****

**TABLE OF CONTENTS**

[1. REPORT OVERVIEW 13](#_Toc53238362)

[1.1 Statement of the Report 13](#_Toc53238363)

[1.2 EXECUTIVE SUMMARY 15](#_Toc53238364)

[1.3 INTRODUCTION 16](#_Toc53238365)

[2. CHIMERIC ANTIGEN RECEPTOR-T (CAR-T) CELL THERAPY: A BRIEF OVERVIEW 17](#_Toc53238366)

[2.1 CAR-T Cell 18](#_Toc53238367)

[2.2 Evolution of CAR-T Cell Development 19](#_Toc53238368)

[2.2.1 The CAR-T Cell Family 19](#_Toc53238369)

[2.2.1.1 First Generation CARs 20](#_Toc53238370)

[2.2.1.2 Second Generation CARs 21](#_Toc53238371)

[2.2.1.3 Third Generation CARs 21](#_Toc53238372)

[2.2.1.4 Fourth Generation CARs 22](#_Toc53238373)

[2.3 Antigens Present on Hematological Cancer Cells 22](#_Toc53238374)

[2.4 Tools for Inserting Receptor Genes into T Cells 23](#_Toc53238375)

[2.5 Transforming T Cells into CAR-T Cells 23](#_Toc53238376)

[2.6 The Three CAR-T Therapies Crossing the Finishing Line 24](#_Toc53238377)

[2.7 Toxicities Associated with CAR-T Treatment 26](#_Toc53238378)

[2.8 The Future of CAR-T Cell Therapy 27](#_Toc53238379)

[2.8.1 Transition from Liquid Cancers to Solid Tumors 28](#_Toc53238380)

[2.8.2 Reduction in the Length of Hospital Stay 28](#_Toc53238381)

[2.8.3 Discovery of New Target Antigens 29](#_Toc53238382)

[2.8.4 Shifting from Autologous to Allogeneic CAR-T Therapy 29](#_Toc53238383)

[2.8.5 CAR-T for the Masses 31](#_Toc53238384)

[2.9 Advantages of CAR-T Therapy 31](#_Toc53238385)

[2.10 Disadvantages of CAR-T Therapy 32](#_Toc53238386)

[3. HISTORY OF CAR-T CELL THERAPY 33](#_Toc53238387)

[3.1 Current Status of CAR-T Therapy Products 34](#_Toc53238388)

[3.2 Prospective CAR-T Product Candidates 34](#_Toc53238389)

[3.3 Transformative Potential of CAR-T Therapy 35](#_Toc53238390)

[3.4 Small Patient Population & Huge Clinical Trial Landscape 36](#_Toc53238391)

[4. MANUFACTURE OF CAR-T CELLS 37](#_Toc53238392)

[4.1 Automation in CAR-T Manufacturing 39](#_Toc53238393)

[4.2 Operating Expenses in Autologous CAR-T Manufacturing 40](#_Toc53238394)

[4.3 Operating Expenses in Allogeneic CAR-T Manufacturing 41](#_Toc53238395)

[5. CAR-T TARGET ANTIGENS: A BRIEF OVERVIEW 42](#_Toc53238396)

[5.1 CAR-T Target Antigens on Hematological Cancers 42](#_Toc53238397)

[5.2 CAR-T Target Antigens on Solid Tumors 43](#_Toc53238398)

[5.3 Common Antigens Targeted by CAR-T Cells 44](#_Toc53238399)

[5.3.1 Cluster of Differentiation 19 (CD19) 45](#_Toc53238400)

[5.3.2 Mesothelin 45](#_Toc53238401)

[5.3.3 B-Cell Maturation Agent (BCMA) 45](#_Toc53238402)

[5.3.4 GD2 46](#_Toc53238403)

[5.3.5 Glypican-3 (GPC3) 46](#_Toc53238404)

[5.3.6 Cluster Differentiation-22 (CD22) 46](#_Toc53238405)

[6. CAR-T PATENT LANDSCAPE 47](#_Toc53238406)

[6.1 Geographical Origin of CAR-T Patent Applications 49](#_Toc53238407)

[6.2 Top Ten CAR-T Patent Jurisdictions 49](#_Toc53238408)

[6.3 Affiliations of CAR-T Cell Patent Applicants 50](#_Toc53238409)

[6.3.1 Top 20 Companies in CAR-T Patent Landscape 51](#_Toc53238410)

[6.3.2 TOP 20 Research Centers in CAR-T Patent Landscape 52](#_Toc53238411)

[6.3.3 Top 20 CAR-T Cell Inventors 53](#_Toc53238412)

[6.3.4 Top Five CAR-T Patents with Most Family Members 54](#_Toc53238413)

[6.3.5 Top Five CAR-T Patents with Most Inventors in Co-Authorship 55](#_Toc53238414)

[6.3.6 Top Five Patents with Most Co-Applicants 56](#_Toc53238415)

[6.3.7 Top Five CAR-T Patents with Most Citations Received 56](#_Toc53238416)

[7. GLOBAL CAR-T CLINICAL TRIALS: AN OVERVIEW 57](#_Toc53238417)

[7.1 CAR-T Targeted Biomarkers in Clinical Trials 58](#_Toc53238418)

[7.1.1 CAR-T Targeted Biomarkers in U.S. Clinical Trials 59](#_Toc53238419)

