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(54) Title: ACTIVE COMPLEX OF ALPHA-LACTALBUMIN (HAMLET) AND COFACTOR

(57) Abrégé/Abstract:

The use of a biologically active complex of α -lactalbumin, selected from HAMLET (human α -lactalbumin made lethal to tumour cells) or a biologically active modification thereof, or a biologically active fragment of either of these, in the preparation of a medicament for use in the treatment of papilloma, such as cutaneous papillomas.

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(54) Title: ACTIVE COMPLEX OF ALPHA-LACTALBUMIN (HAMLET) AND COFACTOR

(57) Abstract: The use of a biologically active complex of α -lactalbumin, selected from HAMLET (human α -lactalbumin made lethal to tumour cells) or a biologically active modification thereof, or a biologically active fragment of either of these, in the preparation of a medicament for use in the treatment of papilloma, such as cutaneous papillomas.

ACTIVE COMPLEX OF ALPHA-LACTALBUMIN (HAMLET) AND COFACTOR

The present invention relates to a method of treatment of papilloma, and to the use of biologically active complexes in the 5 preparation of medicaments for the treatment of papilloma such as cutaneous papillomas or warts.

Papillomas are tumours of the skin and mucosal surfaces, formed by human papilloma virus (HPV) transformed keratinocytes. Most 10 of the skin lesions remain benign, but the mucosal lesions are pre-malignant and cervical cancer is an important sequel of HPV infection, with >750,000 cases reported annually. Most of the cervical cancers contain a restricted number of HPV types (HPV 16 and 18) but cutaneous papillomas lack this virus specificity. 15 They are caused by one or more of about 130 different HPV types and include plantar, common and flat warts. Immuno-suppressed patients run an increased risk to develop papillomas, and may carry multiple HPV types at high frequency. Current treatments include cryotherapy, curettage, cautery, topical virucidal 20 agents, laser, anti-mitotic agents and immuno-activators. HPV vaccine are being developed for cervical papillomas, but they are not yet in use.

HAMLET (human α -lactalbumin made lethal to tumour cells) 25 (formerly known as MAL) is an active folding variant of alpha-lactalbumin (also represented as α -lactalbumin) that induces apoptosis in transformed cells but spares healthy differentiated cells [(M. Svensson, et al., (2000) *Proc Natl Acad Sci USA*, 97, 4221-6). HAMLET has been shown to bind to the surface of tumour 30 cells, to translocate into the cytoplasm and to accumulate in cell nuclei, where it causes DNA fragmentation (M. Svensson, et al., (2000) *Proc Natl Acad Sci USA*, 97, 4221-6). Biologically active complexes of this type, obtained from milk and particularly human milk, together with their use as antibacterial 35 agents is described for example in EP-0776214.

The applicants have found that HAMLET and complexes of this type are useful in the treatment of papilloma and particularly cutaneous papillomas.

5 According to the present invention, there is provided the use of a biologically active complex of α -lactalbumin, selected from HAMLET or a biologically active modification thereof, or a biologically active fragment of either of these, in the preparation of a medicament for use in the treatment of
10 papilloma.

Papilloma which may be treated using the medicament include papilloma of any of the serotypes listed above. These include cutaneous papillomas and genital papillomas.

15 As used herein, the term "HAMLET" refers to a biologically active complex of α -lactalbumin, which is either obtainable by isolation from casein fractions of milk which have been precipitated at pH 4.6, by a combination of anion exchange and gel chromatography as
20 described for example in EP-A-0776214, or by subjecting α -lactalbumin to ion exchange chromatography in the presence of a cofactor from human milk casein, characterized as C18:1 fatty acid as described in WO99/26979.

25 The α -lactalbumin may be from various mammalian sources including human, bovine, sheep and goat milk, but is preferably human or bovine, and most preferably human. Recombinant forms of the protein may also be employed.

30 It has also been found that other reagents and specifically lipids such as oleic acid, are useful in the conversion of human α -lactalbumin to HAMLET. In particular, it has been reported previously that oleic acid (C18:1:9cis) is required for HAMLET production (M. Svensson, et al., (2000) *Proc Natl Acad Sci USA*,
35 **97**, 4221-6). More recently, it has been found that other fatty acids may act as co-factors in a similar way. Optimal cofactors

for the conversion of α -lactalbumin to HAMLET are C18:1 fatty acids with a double bond in the cis conformation at position 9 or 11.

