceutically acceptable carrier and at least one ingredient selected from the group consisting of (a) to (e) below:

(a) one or more types of peptides of any one of [1] to [3];

(b) one or more types of polynucleotides encoding the peptide(s) of any one of [1] to [3] in an expressible form;

(c) an antigen-presenting cell (APC) that presents on its cell surface a complex of the peptide of any one of [1] to [3] and an HLA antigen;

(d) an exosome that presents on its cell surface a complex of the peptide of any one of [1] to [3] and an HLA antigen; and

(e) a CTL that targets the peptide of any one of [1] to [3].

[6] The composition of [5], which is a composition for inducing a CTL(s), wherein the ingredient is at least one ingredient selected from the group consisting of (a) to (d) below:

(a) one or more types of peptides of any one of [1] to [3];

(b) one or more types of polynucleotides encoding the peptide(s) of any one of [1] to [3] in an expressible form;

(c) an antigen-presenting cell (APC) that presents on its cell surface a complex of the peptide of any one of [1] to [3] and an HLA antigen; and

(d) an exosome that presents on its cell surface a complex of the peptide of any one of [1] to [3] and an HLA antigen.

[7] The composition of [5], which is a pharmaceutical composition.

[8] The composition of [7], which is for one or more uses selected from the group consisting of (i) cancer treatment, (ii) cancer prevention (prophylaxis) and (iii) prevention (prophylaxis) of postoperative cancer recurrence.

[9] The composition of [7], which is for inducing an immune response against cancer.

[10] The composition of [8] or [9], wherein the cancer is selected from the group consisting of bladder cancer, cervical cancer, cholangiocellular cancer, chronic myeloid leukemia (CML), colon cancer, rectum cancer, esophagus cancer, diffuse gastric cancer, non-small-cell lung cancer, small-cell lung cancer, lymphoma, osteosarcoma, ovarian cancer, kidney cancer, head and neck cancer, soft tissue tumor and testis cancer.

[11] The composition of any one of [5] to [10], which is formulated for administration to a subject positive for at least one HLA selected from the group consisting of HLA-A11, HLA-A33, HLA-A03 and HLA-A01.

[12] A method of inducing an APC(s) having CTL-inducing ability, which comprises a step selected from the group consisting of (a) and (b) below:

(a) contacting an APC(s) with the peptide of any one of [1] to [3] *in vitro*, *ex vivo* or *in vivo*; and

(b) introducing a polynucleotide encoding the peptide of any one of [1] to [3] into an APC(s).

[13] A method of inducing a CTL(s), which comprises a step selected from the group consisting of (a) to (c) below:

(a) co-culturing a CD8-positive T cell(s) with an APC(s) that presents on its surface a complex of an HLA antigen and the peptide of any one of [1] to [3];

(b) co-culturing a CD8-positive T cell(s) with an exosome(s) that presents on its surface a complex of an HLA antigen and the peptide of any one of [1] to [3]; and

(c) introducing into a CD8-positive T cell(s) a polynucleotide encoding each subunit of a T cell receptor (TCR) capable of binding to the peptide of any one of [1] to [3] presented by an HLA antigen on a cell surface.

[14] An APC that presents on its surface a complex of an HLA antigen and the peptide of any one of [1] to [3].

[15] The APC of [14], which is induced by the method of [12].

[16] A CTL that targets the peptide of any one of [1] to [3].

[17] The CTL of [16], which is induced by the method of [13].

[18] A method of inducing an immune response against cancer, which comprises administering to a subject at least one ingredient selected from the group consisting of (a) to (e) below:

(a) one or more types of peptides of any one of [1] to [3];

(b) one or more types of polynucleotides encoding the peptide(s) of any one of [1] to [3] in an expressible form;

(c) an antigen-presenting cell (APC) that presents on its cell surface a complex of the peptide of any one of [1] to [3] and an HLA antigen;

(d) an exosome that presents on its cell surface a complex of the peptide of any one of [1] to [3] and an HLA antigen; and

(e) a CTL that targets the peptide of any one of [1] to [3].

[19] A method of treating and/or preventing cancer, and/or preventing postoperative recurrence thereof, which comprises administering to a subject at least one ingredient selected from the group consisting of (a) to (e) below:

(a) one or more types of peptides of any one of [1] to [3];

(b) one or more types of polynucleotides encoding the peptide(s) of any one of [1] to [3] in an expressible form;

(c) an antigen-presenting cell (APC) that presents on its cell surface a complex of the peptide of any one of [1] to [3] and an HLA antigen;

(d) an exosome that presents on its cell surface a complex of the peptide of any one of [1] to [3] and an HLA antigen; and

(e) a CTL that targets the peptide of any one of [1] to [3].

[20] An antibody that binds to the peptide of any one of [1] to [3].

[21] A method of screening for a peptide having CTL-inducing ability, which comprises the steps of:

(a) generating candidate sequences consisting of an amino acid sequence in which one, two or several amino acid residues are substituted, deleted, inserted and/or added to an original amino acid sequence consisting of the amino acid sequence selected from the group consisting of SEQ ID NOs: 5, 28, 30, 32, 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, 85, 27, 86, 87, 90, 92, 46, 95 and 41;

(b) selecting from among the candidate sequences generated in (a), a candidate sequence that does not have significant homology (sequence identity) with any known human gene product other than KOC1;

(c) contacting an APC(s) with a peptide consisting of the candidate sequence selected in (b);

(d) contacting the APC(s) of (c) with a CD8-positive T cell(s); and

(e) selecting a peptide having an equal to or higher CTL-inducing ability than that of a peptide consisting of the original amino acid sequence.

[22] Use of at least one ingredient selected from the group consisting of (a) to (e) below in the manufacture of a composition for inducing an immune response against cancer:

(a) one or more types of peptides of any one of [1] to [3];

(b) one or more types of polynucleotides encoding the peptide(s) of any one of [1] to [3] in an expressible form;

(c) an antigen-presenting cell (APC) that presents on its cell surface a complex of the peptide of any one of [1] to [3] and an HLA antigen;

(d) an exosome that presents on its cell surface a complex of the peptide of any one of [1] to [3] and an HLA antigen; and

(e) a CTL that targets the peptide of any one of [1] to [3].

[23] Use of at least one ingredient selected from the group consisting of (a) to (e) below in the manufacture of a pharmaceutical composition for treating and/or preventing cancer, and/or preventing postoperative recurrence thereof:

(a) one or more types of peptides of any one of [1] to [3];

(b) one or more types of polynucleotides encoding the peptide(s) of any one of [1] to [3] in an expressible form;

(c) an antigen-presenting cell (APC) that presents on its cell surface a complex of the peptide of any one of [1] to [3] and an HLA antigen;

(d) an exosome that presents on its cell surface a complex of the peptide of any one of [1] to [3] and an HLA antigen; and

(e) a CTL that targets the peptide of any one of [1] to [3].

[24] Use of at least one ingredient selected from the group consisting of (a) to (e) below for inducing an immune response against cancer:

(a) one or more types of peptides of any one of [1] to [3];

(b) one or more types of polynucleotides encoding the peptide(s) of any one of [1] to [3] in an expressible form;

(c) an antigen-presenting cell (APC) that presents on its cell surface a complex of the peptide of any one of [1] to [3] and an HLA antigen;

(d) an exosome that presents on its cell surface a complex of the peptide of any one of [1] to [3] and an HLA antigen; and

(e) a CTL that targets the peptide of any one of [1] to [3].

[25] Use of at least one ingredient selected from the group consisting of (a) to (e) below for treating and/or preventing cancer and/or preventing postoperative recurrence thereof:

(a) one or more types of peptides of any one of [1] to [3];

(b) one or more types of polynucleotides encoding the peptide(s) of any one of [1] to [3] in an expressible form;

(c) an antigen-presenting cell (APC) that presents on its cell surface a complex of the peptide of any one of [1] to [3] and an HLA antigen;

(d) an exosome that presents on its cell surface a complex of the peptide of any one of [1] to [3] and an HLA antigen; and

(e) a CTL that targets the peptide of any one of [1] to [3].

[26] A method of inducing cytotoxic activity against a KOC1-epxressing cell(s), which comprises a step of administering to a subject at least one ingredient selected from the group consisting of (a) to (e) below:

(a) one or more types of peptides of any one of [1] to [3];

(b) one or more types of polynucleotides encoding the peptide(s) of any one of [1] to [3] in an expressible form;

(c) an antigen-presenting cell (APC) that presents on its cell surface a complex of the peptide of any one of [1] to [3] and an HLA antigen;

(d) an exosome that presents on its cell surface a complex of the peptide of any one of [1] to [3] and an HLA antigen; and

(e) a CTL that targets the peptide of any one of [1] to [3].

[27] A freeze-dried formulation comprising one or more types of peptides of any one of [1] to [3].

[28] A pharmaceutical composition, which is prepared by a method that comprises dissolving one or more types of peptides of any one of [1] to [3] in a water-soluble carrier, and performing filtration sterilization.

[29] A filtration-sterilized aqueous solution, which is an aqueous solution that comprises one or more types of peptides of any one of [1] to [3] and a water-soluble carrier.

[30] An emulsion comprising one or more types of peptides of any one of [1] to [3], a water-soluble carrier and an oil adjuvant.

[31] A kit comprising a container that houses the pharmaceutical composition of any one of [7] to [11] and a container that houses an adjuvant.

[32] A kit comprising a container that stores a freeze-dried formulation comprising the peptide of any one of [1] to [3], a container that stores an adjuvant, and a container that stores a re-dissolving solution the freeze-dried formulation.

The present invention is explained herein in detail with reference to its specific embodiments. However, it should be understood that the above explanation is in fact an illustrative and explanatory explanation, and is intended to explain the present invention and preferred embodiments thereof. 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 present invention. Thus, the present invention is not confined to the above explanation, but is intended to be defined by the appended claims and equivalents thereto.

Hereinbelow, the present invention is described in more detail with reference to the Examples. Nevertheless, while the following materials, method and Examples may serve to assist one of ordinary skill in making and using certain embodiments of the present invention, there are only intended to illustrate aspects of the present invention and thus in no way to limit the scope of the present invention. One of ordinary skill in the art can use methods and materials similar or equivalent to those described herein in the practice or testing of the present invention.

All prior art documents cited herein are incorporated by reference in the present specification.

Examples

[Example 1]

Materials and methods

Cell lines

C1R, an HLA-A- and HLA-B-negative human B lymphoblastoid cell line, and COS7, an African green monkey kidney cell line, were purchased from ATCC.

Generation of stimulator cells with stable HLA-A*1101 expression

C1R (C1R-A11) that stably expresses HLA-A*1101 was used as a stimulator cell. A cDNA encoding the open-reading frame of HLA-A*1101 was amplified by PCR and cloned into an expression vector. C1R cells were transfected with the expression vector, and then selected using G418 (Invitrogen) for two weeks. The G418-selected cells were seeded into wells containing G418-added culture medium in a 96-well plate, and further cultured for 30 days. The exogenous HLA-A*1101 expression in C1R cells was verified by flow cytometric analysis.

Selection of candidate KOC1-derived peptides

KOC1-derived 9mer and 10mer peptides that bind to the HLA-A*1101 molecule were predicted using the binding prediction server "NetMHC 3.2" (www.cbs.dtu.dk/services/NetMHC/) (Buus *et al.*, Tissue Antigens. 2003 Nov, 62(5): 378-84; Nielsen *et al.*, Protein Sci. 2003 May, 12(5): 1007-17; Bioinformatics. 2004 Jun 12: 20(9): 1388-97).

Peptide synthesis

The peptides were synthesized by Biosynthesis (Lewisville, Texas) according to a standard solid-phase synthesis method, and purified by reversed phase high-performance liquid chromatography (HPLC). The peptides were analyzed for their purity (> 90%) and identity by analytical HPLC and mass spectrometry, respectively. The peptides were dissolved in dimethylsulfoxide at 20 mg/ml and stored at -80 degrees C.