[7.1.2 CAR-T Targeted Biomarkers in Chinese Clinical Trials 59](#_Toc53238420)

[7.1.3 CAR-T Targeted Biomarkers in other Countries 60](#_Toc53238421)

[7.2 CAR-T Targeted Indications in the U.S. Clinical Trials 61](#_Toc53238422)

[7.3 Indications Addressed by CAR-T Clinical Trials in China 62](#_Toc53238423)

[7.4 Percent Share of Indications Addressed by the Ongoing CAR-T Clinical Trials 63](#_Toc53238424)

[7.5 Phase of CAR-T Clinical Trials 64](#_Toc53238425)

[7.6 CAR-T Clinical Trial Sponsor Companies and Institutions in the U.S. 65](#_Toc53238426)

[7.7 CAR-T Clinical Trial Sponsor Companies and Institutions in China 67](#_Toc53238427)

[7.8 CAR-T Clinical Trial Sponsor Companies and Institutions in other Countries 70](#_Toc53238428)

[7.9 Ongoing Clinical Trials with Improved CAR-T Constructs 72](#_Toc53238429)

[7.9.1 CAR-T with PD1Fc 72](#_Toc53238430)

[7.9.2 CAR-T with Truncated EGFR (EGFRt) 72](#_Toc53238431)

[7.9.3 CAR-T with IL7 and CCL19 72](#_Toc53238432)

[7.9.4 CAR-T with PD1/CD28 Switch-Receptor 73](#_Toc53238433)

[7.9.5 CAR-T with PD1 shRNA-expressing cassette 73](#_Toc53238434)

[7.9.6 CAR-T with CTLA-4/PD-1 Antibody 73](#_Toc53238435)

[7.9.7 CAR-T with PD-1 Antibodies 73](#_Toc53238436)

[7.10 Geographic Distribution of CAR-T Clinical Trials 79](#_Toc53238437)

[7.11 Distribution of CAR-T Clinical Trials by Type of CAR Generations 79](#_Toc53238438)

[7.12 Distribution of CAR-T Clinical Trials by Type of ScFv Used 80](#_Toc53238439)

[7.13 Distribution of CAR-T Clinical Trials by Type of Vectors Used 81](#_Toc53238440)

[8. PUBLISHED SCIENTIFIC PAPERS & NIH GRANTS 83](#_Toc53238441)

[8.1 Number of Published Papers 83](#_Toc53238442)

[8.2 NIH Funding for CAR-T Research 84](#_Toc53238443)

[9. DEALS IN CAR-T THERAPY SPACE 86](#_Toc53238444)

[9.1 Most Recent CAR-T Deals 86](#_Toc53238445)

[9.1.1 Gilead Sciences/Tango Therapeutics 86](#_Toc53238446)

[9.1.2 Kite/Teneobio 86](#_Toc53238447)

[9.1.3 Fate/Janssen 87](#_Toc53238448)

[9.1.4 Juno/Oxford Biomedica 87](#_Toc53238449)

[9.1.5 Allogene/MaxCyte 87](#_Toc53238450)

[9.1.6 Applied DNA Sciences, Inc. 87](#_Toc53238451)

[9.1.7 Cellectis/Servier 88](#_Toc53238452)

[9.1.8 Cell Therapies, Pvt. Ltd 88](#_Toc53238453)

[9.1.9 Astellas/Adaptimmune 88](#_Toc53238454)

[9.1.10 Astellas/Xyphos 88](#_Toc53238455)

[9.1.11 Carisma Therapeutics, Inc./NYU Langone Health 89](#_Toc53238456)

[10. MARKETED CAR-T PRODUCTS 105](#_Toc53238457)

[10.1 Kymriah (Tisagenlecleucel) 105](#_Toc53238458)

[10.1.1 Mechanism of Action 106](#_Toc53238459)

[10.1.2 Dosing 106](#_Toc53238460)

[10.1.3 Safety and Efficacy of Kymriah 106](#_Toc53238461)

[10.1.4 Kymriah’s Cost 107](#_Toc53238462)

[10.1.5 Current Sales of Kymriah 107](#_Toc53238463)

[10.2 Yescarta (Axicabtagene ciloleucel) 108](#_Toc53238464)

[10.2.1 Mechanism of Action 109](#_Toc53238465)

[10.2.3 Dosing 109](#_Toc53238466)

[10.2.4 Safety and Efficacy of Yescarta 109](#_Toc53238467)

[10.2.5 Manufacturing Network 109](#_Toc53238468)

[10.2.6 Current sales of Yescarta 110](#_Toc53238469)

[10.2.7 Sales of Kymriah and Yescarta: A Comparison 110](#_Toc53238470)

[10.3 Tecartus (Brexucabtagene autoleucel) 112](#_Toc53238471)

[10.3.1 Mechanism of Action 112](#_Toc53238472)

[10.3.2 Dosing 112](#_Toc53238473)

[10.3.3 Safety and Efficacy of Tecartus 113](#_Toc53238474)

[10.3.4 Efficacy, Safety and Composition of Approved CAR-T Products 113](#_Toc53238475)

[10.4 Other Promising CAR-T Product Candidates 114](#_Toc53238476)

[10.4.1 Liso-Cel (Lisocabtagene Maraleucel) 115](#_Toc53238477)

[10.4.2 0Idecabtagene Vicleucel (Ide-cel, bb2121) 115](#_Toc53238478)

