(enriched) and stimulated cell populations for use in such cell therapies often require separate selection and stimulation steps, which can prolong the manufacturing process. Furthermore, selection techniques may involve steps that contaminate selected cells with selection-related particles, such as, for example, selection agents such as Fab fragments and competition reagents and/or free binding agents used to facilitate detachment of the cells from the stationary phase, thus requiring additional wash steps and/or media exchange to purify the output composition. The additional processing steps may result in cell stress, potentially affecting downstream cell processing or even cell biology, in addition to requiring considerable time to complete. Improved methods for generating cell populations suitable for use, for example in cell therapy, which minimize cell handling and processing time, are thus needed. Provided are methods, articles of manufacture, and apparatus that meet such needs.

Summary

[0005] Provided are methods of on-column stimulation of T cells, the method including: adding an oligomeric stimulatory reagent capable of delivering a stimulatory signal in T cells to a stationary phase containing a plurality of immobilized T cells, thereby initiating incubation of the stimulatory reagent with one or more T cells, wherein: the stationary phase includes a selection agent that specifically binds to a selection marker on the surface of one or more T cells or subset thereof; the oligomeric stimulatory reagent includes one or more stimulatory agent including (i) a first stimulatory agent that is an anti-CD3 antibody, and (ii) a second stimulatory agent that is an anti-CD28 antibody; and within 24 hours of initiating incubation, collecting one or more of the plurality of T cells from the stationary phase by gravity flow, thereby generating a composition containing stimulated T cells. In the provided method, the selection agent that specifically binds to a selection marker on the surface of one or more T cells or subsets thereof immobilizes the plurality of T cells on the stationary phase.

[0005a] In one aspect, the present disclosure refers to a method of on-column stimulation of T cells, the method comprising: (a) adding an oligomeric stimulatory reagent capable of delivering a stimulatory signal in T cells to a stationary phase comprised in a chromatography column, wherein a plurality of T cells are immobilized on the stationary phase, thereby initiating incubation of the oligomeric stimulatory reagent with the plurality of T cells, wherein: the stationary phase comprises a selection agent that specifically binds to a selection marker selected from one or more of CD3, CD4, and CD8 on the surface of the plurality of T cells, wherein specific binding of the selection agent to the selection marker expressed by the plurality of T cells immobilizes the plurality of T cells on the stationary phase; and the oligomeric stimulatory reagent is in soluble form and comprises (i) an oligomer or polymer of streptavidin or streptavidin mutein molecules and (ii) one or more stimulatory agents bound to the oligomer or polymer, the one or more stimulatory agents comprising a first stimulatory agent that comprises an anti-CD3 antibody or antigen-binding fragment thereof and a second stimulatory agent that comprises an anti-CD28 antibody or antigen-binding fragment thereof; and (b) within 24 hours of the initiating incubation, collecting one or more T cells of the plurality of T cells from the stationary phase without the addition of an agent to facilitate detachment of immobilized T cells from the stationary phase, thereby generating a composition comprising stimulated T cells.

[0006] Provided are methods of on-column stimulation of T cells, the method including: incubating an oligomeric stimulatory reagent capable of delivering a stimulatory signal in T cells with a plurality of T cells immobilized on a staitionary phase, thereby initiating incubation of the stimulatory reagent with one or more T cells, wherein: the stationary phase includes a selection agent that specifically binds to a selection marker on the surface of one or more T cells or subset thereof; the oligomeric stimulatory reagent includes one or more stimulatory agent including (i) a

first stimulatory agent that is an anti-CD3 antibody, and (ii) a second stimulatory agent that is an anti-CD28 antibody; and within 24 hours of initiating incubation, collecting one or more of the plurality of T cells from the stationary phase by gravity flow, thereby generating a composition containing stimulated T cells. In the provided method, the selection agent that specifically binds to a selection marker on the surface of one or more T cells or subsets thereof immobilizes the plurality of T cells on the stationary phase.