In vitro CTL induction

Monocyte-derived dendritic cells (DCs) were used as the antigen-presenting cell to induce a cytotoxic T lymphocyte (CTL) response against peptides presented on human leukocyte antigens (HLAs). As described in the other sections, DCs were generated *in vitro* (Nakahara S *et al.*, Cancer Res 2003, 63(14): 4112-8). Specifically, peripheral-blood mononuclear cells isolated from healthy volunteers (HLA-A*1101-positive) with the Ficoll-Paque plus solution (Pharmacia) were separated by attaching to plastic tissue culture dishes (Becton Dickinson) and concentrated as a monocyte fraction. The monocyte-concentrated population was cultured in the presence of 1000 IU/ml granulocyte macrophage colony-stimulating factor (R&D System) and 1000 IU/ml interleukin(IL)-4 (R&D System) in an AIM-V medium (Invitrogen) containing 2% heat-

inactivated autologous serum (AS). After seven days of culturing, the cytokine-induced DCs were pulsed with 20 micro-g/ml each of the synthesized peptides in an AIM-V medium at 37 degrees C for three hours in the presence of 3 micro-g/ml beta 2-microglobulin. The generated cells appeared to express on their cell surface DC-associated molecules such as CD80, CD83, CD86 and HLA class II (data not shown). Next, these peptide-pulsed DCs were inactivated by X-ray irradiation (20 Gy), and mixed in a 1:20 ratio with autologous $CD8^+$ T cells obtained by positive selection using the CD8 Positive Isolation Kit (Dynal). These culture products were seeded in a 48-well plate (Corning). Each well was made to contain 1.5 x 10^4 peptide-pulsed DCs, 3 x 10^5 $CD8^+$ T cells and 10 ng/ml IL-7 (R&D System) in 0.5 ml of the AIM-V/2%AS medium. Three days later, these culture products were added with a final concentration of 20 IU/ml IL-2 (CHIRON). On day 7 and day 14, T cells were further stimulated with peptide-pulsed autologous DCs. The DCs were prepared every time by the same method as above. On day 21, after the third peptide stimulation, CTLs were examined against the peptide-pulsed C1R-A11 by a human interferon (IFN)-gamma enzyme-linked immunospot (ELISPOT) assay (Tanaka H *et al.*, Br J Cancer 2001, 84(1): 94-9; Umano Y *et al.*, Br J Cancer 2001, 84(8): 1052-7; Uchida N *et al.*, Clin Cancer Res 2004, 10(24): 8577-86; Suda T *et al.*, Cancer Sci 2006, 97(5): 411-9; Watanabe T *et al.*, Cancer Sci 2005, 96(8): 498-506).

CTL propagation procedure

CTLs were propagated in culture using methods similar to those disclosed by Riddell *et al.* (Walter EA *et al.*, N Engl J Med 1995, 333(16): 1038-44; Riddell SR *et al.*, Nat Med 1996, 2(2): 216-23). The CTLs were co-cultured in a total of 25 ml AIM-V medium containing 5% AS (AIM-V/5%AS) and 40 ng/ml anti-CD3 antibody with two types of Mitomycin C-treated human B lymphoblastoid cell lines at 5 x 10^6 cells/flask. One day after beginning of the culturing, 120 IU/ml IL-2 was added to the culture. On days 5, 8 and 11, a fresh AIM-V/5%AS medium containing 30 IU/ml IL-2 was added to the culture (Tanaka H *et al.*, Br J Cancer 2001, 84(1): 94-9; Umano Y *et al.*, Br J Cancer 2001, 84(8): 1052-7; Uchida N *et al.*, Clin Cancer Res 2004, 10(24): 8577-86; Suda T *et al.*, Cancer Sci 2006, 97(5): 411-9; Watanabe T *et al.*, Cancer Sci 2005, 96(8): 498-506).

Establishment of CTL clones

Dilution of CTLs was carried out to make 0.3, 1 and 3 cells/well in 96 round-bottomed microtiter plates (Nalge Nunc International). The CTLs were co-cultured with two types of Mitomycin C-treated human B lymphoblastoid cell lines at 1 x 10^4 cells/well in a total of 150 micro-l/well AIM-V/5%AS medium with 30 ng/ml anti-CD3 antibody and 125 IU/ml IL-2. Ten days later, IL-2 was added to the medium at 50 micro-l/well to reach a final concentration of 125

IU/ml. On day 14, the CTL activity was tested, and the CTL clones were propagated using the same method as described above (Uchida N *et al.*, Clin Cancer Res 2004, 10(24): 8577-86; Suda T *et al.*, Cancer Sci 2006, 97(5): 411-9; Watanabe T *et al.*, Cancer Sci 2005, 96(8): 498-506).

Specific CTL activity

To examine specific CTL activity, an IFN-gamma ELISPOT assay and an IFN-gamma enzyme-linked immunosorbent assay (ELISA) were performed. Specifically, peptide-pulsed C1R-A11 (1×10^4 cells/well) was prepared as the stimulator cell. The induced CTLs, *i.e.*, CTL lines and CTL clones, were used as the responder cell. The IFN-gamma ELISPOT assay and IFN-gamma ELISA were performed according to the manufacturer's manual.

Establishment of target cells forcibly expressing a target gene and HLA-A*1101

A cDNA encoding the open-reading frame of a target gene or HLA-A*1101 was amplified by PCR. The PCR-amplified product was cloned into an expression vector. Either or both of the target gene-expressing vector and the HLA-A*1101-expressing vector were transfected into COS7, which is a cell line negative for the target gene and HLA, using Lipofectamine 2000 (Invitrogen) following the manufacturer's recommended protocol. Two days after transfection, the transfected cells were harvested using versene (Invitrogen), and used as the target cell for CTL activity assay (5×10^4 cells/well).

Results

Prediction of KOC1-derived HLA-A*1101-binding peptides

Tables 1a and 1b show KOC1-derived 9mer peptides and 10mer peptides that have been predicted to bind to HLA-A*1101 in the descending order of binding affinity. A total of 60 peptides that potentially have an HLA-A*1101-binding ability was selected and investigated to determine epitope peptides.

[Table 1a]

HLA-A11-binding 9mer peptides derived from KOC1

Start position	Amino acid sequence	Kd (nM)	SEQ ID NO
258	KSILEIMHK	16	1
121	VVNVTYSSK	18	2
465	KAQGRIYGK	32	3
517	SSAEVVVPR	45	4
415	LSVGAIIGK	76	5
28	PVSGPFLVK	85	6
52	KAIEALSGK	92	7
142	FQLENFTLK	150	8
215	GATIRNITK	293	9
338	KAEEEIMKK	297	10
497	FAAGRVIGK	405	11
15	PSDLESIFK	451	12
536	VVKITGHFY	757	13
479	FVSPKEEVK	791	14
493	RVPSFAAGR	1100	15
272	KFTEEIPLK	1108	16
226	QSKIDVHRK	1125	17
330	KGNVETCAK	1835	18
544	YACQVAQRK	1841	19
220	NITKQTQSK	2617	20
301	KIEQDTDTK	2631	21
553	IQEILTQVK	3008	22
182	QGSPGSVSK	3293	23
559	QVKQHQQQK	3313	24
58	SGKIELHGK	4377	25
205	QFVGAIIGK	4472	26

[Table 1b]

HLA-A11-binding 10mer peptides derived from KOC1

Start position	Amino acid sequence	Kd (nM)	SEQ ID NO
120	AVVNVTYSSK	13	27
414	ALSVGAIIGK	33	28
456	ITGPPEAQFK	73	29
204	TQFVGAIIGK	86	30
73	SVPKRQRIRK	103	31
14	APSDLESIFK	152	32
183	GSPGSVSKQK	165	33
496	SFAAGRVIGK	168	34
516	LSSAEVVVPR	169	35
552	KIQEILTQVK	214	36
431	LSRFAGASIK	342	37
181	RQGSPGSVSK	368	38
124	VTYSSKDQAR	437	39
225	TQSKIDVHRK	478	40
535	VVVKITGHFY	678	41
224	QTQSKIDVHR	711	42
57	LSGKIELHGK	904	43
141	GFQLENFTLK	911	44
568	ALQSGPPQSR	1065	45
312	ISPLQELTLY	1262	46
441	IAPAEAPDAK	1570	47
27	IPVSGPFLVK	1622	48
570	QSGPPQSRRK	1777	49
95	EVLDSLLVQY	2124	50
336	CAKAEEEIMK	2194	51
281	ILAHNNFVGR	2264	52
466	AQGRIYGKIK	2595	53
160	AQQNPLQQPR	2689	54
420	IIGKQGQHIK	2763	55
558	TQVKQHQQQK	2862	56
257	CKSILEIMHK	3467	57
291	LIGKEGRNLK	3795	58
263	IMHKEAQDIK	4083	59
569	LQSGPPQSRR	4107	60

Start position indicates the number of amino acid residue from the N-terminus of KOC1.

The dissociation constant [Kd (nM)] is derived from "NetMHC3.2".

Induction of CTLs by the predicted KOC1-derived HLA-A*1101-restricted peptides

CTLs against the KOC1-derived peptides were generated according to the protocol described in "Materials and methods". The peptide-specific CTL activity was measured by an IFN-gamma ELISPOT assay (Fig. 1). In comparison with the control, CTLs in Well #6 with KOC1-A11-9-415 (SEQ ID NO: 5) (a), Well #4 with KOC1-A11-10-414 (SEQ ID NO: 28) (b), Well #5 with KOC1-A11-10-204 (SEQ ID NO: 30) (c), and Well #8 with KOC1-A11-10-14 (SEQ ID NO: 32) (d) showed potent IFN-gamma production. Meanwhile, despite that other peptides shown in Tables 1a and 1b potentially have an HLA-A*1101-binding activity, specific CTL activity was not detected as a result of stimulation by those peptides. An example of typical negative data is that specific IFN-gamma production was not observed from CTLs stimulated with KOC1-A11-9-258 (SEQ ID NO: 1) (e). As a result, four types of KOC1-derived peptides were selected as peptides capable of inducing potent CTLs.

Establishment of CTL lines and clones against the KOC1-derived HLA-A*1101-restricted peptides

CTL lines were established by propagating CTLs in Well #6 with KOC1-A11-9-415 (SEQ ID NO: 5) (a), Well #5 with KOC1-A11-10-204 (SEQ ID NO: 30) (b), and Well #8 with KOC1-A11-10-14 (SEQ ID NO: 32) (c), which showed peptide-specific CTL activity in the IFN-gamma ELISPOT assay. The CTL activity of these CTL lines was measured by IFN-gamma ELISA (Fig. 2). These CTL lines showed potent IFN-gamma production against target cells pulsed with the respective peptides, in comparison with target cells that have not been pulsed with the peptides. Further, CTL clones were established from the CTL lines by limiting dilution as described in the "Materials and methods" section above, and IFN-gamma production from the CTL clones against peptide-pulsed C1R-A11 was measured by IFN-gamma ELISA. Potent IFN-gamma production was observed in CTL clones stimulated with KOC1-A11-9-415 (SEQ ID NO: 5) (a) and KOC1-A11-10-14 (SEQ ID NO: 32) (b) (Fig. 3).