[10.4.3 ALLO-501 115](#_Toc53238479)

[10.4.4 CTX110 115](#_Toc53238480)

[10.4.5 UCART19 116](#_Toc53238481)

[10.4.6 AUTO1 116](#_Toc53238482)

[10.4.7 JCARH125 116](#_Toc53238483)

[10.4.8 LCAR-B38M 116](#_Toc53238484)

[10.4.9 PBCAR20A 117](#_Toc53238485)

[10.4.10 UCART123 117](#_Toc53238486)

[10.4.11 PRGN-3006 117](#_Toc53238487)

[10.4.12 UCART22 117](#_Toc53238488)

[10.4.13 UCARTCS1 118](#_Toc53238489)

[11. REIMBURSEMENT FOR CAR-T THERAPIES 119](#_Toc53238490)

[11.1 Hospital Reimbursement in the U.S. for CAR-T Therapy 119](#_Toc53238491)

[11.2 Outcomes-Based Reimbursement for CAR-T Therapies in EU5 Countries 120](#_Toc53238492)

[11.2.1 France 120](#_Toc53238493)

[11.2.2 Germany 121](#_Toc53238494)

[11.2.3 Italy 121](#_Toc53238495)

[11.2.4 Spain 122](#_Toc53238496)

[11.2.5 U.K. 122](#_Toc53238497)

[12. BLOOD CANCERS: AN OVERVIEW 123](#_Toc53238498)

[12.1 Lymphoma 123](#_Toc53238499)

[12.1.1 Hodgkin Lymphoma (HL) 124](#_Toc53238500)

[12.1.2 Non-Hodgkin Lymphoma (NHL) 125](#_Toc53238501)

[12.1.2.1 Diffuse Large B Cell Lymphoma (DLBCL) 126](#_Toc53238502)

[12.1.2.2 Follicular Lymphoma (FL) 127](#_Toc53238503)

[12.2 Leukemia 128](#_Toc53238504)

[12.2.1 Types of Leukemia 129](#_Toc53238505)

[12.2.1.1 Acute Myeloid Leukemia (AML) 129](#_Toc53238506)

[12.2.1.2 Acute Lymphoblastic Leukemia (ALL) 130](#_Toc53238507)

[12.2.1.3 Chronic Myeloid Leukemia (CML) 131](#_Toc53238508)

[12.2.1.4 Chronic Lymphocytic Leukemia (CLL) 132](#_Toc53238509)

[12.3 Multiple Myeloma (MM) 133](#_Toc53238510)

[12.4 Treatment Options for Blood Cancers 134](#_Toc53238511)

[12.4.1 Chemotherapy 135](#_Toc53238512)

[12.4.2 Radiation Therapy 136](#_Toc53238513)

[12.4.3 Targeted Therapy 137](#_Toc53238514)

[12.4.4 Stem Cell Transplantation 138](#_Toc53238515)

[12.4.5 Immunotherapy 138](#_Toc53238516)

[12.4.5.1 Monoclonal Antibodies (mAbs) 138](#_Toc53238517)

[12.4.5.2 Immune Check-point Inhibitors 139](#_Toc53238518)

[12.4.5.3 Adoptive Cell Transfer Therapy/T-Cell Transfer Therapy 140](#_Toc53238519)

[12.5 The Staggering Cost of Cancer Therapy 140](#_Toc53238520)

[13. MARKET ANALYSIS 142](#_Toc53238521)

[13.1 Global Market for CAR-T Cell Therapy by Product 142](#_Toc53238522)

[13.2 Global CAR-T Market by Geography 145](#_Toc53238523)

[13.3 Global Market for CAR-T Therapy by Indication 147](#_Toc53238524)

[13.4 Companies at the Forefront of CAR-T Market 149](#_Toc53238525)

[13.5 Barriers and Strategies for Success in CAR-T 2.0 Market Place 149](#_Toc53238526)

[13.5.1 Barriers to CAR-T 2.0 Commercial Success 150](#_Toc53238527)

[13.5.1.1 Capacity constraints 150](#_Toc53238528)

[13.5.1.2 Competition among Manufacturers 150](#_Toc53238529)

[13.5.1.3 Competition from other Treatments 150](#_Toc53238530)

[13.5.2 Market Development Strategies for CAR-T 2.0 151](#_Toc53238531)

[13.5.2.1 Effective Physician Education 151](#_Toc53238532)

[13.5.2.2 Logistical Excellence 151](#_Toc53238533)

[13.5.2.3 Evidence Generation 151](#_Toc53238534)

[14. COMPANY PROFILES 152](#_Toc53238535)

[14.1 Aleta BioTherapeutics 152](#_Toc53238536)

[14.1.1 Atela’s Pipeline 152](#_Toc53238537)

[14.2 Allogene Therapeutics 153](#_Toc53238538)

[14.2.1 AlloCAR-T Therapy 153](#_Toc53238539)

[14.3 Anixa Biosciences, Inc. 154](#_Toc53238540)

[14.4 Attars Biotherapeutics 155](#_Toc53238541)

[14.4.1 Technology 155](#_Toc53238542)

[14.4.2 Next-Generation CAR-T 155](#_Toc53238543)

[14.5 Autolus Therapeutics, plc 156](#_Toc53238544)

[14.6 Bellicum Pharmaceuticals, Inc. 157](#_Toc53238545)