[0006a] In one aspect, the present disclosure refers to a method of on-column stimulation of T cells, the method comprising: (a) incubating a plurality of T cells immobilized on a stationary phase comprised in a chromatography column with an oligomeric stimulatory agent to deliver a stimulatory signal in one or more T cells of the plurality of T cells, the oligomeric stimulatory agent comprising a first stimulatory agent that comprises an anti-CD3 antibody or antigen-binding fragment thereof and a second stimulatory agent that comprises an anti-CD28 antibody or antigen-binding fragment thereof, and the stationary phase comprising a selection agent that specifically binds to a selection marker selected from one or more of CD3, CD4, and CD8 on the surface of the plurality of T cells, wherein specific binding of the selection agent to the selection marker expressed by the plurality of T cells immobilizes the plurality of T cells on the stationary phase; and (b) within 24 hours of the initiating incubation, collecting the one or more T cells from the stationary phase without the addition of an agent to facilitate detachment of immobilized T cells from the stationary phase, thereby generating a composition comprising stimulated T cells.

[0007] Provided are methods of on-column stimulation of T cells, the method including: combining an oligomeric stimulatory reagent capable of delivering a stimulatory signal in T cells with a plurality of T cells immobilized on a staitionary phase, thereby initiating incubation of the stimulatory reagent with one or more T cells, wherein: the stationary phase includes a selection agent that specifically binds to a selection marker on the surface of one or more T cells or subset thereof; the oligomeric stimulatory reagent includes one or more stimulatory agent including (i) a first stimulatory agent that is an anti-CD3 antibody, and (ii) a second stimulatory agent that is an anti-CD28 antibody; and within 24 hours of initiating incubation, collecting one or more of the plurality of T cells from the stationary phase by gravity flow, thereby generating a composition containing stimulated T cells. In the provided method, the selection agent that specifically binds to a selection marker on the surface of one or more T cells or subsets thereof immobilizes the plurality of T cells on the stationary phase.

[0008] Provided are methods for on-column stimulation of T cells, the method including incubating a plurality of T cells immobilized on a stationary phase with one or more stimulatory agent to deliver a stimulatory signal in one or more T cells of the plurality of T cells, said stationary phase including a selection agent that specifically binds to a selection marker on the surface of the one or more T cells, where specific binding of the selection agent to the selection marker expressed by the one or more T cells effects the immobilization of the one or more T cells on the stationary phase; and within 24 hours of the initiation of the incubation, collecting the one or more T cells from the stationary phase by gravity flow without the addition of a competition agent or free binding agent to elute the plurality of T cells from the stationary phase, thereby generating a composition containing stimulated T cells. Provided are methods for on-column stimulation of T cells, the method including incubating a plurality of T cells immobilized on a stationary phase with one or more stimulatory agent to deliver a stimulatory signal in one or

an ITAM-containing molecule in a T cell. In some examples, the at least one of the one or more first stimulatory agent is capable of delivering a stimulatory signal, wherein the stimulatory signal is through a TCR/CD3 complex in a T cell, a CD3-containing complex in a T cell, and/or an ITAM-containing molecule in a T cell. In some examples, the second stimulatory agent is capable of specifically binding to a costimulatory molecule on the one or more T cells. In some examples, the first stimulatory agent delivers a stimulatory signal through a TCR/CD3 complex in a T cell, a CD3-containing complex in a T cell, and/or an ITAM-containing molecule in a T cell and the second stimulatory agent binds to a costimlatory molecule on the T cell.

[0010] Provided are methods of on-column stimulation of T cells, the method including adding a sample containing a plurality of T cells to a stationary phase, said stationary phase containing a selection agent that binds to a selection marker on the surface of one or more of the plurality of T cells, thereby immobilizing the one or more of the plurality of T cells on the stationary phase; adding, to the stationary phase, a stimulatory reagent containing one or more stimulatory agent capable of delivering a stimulatory signal in one or more of said plurality of T cells, thereby initiating incubation of the stimulatory reagent with the one or more T cells; and within 24 hours of the initiating incubation, collecting one or more of said plurality of T cells from the stationary phase by gravity flow without the addition of a competition agent or free binding agent to elute the plurality of T cells from the stationary phase, thereby generating a composition containing stimulated T cells.