Specific CTL activity against target cells expressing KOC1 and HLA-A*1101

The CTL clone established against KOC1-A11-10-14 (SEQ ID NO: 32) was investigated for its ability to recognize target cells expressing KOC1 and the HLA-A*1101 molecule. COS7 cells transfected with both full-length KOC1 and the HLA-A*1101 gene (a specific model of target cells expressing KOC1 and the HLA-A*1101 gene) were prepared as the target cell. COS7 cells transfected with either full-length KOC1 or HLA-A*1101 were prepared as the control. The KOC1-A11-10-14 (SEQ ID NO: 32)-stimulated CTL clone demonstrated a potent CTL activity against COS7 cells expressing both KOC1 and HLA-A*1101 (Fig. 4). On

the other hand, a significant specific CTL activity was not detected against the control cells. These data clearly proved that KOC1-A11-10-14 (SEQ ID NO: 32) is a peptide generated from endogenous processing of KOC1, and is presented on target cells with the HLA-A*1101 molecule and recognized by CTLs. These results demonstrated the possibility that KOC1-A11-10-14 (SEQ ID NO: 32) may be suitable as a cancer vaccine for patients having a KOC1-expressing cancer.

Homology analysis of antigen peptides

CTLs stimulated with KOC1-A11-9-415 (SEQ ID NO: 5), KOC1-A11-10-414 (SEQ ID NO: 28), KOC1-A11-10-204 (SEQ ID NO: 30), or KOC1-A11-10-14 (SEQ ID NO: 32) demonstrated a significant specific CTL activity. These results may be due to the fact that the KOC1-A11-9-415 (SEQ ID NO: 5), KOC1-A11-10-414 (SEQ ID NO: 28), KOC1-A11-10-204 (SEQ ID NO: 30), and KOC1-A11-10-14 (SEQ ID NO: 32) sequences are homologous to peptides derived from other molecules known for sensitizing the human immune system. In order to exclude this possibility, homology analysis was performed by querying these peptide sequences using the BLAST algorithm (blast.ncbi.nlm.nih.gov/Blast.cgi). This result showed that there is no sequence having a significant homology with the KOC1-A11-9-415 (SEQ ID NO: 5), KOC1-A11-10-414 (SEQ ID NO: 28), KOC1-A11-10-204 (SEQ ID NO: 30), and KOC1-A11-10-14 (SEQ ID NO: 32) sequences. On the other hand, KOC1-A11-10-204 (SEQ ID NO: 30) is identical to a peptide sequence identified in IMP-2 which is another IMP family. It has been previously reported that IMP-2 is not expressed in normal organs except testis and fetal liver (Hammer NA *et al.*, Reproduction. 2005; 130(2): 203-12). It is involved in the proliferation of glioblastoma cancer stem cells (Janiszewska M *et al.*, Genes Dev. 2012; 26(17): 1926-44). IMP-2 is promising as a target antigen for cancer immunotherapy. Therefore, to the knowledge of the present inventors, there is almost no possibility that these peptides would elicit an unintended immune response against other unrelated molecules. In conclusion, novel KOC1-derived HLA-A11-restricted epitope peptides were identified. It was demonstrated that the KOC1-derived epitope peptides are applicable for cancer immunotherapy.

[Example 2]

Materials and methods

Cell lines

C1R, an HLA-A- and HLA-B-negative human B lymphoblastoid cell line, and COS7, an African green monkey kidney cell line, were purchased from ATCC.

Generation of stimulator cells with stable HLA-A*3303 expression

C1R (C1R-A33) that stably expresses HLA-A*3303 was used as a stimulator cell. A cDNA encoding the open-reading frame of HLA-A*3303 was amplified by PCR and cloned into an expression vector. C1R cells were transfected with the expression vector, and then selected using G418 (Invitrogen) for two weeks. The G418-selected cells were seeded into wells containing G418-added culture medium in a 96-well plate, and further cultured for 30 days. The exogenous HLA-A*3303 expression in C1R cells was verified by flow cytometric analysis.

Selection of candidate KOC1-derived peptides

KOC1-derived 9mer and 10mer peptides that bind to the HLA-A*3303 molecule were predicted using the binding prediction server "NetMHCpan2.8" (www.cbs.dtu.dk/services/NetMHCpan/) (Nielsen *et al.*, PLoS One. 2007; 29; 2(8): e796; Hoof *et al.*, Immunogenetics. 2009; 61(1): 1-13).

Peptide synthesis

These peptides were synthesized by Biosynthesis (Lewisville, Texas) according to a standard solid-phase synthesis method, and purified by reversed phase high-performance liquid chromatography (HPLC). The peptides were analyzed for their purity (> 90%) and identity by analytical HPLC and mass spectrometry, respectively. The peptides were dissolved in dimethylsulfoxide at 20 mg/ml and stored at -80 degrees C.

In vitro CTL induction

Monocyte-derived dendritic cells (DCs) were used as the antigen-presenting cell to induce a cytotoxic T lymphocyte (CTL) response against peptides presented on human leukocyte antigens (HLAs). As described in the other sections, DCs were generated *in vitro* (Nakahara S *et al.*, Cancer Res 2003, 63(14): 4112-8). Specifically, peripheral-blood mononuclear cells isolated from healthy volunteers (HLA-A*3303-positive) with the Ficoll-Paque plus solution (Pharmacia) were separated by attaching to plastic tissue culture dishes (Becton Dickinson) and concentrated as a monocyte fraction. The monocyte-concentrated population was cultured in the presence of 1000 IU/ml granulocyte macrophage colony-stimulating factor (R&D System) and 1000 IU/ml interleukin(IL)-4 (R&D System) in an AIM-V medium (Invitrogen) containing 2% heat-inactivated autologous serum (AS). After seven days of culturing, the cytokine-induced DCs were pulsed with 20 micro-g/ml each of the synthesized peptides in an AIM-V medium at 37 degrees C for three hours in the presence of 3 micro-g/ml beta 2-microglobulin. The generated cells appeared to express on their cell surface DC-associated molecules such as CD80, CD83, CD86 and HLA class II (data not shown). Next, these peptide-pulsed DCs were inactivated by X-ray irradiation (20 Gy), and mixed in a 1:20 ratio with autologous $CD8^+$ T cells obtained by

positive selection using the CD8 Positive Isolation Kit (Dynal). These culture products were seeded in a 48-well plate (Corning). Each well was made to contain 1.5 x 10^4 peptide-pulsed DCs, 3 x 10^5 $CD8^+$ T cells and 10 ng/ml IL-7 (R&D System) in 0.5 ml of the AIM-V/2%AS medium. Three days later, these culture products were added with a final concentration of 20 IU/ml IL-2 (CHIRON). On day 7 and day 14, T cells were further stimulated with peptide-pulsed autologous DCs. The DCs were prepared every time by the same method as above. On day 21, after the third peptide stimulation, CTLs were examined against the peptide-pulsed C1R-A33 cell by a human interferon (IFN)-gamma enzyme-linked immunospot (ELISPOT) assay (Tanaka H *et al.*, Br J Cancer 2001, 84(1): 94-9; Umano Y *et al.*, Br J Cancer 2001, 84(8): 1052-7; Uchida N *et al.*, Clin Cancer Res 2004, 10(24): 8577-86; Suda T *et al.*, Cancer Sci 2006, 97(5): 411-9; Watanabe T *et al.*, Cancer Sci 2005, 96(8): 498-506).

CTL propagation procedure

CTLs were propagated in culture using methods similar to those disclosed by Riddell *et al.* (Walter EA *et al.*, N Engl J Med 1995, 333(16): 1038-44; Riddell SR *et al.*, Nat Med 1996, 2(2): 216-23). The CTLs were co-cultured in a total of 25 ml AIM-V medium containing 5% AS (AIM-V/5%AS) and 40 ng/ml anti-CD3 antibody with two types of Mitomycin C-treated human B lymphoblastoid cell lines at 5 x 10^6 cells/flask. One day after beginning of the culturing, 120 IU/ml IL-2 was added to the culture. On days 5, 8 and 11, a fresh AIM-V/5%AS medium containing 30 IU/ml IL-2 was added to the culture (Tanaka H *et al.*, Br J Cancer 2001, 84(1): 94-9; Umano Y *et al.*, Br J Cancer 2001, 84(8): 1052-7; Uchida N *et al.*, Clin Cancer Res 2004, 10(24): 8577-86; Suda T *et al.*, Cancer Sci 2006, 97(5): 411-9; Watanabe T *et al.*, Cancer Sci 2005, 96(8): 498-506).

Establishment of CTL clones

Dilution of CTLs was carried out to make 0.3, 1 and 3 cells/well in 96 round-bottomed microtiter plates (Nalge Nunc International). The CTLs were co-cultured with two types of Mitomycin C-treated human B lymphoblastoid cell lines at 1 x 10^4 cells/well in a total of 150 micro-l/well AIM-V/5%AS medium with 30 ng/ml anti-CD3 antibody and 125 IU/ml IL-2. Ten days later, IL-2 was added to the medium at 50 micro-l/well to reach a final concentration of 125 IU/ml. On day 14, the CTL activity was tested, and the CTL clones were propagated using the same method as described above (Uchida N *et al.*, Clin Cancer Res 2004, 10(24): 8577-86; Suda T *et al.*, Cancer Sci 2006, 97(5): 411-9; Watanabe T *et al.*, Cancer Sci 2005, 96(8): 498-506).

Specific CTL activity

To examine specific CTL activity, an IFN-gamma ELISPOT assay and an IFN-gamma enzyme-linked immunosorbent assay (ELISA) were performed. Specifically, peptide-pulsed C1R-A33 (1 x 10^4 cells/well) was prepared as the stimulator cell. The induced CTLs, *i.e.*, CTL lines and CTL clones, were used as the responder cell. The IFN-gamma ELISPOT assay and IFN-gamma ELISA were performed according to the manufacturer's manual.

Establishment of target cells forcibly expressing a target gene and HLA-A*3303

A cDNA encoding the open-reading frame of a target gene or HLA-A*3303 was amplified by PCR. The PCR-amplified product was cloned into an expression vector. Either or both of the target gene-expressing vector and the HLA-A*3303-expressing vector were transfected into COS7, which is a cell line negative for the target gene and HLA, using Lipofectamine 2000 (Invitrogen) following the manufacturer's recommended protocol. Two days after transfection, the transfected cells were harvested using versene (Invitrogen), and used as the target cell for CTL activity assay (5 x 10^4 cells/well).

Results

Prediction of KOC1-derived HLA-A*3303-binding peptides

Tables 2a and 2b show KOC1-derived 9mer peptides and 10mer peptides that have been predicted to bind to HLA-A*3303 in the descending order of binding affinity. A total of 37 peptides that potentially have an HLA-A*3303-binding ability was selected and investigated to determine epitope peptides.

[Table 2a]

HLA-A33-binding 9mer peptides derived from KOC1

Start position	Amino acid sequence	Kd (nM)	SEQ ID NO
543	FYACQVAQR	98	61
517	SSAEVVVPR	105	4
282	LAHNNFVGR	140	62
493	RVPSFAAGR	182	15
317	ELTLYNPER	260	63
485	EVKLEAHIR	278	64
125	TYSSKDQAR	467	65
461	EAQFKAQGR	555	66
286	NFVGRLIGK	933	67
225	TQSKIDVHR	1039	68
69	EVEHSVPKR	1453	69
161	QQNPLQQPR	1485	70
406	ETVHLFIPA	2340	71
73	SVPKRQRIR	2969	72
570	QSGPPQSRR	3001	73
121	VVNVTYSSK	3272	2
465	KAQGRIYGK	3308	3
142	FQLENFTLK	4063	8
34	LVKTGYAFV	4107	74
211	IGKEGATIR	4197	75
307	DTKITISPL	4676	76

[Table 2b]

HLA-A33-binding 10mer peptides derived from KOC1

Start position	Amino acid sequence	Kd (nM)	SEQ ID NO
542	HFYACQVAQR	16	77
124	VTYSSKDQAR	201	39
224	QTQSKIDVHR	296	42
281	ILAHNNFVGR	320	52
72	HSVPKRQRIR	428	78
516	LSSAEVVVPR	467	35
496	SFAAGRVIGK	1710	34
543	FYACQVAQRK	2635	79
424	QGQHIKQLSR	2752	80
190	KQKPCDLPLR	3492	81
431	LSRFAGASIK	3726	37
568	ALQSGPPQSR	4478	45
210	IIGKEGATIR	4831	82
478	NFVSPKEEVK	4831	83
77	RQRIRKLQIR	4883	84
285	NNFVGRLIGK	4883	85

Start position indicates the number of amino acid residue from the N-terminus of KOC1.
The dissociation constant [Kd (nM)] is derived from "NetMHCpan 2.8".

