

Thus there remains a need to further improve IL-2 immunotherapy. An approach, which may circumvent the problems of tumor-targeting, is to target IL-2 directly to effector cells, in particular CTLs.

5 Ghasemi et al. have described a fusion protein of IL-2 and an NKG2D binding protein (Ghashemi et al., Nat Comm (2016) 7, 12878), for targeting IL-2 to NKG2D-bearing cells such as natural killer (NK) cells.

Programmed cell death protein 1 (PD-1 or CD279) is an inhibitory member of the CD28 family of receptors, that also includes CD28, CTLA-4, ICOS and BTLA. PD-1 is a cell surface receptor
10 and is expressed on activated B cells, T cells, and myeloid cells (Okazaki et al (2002) Curr. Opin. Immunol. 14: 391779-82; Bennett et al. (2003) J Immunol 170:711-8). The structure of PD-1 is a monomeric type 1 transmembrane protein, consisting of one immunoglobulin variable-like extracellular domain and a cytoplasmic domain containing an immunoreceptor tyrosine-based inhibitory motif (ITIM) and an immunoreceptor tyrosine-based switch motif (ITSM). Two
15 ligands for PD-1 have been identified, PD-L1 and PD-L2, that have been shown to downregulate T cell activation upon binding to PD-1 (Freeman et al (2000) J Exp Med 192: 1027-34; Latchman et al (2001) Nat Immunol 2:261-8; Carter et al (2002) Eur J Immunol 32:634-43). Both PD-L1 and PD-L2 are B7 homologs that bind to PD-1, but do not bind to other CD28 family members. One ligand for PD-1, PD-L1 is abundant in a variety of human cancers (Dong et al
20 (2002) Nat. Med 8:787-9). The interaction between PD-1 and PD-L1 results in a decrease in tumor infiltrating lymphocytes, a decrease in T-cell receptor mediated proliferation, and immune evasion by the cancerous cells (Dong et al. (2003) J. Mol. Med. 81:281-7; Blank et al. (2005) Cancer Immunol. Immunother. 54:307-314; Konishi et al. (2004) Clin. Cancer Res. 10:5094-100). Immune suppression can be reversed by inhibiting the local interaction of PD-1 with PD-L1,
25 and the effect is additive when the interaction of PD-1 with PD-L2 is blocked as well (Iwai et al. (2002) Proc. Nat 7. Acad. ScL USA 99: 12293-7; Brown et al. (2003) J. Immunol. 170:1257-66).

Antibodies that bind to PD-1 are described e.g. PCT patent application no. PCT/EP2016/073248.

Summary

The present disclosure provides a novel approach of targeting a mutant form of IL-2 with advantageous properties for immunotherapy directly to immune effector cells, such as cytotoxic

T lymphocytes, rather than tumor cells. Targeting to immune effector cells is achieved by conjugation of the mutant IL-2 molecule to an antibody that binds to PD-1.

The IL-2 mutant used in the present disclosure has been designed to overcome the problems associated with IL-2 immunotherapy, in particular toxicity caused by the induction of VLS, tumor tolerance caused by the induction of AICD, and immunosuppression caused by activation of T_{reg} cells. In addition to circumventing escape of tumors from tumor-targeting as mentioned above, targeting of the IL-2 mutant to immune effector cells may further increase the preferential activation of CTLs over immunosuppressive T_{reg} cells. By using an antibody that binds to PD-1, the suppression of T-cell activity induced by the interaction of PD-1 with its ligand PD-L1 may additionally be reversed, thus further enhancing the immune response.

An IL-2 fusion protein comprising the anti-PD-L1 antibody atezolizumab has been described by Chen et al. (Chen et al., Biochem Biophys Res Comm (2016) 480, 160-165).

Of note, the immunoconjugate of the disclosure, comprising an antibody that binds to PD-1, shows significantly superior anti-tumor efficacy in vivo as compared to a similar immunoconjugate targeting PD-L1 (see Example 3 hereinbelow).