[14.6.1 GoCAR Technology 157](#_Toc53238546)

[14.6.2 Bellicum’s Pipeline 157](#_Toc53238547)

[14.7 BioNTech 158](#_Toc53238548)

[14.7.1 Collaborators 158](#_Toc53238549)

[14.7.2 Services 158](#_Toc53238550)

[14.7.3 Engineered Cell Therapies 159](#_Toc53238551)

[14.7.4 CAR-T Programs 159](#_Toc53238552)

[14.7.4.1 BNT211 159](#_Toc53238553)

[14.7.4.2 BNT212 159](#_Toc53238554)

[14.8 bluebird bio 160](#_Toc53238555)

[14.8.1 CAR-T Collaborations 160](#_Toc53238556)

[14.8.1.1 Collaboration with Celgene 160](#_Toc53238557)

[14.8.1.2 Collaboration with Inhibrx 160](#_Toc53238558)

[14.8.1.3 Collaboration with TC BioPharm 161](#_Toc53238559)

[14.9 Carina Biotech 161](#_Toc53238560)

[14.9.1 New CAR-T Cells 161](#_Toc53238561)

[14.9.2 CAR-T Access Technologies 162](#_Toc53238562)

[14.9.2.1 Chemokine Receptor Mediation 162](#_Toc53238563)

[14.9.2.2 Gel Formulation to Deliver CAR-T Cells 162](#_Toc53238564)

[14.10 CARsgen Therapeutics 163](#_Toc53238565)

[14.11 Cartesian Therapeutics, Inc. 164](#_Toc53238566)

[14.11.1 Cartesian’s Approach 164](#_Toc53238567)

[14.12 CARTherics 165](#_Toc53238568)

[14.12.1 Technology 165](#_Toc53238569)

[14.13 Celgene Corporation 166](#_Toc53238570)

[14.13.1 Lisocabtagene maraleucel (liso-cel) 166](#_Toc53238571)

[14.14 Cellectis 167](#_Toc53238572)

[14.14.1 Universal Chimeric Antigen Receptor T-Cells (UCARTs) 167](#_Toc53238573)

[14.14.1.1 UCART 123 167](#_Toc53238574)

[14.14.1.2 UCART22 168](#_Toc53238575)

[14.14.1.3 UCARTCS1 168](#_Toc53238576)

[14.14.1.4 UCART19 168](#_Toc53238577)

[14.14.1.5 ALLO-501 168](#_Toc53238578)

[14.14.1.6 ALLO-715 168](#_Toc53238579)

[14.15 Celularity, Inc. 169](#_Toc53238580)

[14.15.1 P CAR-T 169](#_Toc53238581)

[14.16 Celyad Oncology 170](#_Toc53238582)

[14.16.1 TIM Technology 170](#_Toc53238583)

[14.16.2 shRNA Technology 170](#_Toc53238584)

[14.17 Creative Biolabs 172](#_Toc53238585)

[14.17.1 CAR Construction and Production Platform 172](#_Toc53238586)

[14.18 CRISPR Therapeutics 174](#_Toc53238587)

[14.18.1 CRISPR/Cas9 Immuno-Oncology Cell Therapy 174](#_Toc53238588)

[14.19 Cytovia Therapeutics 175](#_Toc53238589)

[14.20 DiaCarta, Inc. 176](#_Toc53238590)

[14.20.1 Personalized CAR-T Immunotherapy Platform 176](#_Toc53238591)

[14.21 Empirica Therapeutics 177](#_Toc53238592)

[14.21.1 Technology 177](#_Toc53238593)

[14.22 Eureka Therapeutics, Inc. 178](#_Toc53238594)

[14.23 EXUMA Biotech Corp. 179](#_Toc53238595)

[14.23.1 Logic Gate CAR-T Technology 179](#_Toc53238596)

[14.23.2 Same-Day CAR-T Therapy 179](#_Toc53238597)

[14.24 Fate Therapeutics, Inc. 180](#_Toc53238598)

[14.25 Formula Pharmaceuticals, Inc. 181](#_Toc53238599)

[14.25.1 Technology 181](#_Toc53238600)

[14.26 Gilead Sciences, Inc. 182](#_Toc53238601)

[14.26.1 TECARTUS (Brexucabtagene autoleucel) 182](#_Toc53238602)

[14.26.2 Yescarta (Axicabtagene ciloleucel) 182](#_Toc53238603)

[14.26.3 Cell Therapy 182](#_Toc53238604)

[14.27 Gracell Biotechnologies 183](#_Toc53238605)

[14.27.1 Dual CAR 183](#_Toc53238606)

[14.27.2 FasTCAR 184](#_Toc53238607)

[14.27.3 TrUCAR 184](#_Toc53238608)

[14.28 iCell Gene Therapeutics 185](#_Toc53238609)

[14.28.1 iCell Platforms 185](#_Toc53238610)

[14.28.1.1 CARvac 185](#_Toc53238611)

[14.28.1.2 Non Gene Edited Universal CARs 185](#_Toc53238612)

[14.28.1.3 C-TPS1 186](#_Toc53238613)

[14.28.1.4 T-Cell Targeted CARs 186](#_Toc53238614)

[14.28.1.5 Compound CARs 186](#_Toc53238615)

[14.29 Janssen Biotech, Inc. 187](#_Toc53238616)

[14.29.1 JNJ-4528 187](#_Toc53238617)