Induction of CTLs by the predicted KOC1-derived HLA-A*3303-restricted peptides

CTLs against the KOC1-derived peptides were generated according to the protocol described in "Materials and methods". The peptide-specific CTL activity was measured by an IFN-gamma ELISPOT assay (Fig. 5). In comparison with the control, CTLs in Well #1 with KOC1-A33-9-543 (SEQ ID NO: 61) (a), Well #2 with KOC1-A33-9-282 (SEQ ID NO: 62) (b), Well #3 with KOC1-A33-9-317 (SEQ ID NO: 63) (c), Well #8 with KOC1-A33-9-485 (SEQ ID NO: 64) (d), Well #3 with KOC1-A33-9-286 (SEQ ID NO: 67) (e), Well #8 with KOC1-A33-9-34 (SEQ ID NO: 74) (f), Well #4 with KOC1-A33-10-542 (SEQ ID NO: 77) (g), Well #3 with KOC1-A33-10-281 (SEQ ID NO: 52) (h), Well #6 with KOC1-A33-10-543 (SEQ ID NO: 79) (i), Well #1 with KOC1-A33-10-424 (SEQ ID NO: 80) (j), and Well #5 with KOC1-A33-10-285 (SEQ ID NO: 85) (k) showed potent IFN-gamma production. Meanwhile, despite that other

peptides shown in Tables 2a and 2b potentially have an HLA-A*3303-binding activity, specific CTL activity was not detected as a result of stimulation by those peptides. An example of typical negative data is that specific IFN-gamma production was not observed from CTLs stimulated with KOC1-A33-9-517 (SEQ ID NO: 4) (l). As a result, eleven types of KOC1-derived peptides were selected as peptides capable of inducing potent CTLs.

Establishment of CTL lines and clones against the KOC1-derived HLA-A*3303-restricted peptides

CTL lines were established by propagating CTLs in Well #1 with KOC1-A33-9-543 (SEQ ID NO: 61) (a), Well #2 with KOC1-A33-9-282 (SEQ ID NO: 62) (b), Well #8 with KOC1-A33-9-485 (SEQ ID NO: 64) (c), Well #3 with KOC1-A33-9-286 (SEQ ID NO: 67) (d), Well #4 with KOC1-A33-10-542 (SEQ ID NO: 77) (e), and Well #3 with KOC1-A33-10-281 (SEQ ID NO: 52) (f), which showed peptide-specific CTL activity in the IFN-gamma ELISPOT assay. The CTL activity of these CTL lines was measured by IFN-gamma ELISA (Fig. 6). These CTL lines showed potent IFN-gamma production against target cells pulsed with the respective peptides, in comparison with target cells that have not been pulsed with the peptides. Further, CTL clones were established from the CTL lines by limiting dilution as described in the "Materials and methods" section above, IFN-gamma production from the CTL clones against peptide-pulsed C1R-A33 was measured by IFN-gamma ELISA. Potent IFN-gamma production was observed in CTL clones stimulated with KOC1-A33-9-543 (SEQ ID NO: 61) (a), KOC1-A33-9-282 (SEQ ID NO: 62) (b), KOC1-A33-9-485 (SEQ ID NO: 64) (c), KOC1-A33-9-286 (SEQ ID NO: 67) (d), KOC1-A33-10-542 (SEQ ID NO: 77) (e), and KOC1-A33-10-281 (SEQ ID NO: 52) (f) (Fig. 7).

Specific CTL activity against target cells expressing KOC1 and HLA-A*3303

The CTL lines and CTL clones established against KOC1-A33-9-485 (SEQ ID NO: 64) (a), KOC1-A33-9-286 (SEQ ID NO: 67) (b), and KOC1-A33-10-542 (SEQ ID NO: 77) (c) were investigated for their ability to recognize target cells expressing KOC1 and the HLA-A*3303 molecule. COS7 cells transfected with both full-length KOC1 and the HLA-A*3303 gene (a specific model of target cells expressing KOC1 and the HLA-A*3303 gene) were prepared as the target cell. COS7 cells transfected with either full-length KOC1 or HLA-A*3303 were prepared as the control. The CTL clones stimulated with KOC1-A33-9-485 (SEQ ID NO: 64) (a), KOC1-A33-9-286 (SEQ ID NO: 67) (b), or KOC1-A33-10-542 (SEQ ID NO: 77) (c) demonstrated potent CTL activities against COS7 cells expressing both KOC1 and HLA-A*3303 (Fig. 8). On the other hand, a significant specific CTL activity was not detected against the control cells. These data clearly proved that KOC1-A33-9-485 (SEQ ID NO: 64), KOC1-A33-9-286 (SEQ ID

NO: 67), and KOC1-A33-10-542 (SEQ ID NO: 77) are peptides generated from endogenous processing of KOC1, and are presented on target cells with the HLA-A*3303 molecule and recognized by CTLs. These results demonstrated the possibility that KOC1-A33-9-485 (SEQ ID NO: 64), KOC1-A33-9-286 (SEQ ID NO: 67), and KOC1-A33-10-542 (SEQ ID NO: 77) may be suitable as a cancer vaccine for patients having a KOC1-expressing cancer.

Homology analysis of antigen peptides

CTLs stimulated with KOC1-A33-9-543 (SEQ ID NO: 61), KOC1-A33-9-282 (SEQ ID NO: 62), KOC1-A33-9-317 (SEQ ID NO: 63), KOC1-A33-9-485 (SEQ ID NO: 64), KOC1-A33-9-286 (SEQ ID NO: 67), KOC1-A33-9-34 (SEQ ID NO: 74), KOC1-A33-10-542 (SEQ ID NO: 77), KOC1-A33-10-281 (SEQ ID NO: 52), KOC1-A33-10-543 (SEQ ID NO: 79), KOC1-A33-10-424 (SEQ ID NO: 80), or KOC1-A33-10-285 (SEQ ID NO: 85) demonstrated significant specific CTL activities. These results may be due to the fact that the KOC1-A33-9-543 (SEQ ID NO: 61), KOC1-A33-9-282 (SEQ ID NO: 62), KOC1-A33-9-317 (SEQ ID NO: 63), KOC1-A33-9-485 (SEQ ID NO: 64), KOC1-A33-9-286 (SEQ ID NO: 67), KOC1-A33-9-34 (SEQ ID NO: 74), KOC1-A33-10-542 (SEQ ID NO: 77), KOC1-A33-10-281 (SEQ ID NO: 52), KOC1-A33-10-543 (SEQ ID NO: 79), KOC1-A33-10-424 (SEQ ID NO: 80), and KOC1-A33-10-285 (SEQ ID NO: 85) sequences are homologous to peptides derived from other molecules known for sensitizing the human immune system. In order to exclude this possibility, homology analysis was performed by querying these peptide sequences using the BLAST algorithm (blast.ncbi.nlm.nih.gov/Blast.cgi). This result proved that the KOC1-A33-9-543 (SEQ ID NO: 61), KOC1-A33-9-317 (SEQ ID NO: 63), KOC1-A33-9-485 (SEQ ID NO: 64), KOC1-A33-9-34 (SEQ ID NO: 74), KOC1-A33-10-542 (SEQ ID NO: 77), KOC1-A33-10-543 (SEQ ID NO: 79), and KOC1-A33-10-424 (SEQ ID NO: 80) sequences are unique. On the other hand, KOC1-A33-9-282 (SEQ ID NO: 62), KOC1-A33-9-286 (SEQ ID NO: 67), KOC1-A33-10-281 (SEQ ID NO: 52), and KOC1-A33-10-285 (SEQ ID NO: 85) are identical to peptide sequences identified in IMP-1 which is another IMP family. KOC1-A33-9-485 (SEQ ID NO: 64) is identical to a peptide sequence identified in IMP-2. It has been previously reported that IMP-1 is not expressed in normal organs except testis, fetal liver and placenta (Hammer NA *et al.*, Reproduction. 2005; 130(2): 203-12). It is reported to be associated with tumor progression in lung cancer patients (Kato T *et al.*, Clin Cancer Res. 2007; 13: 434-42). It has been previously reported that IMP-2 is not expressed in normal organs except testis and fetal liver (Hammer NA *et al.*, Reproduction. 2005; 130(2): 203-12). It is involved in the proliferation of glioblastoma cancer stem cells (Janiszewska M *et al.*, Genes Dev. 2012; 26(17): 1926-44). IMP-1 and IMP-2 are promising as target antigens for cancer immunotherapy. Therefore, to the knowledge of the present inventors, there is almost no possibility that these peptides would elicit an unintended

immune response against other unrelated molecules. In conclusion, novel KOC1-derived HLA-A33-restricted epitope peptides were identified. It was demonstrated that the KOC1-derived epitope peptides are applicable for cancer immunotherapy.

[Example 3]

Materials and methods

Cell lines

C1R, an HLA-A- and HLA-B-negative human B lymphoblastoid cell line, and COS7, an African green monkey kidney cell line, were purchased from ATCC.

Generation of stimulator cells with stable HLA-A*0301 expression

C1R (C1R-A03) that stably expresses HLA-A*0301 was used as a stimulator cell. A cDNA encoding the open-reading frame of HLA-A*0301 was amplified by PCR and cloned into an expression vector. C1R cells were transfected with the expression vector, and then selected using G418 (Invitrogen) for two weeks. The G418-selected cells were seeded into wells containing G418-added culture medium in a 96-well plate, and further cultured for 30 days. The exogenous HLA-A*0301 expression in C1R cells was verified by flow cytometric analysis.

Selection of candidate KOC1-derived peptides

KOC1-derived 9mer and 10mer peptides that bind to the HLA-A*0301 molecule were predicted using the binding prediction server "NetMHC 3.2" (www.cbs.dtu.dk/services/NetMHC/) (Buus *et al.*, Tissue Antigens. 2003 Nov, 62(5): 378-84; Nielsen *et al.*, Protein Sci. 2003 May, 12(5): 1007-17; Bioinformatics. 2004 Jun 12: 20(9): 1388-97).

Peptide synthesis

The peptides were synthesized by Biosynthesis (Lewisville, Texas) according to a standard solid-phase synthesis method, and purified by reversed phase high-performance liquid chromatography (HPLC). The peptides were analyzed for their purity (> 90%) and identity by analytical HPLC and mass spectrometry, respectively. The peptides were dissolved in dimethylsulfoxide at 20 mg/ml and stored at -80 degrees C.