The disclosure provides an immunoconjugate comprising an antibody that binds to PD-1 and a polypeptide that signals through IL-2R $\beta\gamma$. The polypeptide signaling through IL-2R $\beta\gamma$ is particularly an IL-2 polypeptide or an IL-15 polypeptide. In a first aspect, the disclosure provides an immunoconjugate comprising (i) an antibody that binds to PD-1 and (ii) a mutant IL-2 polypeptide, wherein the mutant IL-2 polypeptide is a human IL-2 molecule comprising the amino acid substitutions F42A, Y45A and L72G (numbering relative to the human IL-2 sequence SEQ ID NO: 19).

In a further example, the disclosure provides an immunoconjugate comprising a mutant IL-2 polypeptide and an antibody that binds to PD-1, wherein the mutant IL-2 polypeptide is a human IL-2 molecule comprising the amino acid substitutions F42A, Y45A and L72G (numbering relative to the human IL-2 sequence SEQ ID NO: 19); and wherein the antibody comprises (a) a heavy chain variable region (VH) comprising a HVR-H1 comprising

the amino acid sequence of SEQ ID NO:1, a HVR-H2 comprising the amino acid sequence of SEQ ID NO:2, a HVR-H3 comprising the amino acid sequence of SEQ ID NO:3, and a FR-H3 comprising the amino acid sequence of SEQ ID NO:7 at positions 71-73 according to Kabat numbering, and (b) a light chain variable region (VL) comprising a HVR-L1 comprising the amino acid sequence of SEQ ID NO:4, a HVR-L2 comprising the amino acid sequence of SEQ ID NO:5, and a HVR-L3

comprising the amino acid sequence of SEQ ID NO:6, or wherein the antibody comprises (a) a heavy chain variable region (VH) comprising a HVR-H1 comprising the amino acid sequence of SEQ ID NO:8, a HVR-H2 comprising the amino acid sequence of SEQ ID NO:9, and a HVR-H3 comprising the amino acid sequence of SEQ ID NO:10, and (b) a light chain variable region (VL) comprising a HVR-L1 comprising the amino acid sequence of SEQ ID NO:11, a HVR-L2 comprising the amino acid sequence of SEQ ID NO:12, and a HVR-L3 comprising the amino acid sequence of SEQ ID NO:13.

In another example, the disclosure provides an immunoconjugate comprising a mutant IL-2 polypeptide and an antibody that binds to PD-1, wherein the mutant IL-2 polypeptide is a human IL-2 molecule comprising the amino acid substitutions F42A, Y45A and L72G (numbering relative to the human IL-2 sequence SEQ ID NO: 19); and wherein the antibody comprises (a) a heavy chain variable region (VH) comprising an amino acid sequence that is at least about 95%, 96%, 97%, 98%, 99% or 100% identical to the amino acid sequence of SEQ ID NO:14, and (b) a light chain variable region (VL) comprising an amino acid sequence that is at least about 95%, 96%, 97%, 98%, 99% or 100% identical to an amino acid sequence selected from the group consisting of SEQ ID NO:15, SEQ ID NO:16, SEQ ID NO: 17, and SEQ ID NO:18.

In some examples of the immunoconjugate according to the disclosure, the mutant IL-2 polypeptide further comprises the amino acid substitution T3A and/or the amino acid substitution C125A. In some examples, the mutant IL-2 polypeptide comprises the sequence of SEQ ID NO: 20. In some examples, the immunoconjugate comprises not more than one mutant IL-2 polypeptide. In some examples, the antibody comprises an Fc domain composed of a first and a second subunit. In some such examples, the Fc domain is an IgG class, particularly an IgG₁ subclass, Fc domain, and/or the Fc domain is a human Fc domain. In some examples, the antibody is an IgG class, particularly an IgG₁ subclass immunoglobulin.