[14.30 Juno Therapeutics 188](#_Toc53238618)

[14.31 JW Therapeutics, Co., Ltd. 189](#_Toc53238619)

[14.31.1 Relmacabtagene autoleucel (Relma-cel) 189](#_Toc53238620)

[14.32 Kite Pharma, Inc. 190](#_Toc53238621)

[14.32.1 Kite’s Technologies (CAR-T & TCR) 190](#_Toc53238622)

[14.32.2 Kite’s Therapies 190](#_Toc53238623)

[14.32.2.1 Yescarta (Axicabtagene ciloleucel) 190](#_Toc53238624)

[14.32.2.2 Tecartus (Brexucabtagene autoleucel) 191](#_Toc53238625)

[14.33 MaxCyte, Inc. 192](#_Toc53238626)

[14.33.1 CARMA Cell Therapies 192](#_Toc53238627)

[14.33.2 Flow Electroporation Technology 192](#_Toc53238628)

[14.34 Minerva Biotechnologies Corporation 193](#_Toc53238629)

[14.34.1 HuMNC2-CAR44 193](#_Toc53238630)

[4.35 Mustang Bio, Inc. 194](#_Toc53238631)

[14.36 Nanjing Legend Biotechnology Co., Ltd. 195](#_Toc53238632)

[14.36.1 LCAR-B38M/JNJ-4528 195](#_Toc53238633)

[14.37 Noile-Immune Biotech 196](#_Toc53238634)

[14.38 Novartis International, AG 197](#_Toc53238635)

[14.38.1 Kymriah (Tisagenlecleucel) 197](#_Toc53238636)

[14.39 Oxford Biomedica plc 198](#_Toc53238637)

[14.40 PeproMene Bio, Inc. 199](#_Toc53238638)

[14.40.1 BAFF-R CAR-T Cells 199](#_Toc53238639)

[14.41 Poseida Therapeutics, Inc. 200](#_Toc53238640)

[14.41.1 PiggyBac DNA Modification System 200](#_Toc53238641)

[14.41.2 Autologous & Allogeneic Programs 200](#_Toc53238642)

[14.41.2.1 P-BCMA-101 201](#_Toc53238643)

[14.41.2.2 P-PSMA-101 201](#_Toc53238644)

[14.41.2.3 P-BCMA-ALLO1 201](#_Toc53238645)

[14.41.2.4 P-MUC1C-ALLO1 202](#_Toc53238646)

[14.41.2.5 P-PSMA-ALLO1 202](#_Toc53238647)

[14.42 Precigen, Inc. 203](#_Toc53238648)

[14.43 Precision Biosciences 204](#_Toc53238649)

[14.44 Prescient Therapeutics 205](#_Toc53238650)

[14.44.1 OmniCAR Technology 205](#_Toc53238651)

[14.45 ProMab Biotechnologies, Inc. 206](#_Toc53238652)

[14.45.1 Custom CAR-T Cell Development 206](#_Toc53238653)

[14.46 Protheragen 207](#_Toc53238654)

[14.46.1 PR-18-01 207](#_Toc53238655)

[14.47 Sorrento Therapeutics, Inc. 208](#_Toc53238656)

[14.48 TC Biopharm 209](#_Toc53238657)

[14.48.1 Co-Stim CAR-T 209](#_Toc53238658)

[14.49 T-CURX 210](#_Toc53238659)

[14.49.1 CARAMBA 210](#_Toc53238660)

[14.50 Tessa Therapeutics, Pvt. Ltd. 211](#_Toc53238661)

[14.50.1 CD30 CAR-T Cells 211](#_Toc53238662)

[14.50.2 Allogeneic CD30-CAR EBVSTs 211](#_Toc53238663)

[14.51 Tmunity Therapeutics, Inc. 212](#_Toc53238664)

[14.52 Wugen 213](#_Toc53238665)

[14.53 Xyphos Biosciences, Inc. 214](#_Toc53238666)

[14.53.1 Xyphos’ Strategy 214](#_Toc53238667)

[14.54 Ziopharm Oncology, Inc. 215](#_Toc53238668)

[14.54.1 Non-Viral CAR-T Therapy 215](#_Toc53238669)

**APPENDIX**

[Appendix 1: Medical Centers offering CAR-T Therapies in the U.S. 216](#_Toc53242925)

[Appendix 2: Robyn Stacy-Humphrie’s Cancer Odyssey And CAR-T Therapy 232](#_Toc53242926)

[Appendix 2.1: Proactivity Pays Dividends 232](#_Toc53242927)

[Appendix 2.2: Like Melting Ice Cubes 233](#_Toc53242928)

[Appendix 2.3: Managing Adverse Effects 233](#_Toc53242929)

[Appendix 2.4: Paying for the Treatment in a Clinical Trial 233](#_Toc53242930)

**INDEX OF FIGURES**

[FIGURE 2.1: The Basic Structure of a T Cell 17](#_Toc53238670)

[FIGURE 2.2: The Binding of T Cells onto an Infected Cell 18](#_Toc53238671)

[FIGURE 2.3: Components of a CAR-T Cell 19](#_Toc53238672)

[FIGURE 2.4: The Three Domains of a CAR 20](#_Toc53238673)

[FIGURE 2.5: First Generation CARs 20](#_Toc53238674)

[FIGURE 2.6: Second Generation CARs 21](#_Toc53238675)

