

Claims

1. A vaccine comprising an immunologically effective amount of:
 - (i) a polynucleotide comprising a nucleotide sequence encoding a targeting unit, a dimerization unit and an antigenic unit, wherein the antigenic unit comprises at least one betacoronavirus epitope; or
 - (ii) a polypeptide encoded by the polynucleotide as defined in (i), or
 - (iii) a dimeric protein consisting of two polypeptides encoded by the polynucleotide as defined in (i); and
- 10 a pharmaceutically acceptable carrier.

2. The vaccine according to claim 1, wherein the at least one betacoronavirus epitope is a full-length viral surface protein of a betacoronavirus or a part thereof, preferably wherein the viral surface protein is selected from the group consisting of envelope protein, spike protein, membrane protein and hemagglutinin esterase, preferably
- 15 wherein the at least one betacoronavirus epitope comprises or is the spike protein.

3. The vaccine according to claim 2, wherein the at least one betacoronavirus epitope comprises or is a part of the spike protein, preferably wherein the part of the spike protein is one selected from the group consisting of receptor binding domain (RBD), heptad repeat 1 (HR1) domain and heptad repeat 2 (HR2) domain.
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4. The vaccine according to claim 3, wherein the at least one betacoronavirus epitope comprises or is the RBD or a part of the RBD, preferably wherein the at least one betacoronavirus epitope comprises or consists of an amino acid sequence having at least 70% sequence identity to the amino acid sequence of SEQ ID NO: 802 or SEQ ID NO: 803, preferably SEQ ID NO: 803, such as at least 75%, such as at least 77%, such as at least 80%, such as at least 85%, such as at least 90%, such as at least 91%, such as at least 92%, such as at least 93%, such as at least 94%, such as at least 95%, such as at least 96%, such as at least 97%, such as at least 98% or such as at least 99% sequence identity or such as 100% sequence identity, and/or wherein the antigenic unit comprises multiple copies of the RBD or parts thereof which copies are identical or differ in their amino acid sequences.
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5. The vaccine according to any of claims 2 to 4, wherein the at least one betacoronavirus epitope is a B cell epitope comprised in the viral surface protein or a part thereof, and/or wherein the antigenic unit comprises multiple B cell epitopes comprised in the viral surface protein or a part thereof.

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6. The vaccine according to claim 1, wherein the at least one betacoronavirus epitope is a T cell epitope, preferably

wherein the antigenic unit comprises multiple T cell epitopes, and/or wherein the T cell epitope is conserved between different genus and/or species and/or strains of betacoronaviruses, preferably between SARS-Cov2 and SARS-CoV, and/or wherein the T cell epitope has a length of from 7 to about 200 amino acids, preferably of from 7 to 100 amino acids or the T cell epitope has a length suitable for presentation by HLA class I/II alleles, preferably a length of from 7 to 30 amino acids, more preferably a length of from 8 to 15 amino acids, and/or wherein the T cell epitope is known to be immunogenic or is selected based on the predicted ability to bind to HLA class I/II alleles, and/or wherein the T cell epitope is selected from epitopes having an amino acid sequence of any of SEQ ID NO: 1 to SEQ ID NO: 444.

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7. The vaccine according to claim 6, wherein the antigenic unit further comprises at least one betacoronavirus epitope which is a full-length viral surface protein of a betacoronavirus or a part thereof, such as wherein the at least one betacoronavirus epitope comprises or is the spike protein, and/or wherein the at least one betacoronavirus epitope comprises or is the full-length spike protein, and/or wherein the at least one betacoronavirus epitope comprises or is a part of the spike protein, preferably wherein the at least one betacoronavirus epitope comprises or is the RBD or a part thereof.

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8. The vaccine according to any of the preceding claims, wherein the antigenic unit comprises up to 3500 amino acids, such as from 21 to 3500 amino acids, preferably from about 30 amino acids to about 2000 amino acids such as from about 50 to about 1500 amino acids, more preferably from about 100 to about 1500 amino acids, such as from about 100 to about 1000 amino acids or from about 100 to about 500 amino acids or from about 100 to about 300 amino acids, and/or wherein the antigenic unit comprises one or more linkers, preferably one or more non-immunogenic and/or flexible linkers,

and/or wherein the antigenic unit comprises 10, 20, 30, 40 or 50 epitopes, preferably T cell epitopes.