In some examples wherein the immunoconjugate comprises an Fc domain, the Fc domain comprises a modification promoting the association of the first and the second subunit of the Fc domain. In some examples, in the CH3 domain of the first subunit of the Fc domain an amino acid residue is replaced with an amino acid residue having a larger side chain volume, thereby generating a protuberance within the CH3 domain of the first subunit which is positionable in a cavity within the CH3 domain of the second subunit, and in the CH3 domain of

the second subunit of the Fc domain an amino acid residue is replaced with an amino acid residue having a smaller side chain volume, thereby generating a cavity within the CH3 domain of the second subunit within which the protuberance within the CH3 domain of the first subunit

is positionable. In some examples, in the first subunit of the Fc domain the threonine residue at position 366 is replaced with a tryptophan residue (T366W), and in the second subunit of the Fc domain the tyrosine residue at position 407 is replaced with a valine residue (Y407V) and optionally the threonine residue at position 366 is replaced with a serine residue (T366S) and the leucine residue at position 368 is replaced with an alanine residue (L368A) (numberings according to Kabat EU index). In some such examples, in the first subunit of the Fc domain additionally the serine residue at position 354 is replaced with a cysteine residue (S354C) or the glutamic acid residue at position 356 is replaced with a cysteine residue (E356C), and in the second subunit of the Fc domain additionally the tyrosine residue at position 349 is replaced by a cysteine residue (Y349C) (numberings according to Kabat EU index). In some examples, the mutant IL-2 polypeptide is fused at its amino-terminal amino acid to the carboxy-terminal amino acid of one of the subunits of the Fc domain, particularly the first subunit of the Fc domain, optionally through a linker peptide. In some such examples, the linker peptide has the amino acid sequence of SEQ ID NO:21.

In some examples wherein the immunoconjugate comprises an Fc domain, the Fc domain comprises one or more amino acid substitution that reduces binding to an Fc receptor, particularly an Fc γ receptor, and/or effector function, particularly antibody-dependent cell-mediated cytotoxicity (ADCC). In some such examples, said one or more amino acid substitution is at one or more position selected from the group of L234, L235, and P329 (Kabat EU index numbering). In some examples, each subunit of the Fc domain comprises the amino acid substitutions L234A, L235A and P329G (Kabat EU index numbering).

In some examples, the immunoconjugate according to the disclosure comprises a polypeptide comprising an amino acid sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of SEQ ID NO:22, a polypeptide comprising an amino acid sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of SEQ ID NO:23 or SEQ ID NO:24, and a polypeptide comprising an amino acid sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of SEQ ID NO:25. In some examples, the immunoconjugate essentially consists of a mutant IL-2 polypeptide and an IgG₁ immunoglobulin molecule, joined by a linker sequence.

The disclosure further provides one or more isolated polynucleotide encoding an immunoconjugate of the disclosure, one or more vector (particularly expression vector)

comprising said polynucleotides, and host cells comprising said polynucleotide(s) or said vector(s).

In another aspect, the present disclosure provides for one or more isolated polynucleotide encoding the immunoconjugate as described herein.

- 5 In another aspect, the present disclosure provides for one or more vector, particularly expression vector, comprising the polynucleotide(s) as described herein.

In another aspect, the present disclosure provides for a host cell comprising the polynucleotide(s) as described herein or the vector as described herein.

- 10 In another aspect, the present disclosure provides for a method of producing an immunoconjugate comprising a mutant IL-2 polypeptide and an antibody that binds to PD-1, comprising (a) culturing the host cell of the disclosure under conditions suitable for the expression of the immunoconjugate, and optionally (b) recovering the immunoconjugate. Also provided by the disclosure is an immunoconjugate comprising a mutant IL-2 polypeptide and an antibody that binds to PD-1, produced by said method.

- 15 The disclosure further provides a pharmaceutical composition comprising an immunoconjugate of the disclosure and a pharmaceutically acceptable carrier, and methods of using an immunoconjugate of the disclosure.

In another aspect, the present disclosure provides for a pharmaceutical composition comprising the immunoconjugate as described herein and a pharmaceutically acceptable carrier.

- 20 In particular, the disclosure encompasses an immunoconjugate according to the disclosure for use as a medicament, and for use in the treatment of a disease. In a particular example, said disease is cancer.

In another aspect, the present disclosure provides for the immunoconjugate as described herein for use as a medicament.

- 25 In another aspect, the present disclosure provides for the immunoconjugate as described herein for use in the treatment of a disease, wherein said disease is cancer.

Also encompassed by the disclosure is the use of an immunoconjugate according to the disclosure in the manufacture of a medicament for the treatment of a disease. In a particular example, said disease is cancer.