[FIGURE 2.7: Third Generation CARs 21](#_Toc53238676)

[FIGURE 2.8: Fourth Generation CARs 22](#_Toc53238677)

[FIGURE 2.9: Flow Chart Showing the Process of Manufacture of CAR-T Cells 24](#_Toc53238678)

[FIGURE 2.10: Diagrammatic Illustration of Autologous CAR-T 30](#_Toc53238679)

[FIGURE 2.11: Diagrammatic Illustration of Allogeneic CAR-T 30](#_Toc53238680)

[FIGURE 4.1: Leukopheresis and T Cell Isolation 37](#_Toc53238681)

[FIGURE 4.2: T Cell Culture and Transduction 38](#_Toc53238682)

[FIGURE 4.3: The Workflow in an Automated Manufacturing Unit 39](#_Toc53238683)

[FIGURE 4.4: Operating Expenses in Autologous CAR-T Manufacturing 40](#_Toc53238684)

[FIGURE 4.5: Operating Expenses in Allogeneic CAR-T Manufacturing 41](#_Toc53238685)

[FIGURE 5.1: The CAR-T Target Distribution in Global Clinical Trials 42](#_Toc53238686)

[FIGURE 6.1: CAR-T-Related Patent Publications, 2012-2019 47](#_Toc53238687)

[FIGURE 6.2: Granted CAR-T-Related Patents, 2012-2019 48](#_Toc53238688)

[FIGURE 6.3: Geographical Origin of CAR-T Patent Applications 49](#_Toc53238689)

[FIGURE 6.4: Top Ten CAR-T Patent Jurisdictions 50](#_Toc53238690)

[FIGURE 6.5: Affiliations of CAR-T Cell Patent Applicants 51](#_Toc53238691)

[FIGURE 7.1: Number of Clinical Trials per Year, U.S. vs. China, 2003-2019 57](#_Toc53238692)

[FIGURE 7.2: CAR-T Targeted Biomarkers in other Countries 61](#_Toc53238693)

[FIGURE 7.3: Percent Share of Indications Addressed by the Ongoing CAR-T Clinical Trials 64](#_Toc53238694)

[FIGURE 7.4: CAR-T Clinical Trials Phase Summary, U.S. vs. China 65](#_Toc53238695)

[FIGURE 7.5: Geographic Distribution of CAR-T Clinical Trials 79](#_Toc53238696)

[FIGURE 7.6: Distribution of CAR-T Clinical Trials by Type of CAR Generations 80](#_Toc53238697)

[FIGURE 7.7: Distribution of CAR-T Clinical Trials by Type of ScFv Used 81](#_Toc53238698)

[FIGURE 7.8: Distribution of CAR-T Clinical Trials by Type of Vectors Used 82](#_Toc53238699)

[FIGURE 8.1: Number of CAR-T-Related Published Papers in PubMed.gov 83](#_Toc53238700)

[FIGURE 10.1: Sales Revenues for Kymriah, 2018-2020 108](#_Toc53238701)

[FIGURE 10.2: Sales Revenues for Yescarta, 2018-2020 110](#_Toc53238702)

[FIGURE 10.3: Sales Data for Kymriah and Yescarta, Q1 of 2018 to Q2 of 2020 111](#_Toc53238703)

[FIGURE 12.1: Global Incidence of Blood Cancers in 2018 123](#_Toc53238704)

[FIGURE 12.2: Rate of Incidence and Death for Hodgkin Lymphoma in the U.S. 124](#_Toc53238705)

[FIGURE 12.3: Rate of New NHL Cases in the U.S. 125](#_Toc53238706)

[FIGURE 12.4: Rate of New DLBCL Cases in the U.S. 126](#_Toc53238707)

[FIGURE 12.5: Rate of New FL Cases in the U.S. 127](#_Toc53238708)

[FIGURE 12.6: Rate of New Leukemia Cases in the U.S. 128](#_Toc53238709)

[FIGURE 12.7: Distribution of New Leukemia Cases in the U.S. by Type 129](#_Toc53238710)

[FIGURE 12.8: Rate of New AML Cases in the U.S. 130](#_Toc53238711)

[FIGURE 12.9: Rate of New ALL Cases in the U.S. 131](#_Toc53238712)

[FIGURE 12.10: Rate of New CML Cases in the U.S. 132](#_Toc53238713)

[FIGURE 12.11: Rate of New CLL Cases in the U.S. 133](#_Toc53238714)

[FIGURE 12.12: Rate of New MM Cases in the U.S. 134](#_Toc53238715)

[FIGURE 13.1: Estimated Global Market for CAR-T Therapy by Products, 2019-2027 145](#_Toc53238716)

[FIGURE 13.2: Global Market for CAR-T Therapy by Geography, 2019-2027 147](#_Toc53238717)

[FIGURE 13.3: Global Market for CAR-T Therapy by Indication, 2019-2027 148](#_Toc53238718)

[FIGURE 14.1: Illustration of a Dual CAR 184](#_Toc53238719)

**INDEX OF TABLES**

[TABLE 2.1: CAR-Targeted Antigens Present on Hematological Malignancies 23](#_Toc53238808)

[TABLE 2.2: The Three CAR-T Therapies Crossing the Finishing Line: An Overview 25](#_Toc53238809)

[TABLE 2.2: (CONTINUED) 26](#_Toc53238810)