[0010a] In one aspect, the present disclosure refers to a method of on-column stimulation of T cells, the method comprising: (a) adding a sample comprising a plurality of T cells to a stationary phase comprised in a chromatography column, the stationary phase comprising a selection agent that specifically binds to a selection marker selected from one or more of CD3, CD4, and CD8 on the surface of one or more T cells of the plurality of T cells, thereby immobilizing the one or more T cells on the stationary phase; (b) adding, to the stationary phase, an oligomeric stimulatory reagent that is in soluble form and comprises (i) an oligomer or polymer of streptavidin or streptavidin mutein molecules and (ii) one or more stimulatory agents bound to the oligomer or polymer, the one or more stimulatory agents comprising a first stimulatory agent that comprises an anti-CD3 antibody or antigen-binding fragment thereof and a second stimulatory agent that comprises an anti-CD28 antibody or antigen-binding fragment thereof, thereby initiating incubation of the oligomeric stimulatory reagent with the one or more T cells; and (c) within 24 hours of the initiating incubation, collecting the one or more T cells from the stationary phase without the addition of an agent to facilitate detachment of immobilized T cells from the stationary phase, thereby generating a composition comprising stimulated T cells.

[0011] Provided are methods of on-column stimulation of T cells, the method including adding a sample containing a plurality of T cells to a stationary phase, said stationary phase containing a selection agent that binds to a selection marker on the surface of one or more of the plurality of T cells, thereby immobilizing the one or more of the plurality of T cells on the stationary phase; adding, to the stationary phase, a stimulatory reagent containing one or more stimulatory agent capable of delivering a stimulatory signal in one or more of said plurality of T cells, thereby initiating incubation of the stimulatory reagent with the one or more T cells; and within 24 hours of the initiating incubation, collecting one or more of said plurality of T cells from the stationary phase by gravity flow, thereby generating a composition containing stimulated T cells.

competition agent or free binding agent is or contains biotin or a biotin analog, optionally wherein the biotin analog is D-biotin. In some examples, the competition agent or free binding agent is D-biotin. In some examples, the method includes after said collecting, further incubating the composition containing the stimulated T cells. In some examples, the further incubation is carried out at or about 37 ºC ± 2 ºC; and/or the further incubation is carried out in the presence of a further agent that is capable of delivering a signal to T cells. In some examples, the further agent is contained in the media used for washing the stationary phase. In some examples, the further agent is capable of enhancing or inducing proliferation of T cells, CD4+ T cells and/or CD8+ T cells. In some examples, the further agent is a cytokine selected from among IL-2, IL-15 and IL-7. In some examples, the further incubation is carried out for a time that is 72 hours, no more than 48 hours, no more than 24 hours, or no more than 12 hours.

[0040] In one aspect, the disclosure provides a method of producing a composition comprising engineered T cells, the method comprising (a) performing on-column stimulation of T cells according to the method of any of claims 1-29 to generate a composition comprising stimulated T cells; and (b) introducing a recombinant nucleic acid molecule into T cells of the composition comprising stimulated T cells, wherein the nucleic acid molecule encodes a recombinant protein, thereby producing a composition comprising engineered T cells.. In some examples, the recombinant protein is an antigen receptor. In some examples, the recombinant protein is a chimeric antigen receptor.

[0041] In some examples, the chimeric antigen receptor (CAR) contains an extracellular antigen-recognition domain that specifically binds to a target antigen and an intracellular signaling domain comprising an ITAM. In some examples, the intracellular signaling domain comprises an intracellular domain of a CD3-zeta (CD3ζ) chain. In some examples, further included is a transmembrane domain linking the extracellular domain and the intracellular signaling domain. In some examples, the transmembrane domain comprises a transmembrane portion of CD28. In some examples, the intracellular signaling domain further contains an intracellular signaling domain of a T cell costimulatory molecule. In some examples, the T cell costimulatory molecule is selected from the group consisting of CD28 and 41BB. In some examples, the nucleic acid further contains a promoter operably linked to the nucleic acid encoding the recombinant antigen receptor.

