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(54) Titre : IMMUNISATION D'UN INDIVIDU CONTRE DES CARCINOMES ET LEURS STADES PREALABLES
(54) Title: IMMUNIZATION OF AN INDIVIDUAL AGAINST CARCINOMA AND THE PRELIMINARY STAGES THEREOF

(57) Abrégé/Abstract:
The invention concerns a pharmaceutical preparation comprising a cell cycle regulatory protein and/or an expressible nucleic acid which codes for said protein in an amount suitable for immunization of an individual against carcinoma and the preliminary stages thereof, in addition to conventional auxiliary agents. The invention also concerns the use of a cell cycle regulatory protein and/or an expressible nucleic acid which codes for said protein for the immunization of an individual against carcinoma and the preliminary stages thereof.

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Zur Erklärung der Zweibuchstaben-Codes und der anderen Abkürzungen wird auf die Erklärungen ("Guidance Notes on Codes and Abbreviations") am Anfang jeder regulären Ausgabe der PCT-Gazette verwiesen.

(54) **Title:** IMMUNIZATION OF AN INDIVIDUAL AGAINST CARCINOMA AND THE PRELIMINARY STAGES THEREOF

(54) **Bezeichnung:** IMMUNISIERUNG EINES INDIVIDUUMS GEGEN CARCINOME UND IHRE VORSTUFEN

(57) **Abstract:** The invention concerns a pharmaceutical preparation comprising a cell cycle regulatory protein and/or an expressible nucleic acid which codes for said protein in an amount suitable for immunization of an individual against carcinoma and the preliminary stages thereof, in addition to conventional auxiliary agents. The invention also concerns the use of a cell cycle regulatory protein and/or an expressible nucleic acid which codes for said protein for the immunization of an individual against carcinoma and the preliminary stages thereof.

(57) **Zusammenfassung:** Die vorliegende Erfindung betrifft eine pharmazeutische Zusammensetzung, umfassend ein Zellzyklus-Regulatorprotein und/oder eine exprimierbare, hierfür kodierende Nukleinsäure in einer für eine Immunisierung eines Individuums gegen Carcinome und ihre Vorstufen geeigneten Menge sowie übliche Hilfsstoffe, und die Verwendung eines Zellzyklus-Regulatorproteins und/oder einer exprimierbaren hierfür kodierenden Nukleinsäure zur Immunisierung eines Individuums gegen Carcinome und ihre Vorstufen.

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Immunization of an Individual against Carcinomas and the Preliminary Stages thereof

The present invention relates to a pharmaceutical composition containing a cell cycle regulatory protein and to the use of the pharmaceutical composition for immunizing an individual against carcinomas and the preliminary stages thereof.

Several million people fall ill with, and die of, carcinomas world-wide every year. These mortality rates have remained unchanged for many years despite intensive therapy research. Until now, patients suffering from carcinomas often have to undergo carcinoma-removing surgery or chemotherapy or radiation therapy. However, this is accompanied by very massive side-effects which then contribute to the mortality rates of patients suffering from carcinomas.

It is thus the object of the present invention to provide a product by means of which therapeutic and prophylactic steps can be taken against carcinomas, the above side-effects being avoided.

According to the invention this is achieved by the subject matters defined in the claims.

The present invention is based on Applicant's findings that in carcinomas or the preliminary stages thereof cell cycle regulatory proteins are available in modified form or amount. For example, overexpression of cyclin-dependent kinase inhibitors is found in carcinomas (cf. Applicant's German patent 198 29 473). Applicant also found out that individuals can be immunized against cell cycle regulatory proteins modified as regards form or amount so as to take therapeutic and prophylactic steps

against carcinomas and the preliminary stages thereof. Applicant showed this by way of *in vitro* and *in vivo* experiments (*cf.* below example).

The present invention thus relates to a pharmaceutical composition, comprising a cell cycle regulatory protein and/or an expressible nucleic acid coding for this in an amount suitable for immunization of an individual against carcinomas and the preliminary stages thereof as well as common auxiliary agents.

The employed term "cell cycle regulatory protein" comprises cell cycle regulatory proteins of any kind and origin. For example, these may be cyclins. In particular, these may be cyclin-dependent kinases, such as cdk4 and cdk6, which regulate the cyclins. More particularly, these may be cyclin-dependent kinase inhibitors which, in turn, regulate the cyclin-dependent kinases. Examples of cyclin-dependent kinase inhibitors are the proteins p15, p16, p18, p19, with p16 being preferred. The cell cycle regulatory proteins may be available in wild-type or modified form. The latter form comprises modifications of the amino acid sequence, such as additions, deletions, substitutions and/or inversions of one or more amino acids. Fragments of cell cycle regulatory proteins as such or in combination with carriers may also be present, the fragments being able to have a wild-type or modified amino acid sequence. It is favorable for the carriers in the individual not to be immunogenic. Such carriers may be the individual's own proteins or foreign proteins or fragments thereof. Carriers, such as serum albumin, fibrinogen or transferrin or a fragment thereof are preferred. It is particularly favorable for the fragments of the cell cycle regulatory proteins to contain epitopes which are recognized by cytotoxic T cells, e.g. $CD8^+$ T cells, and may induce a cytotoxic immune response. Such epitopes of cell cycle regulatory proteins can be determined by methods with which a person skilled in the art is familiar, in particular by using an NIH software system. It can also be advantageous for different cell cycle regulatory proteins or

fragment thereof, to which the above explanations apply correspondingly, to be simultaneously present. For the production of the above cell cycle regulatory proteins, reference is made e.g. to Sambrook *et al.*, Molecular Cloning: A Laboratory Manual, 2nd edition, Cold Spring Harbor Laboratory Press, Cold Spring Harbor NY (1989).