In vitro CTL induction

Monocyte-derived dendritic cells (DCs) were used as the antigen-presenting cell to induce a cytotoxic T lymphocyte (CTL) response against peptides presented on human leukocyte antigens (HLAs). As described in the other sections, DCs were generated *in vitro* (Nakahara S *et*

al., Cancer Res 2003, 63(14): 4112-8). Specifically, peripheral-blood mononuclear cells isolated from healthy volunteers (HLA-A*0301-positive) with the Ficoll-Paque plus solution (Pharmacia) were separated by attaching to plastic tissue culture dishes (Becton Dickinson) and concentrated as a monocyte fraction. The monocyte-concentrated population was cultured in the presence of 1000 IU/ml granulocyte macrophage colony-stimulating factor (R&D System) and 1000 IU/ml interleukin(IL)-4 (R&D System) in an AIM-V medium (Invitrogen) containing 2% heat-inactivated autologous serum (AS). After seven days of culturing, the cytokine-induced DCs were pulsed with 20 micro-g/ml each of the synthesized peptides in an AIM-V medium at 37 degrees C for three hours in the presence of 3 micro-g/ml beta 2-microglobulin. The generated cells appeared to express on their cell surface DC-associated molecules such as CD80, CD83, CD86 and HLA class II (data not shown). Next, these peptide-pulsed DCs were inactivated by X-ray irradiation (20 Gy), and mixed in a 1:20 ratio with autologous $CD8^+$ T cells obtained by positive selection using the CD8 Positive Isolation Kit (Dynal). These culture products were seeded in a 48-well plate (Corning). Each well was made to contain 1.5×10^4 peptide-pulsed DCs, 3×10^5 $CD8^+$ T cells and 10 ng/ml IL-7 (R&D System) in 0.5 ml of the AIM-V/2%AS medium. Three days later, these culture products were added with a final concentration of 20 IU/ml IL-2 (CHIRON). On day 7 and day 14, T cells were further stimulated with peptide-pulsed autologous DCs. The DCs were prepared every time by the same method as above. On day 21, after the third peptide stimulation, CTLs were examined against the peptide-pulsed C1R-A03 by a human interferon (IFN)-gamma enzyme-linked immunospot (ELISPOT) assay (Tanaka H *et al.*, Br J Cancer 2001, 84(1): 94-9; Umano Y *et al.*, Br J Cancer 2001, 84(8): 1052-7; Uchida N *et al.*, Clin Cancer Res 2004, 10(24): 8577-86; Suda T *et al.*, Cancer Sci 2006, 97(5): 411-9; Watanabe T *et al.*, Cancer Sci 2005, 96(8): 498-506).

CTL propagation procedure

CTLs were propagated in culture using methods similar to those disclosed by Riddell *et al.* (Walter EA *et al.*, N Engl J Med 1995, 333(16): 1038-44; Riddell SR *et al.*, Nat Med 1996, 2(2): 216-23). The CTLs were co-cultured in a total of 25 ml AIM-V medium containing 5% AS (AIM-V/5%AS) and 40 ng/ml anti-CD3 antibody with two types of Mitomycin C-treated human B lymphoblastoid cell lines at 5×10^6 cells/flask. One day after beginning of the culturing, 120 IU/ml IL-2 was added to the culture. On days 5, 8 and 11, a fresh AIM-V/5%AS medium containing 30 IU/ml IL-2 was added to the culture (Tanaka H *et al.*, Br J Cancer 2001, 84(1): 94-9; Umano Y *et al.*, Br J Cancer 2001, 84(8): 1052-7; Uchida N *et al.*, Clin Cancer Res 2004, 10(24): 8577-86; Suda T *et al.*, Cancer Sci 2006, 97(5): 411-9; Watanabe T *et al.*, Cancer Sci 2005, 96(8): 498-506).

Establishment of CTL clones

Dilution of CTLs was carried out to make 0.3, 1 and 3 cells/well in 96 round-bottomed microtiter plates (Nalge Nunc International). The CTLs were co-cultured with two types of Mitomycin C-treated human B lymphoblastoid cell lines at 1 x 10^4 cells/well in a total of 150 micro-l/well AIM-V/5%AS medium with 30 ng/ml anti-CD3 antibody and 125 IU/ml IL-2. Ten days later, IL-2 was added to the medium at 50 micro-l/well to reach a final concentration of 125 IU/ml. On day 14, the CTL activity was tested, and the CTL clones were propagated using the same method as described above (Uchida N *et al.*, Clin Cancer Res 2004, 10(24): 8577-86; Suda T *et al.*, Cancer Sci 2006, 97(5): 411-9; Watanabe T *et al.*, Cancer Sci 2005, 96(8): 498-506).

Specific CTL activity

To examine specific CTL activity, an IFN-gamma ELISPOT assay and an IFN-gamma enzyme-linked immunosorbent assay (ELISA) were performed. Specifically, peptide-pulsed C1R-A03 (1 x 10^4 cells/well) was prepared as the stimulator cell. The induced CTLs, *i.e.*, CTL lines and CTL clones, were used as the responder cell. The IFN-gamma ELISPOT assay and IFN-gamma ELISA were performed according to the manufacturer's manual.

Establishment of target cells forcibly expressing a target gene and HLA-A*0301

A cDNA encoding the open-reading frame of a target gene or HLA-A*0301 was amplified by PCR. The PCR-amplified product was cloned into an expression vector. Either or both of the target gene-expressing vector and the HLA-A*0301-expressing vector were transfected into COS7, which is a cell line negative for the target gene and HLA, using Lipofectamine 2000 (Invitrogen) following the manufacturer's recommended protocol. Two days after transfection, the transfected cells were harvested using versene (Invitrogen), and used as the target cell for CTL activity assay (5 x 10^4 cells/well).

Results

Prediction of KOC1-derived HLA-A*0301-binding peptides

Tables 3a and 3b show KOC1-derived 9mer peptides and 10mer peptides that have been predicted to bind to HLA-A*0301 in the descending order of binding affinity. A total of 23 peptides that potentially have an HLA-A*0301-binding ability was selected and investigated to determine epitope peptides.

[Table 3a]

HLA-A3-binding 9mer peptides derived from KOC1

Start position	Amino acid sequence	Kd (nM)	SEQ ID NO
121	VVNVTYSSK	84	2
258	KSILEIMHK	124	1
52	KAIEALSGK	496	7
28	PVSGPFLVK	613	6
465	KAQGRIYGK	650	3
142	FQLENFTLK	752	8
415	LSVGAIIGK	764	5
497	FAAGRVIGK	927	11
559	QVKQHQQQK	1152	24

[Table 3b]

HLA-A3-binding 10mer peptides derived from KOC1

Start position	Amino acid sequence	Kd (nM)	SEQ ID NO
120	AVVNVTYSSK	17	27
414	ALSVGAIIGK	37	28
431	LSRFAGASIK	69	37
181	RQGSPGSVSK	104	38
456	ITGPPEAQFK	211	29
204	TQFVGAIIGK	211	30
496	SFAAGRVIGK	215	34
552	KIQEILTQVK	365	36
281	ILAHNNFVGR	459	52
73	SVPKRQRIRK	521	31
535	VVVKITGHFY	682	41
420	IIGKQGQHIK	858	55
141	GFQLENFTLK	1112	44
14	APSDLESIFK	1275	32

Start position indicates the number of amino acid residue from the N-terminus of KOC1.

The dissociation constant [Kd (nM)] is derived from "NetMHC3.2".

5

Induction of CTLs by the predicted KOC1-derived HLA-A*0301-restricted peptides

CTLs against the KOC1-derived peptides were generated according to the protocol described in "Materials and methods". The peptide-specific CTL activity was measured by an IFN-gamma ELISPOT assay (Fig. 9). In comparison with the control, CTLs in Well #5 with KOC1-A03-10-120 (SEQ ID NO: 27) (a), Well #3 with KOC1-A03-10-204 (SEQ ID NO: 30) (b), and Well #5 with KOC1-A03-10-281 (SEQ ID NO: 52) (c) showed potent IFN-gamma production. Meanwhile, despite that other peptides shown in Tables 3a and 3b potentially have an HLA-A*0301-binding activity, specific CTL activity was not detected as a result of stimulation by those peptides. An example of typical negative data is that specific IFN-gamma production was not observed from CTLs stimulated with KOC1-A03-10-414 (SEQ ID NO: 28) (d). As a result, three types of KOC1-derived peptides were selected as peptides capable of inducing potent CTLs.

Establishment of CTL lines and clones against the KOC1-derived HLA-A*0301-restricted peptides

CTL line was established by propagating CTLs in Well #5 with KOC1-A03-10-120 (SEQ ID NO: 27), which showed peptide-specific CTL activity in the IFN-gamma ELISPOT assay. The CTL activity of these CTL lines was measured by IFN-gamma ELISA (Fig. 10). These CTL lines showed potent IFN-gamma production against target cells pulsed with the respective peptides, in comparison with target cells that have not been pulsed with the peptides. Further, CTL clones were established from the CTL lines by limiting dilution as described in the "Materials and methods" section above, IFN-gamma production from the CTL clones against peptide-pulsed C1R-A03 was measured by IFN-gamma ELISA. Potent IFN-gamma production was observed in CTL clone stimulated with KOC1-A03-10-120 (SEQ ID NO: 27) (Fig. 11).

Specific CTL activity against target cells expressing KOC1 and HLA-A*0301

The CTL clone established against KOC1-A03-10-120 (SEQ ID NO: 27) was investigated for their ability to recognize target cells expressing KOC1 and the HLA-A*0301 molecule. COS7 cells transfected with both full-length KOC1 and the HLA-A*0301 gene (a specific model of target cells expressing KOC1 and the HLA-A*0301 gene) were prepared as the target cell. COS7 cells transfected with either full-length KOC1 or HLA-A*0301 were prepared as the control. The CTL clone stimulated with KOC1-A03-10-120 (SEQ ID NO: 27) demonstrated potent CTL activities against COS7 cells expressing both KOC1 and HLA-A*0301 (Fig. 12). On the other hand, a significant specific CTL activity was not detected against the control cells. These data clearly proved that KOC1-A03-10-120 (SEQ ID NO: 27) is a peptide generated from endogenous processing of KOC1, and is presented on target cells with the HLA-

A*0301 molecule and recognized by CTLs. These results demonstrated the possibility that KOC1-A03-10-120 (SEQ ID NO: 27) may be suitable as a cancer vaccine for patients having a KOC1-expressing cancer.

Homology analysis of antigen peptides

CTLs stimulated with KOC1-A03-10-120 (SEQ ID NO: 27), KOC1-A03-10-204 (SEQ ID NO: 30), or KOC1-A03-10-281 (SEQ ID NO: 52) demonstrated significant specific CTL activities. These results may be due to the fact that the KOC1-A03-10-120 (SEQ ID NO: 27), KOC1-A03-10-204 (SEQ ID NO: 30) and KOC1-A03-10-281 (SEQ ID NO: 52) sequences are homologous to peptides derived from other molecules known for sensitizing the human immune system. In order to exclude this possibility, homology analysis was performed by querying these peptide sequences using the BLAST algorithm (blast.ncbi.nlm.nih.gov/Blast.cgi). This result showed that there is no sequence having a significant homology with the KOC1-A03-10-120 (SEQ ID NO: 27) sequence. On the other hand, KOC1-A03-10-204 (SEQ ID NO: 30) is identical to a peptide sequence identified in IMP-2 which is another IMP family. KOC1-A03-10-281 (SEQ ID NO: 52) is identical to a peptide sequence identified in IMP-1 which is another IMP family. It has been previously reported that IMP-1 is not expressed in normal organs except testis, fetal liver and placenta (Hammer NA *et al.*, Reproduction. 2005; 130(2): 203-12). It is reported to be associated with tumor progression in lung cancer patients (Kato T *et al.*, Clin Cancer Res. 2007; 13: 434-42). It has been previously reported that IMP-2 is not expressed in normal organs except testis and fetal liver (Hammer NA *et al.*, Reproduction. 2005; 130(2): 203-12). It is involved in the proliferation of glioblastoma cancer stem cells (Janiszewska M *et al.*, Genes Dev. 2012; 26(17): 1926-44). IMP-1 and IMP-2 are promising as target antigens for cancer immunotherapy. Therefore, to the knowledge of the present inventors, there is almost no possibility that these peptides would elicit an unintended immune response against other unrelated molecules. In conclusion, novel KOC1-derived HLA-A03-restricted epitope peptides were identified. It was demonstrated that the KOC1-derived epitope peptides are applicable for cancer immunotherapy.

[Example 4]

Materials and methods

Cell lines

C1R, an HLA-A- and HLA-B-negative human B lymphoblastoid cell line, and COS7, an African green monkey kidney cell line, were purchased from ATCC.