5 α -Lactalbumin is a 14.2 kDa globular protein with four α -helices (residues 1-34, 86-123) and an anti-parallel β -sheet (residues 38-82), linked by four disulphide bonds (61-77; 73-91; 28-111 and 6-120) (K. R. Acharya, et al., (1991) *J Mol Biol*, **221**, 571-81). The native conformation of α -lactalbumin is defined by a high 10 affinity Ca^{2+} binding site, co-ordinated by the side chain carboxylates of Asp82, Asp87 and Asp88, the carbonyl oxygens of Lys79 and Asp84, and two water molecules (K. R. Acharya, et al., (1991) *J Mol Biol*, **221**, 571-81). The protein adopts the so 15 called apo-conformation found in HAMLET when exposed to low pH, or in the presence of chelators, that release the strongly bound Ca^{2+} ion (D. A. Dolgikh, et al., (1981) *FEBS Lett*, **136**, 311-5; K. Kuwajima, (1996) *Faseb J*, **10**, 102-09).

20 In order to form biologically active complexes, α -lactalbumin generally requires both a conformational or folding change as well as the presence of a lipid cofactor. The conformational change is suitably effected by removing calcium ions from α -lactalbumin. In a preferred embodiment, this is suitably 25 facilitated using a variant of α -lactalbumin which does not have a functional calcium binding site.

Biologically active complexes which contain such variants are 30 encompassed by the term "modifications" of HAMLET as used herein. However, the applicants have found that, once formed, the presence of a functional calcium binding site, and/or the presence of calcium, does not affect stability or the biological activity of the complex. Biologically active complexes have been found to retain affinity for calcium, without loss of activity. Therefore complex of the invention may further comprise calcium 35 ions.

Thus in particular, the invention uses a biologically active complex comprising alpha-lactalbumin or a variant of alpha-lactalbumin which is in the apo folding state, or a fragment of either of any of these, and a cofactor which stabilises the complex in a biologically active form, provided that any fragment of alpha-lactalbumin or a variant thereof comprises a region corresponding to the region of α -lactalbumin which forms the interface between the alpha and beta domains.

10 Suitably the cofactor is a cis C18:1:9 or C18:1:11 fatty acid or a different fatty acid with a similar configuration.

In a particular convenient embodiment, the biologically active complex used in the invention comprises

15 (i) a cis C18:1:9 or C18:1:11 fatty acid or a different fatty acid with a similar configuration; and
(ii) α -lactalbumin from which calcium ions have been removed, or a variant of α -lactalbumin from which calcium ions have been released or which does not have a functional calcium binding site; or a fragment of either of any of these, provided that any fragment comprises a region corresponding to the region of α -lactalbumin which forms the interface between the alpha and beta domains.

25 As used herein the expression "variant" refers to polypeptides or proteins which are homologous to the basic protein, which is suitably human or bovine α -lactalbumin, but which differ from the base sequence from which they are derived in that one or more amino acids within the sequence are substituted for other amino acids. Amino acid substitutions may be regarded as
30 "conservative" where an amino acid is replaced with a different amino acid with broadly similar properties. Non-conservative substitutions are where amino acids are replaced with amino acids of a different type. Broadly speaking, fewer non-conservative substitutions will be possible without altering the biological activity of the polypeptide. Suitably variants will be at least
35

60% identical, preferably at least 70%, even more preferably 80% or 85% and, especially preferred are 90%, 95% or 98% or more identity.

5 When comparing amino acid sequences for the purposes of determining the degree of identity, programs such as BESTFIT and GAP (both from Wisconsin Genetics Computer Group (GCG) software package). BESTFIT, for example, compares two sequences and produces an optimal alignment of the most similar segments. GAP
10 enables sequences to be aligned along their whole length and finds the optimal alignment by inserting spaces in either sequence as appropriate. Suitably, in the context of the present invention when discussing identity of sequences, the comparison is made by alignment of the sequences along their whole length.