The employed term "expressible nucleic acid coding for a cell cycle regulatory protein" comprises any nucleic acid, e.g. RNA or DNA, expressible in an individual and coding for a cell cycle regulatory protein, to which the above explanations apply correspondingly. The nucleic acid can be present as such, *i.e.* together with elements suitable for the expression thereof, or in combination with a vector. Examples of such elements are promoters and enhancers, such as CMV, SV40, RSV metallothionein I and polyhedrin promoter or CMV and SV40 enhancers. Further sequences suitable for expression are disclosed in Goeddel: Gene Expression Technology: Methods in Enzymology 185, Academic Press, San Diego, CA (1990). Moreover, any vectors suitable for expression in mammalian cells can be used as vectors. These are e.g. pcDNA3, pMSX, pKCR, pEFBOS, cDM8 and pCEV4 as well as vectors derived from pcDNAI/amp, pcDNAI/neo, pRc/CMV, pSV2gpt, pSV2neo, pSV2-dhfr, pTk2, pRSVneo, pMSG, pSVT7, pko-neo and pHyg. Recombinant viruses, e.g. adenovirus, vaccinia virus or adeno-associated virus, can also be used as vectors. As regards the production of the above nucleic acids, in particular vectors containing such nucleic acids, reference is made to Sambrook *et al., supra*, for example.

The employed term "carcinomas and the preliminary stages thereof" comprises carcinomas of any kind and origin and preliminary stages thereof. For example, these may be carcinomas of the upper respiratory tract or anogenital carcinomas, in particular the cervical carcinoma and the preliminary stages thereof, such as cervical intraepithelial neoplasia (CIN I-III), carcinoma *in situ* (CIS), *etc.* Likewise benign modifications such as papillomas, adenomas, hyperplasias or similar proliferations of

epithelial, mesenchymal or hematopoietic proliferations are also to be counted thereamong.

The employed term "individual" comprises an individual of any kind and origin having cell cycle regulatory proteins and being able to fall ill with carcinomas and/or their preliminary stages. Examples of such individuals are humans and animals as well as cells thereof.

The employed term "amount suitable for immunization of an individual" comprises any amount of a cell cycle regulatory protein, to which the above explanations apply correspondingly, or an expressible nucleic acid coding for this, to which the above explanations apply correspondingly, and with which an individual can be immunized. The amount depends on whether a cell cycle regulatory protein or an expressible nucleic acid coding for this is used. The amount also depends on whether immunization of the individual rather aims at an induction of antibodies directed against modified cell cycle regulatory proteins or a stimulation of cytotoxic T cells, e.g. $CD8^+$ T cells, directed against modified cell cycle regulatory proteins. Both possibilities of immunization can be achieved by the present invention. Furthermore, the amount depends on whether immunization is intended as a prophylactic or therapeutic treatment. In addition, the individual's age, sex and weight play a role for determining the amount. It is favorable to give the individual 100 µg - 1 g of a cell cycle regulatory protein or 10^6 - 10^{12} MOI of a recombinant virus containing an expressible nucleic acid coding for a cell cycle regulatory protein by means of injection. The injection may be made at various sites of the individual intramuscularly, subcutaneously, intradermally or in any other form of application. It may also be favorable to carry out one or more "booster injections" having about equal amount. In this case, it may be particularly favorable to use different fragments of the respective cell cycle regulatory proteins for the individual injections.

The employed term "common auxiliary agents" comprises any auxiliary agents suitable for a pharmaceutical composition to immunize an individual. Such auxiliary agents are e.g. immunization adjuvants, such as GM-CSF or Freund's adjuvant, buffered common salt solutions, water, emulsions, such as oil/water emulsions, wetting agents, sterile solutions, *etc.*

By means of the present invention it is possible to immunize individuals, in particular humans and animals, against modified cell cycle regulatory proteins. Immunization takes place by both induction of antibodies and stimulation of $CD8^+$ T cells, directed against modified cell cycle regulatory proteins. Thus, it is possible to take prophylactic and therapeutic steps against carcinomas and the preliminary stages thereof.

The invention is explained by the below example.

Example: Stimulation of $CD8^+$ T cells against the cyclin-dependent kinase inhibitor p16 and lysis of p16-overexpressing carcinoma cells.

(A) Stimulation of $CD8^+$ T cells against p16.