Claims

WHAT IS CLAIMED:

1. A method of on-column stimulation of T cells, the method comprising:

(a) adding an oligomeric stimulatory reagent capable of delivering a stimulatory signal in T cells to a stationary phase comprised in a chromatography column, wherein a plurality of T cells are immobilized on the stationary phase, thereby initiating incubation of the oligomeric stimulatory reagent with the plurality of T cells, wherein:

the stationary phase comprises a selection agent that specifically binds to a selection marker selected from one or more of CD3, CD4, and CD8 on the surface of the plurality of T cells, wherein specific binding of the selection agent to the selection marker expressed by the plurality of T cells immobilizes the plurality of T cells on the stationary phase; and

the oligomeric stimulatory reagent is in soluble form and comprises (i) an oligomer or polymer of streptavidin or streptavidin mutein molecules and (ii) one or more stimulatory agents bound to the oligomer or polymer, the one or more stimulatory agents comprising a first stimulatory agent that comprises an anti-CD3 antibody or antigen-binding fragment thereof and a second stimulatory agent that comprises an anti-CD28 antibody or antigen-binding fragment thereof; and

(b) within 24 hours of the initiating incubation, collecting one or more T cells of the plurality of T cells from the stationary phase without the addition of an agent to facilitate detachment of immobilized T cells from the stationary phase, thereby generating a composition comprising stimulated T cells.

2. A method of on-column stimulation of T cells, the method comprising:

(a) incubating a plurality of T cells immobilized on a stationary phase comprised in a chromatography column with an oligomeric stimulatory agent to deliver a stimulatory signal in one or more T cells of the plurality of T cells,

the oligomeric stimulatory agent comprising a first stimulatory agent that comprises an anti-CD3 antibody or antigen-binding fragment thereof and a second stimulatory agent that comprises an anti-CD28 antibody or antigen-binding fragment thereof, and

the stationary phase comprising a selection agent that specifically binds to a selection marker selected from one or more of CD3, CD4, and CD8 on the surface of the plurality of T cells, wherein specific binding of the selection agent to the selection marker expressed by the plurality of T cells immobilizes the plurality of T cells on the stationary phase; and

(b) within 24 hours of the initiating incubation, collecting the one or more T cells from the stationary phase without the addition of an agent to facilitate detachment of immobilized T cells from the stationary phase, thereby generating a composition comprising stimulated T cells.

3. The method of claim 2, wherein the oligomeric stimulatory reagent is in soluble form and comprises (i) an oligomer or polymer of streptavidin or streptavidin mutein molecules and (ii) the first and second stimulatory agents bound to the oligomer or polymer.

4. A method of on-column stimulation of T cells, the method comprising:

(a) adding a sample comprising a plurality of T cells to a stationary phase comprised in a chromatography column, the stationary phase comprising a selection agent that specifically binds to a selection marker selected from one or more of CD3, CD4, and CD8 on the surface of one or more T cells of the plurality of T cells, thereby immobilizing the one or more T cells on the stationary phase;

(b) adding, to the stationary phase, an oligomeric stimulatory reagent that is in soluble form and comprises (i) an oligomer or polymer of streptavidin or streptavidin mutein molecules and (ii) one or more stimulatory agents bound to the oligomer or polymer, the one or more stimulatory agents comprising a first stimulatory agent that comprises an anti-CD3 antibody or antigen-binding fragment thereof and a second stimulatory agent that comprises an anti-CD28 antibody or antigen-binding fragment thereof, thereby initiating incubation of the oligomeric stimulatory reagent with the one or more T cells; and

(c) within 24 hours of the initiating incubation, collecting the one or more T cells from the stationary phase without the addition of an agent to facilitate detachment of immobilized T cells from the stationary phase, thereby generating a composition comprising stimulated T cells.

5. The method of claim 4, wherein the initiating incubation with the oligomeric stimulatory reagent is carried out within 10 minutes, within 20 minutes, within 30 minutes, within 45 minutes, within 60 minutes, within 90 minutes, or within 120 minutes after adding the sample comprising the plurality of T cells to the stationary phase.

6. The method of any of claims 1 and 3-5, wherein the oligomeric stimulatory reagent comprises an oligomer or polymer of at least 100 tetramers of the streptavidin or streptavidin mutein molecules.

7. The method of any of claims 1 and 3-6, wherein the oligomeric stimulatory reagent comprises an oligomer of streptavidin mutein molecules that reversibly bind to biotin, a biotin analog, or a streptavidin-binding peptide.