Generation of stimulator cells with stable HLA-A*0101 expression

C1R (C1R-A01) that stably expresses HLA-A*0101 was used as a stimulator cell. A cDNA encoding the open-reading frame of HLA-A*0101 was amplified by PCR and cloned into an expression vector. C1R cells were transfected with the expression vector, and then selected using G418 (Invitrogen) for two weeks. The G418-selected cells were seeded into wells containing G418-added culture medium in a 96-well plate, and further cultured for 30 days. The exogenous HLA-A*0101 expression in C1R cells was verified by flow cytometric analysis.

Selection of candidate KOC1-derived peptides

KOC1-derived 9mer and 10mer peptides that bind to the HLA-A*0101 molecule were predicted using the binding prediction server "NetMHC 3.2" (www.cbs.dtu.dk/services/NetMHC/) (Buus *et al.*, Tissue Antigens. 2003 Nov, 62(5):378-84; Nielsen *et al.*, Protein Sci. 2003 May, 12(5): 1007-17; Bioinformatics. 2004 Jun 12: 20(9): 1388-97).

Peptide synthesis

The peptides were synthesized by American Peptide Company (Sunnyvale, CA) according to a standard solid-phase synthesis method, and purified by reversed phase high-performance liquid chromatography (HPLC). The peptides were analyzed for their purity (> 90%) and identity by analytical HPLC and mass spectrometry, respectively. The peptides were dissolved in dimethylsulfoxide at 20 mg/ml and stored at -80 degrees C.

In vitro CTL induction

Monocyte-derived dendritic cells (DCs) were used as the antigen-presenting cell to induce a cytotoxic T lymphocyte (CTL) response against peptides presented on human leukocyte antigens (HLAs). As described in the other sections, DCs were generated *in vitro* (Nakahara S *et al.*, Cancer Res 2003, 63(14): 4112-8). Specifically, peripheral-blood mononuclear cells isolated from healthy volunteers (HLA-A*0101-positive) with the Ficoll-Paque plus solution (Pharmacia) were separated by attaching to plastic tissue culture dishes (Becton Dickinson) and concentrated as a monocyte fraction. The monocyte-concentrated population was cultured in the presence of 1000 IU/ml granulocyte macrophage colony-stimulating factor (R&D System) and 1000 IU/ml interleukin(IL)-4 (R&D System) in an AIM-V medium (Invitrogen) containing 2% heat-inactivated autologous serum (AS). After seven days of culturing, the cytokine-induced DCs were pulsed with 20 micro-g/ml each of the synthesized peptides in an AIM-V medium at 37 degrees C for three hours in the presence of 3 micro-g/ml beta 2-microglobulin. Next, these peptide-pulsed DCs were inactivated by X-ray irradiation (20 Gy), and mixed in a 1:20 ratio with autologous $CD8^+$ T cells obtained by positive selection using the CD8 Positive Isolation Kit

(Dynal). These culture products were seeded in a 48-well plate (Corning). Each well was made to contain 1.5 x 10^4 peptide-pulsed DCs, 3 x 10^5 $CD8^+$ T cells and 10 ng/ml IL-7 (R&D System) in 0.5 ml of the AIM-V/2%AS medium. Three days later, these culture products were added with a final concentration of 20 IU/ml IL-2 (CHIRON). On day 7 and day 14, T cells were further stimulated with peptide-pulsed autologous DCs. The DCs were prepared every time by the same method as above. On day 21, after the third peptide stimulation, CTL activities were examined against the peptide-pulsed C1R-A01 cells (Tanaka H *et al.*, Br J Cancer 2001, 84(1): 94-9; Umano Y *et al.*, Br J Cancer 2001, 84(8): 1052-7; Uchida N *et al.*, Clin Cancer Res 2004, 10(24): 8577-86; Suda T *et al.*, Cancer Sci 2006, 97(5): 411-9; Watanabe T *et al.*, Cancer Sci 2005, 96(8): 498-506).

CTL propagation procedure

CTLs were propagated in culture using methods similar to those disclosed by Riddell *et al.* (Walter EA *et al.*, N Engl J Med 1995, 333(16): 1038-44; Riddell SR *et al.*, Nat Med 1996, 2(2): 216-23). The CTLs were co-cultured in a total of 25 ml AIM-V medium containing 5% AS and 40 ng/ml anti-CD3 antibody with two types of Mitomycin C-treated human B lymphoblastoid cell lines at 5 x 10^6 cells. One day after beginning of the culturing, 120 IU/ml IL-2 was added to the culture. On days 5, 8 and 11, a fresh AIM-V/5%AS medium containing 30 IU/ml IL-2 was added to the culture (Tanaka H *et al.*, Br J Cancer 2001, 84(1): 94-9; Umano Y *et al.*, Br J Cancer 2001, 84(8): 1052-7; Uchida N *et al.*, Clin Cancer Res 2004, 10(24): 8577-86; Suda T *et al.*, Cancer Sci 2006, 97(5): 411-9; Watanabe T *et al.*, Cancer Sci 2005, 96(8): 498-506).

Establishment of CTL clones

CTLs were seeded to make 1 or 10 cells/well in 96 round-bottomed microtiter plates (Nalge Nunc International). The CTLs were co-cultured with two types of Mitomycin C-treated human B lymphoblastoid cell lines at 1 x 10^4 cells in a total of 150 micro-l/well 5% AS-containing AIM-V medium with 30 ng/ml anti-CD3 antibody and 125 IU/ml IL-2. Ten days later, 50 micro-l of IL-2 was added to the medium to reach a final IL-2 concentration of 125 IU/ml. On day 14, the CTL activity was tested, and the CTL clones were propagated using the same method as described above (Uchida N *et al.*, Clin Cancer Res 2004, 10(24): 8577-86; Suda T *et al.*, Cancer Sci 2006, 97(5): 411-9; Watanabe T *et al.*, Cancer Sci 2005, 96(8): 498-506).

Specific CTL activity

To examine specific CTL activity, an IFN-gamma ELISPOT assay and an IFN-gamma enzyme-linked immunosorbent assay (ELISA) were performed. Specifically, peptide-pulsed

C1R-A01 (1 x 10^4 cells/well) was prepared as the stimulator cell. The induced CTLs, *i.e.*, CTL lines and CTL clones, were used as the responder cell. The IFN-gamma ELISPOT assay and IFN-gamma ELISA were performed according to the manufacturer's manual.

Establishment of target cells forcibly expressing a target gene and HLA-A*0101

A cDNA encoding the open-reading frame of a target gene or HLA-A*0101 was amplified by PCR. The PCR-amplified product was cloned into an expression vector. Expression vectors were transfected using Lipofectamine 2000 (Invitrogen) following the manufacturer's recommended protocol. Two days after transfection, the transfected cells were harvested using versene (Invitrogen), and used as the stimulator cell for CTL activity assay (5 x 10^4 cells/well).

Results

Prediction of KOC1-derived HLA-A*0101-binding peptides

Tables 4a and 4b show KOC1-derived 9mer peptides and 10mer peptides that have been predicted to bind to HLA-A*0101 in the descending order of binding affinity. A total of 27 peptides that potentially have an HLA-A*0101-binding ability was selected and investigated to determine epitope peptides.

[Table 4a]

HLA-A1-binding 9mer peptides derived from KOC1

Start position	Amino acid sequence	Kd (nM)	SEQ ID NO
96	VLDSLLVQY	56	86
118	ETAVVNVTY	57	87
114	NTDSETAVV	453	88
273	FTEEIPLKI	528	89
404	ETETVHLFI	1528	90
536	VVKITGHFY	5589	13
15	PSDLESIFK	5882	12
143	QLENFTLKV	11578	91
402	QSETETVHL	13101	92
305	DTDTKITIS	13406	93
313	SPLQELTLY	21305	94
338	KAEEEIMKK	23866	10
301	KIEQDTDTK	24016	21
69	EVEHSVPKR	24734	69

[Table 4b]

HLA-A1-binding 10mer peptides derived from KOC1

Start position	Amino acid sequence	Kd (nM)	SEQ ID NO
312	ISPLQELTLY	146	46
95	EVLDSLLVQY	498	50
402	QSETETVHLF	1737	95
9	LSENAAPSDL	2164	96
535	VVVKITGHFY	3359	41
273	FTEEIPLKIL	4478	97
462	AQFKAQGRIY	6263	98
342	EIMKKIRESY	7665	99
252	GTSAACKSIL	9689	100
30	SGPFLVKTGY	17794	101
114	NTDSETAVVN	22411	102
305	DTDTKITISP	29728	103
17	DLESIFKDAK	35078	104

Start position indicates the number of amino acid residue from the N-terminus of KOC1. The dissociation constant [Kd (nM)] is derived from "NetMHC3.2".

Induction of CTLs by the predicted KOC1-derived HLA-A*0101-restricted peptides

CTLs against the KOC1-derived peptides were generated according to the protocol described in "Materials and methods". The peptide-specific CTL activity was measured by an IFN-gamma ELISPOT assay (Fig. 13). In comparison with the control, CTLs in Well #2 with KOC1-A01-9-96 (SEQ ID NO: 86) (a), Well #4 with KOC1-A01-9-118 (SEQ ID NO: 87) (b), Well #3 with KOC1-A01-9-404 (SEQ ID NO: 90) (c), Well #4 with KOC1-A01-9-402 (SEQ ID NO: 92) (d), Well #7 with KOC1-A01-10-312 (SEQ ID NO: 46) (e), Well #1 with KOC1-A01-10-402 (SEQ ID NO: 95) (f) and Well #1 with KOC1-A01-10-535 (SEQ ID NO: 41) (g) showed potent IFN-gamma production. Meanwhile, despite that other peptides shown in Tables 4a and 4b potentially have an HLA-A*0101-binding activity, specific CTL activity was not detected as a result of stimulation by those peptides. An example of typical negative data is that specific IFN-gamma production was not observed from CTLs stimulated with KOC1-A01-9-536 (SEQ ID NO: 13) (h). As a result, seven types of KOC1-derived peptides were selected as peptides capable of inducing potent CTLs.

Establishment of CTL lines and clones against the KOC1-derived peptides

CTL lines were established by propagating CTLs in Well #2 with KOC1-A01-9-96 (SEQ ID NO: 86) (a) and Well #4 with KOC1-A01-9-118 (SEQ ID NO: 87) (b), which showed peptide-specific CTL activity in the IFN-gamma ELISPOT assay. The CTL activity of these CTL lines was measured by IFN-gamma ELISA (Fig. 14). These CTL lines showed potent IFN-gamma production against target cells pulsed with the respective peptides, in comparison with target cells that have not been pulsed with the peptides. Further, CTL clones were established from the CTL lines by limiting dilution as described in the "Materials and methods" section above, IFN-gamma production from the CTL clones against peptide-pulsed C1R-A01 cell was measured by IFN-gamma ELISA. Potent IFN-gamma production was observed in CTL clone stimulated with KOC1-A01-9-96 (SEQ ID NO: 86) (Fig. 15).

Specific CTL activity against target cells expressing KOC1 and HLA-A*0101

The CTL clone established against KOC1-A01-9-96 (SEQ ID NO: 86) was investigated for its ability to recognize target cells expressing KOC1 and the HLA-A*0101 molecule. COS7 cells transfected with both full-length KOC1 and the HLA-A*0101 gene (a specific model of target cells expressing KOC1 and the HLA-A*0101 gene) were prepared as the target cell. COS7 cells transfected with either full-length KOC1 or HLA-A*0101 were prepared as the control. The CTL clone stimulated with KOC1-A01-9-96 (SEQ ID NO: 86) demonstrated potent CTL activities against COS7 cells expressing both KOC1 and HLA-A*0101 (Fig. 16). On the other hand, a significant specific CTL activity was not detected against the control cells. These data clearly proved that KOC1-A01-9-96 (SEQ ID NO: 86) is a peptide generated from endogenous processing of KOC1, and is presented on target cells with the HLA-A*0101 molecule and recognized by CTLs. These results demonstrated the possibility that KOC1-A01-9-96 (SEQ ID NO: 86) may be suitable as a cancer vaccine for patients having a KOC1-expressing cancer.