15 The term "fragment thereof" refers to any portion of the given amino acid sequence which will form a complex with the similar activity to complexes including the complete α -lactalbumin amino acid sequence. Fragments may comprise more than one portion from
20 within the full length protein, joined together. Portions will suitably comprise at least 5 and preferably at least 10 consecutive amino acids from the basic sequence.
Suitable fragments will be deletion mutants suitably comprise at least 20 amino acids, and more preferably at least 100 amino
25 acids in length. They include small regions from the protein or combinations of these.

The region which forms the interface between the alpha and beta domains is, in human α -lactalbumin, defined by amino acids 34-38 and 82-86 in the structure. Thus suitable fragments will include
30 these regions, and preferably the entire region from amino acid 34-86 of the native protein.

In a particularly preferred embodiment, the biologically active
35 complex comprises a variant of α -lactalbumin in which the calcium

binding site has been modified so that the affinity for calcium is reduced, or it is no longer functional.

It has been found that in bovine α -lactalbumin, the calcium 5 binding site is coordinated by the residues K79, D82, D84, D87 and D88. Thus modification of this site or its equivalent in non-bovine α -lactalbumin, for example by removing one or more of the acidic residues, can reduce the affinity of the site for calcium, or eliminate the function completely and mutants of this 10 type are a preferred aspect of the invention.

The Ca^{2+} -binding site of bovine α -lactalbumin consists of a 3_{10} helix and an α -helix with a short turn region separating the two helices (Acharya K. R., et al., (1991) *J Mol Biol* **221**, 571-581). 15 It is flanked by two disulfide bridges making this part of the molecule fairly inflexible. Five of the seven oxygen groups that co-ordinate the Ca^{2+} are contributed by the side chain carboxylates of Asp82, 87 and 88 or carbonyl oxygen's of Lys79 and Asp84. Two water molecules supply the remaining two oxygen's 20 (Acharya K. R., et al., (1991) *J Mol Biol* **221**, 571-581).

Site directed mutagenesis of the aspartic acid at position 87 to alanine (D87A) has previously been shown to inactivate the strong calcium-binding site (Anderson P. J., et al., (1997) *Biochemistry* 25 **36**, 11648-11654) and the mutant proteins adopted the apo-conformation.

Therefore in a particular embodiment, the aspartic acid residue at amino acid position 87 within the bovine α -lactalbumin protein 30 sequence is mutated to a non-acidic residue, and in particular a non-polar or uncharged polar side chain.

Non-polar side chains include alanine, glycine, valine, leucine, isoleucine, proline, phenylalanine, methionine, tryptophan or 35 cysteine. A particularly preferred examples is alanine.

Uncharged polar side chains include asparagine, glutamine, serine, threonine or tyrosine.

In order to minimize the structural distortion in the mutant 5 protein, D87 has also been replaced by an asparagine (N) (Permyakov S. E., et al., (2001) *Proteins Eng* **14**, 785-789), which lacks the non-compensated negative charge of a carboxylate group, but has the same side chain volume and geometry. The mutant 10 protein (D87N) was shown to bind calcium with low affinity ($K_{Ca2} \times 10^5 M^{-1}$) (Permyakov S. E., et al., (2001) *Proteins Eng* **14**, 785-789). Such a mutant forms an element of the biologically active complex in a further preferred embodiment of the invention.

Thus particularly preferred variants for use in the complexes of 15 the invention are D87A and D87N variants of α -lactalbumin, or fragments which include this mutation.

This region of the molecule differs between the bovine and the 20 human proteins, in that one of the three basic amino acids (R70) is changed to S70 in bovine α -lactalbumin thus eliminating one co-ordinating side chain. It may be preferable therefore, that where the bovine α -lactalbumin is used in the complex of the 30 invention, an S70R mutant is used.

25 The Ca^{2+} binding site is 100% conserved in α -lactalbumin from different species (Acharya K. R., et al., (1991) *J Mol Biol* **221**, 571-581), illustrating the importance of this function for the protein. It is co-ordinated by five different amino acids and two water molecules. The side chain carboxylate of D87 together 30 with D88 initially dock the calcium ion into the cation-binding region, and form internal hydrogen bonds that stabilise the structure (Anderson P. J., et al., (1997) *Biochemistry* **36**, 11648-11654). A loss of either D87 or D88 has been shown to impair Ca^{2+} binding, and to render the molecule stable in the partially 35 unfolded state (Anderson P. J., et al., (1997) *Biochemistry* **36**, 11648-11654).