[TABLE 2.3: Toxicities Associated with CAR-T Treatment 27](#_Toc53238811)

[TABLE 2.4: Strategies to Improve the Safety and Efficacy of CAR-T Therapy 28](#_Toc53238812)

[TABLE 2.5: New Target Antigens and New Target Cancers 29](#_Toc53238813)

[TABLE: 2.6: A Partial List of Allogeneic CAR-T Companies 31](#_Toc53238814)

[TABLE 3.1: History of Development of CAR-T Cells 33](#_Toc53238815)

[TABLE 3.2: Approved CAR-T Products and Indications 34](#_Toc53238816)

[TABLE 3.3: The Next-Wave of CAR-T Approvals 35](#_Toc53238817)

[TABLE 3.4: Increased CAR-T Activity 35](#_Toc53238818)

[TABLE 3.5: Very Small Patient Population Addressed by CAR-T Clinical Trials 36](#_Toc53238819)

[TABLE 5.1: CAR-T Cell Target Antigens for Hematological Malignancies 43](#_Toc53238820)

[TABLE 5.2: CAR-T Target Antigens on Solid Tumors 44](#_Toc53238821)

[TABLE 6.1: Top 20 Companies in CAR-T Patent Landscape 52](#_Toc53238822)

[TABLE 6.2: TOP 20 Research Centers in CAR-T Patent Landscape 53](#_Toc53238823)

[TABLE 6.3: Top 20 CAR-T Inventors 54](#_Toc53238824)

[TABLE 6.4: Top Five CAR-T Patents with Maximum Patent Families 55](#_Toc53238825)

[TABLE 6.5: Top Five CAR-T Patents with Most Inventors in Co-Authorship 55](#_Toc53238826)

[TABLE 6.6: Top Five Patents with Most Co-Applicants 56](#_Toc53238827)

[TABLE 6.7: Top Five Patents with Most Co-Applicants 56](#_Toc53238828)

[TABLE 7.1: Percent Target Distribution of World’s CAR-T Clinical Trials 58](#_Toc53238829)

[TABLE 7.2: Targeted Biomarkers in the U.S. CAR-T Clinical Trials 59](#_Toc53238830)

[TABLE 7.3: Targeted Biomarkers in Chinese CAR-T Clinical Trials 60](#_Toc53238831)

[TABLE 7.4: Indications Addressed by CAR-T Clinical Trials in the U.S. 62](#_Toc53238832)

[TABLE 7.5: Indications Addressed by CAR-T Clinical Trials in China 63](#_Toc53238833)

[TABLE 7.6: CAR-T Clinical Trial Sponsor Companies and Institutions in the U.S. 66](#_Toc53238834)

[TABLE 7.6: (CONTINUED) 67](#_Toc53238835)

[TABLE 7.7: CAR-T Clinical Trial Sponsor Companies and Institutions in China 68](#_Toc53238836)

[TABLE 7.7: (CONTINUED) 69](#_Toc53238837)

[TABLE 7.7: (CONTINUED) 70](#_Toc53238838)

[TABLE 7.8: CAR-T Clinical Trial Sponsor Companies and Institutions in Other Countries 71](#_Toc53238839)

[TABLE 7.9: Clinical Trials of Fourth Generation/Next-Generation and Gene-Edited CAR-T 74](#_Toc53238840)

[TABLE 7.9: (CONTINUED) 75](#_Toc53238841)

[TABLE 7.9: (CONTINUED) 76](#_Toc53238842)

[TABLE 7.9: (CONTINUED) 77](#_Toc53238843)

[TABLE 7.9: (CONTINUED) 78](#_Toc53238844)

[TABLE 8.1: A Partial List of NIH Funding for CAR-T Research in 2020 84](#_Toc53238845)

[TABLE 8.1: (CONTINUED) 85](#_Toc53238846)

[TABLE 9.1: Deals in CAR-T Therapy Space, 2012-2019 89](#_Toc53238847)

[TABLE 9.1: (CONTINUED) 90](#_Toc53238848)

[TABLE 9.1: (CONTINUED) 91](#_Toc53238849)

[TABLE 9.1: (CONTINUED) 92](#_Toc53238850)

[TABLE 9.1: (CONTINUED) 93](#_Toc53238851)

[TABLE 9.1: (CONTINUED) 94](#_Toc53238852)

[TABLE 9.1: (CONTINUED) 95](#_Toc53238853)

[TABLE 9.1: (CONTINUED) 96](#_Toc53238854)

[TABLE 9.1: (CONTINUED) 97](#_Toc53238855)

[TABLE 9.1: (CONTINUED) 98](#_Toc53238856)

[TABLE 9.1: (CONTINUED) 99](#_Toc53238857)

[TABLE 9.1: (CONTINUED) 100](#_Toc53238858)

[TABLE 9.1: (CONTINUED) 101](#_Toc53238859)

[TABLE 9.1: (CONTINUED) 102](#_Toc53238860)

[TABLE 9.1: (CONTINUED) 103](#_Toc53238861)

[TABLE 9.1: (CONTINUED) 104](#_Toc53238862)

[TABLE 10.1: Sales Data for Kymriah and Yescarta, 2018 Full Year to 2020 Mid-Year 111](#_Toc53238863)

[TABLE 10.2: Efficacy, Safety and Composition of Approved CAR-T Products 113](#_Toc53238864)