Peripheral mononuclear cells are obtained from a healthy donor and subjected to what is called ELISPOT analysis. It is the principle of this experiment to stimulate lymphocytes in culture vessels with specific antigens. Whenever the lymphocytes are activated as they recognize the antigen, the activated lymphocytes release cytokines which, in turn, bind to specific antibodies immobilized on the bottom surface of the culture vessels. Having washed out the lymphocytes, the bound cytokines can be detected in the culture vessels by means of a second antibody made visible in a subsequent color reaction.

Peripheral blood lymphocytes (PBL) from an HLA-A0201-positive healthy proband are purified by density centrifugation via a Ficoll Paque®

gradient. T-lymphocytes are obtained by separating the B-lymphocytes or the monocytes using antibody-coupled magnetobeads (CD11, CD16, CD19, CD36 and CD56) (Pant T cell isolation Kit®, Milteny, Bergisch Gladbach, Germany). About 2 x 10^7 T cells are obtained from 30 ml blood.

HLA-A0201-restricted peptides of p16 are identified by means of an NIH software system. These are the below peptides:

9mer peptides:

score1: VMMMGSARV

score 2: VLHRAGARL

score 3: TLTRPVHDA

score 4: LLHGAEPNC

score 5: SMEPSADML

10mer peptides:

score 1: MMGSARVAEL

score 2: LLLHGAEPNC

score 3: GVMMMGSARV

The isolated T cells are incubated with T2 cells, which (a) have been loaded with a mixture of the above 9mer peptides (10 µg/peptide) and (b) with a mixture of the above 10mer peptides (10 µg/peptide). The T cells are restimulated once a week for a period of 6 weeks. 10^7 T cells each are cocultured with 2 x 10^6 peptide-loaded T2 cells in 24-well plates.

The reactivity over the peptide-loaded T2 cells is determined once a week, starting on day 0 of the experiment, by carrying out IFN-γ elispot analysis. On day 28, a reactivity is observed by the mixture of (a) (400 specific cells per million cells). The main reactivity is in this case directed against the peptide VMMMGSARV (1,000 specific cells / 1,000,000 cells).

A less intensive activity is observed against the mixture of (b) (150 specific cells /1,000,000 cells). Here, the peptide MMGSARVAEL shows maximum reactivity (600 specific cells / 1,000,000 cells).

Hence it is evident that it is possible to stimulate $CD8^+$ T cells activated against p16.

(B) Lysis of p16-overexpressing carcinoma cells

Following another restimulation, the activated $CD8^+$ T cells are incubated with the HLA A0201+ cervical carcinoma cells Caski, which overexpress p16. The colon carcinoma cells SW480 which do not overexpress p16 are used as controls. 10^6 Caski cells are labeled with ^{52}Cr (100 µCi) at 37°C for 1 h and cocultured with increasing numbers of activated $CD8^+$ T cells for 3 hours. Specific lysis of the Caski cells is determined by the amount of released radioactivity in the supernatant.

It turns out that Caski cells are lyzed by the activating $CD8^+$ T cells but not by the control cells SW480.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A pharmaceutical composition, comprising a) a cyclin-dependent kinase inhibitor p16 protein, an immunogenic fragment of the p16 protein or an expressible nucleic acid coding for the p16 protein in an amount suitable for immunizing an individual against carcinomas and the preliminary stages thereof and b) auxiliary agents, wherein the carcinoma is an upper respiratory tract carcinoma or anogenital carcinoma.

2. The pharmaceutical composition according to claim 1, wherein the p16 protein is in the form of one or more immunogenic fragments.

3. The pharmaceutical composition according to claim 2, wherein the fragment or fragments contain epitopes which can be detected by cytotoxic T cells and elicit a cytotoxic immune response.

4. The pharmaceutical composition according to any one of claims 1 to 3 wherein the fragment of p16 is selected from the group consisting of VMMMGSARV, VLHRAGARL, TLTRPVHDA, LLHGAEPNC, MMGSARVAEL, LLLHGAEPNC and GVMMMGSARV.

5. The pharmaceutical composition according to any one of claims 1 to 4, wherein the anogenital carcinoma is a cervical carcinoma.

6. Use of a cyclin-dependent kinase inhibitor p16 protein, an immunogenic fragment of the p16 protein or an expressible nucleic acid coding for the p16 protein for immunizing an individual against carcinomas and the preliminary stages thereof, wherein the carcinoma is upper respiratory tract carcinoma or anogenital carcinoma.

7. Use according to claim 6, wherein the p16 protein is in the form of one or more immunogenic fragments.

8. Use according to claim 7, wherein the fragment or fragments contain epitopes which can be detected by cytotoxic T cells and elicit a cytotoxic immune response.

9. The use according to any one of claims 6 to 8 wherein the fragment of p16 is selected from the group consisting of VMMMGSARV, VLHRAGARL, TLTRPVHDA, LLHGAEPNC, MMGSARVAEL, LLLHGAEPNC and GVMMMGSARV.

10. Use according to any of claims 5 to 8, the anogenital carcinoma is a cervical carcinoma.