Further, mutant proteins with two different point mutations in the calcium-binding site of bovine α -lactalbumin may be used.

For example, substitution of the aspartic acid at position 87 by an alanine (D87A) has been found to totally abolish calcium 5 binding and disrupt the tertiary structure of the protein.

Substitution of the aspartic acid by asparagine, the protein (D87N) still bound calcium but with lower affinity and showed a loss of tertiary structure, although not as pronounced as for the D87A mutant (Permyakov S. E., et al., (2001) *Proteins Eng* **14**, 10 785-789).

The mutant protein showed a minimal change in packing volume as both amino acids have the same average volume of 125 \AA^3 , and the carboxylate side chain of asparagines allow the protein to co-ordinate calcium, but less efficiently (Permyakov S. E., et al., (2001) *Proteins Eng* **14**, 785-789). Both mutant proteins were 15 stable in the apo-conformation at physiologic temperatures but despite this conformational change they were biologically inactive. The results demonstrate that a conformational change to the apo-conformation alone is not sufficient to induce biological activity.

20

The structure of α -lactalbumin is known in the art, and the precise amino acid numbering of the residues referred to herein can be identified by reference to the structures shown for example in Anderson et al. *supra*. and Permyakov et al *supra*.

25

The medicaments produced in accordance with the invention are suitably pharmaceutical compositions in a form suitable for topical use, for example as creams, ointments, gels, or aqueous or oily solutions or suspensions. These may include the commonly 30 known carriers, fillers and/or expedients, which are pharmaceutically acceptable.

Topical solutions or creams suitably contain an emulsifying agent for the protein complex together with a diluent or cream base.

35 Such formulations can be applied directly to the papilloma.

The daily dose of the active compound varies and is dependant on the patient, the nature of the papilloma being treated etc. in accordance with normal clinical practice. As a general rule from 2 to 200 mg/dose of the biologically active complex is used for 5 topical administration.

The applicants have carried out three studies on the effect of topical HAMLET treatment on papilloma in the form of cutaneous papillomas of immunocompetent and immunosuppressed patients. The 10 first study was performed as a double-blind, placebo-controlled investigation on 42 patients receiving either placebo solution (0.15M NaCl) or HAMLET (10 mg/ml, 0.7mM in NaCl). One drop of substance was applied topically on the papilloma once a day for three weeks and the papillomas were measured and photographed 15 once every week during the treatment period. Follow up visits were one and two months after completed treatment. All patients continued in a second open HAMLET study for a same period of time, and follow up was performed 1 month after completed treatment. A third open study was performed with 1.8mM (25 mg/ml) 20 HAMLET. Effective treatment was defined as a >75% reduction in papilloma volume.

As detailed below, in the placebo-controlled study HAMLET 0.7mM (10 mg/ml) showed an effect ($p<0.001$) on 100% (20/20) of the 25 patients (88/92 papillomas) that received HAMLET while 15% (3/20) of the patients (15/79 papillomas) receiving placebo showed effect. 45% (9/20) of the patients (19/92 papillomas) receiving HAMLET and 15% (3/20) of the patients (11/74 papillomas) receiving placebo had papillomas that disappeared totally during 30 treatment or one month after treatment. In the second open HAMLET study an effect ($p<0.001$) was observed in 68% (23/34) of the patients. 29% (10/34) of the patients had papillomas (18/139) that disappeared totally during treatment or one month after treatment. In the third open study with 1.8mM(25 mg/ml) 35 HAMLET an effect ($p<0.001$) was observed in 70% (7/10) of the patients and in 66% (21/32) of their papillomas. 10% (1/10) of

the patients had papillomas (1/32) that disappeared totally during treatment or one month after treatment. No adverse reactions were recorded.