[TABLE 10.3: Other Promising CAR-T Product Candidates 114](#_Toc53238865)

[TABLE 11.1: 2020 CAR-T Payment Disparities per Case in the U.S. 119](#_Toc53238866)

[TABLE 11.2: Reimbursement of CAR-T Cell Therapies in France 120](#_Toc53238867)

[TABLE 11.3: Reimbursement of CAR-T Cell Therapies in Germany 121](#_Toc53238868)

[TABLE 11.4: Reimbursement of CAR-T Cell Therapies in Italy 121](#_Toc53238869)

[TABLE 11.5: Reimbursement of CAR-T Cell Therapies in Spain 122](#_Toc53238870)

[TABLE 11.6: Reimbursement of CAR-T Cell Therapies in U.K. 122](#_Toc53238871)

[TABLE 12.1: Cost of Treating Blood Cancers 141](#_Toc53238872)

[TABLE 13.1: Estimated Global Market for CAR-T Therapy by Products, 2019-2027 144](#_Toc53238873)

[TABLE 13.2: Global Market for CAR-T Therapy by Geography, 2019-2027 146](#_Toc53238874)

[TABLE 13.3: Global Market for CAR-T Therapy by Indication, 2019-2027 148](#_Toc53238875)

[TABLE 13.4: Top Five CAR-T Companies by Marketed Products and Product Candidates 149](#_Toc53238876)

[TABLE 14.1: Atela’s Pipeline of Product Candidates 153](#_Toc53238877)

[TABLE 14.2: Allogene’s Product Pipeline 154](#_Toc53238878)

[TABLE 14.3: Anixa’s Product Pipeline 154](#_Toc53238879)

[TABLE 14.4: Autolus’ Pipeline of Clinical and Next Generation Programs 156](#_Toc53238880)

[TABLE 14.5: Bellicum Pharmaceutical’s Product Candidates 158](#_Toc53238881)

[TABLE 14.6: CARsgen’s Product Pipeline 163](#_Toc53238882)

[TABLE 14.7: Cartesian’s Product Pipeline 164](#_Toc53238883)

[TABLE 14.8: Celyad’s Product Pipeline 171](#_Toc53238884)

[TABLE 14.9: Creative Biolab’s CAR Construction and Production Platform 172](#_Toc53238885)

[TABLE 14.9: (CONTINUED) 173](#_Toc53238886)

[TABLE 14.10: CRISPR Therapeutics’ Immuno-Oncology Programs 174](#_Toc53238887)

[TABLE 14.11: Cartesian’s Product Pipeline 175](#_Toc53238888)

[TABLE 14.12: Eureka’s CAR Products in Development for Juno Therapeutics 178](#_Toc53238889)

[TABLE 14.13: iPSC-Derived Product Candidates from Fate Therapeutics 180](#_Toc53238890)

[TABLE 14.14: Formula’s Product Candidates 181](#_Toc53238891)

[TABLE 14.15: Gilead’s Cell Therapy Programs in Oncology 183](#_Toc53238892)

[TABLE 14.16: iCell’s Product Candidates 186](#_Toc53238893)

[TABLE 14.17: Juno’s CAR-T Product Candidates 188](#_Toc53238894)

[TABLE 14.18: Kite’s Pipeline of Product Candidates 191](#_Toc53238895)

[TABLE 14.19: Mustang Bio’s Product Candidates 194](#_Toc53238896)

[TABLE 14.20: Nanjing’s Autologous Product Pipeline for Hematologic Malignancies 195](#_Toc53238897)

[TABLE 14.21: Nanjing’s Allogeneic Product Pipeline for Hematologic and Solid Cancers 196](#_Toc53238898)

[TABLE 14.22: Noil’s Product Candidates for Solid Cancers 196](#_Toc53238899)

[TABLE 14.23: Oxford Biomedica’s IP Enabled and Royalty Bearing Product Candidates 198](#_Toc53238900)

[TABLE 14.24: Poseida’s Product Pipeline 201](#_Toc53238901)

[TABLE 14.25: Precigen’s CAR-T Programs 203](#_Toc53238902)

[TABLE 14.26: Precision Bioscience’s Off-the-Shelf Immunotherapy Pipeline 204](#_Toc53238903)

[TABLE 14.27: Sorrento’s Immunotherapy Pipeline 208](#_Toc53238904)

[TABLE 14.28: TC Biopharm’s Product Candidates 209](#_Toc53238905)

[TABLE 14.29: Tmunity’s CAR-T Programs for Liquid and Solid Tumors 212](#_Toc53238906)

[TABLE 14.30: Wugen’s Pipeline of Product Candidates 213](#_Toc53238907)

[TABLE 14.31: Xyphos’ Product Pipeline 214](#_Toc53238908)

[TABLE 14.32: Ziopharm’s CAR-T Product Candidates 215](#_Toc53238909)

About BioInformant

**As the first and only market research firm to specialize in the stem cell industry, BioInformant research is cited by the Wall Street Journal, Nature Biotechnology, Xconomy, and Vogue Magazine.**

**Serving market leaders that include Pfizer, Goldman Sachs, Beckton Dickinson, and GE, BioInformant is your global leader in stem cell industry data.**

**Learn more at** [www.BioInformant.com](http://www.BioInformant.com).

**BioInformant Worldwide, LLC**

**www.BioInformant.com**