Homology analysis of antigen peptides

CTLs stimulated with KOC1-A01-9-96 (SEQ ID NO: 86), KOC1-A01-9-118 (SEQ ID NO: 87), KOC1-A01-9-404 (SEQ ID NO: 90), KOC1-A01-9-402 (SEQ ID NO: 92), KOC1-A01-10-312 (SEQ ID NO: 46), KOC1-A01-10-402 (SEQ ID NO: 95), or KOC1-A01-10-535 (SEQ ID NO: 41) demonstrated significant specific CTL activities. These results may be due to the fact that the KOC1-A01-9-96 (SEQ ID NO: 86), KOC1-A01-9-118 (SEQ ID NO: 87), KOC1-A01-9-404 (SEQ ID NO: 90), KOC1-A01-9-402 (SEQ ID NO: 92), KOC1-A01-10-312 (SEQ ID NO: 46), KOC1-A01-10-402 (SEQ ID NO: 95), and KOC1-A01-10-535 (SEQ ID NO: 41) sequences are homologous to peptides derived from other molecules known for sensitizing the human immune system. In order to exclude this possibility, homology analysis was

performed by querying these peptide sequences using the BLAST algorithm (blast.ncbi.nlm.nih.gov/Blast.cgi). This result showed that there is no sequence having a significant homology with the KOC1-A01-9-96 (SEQ ID NO: 86), KOC1-A01-9-118 (SEQ ID NO: 87), KOC1-A01-9-404 (SEQ ID NO: 90), KOC1-A01-9-402 (SEQ ID NO: 92), KOC1-A01-10-312 (SEQ ID NO: 46), KOC1-A01-10-402 (SEQ ID NO: 95), and KOC1-A01-10-535 (SEQ ID NO: 41) sequences. On the other hand, KOC1-A01-9-118 (SEQ ID NO: 87) is identical to peptide sequences identified in IMP-1 and IMP-2 which are the other IMP families. It has been previously reported that IMP-1 is not expressed in normal organs except testis, fetal liver and placenta (Hammer NA *et al.*, Reproduction. 2005; 130(2): 203-12). It is reported to be associated with tumor progression in lung cancer patients (Kato T *et al.*, Clin Cancer Res. 2007; 13: 434-42). It has been previously reported that IMP-2 is not expressed in normal organs except testis and fetal liver (Hammer NA *et al.*, Reproduction. 2005; 130(2): 203-12). It is involved in the proliferation of glioblastoma cancer stem cells (Janiszewska M *et al.*, Genes Dev. 2012; 26(17): 1926-44). IMP-1 and IMP-2 are promising as target antigens for cancer immunotherapy. Therefore, to the knowledge of the present inventors, there is almost no possibility that these peptides would elicit an unintended immune response against other unrelated molecules. In conclusion, novel KOC1-derived HLA-A01-restricted epitope peptides were identified. It was demonstrated that the KOC1-derived epitope peptides are applicable for cancer immunotherapy.

[Example 5]

Preparation of emulsion formulations

A peptide was dissolved in an injection solvent or sterile physiological saline to become 1.0 mg/ml to 10.0 mg/ml, and collected into a syringe. This was connected *via* a connector to a syringe filled with an IFA in an amount equivalent to an injection solvent or sterile physiological saline, and mixed by alternately pushing the syringe plungers of the two connected syringes. After several minutes of mixing, completion of the emulsion was assessed by the drop test method. The drop test method can be performed by dropping one drop of the mixed sample on water. The emulsion is assessed as completed when the sample dropped on water does not immediately diffuse in water; and the emulsion is assessed as incompleted when the sample dropped on water diffuses right away in water. When the emulsion is assessed as incompleted, further mixing is carried out to complete the emulsion. The completed emulsion can be administered to a cancer patient by subcutaneous injection. The cancer patient subject to administration can be selected from patients affected by bladder cancer, cervical cancer, cholangiocellular cancer, chronic myeloid leukemia (CML), colon cancer, rectum cancer, esophagus cancer, diffuse gastric cancer, non-small-cell lung cancer, small-cell lung cancer,

lymphoma, osteosarcoma, ovarian cancer, kidney cancer, head and neck cancer, soft tissue tumor, testis cancer or such.

Preparation of freeze-dried formulations

A peptide was dissolved in an injection solvent to become 1.0 mg/ml to 10.0 mg/ml, and sterilized by filtration. This was filled into a sterilized vial, and half-capped with a sterilized rubber plug. After this vial was freeze-dried, it was completely capped and seamed with an aluminum cap to produce a freeze-dried formulation. When in use, an injection solvent or sterile physiological saline was injected into the vial to re-dissolve the freeze-dried powder. The re-dissolved solution in the vial was collected using a syringe, and the syringe was connected *via* a connector with a syringe filled with an IFA in an amount equivalent to the collected re-dissolved solution. The re-dissolved solution and IFA were mixed by alternately pushing the syringe plungers of the two connected syringes. After several minutes of mixing, completion of the emulsion was assessed by the drop test method. The completed emulsion can be administered to a cancer patient by subcutaneous injection. The cancer patient subject to administration can be selected from patients affected by bladder cancer, cervical cancer, cholangiocellular cancer, chronic myeloid leukemia (CML), colon cancer, rectum cancer, esophagus cancer, diffuse gastric cancer, non-small-cell lung cancer, small-cell lung cancer, lymphoma, osteosarcoma, ovarian cancer, kidney cancer, head and neck cancer, soft tissue tumor, testis cancer or such.

Industrial applicability

The present invention provides KOC1-derived novel HLA-A11-restricted, HLA-A33-restricted, HLA-A03-restricted and HLA-A01-restricted epitope peptides that induce a potent and specific anti-tumor immune response and thus have applicability for a wide range of cancer types. The peptides, compositions, APCs, and CTLs in the present invention can be used as a peptide vaccine for cancer expressing KOC1, for example, bladder cancer, cervical cancer, cholangiocellular cancer, chronic myeloid leukemia (CML), colon cancer, rectum cancer, esophagus cancer, diffuse gastric cancer, non-small-cell lung cancer, small-cell lung cancer, lymphoma, osteosarcoma, ovarian cancer, kidney cancer, head and neck cancer, soft tissue tumor, and testis cancer.

While the present invention is herein described in detail and with respect 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 present 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 present invention, the metes and bounds of which are defined by the appended claims.

CLAIMS

1. A peptide of less than 15 amino acids having cytotoxic T cell (CTL)-inducing ability, which comprises the amino acid sequence selected from the group below:

(a) the amino acid sequence selected from the group consisting of SEQ ID NOs: 5, 28, 30, 32, 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, 85, 27, 86, 87, 90, 92, 46, 95 and 41; and

(b) the amino acid sequence in which one, two or several amino acids are substituted, deleted, inserted and/or added to the amino acid sequence selected from the group consisting of SEQ ID NOs: 5, 28, 30, 32, 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, 85, 27, 86, 87, 90, 92, 46, 95 and 41.

2. The peptide of claim 1, which is selected from the group consisting of (i) to (iv) below:

(i) a peptide comprising the amino acid sequence in which one or more substitution(s) selected from the group consisting of (a) to (d) below is introduced into the amino acid sequence selected from the group consisting of SEQ ID NOs: 5, 28, 30 and 32:

(a) the second amino acid from the N terminus is substituted with an amino acid selected from the group consisting of threonine, valine, isoleucine, leucine, phenylalanine and tyrosine;

(b) the third amino acid from the N terminus is substituted with an amino acid selected from the group consisting of leucine, phenylalanine, tyrosine, isoleucine and alanine;

(c) the seventh amino acid from the N terminus is substituted with an amino acid selected from the group consisting of leucine, isoleucine, tyrosine, valine and phenylalanine; and

(d) the C-terminal amino acid is substituted with an amino acid selected from the group consisting of lysine and arginine;

(ii) a peptide comprising the amino acid sequence in which one or more substitution(s) selected from the group consisting of (a) to (c) below is introduced into the amino acid sequence selected from the group consisting of SEQ ID NOs: 61, 62, 63, 64, 67, 74, 77, 52, 79, 80 and 85:

(a) the first amino acid from the N terminus is substituted with an amino acid selected from the group consisting of aspartic acid and glutamic acid;

(b) the second amino acid from the N terminus is substituted with an amino acid selected from the group consisting of phenylalanine, tyrosine, alanine, isoleucine, leucine and valine; and

(c) the C-terminal amino acid is substituted with an amino acid selected from the group consisting of arginine and lysine;

(iii) a peptide comprising the amino acid sequence in which one or more substitution(s) selected from the group consisting of (a) to (b) below is introduced into the amino acid sequence selected from the group consisting of SEQ ID NOs: 27, 30 and 52:

(a) the second amino acid from the N terminus is substituted with an amino acid selected from the group consisting of leucine, methionine, valine, alanine, isoleucine, serine and threonine; and

(b) the C-terminal amino acid is substituted with an amino acid selected from the group consisting of arginine, lysine, tyrosine and phenylalanine;

(iv) a peptide comprising the amino acid sequence in which one or more substitution(s) selected from the group consisting of (a) to (c) below is introduced into the amino acid sequence selected from the group consisting of SEQ ID NOs: 86, 87, 90, 92, 46, 95 and 41:

(a) the second amino acid from the N terminus is substituted with an amino acid selected from the group consisting of threonine and serine;

(b) the third amino acid from the N terminus is substituted with an amino acid selected from the group consisting of aspartic acid and glutamic acid; and

(c) the C-terminal amino acid is substituted with tyrosine.

3. The peptide of claim 1, which consists of the amino acid sequence selected from the group consisting of SEQ ID NOs: 5, 28, 30, 32, 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, 85, 27, 86, 87, 90, 92, 46, 95 and 41.

4. A polynucleotide, which encodes the peptide of any one of claims 1 to 3.

5. A composition comprising a pharmaceutically acceptable carrier and at least one ingredient selected from the group consisting of (a) to (e) below:

(a) one or more types of peptides of any one of claims 1 to 3;

(b) one or more types of polynucleotides encoding the peptide(s) of any one of claims 1 to 3 in an expressible form;

(c) an antigen-presenting cell (APC) that presents on its cell surface a complex of the peptide of any one of claims 1 to 3 and an HLA antigen;

(d) an exosome that presents on its cell surface a complex of the peptide of any one of claims 1 to 3 and an HLA antigen; and

(e) a CTL that targets the peptide of any one of claims 1 to 3.

6. The composition of claim 5, which is a composition for inducing a CTL(s), wherein the ingredient is at least one ingredient selected from the group consisting of (a) to (d) below:

(a) one or more types of peptides of any one of claims 1 to 3;
(b) one or more types of polynucleotides encoding the peptide(s) of any one of claims 1 to 3 in an expressible form;
(c) an antigen-presenting cell (APC) that presents on its cell surface a complex of the peptide of any one of claims 1 to 3 and an HLA antigen; and
(d) an exosome that presents on its cell surface a complex of the peptide of any one of claims 1 to 3 and an HLA antigen.

7. The composition of claim 5, which is a pharmaceutical composition.

8. The composition of claim 7, which is for one or more uses selected from the group consisting of (i) cancer treatment, (ii) cancer prevention (prophylaxis) and (iii) prevention (prophylaxis) of postoperative cancer recurrence.

9. The composition of claim 7, which is for inducing an immune response against cancer.

10. The composition of claim 8 or 9, wherein the cancer is selected from the group consisting of bladder cancer, cervical cancer, cholangiocellular cancer, chronic myeloid leukemia (CML), colon cancer, rectum cancer, esophagus cancer, diffuse gastric cancer, non-small-cell lung cancer, small-cell lung cancer, lymphoma, osteosarcoma, ovarian cancer, kidney cancer, head and neck cancer, soft tissue tumor and testis cancer.