5 To examine if the status of the immunesystem played a role in HAMLET treatment, immunocompetent and immunosuppressed (non-immunocompetent) patients were included in the study. There was no significant difference in response between these groups (p<0.001). Similarly, the effect of HAMLET was independent of
10 gender of the patients.

Clearly then, HAMLET produced a highly beneficial therapy for papilloma.

15 In a further aspect of the invention, there is provided a method for treating papilloma which comprises administering to a patient in need thereof, a biologically active complex of α -lactalbumin, selected from HAMLET or a biologically active modification thereof, or a biologically active fragment of either of these.

20 Preferred examples of the biologically active complex are illustrated above. Preferably the biologically active complex is administered in the form of a topical composition, also as described above.

25

Materials and Methods

Preparation of substance and randomisation of patients

Donors of breastmilk were non-smokers and were screened for HIV prior to preparation of HAMLET. Alpha-lactalbumin was purified
30 from human milk whey by ammonium sulphate precipitation followed by phenyl-Sepharose chromatography and size-exclusion chromatography. Excess milk from the hospital milk bank was used according to regulations for administration to premature babies. HAMLET was generated from native α -lactalbumin on an oleic acid
35 conditioned ion-exchange chromatography column, as described in

the literature. The eluted fractions were dialysed against distilled water, lyophilised and stored at -20°C.

Furthermore, HAMLET was screened for bacterial contamination and 5 was stored as dry substance in -20°C.

Patients

Patients with a history of recalcitrant papillomas were enrolled in a placebo-controlled study of topical HAMLET treatment. The 10 majority was immuno-competent (n=31) and suffered no other illness. Eleven patients were immuno-suppressed after organ transplantation (n=7), systemic lupus erythematosus (n=1) or Sjorgens syndrome (n=1), and two had hypo-gamma-globulinemia. There were 27 females (64%) and 15 males (36%), with a median age 15 of 22.5 years (range 6 to 60). Most lesions has not responded to salicylic acid or cryotherapy. Diagnosis was based on visual inspection by an experienced dermatologist. The included papillomas (n=173) were nodular or flat and localised on hands, lower arms of feet. Most patients had several lesions (median 20 n=4, range 1 to 9).

Patients were randomised to the HAMLET or placebo group. The papillomas were inspected, measured and photographed at enrolment, weekly for three weeks and one month after completed 25 treatment. A drop of HAMLET or placebo (0.15M NaCl) was applied topically on the lesion once a day and the lesion was covered with Comfeel^R (Coloplast AB, Sweden) and Micropore tape (3M Health Care, MN, U.S.A). Patients who cut or scratched the lesions during the treatment period were excluded from the analysis. The 30 code was broken when all patients had completed the study.

Analysis

Groups were compared using the Student T test and the Chi 2 test.

Results:**HAMLET has treatment effect on papillomas**

In the placebo controlled study, HAMLET had remarkable influence on the papillomas. Topical application of HAMLET was shown to 5 significantly decrease the volume of skin papillomas as compared to the placebo control group. The effect was evaluated as the lowest recorded lesion volum within one month after the end of treatment. All the HAMLET treated patients showed a decrease in lesion volume, resulting in a median remaining volume of 14% 10 (range 0-33%). A decrease by $\geq 75\%$ was recorded in all HAMLET-treated patients (20/20 patients) and in 96% (88/92) of their lesions. Complete resolution of ≥ 1 lesion was recorded in 15% (3/20) of the patients, and in 21% of their lesions.

15 In contrast, no significant reduction in lesion volume was recorded in the placebo control group. The median remaining lesion volume was 81% (range 0-74%) and a decrease by $\geq 75\%$ was recorded in 20% (15/74) of the lesions. Complete resolution of ≥ 1 lesion was observed in 15% (3/20) of the patients and 15% of 20 the lesions (11/74).

The effect of HAMLET was independent of gender and immune status of the patients. The four immuno-suppressed patients who received HAMLET showed a signficant decrease in lesion size 25 ($\geq 75\%$), and in three of them, at least one lesion disappearad. In contrast, the five immuno-suppressed patients in the placebo group showed no decrease in lesion size. HAMLET caused a significant reduction in all the females and males while complete resolution was observed in 8 of 14 females and in one of six 30 males.