In another aspect, the present disclosure provides for use of the immunoconjugate as described herein in the manufacture of a medicament for the treatment of cancer.

Further provided is a method of treating disease in an individual, comprising administering to said individual a therapeutically effective amount of a composition comprising an immunoconjugate according to the disclosure in a pharmaceutically acceptable form. In a particular example, said disease is cancer.

Also provided is a method of stimulating the immune system of an individual, comprising administering to said individual an effective amount of a composition comprising an immunoconjugate according to the disclosure in a pharmaceutically acceptable form.

Detailed Description of the Invention

Definitions

Terms are used herein as generally used in the art, unless otherwise defined in the following.

The term “interleukin-2” or “IL-2” as used herein, refers to any native IL-2 from any vertebrate source, including mammals such as primates (e.g. humans) and rodents (e.g., mice and rats), unless otherwise indicated. The term encompasses unprocessed IL-2 as well as any form of IL-2 that results from processing in the cell. The term also encompasses naturally occurring variants

Claims

1. An immunoconjugate comprising (i) an antibody that binds to PD-1 and (ii) a mutant IL-2 polypeptide,
wherein the mutant IL-2 polypeptide is a human IL-2 molecule comprising the amino acid substitutions F42A, Y45A and L72G (numbering relative to the human IL-2 sequence SEQ ID NO: 19).
2. The immunoconjugate according to claim 1, wherein the antibody comprises (a) a heavy chain variable region (VH) comprising a HVR-H1 comprising the amino acid sequence of SEQ ID NO:1, a HVR-H2 comprising the amino acid sequence of SEQ ID NO:2, a HVR-H3 comprising the amino acid sequence of SEQ ID NO:3, and a FR-H3 comprising the amino acid sequence of SEQ ID NO:7 at positions 71-73 according to Kabat numbering, and (b) a light chain variable region (VL) comprising a HVR-L1 comprising the amino acid sequence of SEQ ID NO:4, a HVR-L2 comprising the amino acid sequence of SEQ ID NO:5, and a HVR-L3 comprising the amino acid sequence of SEQ ID NO:6.
3. The immunoconjugate according to claim 1, wherein the antibody comprises (a) a heavy chain variable region (VH) comprising a HVR-H1 comprising the amino acid sequence of SEQ ID NO:8, a HVR-H2 comprising the amino acid sequence of SEQ ID NO:9, and a HVR-H3 comprising the amino acid sequence of SEQ ID NO:10, and (b) a light chain variable region (VL) comprising a HVR-L1 comprising the amino acid sequence of SEQ ID NO:11, a HVR-L2 comprising the amino acid sequence of SEQ ID NO:12, and a HVR-L3 comprising the amino acid sequence of SEQ ID NO:13.
4. The immunoconjugate according to claim 1, wherein the antibody comprises (a) a heavy chain variable region (VH) comprising an amino acid sequence that is at least 95%, 96%, 97%, 98%, 99% or 100% identical to the amino acid sequence of SEQ ID NO:14, and (b) a light chain variable region (VL) comprising an amino acid sequence that is at least 95%, 96%, 97%, 98%, 99% or 100% identical to an amino acid sequence selected from the group consisting of SEQ ID NO:15, SEQ ID NO:16, SEQ ID NO: 17, and SEQ ID NO:18.
5. The immunoconjugate of any one of claims 1 to 4, wherein the mutant IL-2 polypeptide further comprises the amino acid substitution T3A and/or the amino acid substitution C125A.