11. The composition of any one of claims 5 to 10, which is formulated for administration to a subject positive for at least one HLA selected from the group consisting of HLA-A11, HLA-A33, HLA-A03 and HLA-A01.

12. A method of inducing an APC(s) having CTL-inducing ability, which comprises a step selected from the group consisting of:
(a) contacting an APC(s) with the peptide of any one of claims 1 to 3 *in vitro*, *ex vivo* or *in vivo*; and
(b) introducing a polynucleotide encoding the peptide of any one of claims 1 to 3 into an APC(s).

13. A method of inducing a CTL(s), which comprises a step selected from the group consisting of :

(a) co-culturing a CD8-positive T cell(s) with an APC(s) that presents on its surface a complex of an HLA antigen and the peptide of any one of claims 1 to 3;
(b) co-culturing a CD8-positive T cell(s) with an exosome(s) that presents on its surface a complex of an HLA antigen and the peptide of any one of claims 1 to 3; and
(c) introducing into a CD8-positive T cell(s) a polynucleotide encoding each subunit of a T cell receptor (TCR) capable of binding to the peptide of any one of claims 1 to 3 presented by an HLA antigen on a cell surface.

14. An APC that presents on its surface a complex of an HLA antigen and the peptide of any one of claims 1 to 3.

15. The APC of claim 14, which is induced by the method of claim 12.

16. A CTL that targets the peptide of any one of claims 1 to 3.

17. The CTL of claim 16, which is induced by the method of claim 13.

18. A method of inducing an immune response against cancer, which comprises administering to a subject at least one ingredient selected from the group consisting of (a) to (e) below:
(a) one or more types of peptides of any one of claims 1 to 3;
(b) one or more types of polynucleotides encoding the peptide(s) of any one of claims 1 to 3 in an expressible form;
(c) an APC that presents on its cell surface a complex of the peptide of any one of claims 1 to 3 and an HLA antigen;
(d) an exosome that presents on its cell surface a complex of the peptide of any one of claims 1 to 3 and an HLA antigen; and
(e) a CTL that targets the peptide of any one of claims 1 to 3.

19. A method of treating and/or preventing cancer, and/or preventing postoperative recurrence thereof, which comprises administering to a subject at least one ingredient selected from the group consisting of (a) to (e) below:
(a) one or more types of peptides of any one of claims 1 to 3;
(b) one or more types of polynucleotides encoding the peptide(s) of any one of claims 1 to 3 in an expressible form;
(c) an APC that presents on its cell surface a complex of the peptide of any one of claims 1 to 3 and an HLA antigen;

(d) an exosome that presents on its cell surface a complex of the peptide of any one of claims 1 to 3 and an HLA antigen; and

(e) a CTL that targets the peptide of any one of claims 1 to 3.

20. An antibody that binds to the peptide of any one of claims 1 to 3.

21. A method of screening for a peptide having CTL-inducing ability, which comprises the steps of:

(a) generating candidate sequences consisting of an amino acid sequence in which one, two or several amino acid residues are substituted, deleted, inserted and/or added to an original amino acid sequence consisting of the amino acid sequence selected from the group consisting of SEQ ID NOs: 5, 28, 30, 32, 61, 62, 63, 64, 67, 74, 77, 52, 79, 80, 85, 27, 86, 87, 90, 92, 46, 95 and 41;

(b) selecting from among the candidate sequences generated in (a), a candidate sequence that does not have significant homology (sequence identity) with any known human gene product other than KOC1;

(c) contacting an APC with a peptide consisting of the candidate sequence selected in (b);

(d) contacting the APC of (c) with a CD8-positive T cell; and

(e) selecting a peptide having an equal to or higher CTL-inducing ability than that of a peptide consisting of the original amino acid sequence.

22. An emulsion comprising one or more types of peptides of any one of claims 1 to 3, a water-soluble carrier and an oil adjuvant.

23. A kit comprising a container that houses the composition of any one of claims 5 to 11 and a container that houses an adjuvant.

SEQUENCE LISTING

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aaaccagctg gatccatcca tcaccgtggg tggttttaat ttttcgtttt ttctcgttat 240

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Lys Ile Pro Val Ser Gly Pro Phe Leu Val Lys Thr Gly Tyr Ala Phe
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gtg gac tgc ccg gac gag agc tgg gcc ctc aag gcc atc gag gcg ctt      437
Val Asp Cys Pro Asp Glu Ser Trp Ala Leu Lys Ala Ile Glu Ala Leu
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tca ggt aaa ata gaa ctg cac ggg aaa ccc ata gaa gtt gag cac tcg      485
Ser Gly Lys Ile Glu Leu His Gly Lys Pro Ile Glu Val Glu His Ser
        60                  65                  70

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Val Pro Lys Arg Gln Arg Ile Arg Lys Leu Gln Ile Arg Asn Ile Pro
    75                  80                  85

cct cat tta cag tgg gag gtg ctg gat agt tta cta gtc cag tat gga      581
Pro His Leu Gln Trp Glu Val Leu Asp Ser Leu Leu Val Gln Tyr Gly
90                  95                  100                 105

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Val Val Glu Ser Cys Glu Gln Val Asn Thr Asp Ser Glu Thr Ala Val
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Val Asn Val Thr Tyr Ser Ser Lys Asp Gln Ala Arg Gln Ala Leu Asp
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atc cct gat gaa atg gcc gcc cag caa aac ccc ttg cag cag ccc cga      773
Ile Pro Asp Glu Met Ala Ala Gln Gln Asn Pro Leu Gln Gln Pro Arg
    155                 160                 165

ggt cgc cgg ggg ctt ggg cag agg ggc tcc tca agg cag ggg tct cca      821
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170                 175                 180                 185
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Val Pro Thr Gln Phe Val Gly Ala Ile Ile Gly Lys Glu Gly Ala Thr
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att cgg aac atc acc aaa cag acc cag tct aaa atc gat gtc cac cgt      965
Ile Arg Asn Ile Thr Lys Gln Thr Gln Ser Lys Ile Asp Val His Arg
        220                 225                 230

aaa gaa aat gcg ggg gct gct gag aag tcg att act atc ctc tct act     1013
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    235                 240                 245

cct gaa ggc acc tct gcg gct tgt aag tct att ctg gag att atg cat     1061
Pro Glu Gly Thr Ser Ala Ala Cys Lys Ser Ile Leu Glu Ile Met His
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ccc act tca ggg atg cca cct ccc acc tca ggg ccc cct tca gcc atg     1445
Pro Thr Ser Gly Met Pro Pro Pro Thr Ser Gly Pro Pro Ser Ala Met
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Thr Pro Pro Tyr Pro Gln Phe Glu Gln Ser Glu Thr Glu Thr Val His
    395                 400                 405

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410                 415                 420                 425

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Gln His Ile Lys Gln Leu Ser Arg Phe Ala Gly Ala Ser Ile Lys Ile
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Gly Pro Pro Glu Ala Gln Phe Lys Ala Gln Gly Arg Ile Tyr Gly Lys
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Ala His Ile Arg Val Pro Ser Phe Ala Ala Gly Arg Val Ile Gly Lys
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<212> PRT
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<400> 110

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Asp Leu Glu Ser Ile Phe Lys Asp Ala Lys Ile Pro Val Ser Gly Pro
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Phe Leu Val Lys Thr Gly Tyr Ala Phe Val Asp Cys Pro Asp Glu Ser
35 40 45

Trp Ala Leu Lys Ala Ile Glu Ala Leu Ser Gly Lys Ile Glu Leu His
50 55 60

Gly Lys Pro Ile Glu Val Glu His Ser Val Pro Lys Arg Gln Arg Ile
65 70 75 80

Arg Lys Leu Gln Ile Arg Asn Ile Pro Pro His Leu Gln Trp Glu Val
85 90 95

Leu Asp Ser Leu Leu Val Gln Tyr Gly Val Val Glu Ser Cys Glu Gln
100 105 110

Val Asn Thr Asp Ser Glu Thr Ala Val Val Asn Val Thr Tyr Ser Ser
115 120 125

Lys Asp Gln Ala Arg Gln Ala Leu Asp Lys Leu Asn Gly Phe Gln Leu
130 135 140

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Glu Asn Phe Thr Leu Lys Val Ala Tyr Ile Pro Asp Glu Met Ala Ala
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Gln Gln Asn Pro Leu Gln Gln Pro Arg Gly Arg Arg Gly Leu Gly Gln
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Arg Gly Ser Ser Arg Gln Gly Ser Pro Gly Ser Val Ser Lys Gln Lys
            180                 185                 190

Pro Cys Asp Leu Pro Leu Arg Leu Leu Val Pro Thr Gln Phe Val Gly
        195                 200                 205

Ala Ile Ile Gly Lys Glu Gly Ala Thr Ile Arg Asn Ile Thr Lys Gln
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Thr Gln Ser Lys Ile Asp Val His Arg Lys Glu Asn Ala Gly Ala Ala
225                 230                 235                 240

Glu Lys Ser Ile Thr Ile Leu Ser Thr Pro Glu Gly Thr Ser Ala Ala
                245                 250                 255

Cys Lys Ser Ile Leu Glu Ile Met His Lys Glu Ala Gln Asp Ile Lys
            260                 265                 270

Phe Thr Glu Glu Ile Pro Leu Lys Ile Leu Ala His Asn Asn Phe Val
        275                 280                 285

Gly Arg Leu Ile Gly Lys Glu Gly Arg Asn Leu Lys Lys Ile Glu Gln
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Asp Thr Asp Thr Lys Ile Thr Ile Ser Pro Leu Gln Glu Leu Thr Leu
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305 310 315 320

Tyr Asn Pro Glu Arg Thr Ile Thr Val Lys Gly Asn Val Glu Thr Cys
325 330 335

Ala Lys Ala Glu Glu Glu Ile Met Lys Lys Ile Arg Glu Ser Tyr Glu
340 345 350

Asn Asp Ile Ala Ser Met Asn Leu Gln Ala His Leu Ile Pro Gly Leu
355 360 365

Asn Leu Asn Ala Leu Gly Leu Phe Pro Pro Thr Ser Gly Met Pro Pro
370 375 380

Pro Thr Ser Gly Pro Pro Ser Ala Met Thr Pro Pro Tyr Pro Gln Phe
385 390 395 400

Glu Gln Ser Glu Thr Glu Thr Val His Leu Phe Ile Pro Ala Leu Ser
405 410 415

Val Gly Ala Ile Ile Gly Lys Gln Gly Gln His Ile Lys Gln Leu Ser
420 425 430

Arg Phe Ala Gly Ala Ser Ile Lys Ile Ala Pro Ala Glu Ala Pro Asp
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Ala Lys Val Arg Met Val Ile Ile Thr Gly Pro Pro Glu Ala Gln Phe
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Lys Ala Gln Gly Arg Ile Tyr Gly Lys Ile Lys Glu Glu Asn Phe Val
465 470 475 480

Ser Pro Lys Glu Glu Val Lys Leu Glu Ala His Ile Arg Val Pro Ser
485 490 495

Phe Ala Ala Gly Arg Val Ile Gly Lys Gly Gly Lys Thr Val Asn Glu
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Leu Gln Asn Leu Ser Ser Ala Glu Val Val Val Pro Arg Asp Gln Thr
515 520 525

Pro Asp Glu Asn Asp Gln Val Val Val Lys Ile Thr Gly His Phe Tyr
530 535 540

Ala Cys Gln Val Ala Gln Arg Lys Ile Gln Glu Ile Leu Thr Gln Val
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Arg Arg Lys

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Asn Lys Arg Lys
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