The effect of HAMLET was also independent of localisation and lesion characteristics. HAMLET treatment decreased the lesion volume by $\geq 75\%$ in 96% (76/79) of the nodular lesions, and 24% 35 (19/79) resolved. Similarly, HAMLET treatment reduced the volume in 92% (12/13) of the flat papillomas, but none resolved. The

hand lesion volume decrease significantly in 97% (66/68) and 24% (16/68) of the lesions disappeared. Similarly, the foot lesions decreased in 92% (22/24) and 13% (3/24) of the lesions disappeared.

5

Additional open study

Ten new patients were recruited to an open study with the same protocol as described above. Five patients were immuno-competent and five were immunosuppressed. There were eight females (80%) and two males (20%), with a median age of 47 years (range 11 to 57). The included papillomas (n=32) were nodular (n=27) or flat and localised on hands (n=27) or feet. Most patients had several lesions (median n=3, range 1 to 7).

15 The effect of HAMLET was reproduced in this trial. The patients received 1.8mM HAMLET. This caused a significant decrease in lesion volume in 7/10 patients and in 66% (21/32) of their lesions. In 10% (1/10) of the patients at least one lesion resolved completely comprising 3% of all lesions (1/32).

20

Claims

1. The use of a biologically active complex of α -lactalbumin, selected from HAMLET or a biologically active modification thereof, or a biologically active fragment of either of these, in the preparation of a medicament for use in the treatment of papilloma.
2. The use according to claim 1 wherein the biologically active complex comprising alpha-lactalbumin or a variant of alpha-lactalbumin which is in the apo folding state, or a fragment of either of any of these, and a cofactor which stabilises the complex in a biologically active form, provided that any fragment of alpha-lactalbumin or a variant thereof comprises a region corresponding to the region of α -lactalbumin which forms the interface between the alpha and beta domains.
3. The use according to claim 2 wherein the cofactor is a cis C18:1:9 or C18:1:11 fatty acid or a different fatty acid with a similar configuration.
4. The use according to any one of claims 1 to 3 wherein the biologically active complex comprises HAMLET, which is obtainable either by isolation from casein fractions of milk which have been precipitated at pH 4.6, by a combination of anion exchange and gel chromatography, or by subjecting α -lactalbumin to ion exchange chromatography in the presence of a cofactor from human milk casein, characterized as C18:1 fatty acid.
5. The use according to any one of claims 1 to 3 wherein the biologically active complex of α -lactalbumin comprises
 - (i) a cis C18:1:9 or C18:1:11 fatty acid or a different fatty acid with a similar configuration; and
 - (ii) α -lactalbumin from which calcium ions have been removed, or a variant of α -lactalbumin from which calcium ions have been

removed or which does not have a functional calcium binding site; or a fragment of either of any of these, provided that any fragment comprises a region corresponding to the region of α -lactalbumin which forms the interface between the alpha and beta domains.

6. The use according to claim 5 wherein the biologically active complex includes a variant of α -lactalbumin in which the calcium binding site has been modified so that the affinity for calcium is reduced, or it is no longer functional.

7. The use according to claim 6 wherein the variant has a mutation at one of the amino acids equivalent to K79, D82, D84, D87 and D88 of bovine α -lactalbumin.

15 8. The use according to claim 7 wherein the modification is at D87 which includes a variant of α -lactalbumin having a D87A or D87N variants.

20 9. The use according to any one of claims 1 to 3 wherein the biologically active complex comprises a fragment of α -lactalbumin or a variant thereof, and where the fragment includes the entire region from amino acid 34-86 of the native protein.

25 10. The use according to any one of the preceding claims wherein the α -lactalbumin is human or bovine α -lactalbumin or a variant of either of these.

11. The use according to claim 10 wherein the α -lactalbumin is 30 human α -lactalbumin.

12. The use according to claim 10 wherein the α -lactalbumin is mutant bovine α -lactalbumin which includes an S70R mutation.

13. A method for treating papilloma which comprises administering to a patient in need thereof, a biologically active complex of α -lactalbumin, selected from HAMLET or a biologically active modification thereof, or a biologically active fragment of 5 either of these.

14. The use according to claim 1 substantially as hereinbefore described with reference to the Example.