5 9. The vaccine according to any of the preceding claims, wherein said targeting unit comprises antibody binding regions with specificity for surface molecules or receptors on antigen presenting cells (APCs), preferably specificity for CD14, CD40, Toll- like receptor, CCR1, CCR3, CCR5, MHC class I proteins or MHC class II proteins, and/or wherein the targeting unit has affinity for a chemokine receptor selected from CCR1, CCR3 and CCR5, or wherein said targeting unit has affinity for MHC class II proteins, 10 preferably MHC class II proteins selected from the group consisting of anti-HLA-DP, anti-HLA-DR and anti-pan HLA class II, preferably wherein the targeting unit is selected from anti-pan HLA class II and MIP-1 α and preferably selected from anti-pan HLA class II and human MIP-1 α .

15 10. The vaccine according to claim 9, wherein the targeting unit is human MIP-1 α .

11. The vaccine according to any of the preceding claims, wherein the targeting unit comprises or consists of an amino acid sequence having at least 80% sequence identity to the amino acid sequence 24-93 of SEQ ID NO: 234.

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12. The vaccine according to any of the preceding claims, wherein the dimerization unit comprises a hinge region, preferably wherein the dimerization unit further comprises another domain that facilitates dimerization, preferably wherein the other domain is an immunoglobulin domain, preferably an immunoglobulin constant domain, preferably 25 wherein the dimerization unit further comprises a dimerization unit linker, which connects the hinge region and the other domain that facilitates dimerization.

13. The vaccine according to any of the preceding claims, wherein the dimerization unit comprises or consists of an amino acid sequence having at least 80% sequence identity to the amino acid sequence 94-237 of SEQ ID NO: 233.

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14. The vaccine according to any of the preceding claims, wherein the vaccine comprises the polynucleotide, preferably wherein the polynucleotide further comprises a nucleotide sequence encoding a signal peptide, preferably wherein the signal peptide comprises or

consists of an amino acid sequence having at least 80% sequence identity to the amino acid sequence 1-23 of SEQ ID NO: 234 and preferably wherein the polypeptide encoded by said polynucleotide comprises said targeting unit, dimerization unit and antigenic unit in said in the N-terminal to C-terminal order of targeting unit, dimerization unit and antigenic unit.

15. The vaccine according to any of the preceding claims, wherein said betacoronavirus is one selected from the group consisting of SARS-CoV, MERS-CoV, SARS-CoV-2, HCoV-OC43 and HCoV-HKU1, preferably selected from the group consisting of SARS-CoV and SARS-CoV2, most preferably wherein said betacoronavirus is SARS-CoV2.

16. A polynucleotide as defined in any of the claims 1 to 15.

17. A vector comprising the polynucleotide according to claim 16.

18. A polypeptide encoded by the polynucleotide as defined in any of claims 1 to 15 or a dimeric protein consisting of two of said polypeptides.

19. The polynucleotide according to claim 16 or the polypeptide or the dimeric protein according to claim 18 for use as a medicament.

20. A method of preparing the vaccine according to any one of the preceding claims 1 to 15, wherein the vaccine comprises the polypeptide or the dimeric protein and wherein said method comprises:

- a) transfecting cells with the polynucleotide as defined in any of the claims 1 to 15;
- b) culturing the cells;
- c) collecting and purifying the dimeric protein or the polypeptide expressed from the cells; and
- d) mixing the dimeric protein or polypeptide obtained from step c) with the pharmaceutically acceptable carrier.

21. A method for preparing the vaccine according to any one of the preceding claims 1 to 15, wherein the vaccine comprises the polynucleotide and wherein the method comprises:

- a) preparing the polynucleotide;
- b) optionally cloning the polynucleotide into an expression vector; and
- c) mixing the polynucleotide obtained from step a) or the vector obtained from step b) with the pharmaceutically acceptable carrier.

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22. Use of the polynucleotide according to claim 16 or the polypeptide or the dimeric protein according to claim 18 in the manufacture of a vaccine for treating a subject suffering from a betacoronavirus infection or being in need of prevention thereof.