8. The method of claim 7, wherein the streptavidin mutein comprises the amino acid sequence Ile^{44}-Gly^{45}-Ala^{46}-Arg^{47} or Val^{44}-Thr^{45}-Ala^{46}-Arg^{47} at sequence positions corresponding to positions 44 to 47 with reference to positions in streptavidin in the sequence of amino acids set forth in SEQ ID NO: 1.

9. The method of claim 7 or claim 8, wherein the streptavidin mutein comprises the amino acid sequence set forth in any of SEQ ID NO: 3-6, 27, 28, 104, and 105.

10. The method of any of claims 1-9, wherein

the selection agent comprises an agent selected from the group consisting of antibodies, antibody fragments,proteinaceous binding molecules with immunoglobulin-like functions, molecules containing Ig domains, cytokines, chemokines, aptamers, MHC molecules, MHC-peptide complexes, receptor ligands, and binding fragments of any of the foregoing.

11. The method of any of claims 1-10, wherein the one or more stimulatory agents and/or the selection agent comprises a monovalent antibody fragment.

12. The method of any of claims 1-11, wherein the one or more stimulatory agents and/or the selection agent comprises a monovalent antibody fragment that is independently selected

from the group consisting of a Fab fragment, an Fv fragment, and a single-chain Fv fragment (scFv).

13. The method of any of claims 1-12, wherein the first stimulatory agent comprises an anti-CD3 Fab and the second stimulatory agent comprises an anti-CD28 Fab.

14. The method of any of claims 1-13, wherein the collecting the one or more T cells from the stationary phase occurs within 2 to 24, 3 to 24, 4 to 24, 5, to 24, 6 to 24, 7 to 24, 8 to 24, 9 to 24, 10 to 24, 11 to 24, 12 to 24, 13 to 24, 14 to 24, 15 to 24, 16 to 24, 17 to 24, 18 to 24, 19 to 24, 20 to 24, 21 to 24, 22 to 24, 23 to 24, 2 to 23, 2 to 22, 2 to 21, 2 to 20, 2 to 19, 2 to 18, 2 to 17, 2 to 16, 2 to 15, 2 to 14, 2 to 13, 2 to 12, 2 to 11, 2 to 10, 2 to 9, 2 to 8, 2 to 7, 2 to 6, 2 to 5, 2 to 4, or 2 to 3 hours of the initiating incubation.

15. The method of any of claims 1-14, wherein the T cells are from a whole blood sample, a buffy coat sample, a peripheral blood mononuclear cells (PBMC) sample, an unfractionated T cell sample, a lymphocyte sample, a white blood cell sample, an apheresis product, or a leukapheresis product.

16. The method of any of claims 1-15, wherein
the one or more stimulatory agents and/or the selection agent comprises biotin; a biotin analog; or a streptavidin-binding peptide.

17. The method of any of claims 1-16, wherein the one or more stimulatory agents and/or the selection agent comprises a streptavidin-binding peptide that is independently selected from the group consisting of Trp-Arg-His-Pro-Gln-Phe-Gly-Gly (SEQ ID NO: 7), Trp-Ser-His-Pro-Gln-Phe-Glu-Lys (SEQ ID NO: 8), Ser-Ala-Trp-Ser-His-Pro-Gln-Phe-Glu-Lys-(GlyGlyGlySer)3-Trp-Ser-His-Pro-Gln-Phe-Glu-Lys (SEQ ID NO:15), Trp-Ser-His-Pro-Gln-Phe-Glu-Lys-(GlyGlyGlySer)3-Trp-Ser-His-Pro-Gln-Phe-Glu-Lys (SEQ ID NO: 17), SAWSHPQFEKGGGSGGGSGGSAWSHPQFEK (SEQ ID NO: 16), Trp-Ser-His-Pro-Gln-Phe-Glu-Lys-(GlyGlyGlySer)2-Trp-Ser-His-Pro-Gln-Phe-Glu-Lys (SEQ ID NO: 18), and Trp-Ser-His-Pro-Gln-Phe-Glu-Lys-(GlyGlyGlySer)2Gly-Gly-Ser-Ala-Trp-Ser-His-Pro-Gln-Phe-Glu-Lys (SEQ ID NO: 19).