6. The immunoconjugate of any one of claims 1 to 5, wherein the mutant IL-2 polypeptide comprises the sequence of SEQ ID NO: 20.
7. The immunoconjugate of any one of claims 1 to 6, wherein the immunoconjugate comprises not more than one mutant IL-2 polypeptide.
8. The immunoconjugate of any one of claims 1 to 7, wherein the antibody comprises an Fc domain composed of a first and a second subunit.
9. The immunoconjugate of claim 8, wherein the Fc domain is an IgG class, particularly an IgG₁ subclass, Fc domain.
10. The immunoconjugate of claim 8 or 9, wherein the Fc domain is a human Fc domain.
11. The immunoconjugate of any one of claims 1 to 10, wherein the antibody is an IgG class, particularly an IgG₁ subclass immunoglobulin.
12. The immunoconjugate of any one of claims 8 to 11, wherein the Fc domain comprises a modification promoting the association of the first and the second subunit of the Fc domain, wherein the modification is the following: the CH3 domain of the first subunit of the Fc domain an amino acid residue is replaced with an amino acid residue having a larger side chain volume, thereby generating a protuberance within the CH3 domain of the first subunit which is positionable in a cavity within the CH3 domain of the second subunit, and in the CH3 domain of the second subunit of the Fc domain an amino acid residue is replaced with an amino acid residue having a smaller side chain volume, thereby generating a cavity within the CH3 domain of the second subunit within which the protuberance within the CH3 domain of the first subunit is positionable.
13. The immunoconjugate of any one of claims 8 to 12, wherein in the first subunit of the Fc domain the threonine residue at position 366 is replaced with a tryptophan residue (T366W), and in the second subunit of the Fc domain the tyrosine residue at position 407 is replaced with a valine residue (Y407V) and optionally the threonine residue at position 366 is replaced with a serine residue (T366S) and the leucine residue at position 368 is replaced with an alanine residue (L368A) (numberings according to Kabat EU index).
14. The immunoconjugate of claim 13, wherein in the first subunit of the Fc domain additionally the serine residue at position 354 is replaced with a cysteine residue (S354C) or the glutamic

acid residue at position 356 is replaced with a cysteine residue (E356C), and in the second subunit of the Fc domain additionally the tyrosine residue at position 349 is replaced by a cysteine residue (Y349C) (numberings according to Kabat EU index).

15. The immunoconjugate of any one of claims 8 to 14, wherein the mutant IL-2 polypeptide is fused at its amino-terminal amino acid to the carboxy-terminal amino acid of one of the subunits of the Fc domain, particularly the first subunit of the Fc domain, optionally through a linker peptide.

16. The immunoconjugate of claim 15, wherein the linker peptide has the amino acid sequence of SEQ ID NO:21.

17. The immunoconjugate of any one of claims 8 to 15, wherein the Fc domain comprises one or more amino acid substitution that reduces binding to an Fc receptor, particularly an Fc γ receptor, and/or effector function, particularly antibody-dependent cell-mediated cytotoxicity (ADCC), wherein said one or more amino acid substitution is at one or more position selected from the group of L234, L235, and P329 (Kabat EU index numbering).

18. The immunoconjugate of any one of claims 8 to 17, wherein each subunit of the Fc domain comprises the amino acid substitutions L234A, L235A and P329G (Kabat EU index numbering).

19. The immunoconjugate of any one of claims 1 to 18, comprising a polypeptide comprising an amino acid sequence that is at least 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of SEQ ID NO:22, a polypeptide comprising an amino acid sequence that is at least 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of SEQ ID NO:23 or SEQ ID NO:24, and a polypeptide comprising an amino acid sequence that is at least 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of SEQ ID NO:25.

20. The immunoconjugate of any one of claims 1 to 19, essentially consisting of a mutant IL-2 polypeptide and an IgG₁ immunoglobulin molecule, joined by a linker sequence.

21. One or more isolated polynucleotide encoding the immunoconjugate of any one of claims 1 to 20.

22. One or more vector, particularly expression vector, comprising the polynucleotide(s) of claim 21.

23. A host cell comprising the polynucleotide(s) of claim 21 or the vector(s) of claim 22.
24. A method of producing an immunoconjugate comprising a mutant IL-2 polypeptide and an antibody that binds to PD-1, comprising (a) culturing the host cell of claim 23 under conditions suitable for the expression of the immunoconjugate, and optionally (b) recovering the immunoconjugate.
25. A pharmaceutical composition comprising the immunoconjugate of any one of claims 1 to 20 and a pharmaceutically acceptable carrier.
26. The immunoconjugate of any one of claims 1 to 20 for use as a medicament.
27. The immunoconjugate of any one of claims 1 to 20 for use in the treatment of a disease, wherein said disease is cancer.
28. Use of the immunoconjugate of any one of claims 1 to 20 in the manufacture of a medicament for the treatment of cancer.