18. The method of any of claims 1-17, wherein the selection agent comprises an anti-CD3 Fab, an anti-CD8 Fab, or an anti-CD4 Fab.

19. The method of any of claims 1-18, wherein the specific binding between the selection agent and the selection marker does not induce a stimulatory or proliferative signal to the T cells.

20. The method of any of claims 1-19, wherein the oligomeric stimulatory reagent comprises

between 1,000 and 20,000 tetramers, between 1,000 and 10,000 tetramers, or between 2,000 and 5,000 tetramers of the streptavidin or streptavidin mutein molecules.

21. The method of any of claims 1-20, wherein the oligomeric stimulatory reagent is added to the stationary phase at a concentration of between 1 µg/1 million cells to 2 µg/1 million cells.

22. The method of any of claims 1-21, wherein the collecting comprises adding media to the stationary phase.

23. The method of any of claims 1-22, wherein the collecting is without the addition of a competition agent or free binding agent that dissociates the one or more stimulatory agents from the oligomer or polymer.

24. The method of any of claims 1-23, wherein the collecting is without the addition of biotin or a biotin analog.

25. The method of any of claims 1-24, wherein the collecting is without the addition of D-biotin, iminobiotin, lipoic acid, desthiobiotin, diaminobiotin, hydroxyazobenzene-benzoic acid (HABA), or dimethyl-HABA.

26. The method of any of claims 1-25, wherein the collecting is by gravity flow.

27. The method of any of claims 1-26, wherein the stationary phase is of a non-magnetic material or non-magnetizable material.

28. The method of any of claims 1-27, wherein the stationary phase has a binding capacity of between 75 million and 125 million T cells per mL of stationary phase.

29. The method of any of claims 1-28, wherein the stationary phase comprises a chromatography matrix that is for column chromatography.

30. A method of producing a composition comprising engineered T cells, the method comprising (a) performing on-column stimulation of T cells according to the method of any of claims 1-29 to generate a composition comprising stimulated T cells; and (b) introducing a recombinant nucleic acid molecule into T cells of the composition comprising stimulated T cells, wherein the nucleic acid molecule encodes a recombinant protein, thereby producing a composition comprising engineered T cells.

31. The method of claim 30, wherein the introduction of the recombinant nucleic acid is achieved by transduction with a viral particle.

32. The method of claim 30 or claim 31, further comprising cultivating the composition comprising engineered T cells under conditions for viral integration.

33. The method of claim 32, wherein the cultivating the composition comprising engineered T cells is carried out for at least 18 hours and for up to 96, 72, 48, or 24 hours subsequent to the introducing.

34. The method of any of claims 30-33, further comprising cultivating the composition comprising engineered T cells under conditions to expand the T cells.

35. The method of claim 34, wherein the cultivating under conditions to expand the T cells is carried out for a time that is no more than 14 days, no more than 12 days, no more than 10 days, no more than 8 days, no more than 6 days, or no more than 5 days.

36. The method of any of claims 32-35, wherein the cultivating under conditions for viral integration and/or the cultivating under conditions to expand the T cells is at a temperature of at or 37º± 2º C.

37. The method of any of claims 30-36, further comprising harvesting the engineered T cells, thereby producing an output population of engineered T cells.

38. The method of claim 35, wherein the harvesting of the engineered T cells is at a time between 48 and 120 hours, inclusive, after the initiating incubation.

39. The method of claim 37 or claim 38, wherein at the time of harvesting, the percentage of naïve-like cells is greater than or greater than 60% among total T cells in the population, total CD4+ T cells in the population, total CD8+ T cells in the population, or of recombinant protein-expressing cells of any of the foregoing in the population.

40. The method of any of claims 37-39, further comprising formulating the harvested cells for cryopreservation and/or administration to a subject.

41. The method of any of claims 30-40, wherein the introducing, cultivating under conditions for viral integration, and/or cultivating under conditions to expand the T cells is carried out in a serum free medium.

42. The method of claim 41, wherein the serum free medium does not comprise recombinant human IL-2, recombinant human IL-15, or recombinant human IL-7.

43. The method of any of claims 1-42, wherein the method is carried out in an automated fashion.