



Editorial: $\gamma\delta$ T Cells in Cancer

Seth B. Coffelt^{1,2*}, Dieter Kabelitz^{3*}, Bruno Silva-Santos^{4*}, Jurgen Kuball^{5*}, Willi Born^{6*} and Ilan Bank^{7*}

¹ Institute of Cancer Sciences, University of Glasgow, Glasgow, United Kingdom, ² Cancer Research UK Beatson Institute, Glasgow, United Kingdom, ³ Institute of Immunology, University of Kiel, Kiel, Germany, ⁴ Faculdade de Medicina, Instituto de Medicina Molecular, Universidade de Lisboa, Lisbon, Portugal, ⁵ Department of Hematology and Center for Translational Immunology, Utrecht Medical Center (UMC), Utrecht, Netherlands, ⁶ Department of Immunology and Genomic Medicine, National Jewish Health, Denver, CO, United States, ⁷ Rheumatology Unit, Division of Medicine, Sheba Medical Center, Tel Hashomer, Israel

Keywords: $\gamma\delta$ T cells, cancer, butyrophilin, immunotherapy, bisphosphonates

Editorial on the Research Topic

$\gamma\delta$ T Cells in Cancer

Since the discovery of $\gamma\delta$ T cells, this rare and unique component of the immune system has been recognized for its potential in cancer immunology and immunotherapy. In the mid-1980s, it became clear that a major component of adaptive immune responses is the ability of T cell receptors (TCR) to undergo somatic recombination in order to recognize multiple antigens. TCRs consisting of either $\alpha\beta$ and $\gamma\delta$ chains were discovered in rapid succession (1–6). An important observation was made in these initial studies: $\gamma\delta$ T cells stimulated through their TCR are able to kill cancer cells (2). Over these past decades, researchers have learned that $\gamma\delta$ T cells share many similarities with $\alpha\beta$ T cells, as well as major differences. However, discoveries in $\gamma\delta$ T cell biology have failed to keep the same pace as $\alpha\beta$ T cell biology. The molecular targets of $\gamma\delta$ TCRs and functions of these cells have largely eluded researchers, partly because $\gamma\delta$ T cell recognition of cancer cells and their response kinetics are very different to $\alpha\beta$ T cells (7, 8). Recent years have seen major advances in $\gamma\delta$ T cell biology and established the non-redundancy of this lymphocyte subset, particularly in the context of cancer (9–11). $\gamma\delta$ T cells are being used as cellular vehicles to target tumors and prognostic indicators of cancer progression. The aim of the articles collected in this Research Topic is to describe new developments and approaches to enhance the anti-tumor functions of $\gamma\delta$ T cells, and to discuss how expression of their ligands can assist with prognosis of cancer patients.

Given the robust ability of $\gamma\delta$ T cells to kill cancer cells, various strategies to enhance their cytotoxic behavior are being pursued in the laboratory. The V γ 9V δ 2 cell subset in humans recognizes transformed cells with dysfunctional metabolism, primarily through the up-regulation of phosphoantigens stemming from abnormalities in the mevalonate pathway. One of the best studied phosphoantigens is isopentenyl pyrophosphate (IPP), which activates a receptor complex in cancer cells consisting of butyrophilin (BTN)-3A1 and BTN2A1 (12, 13). However, very little information exists on how this receptor complex is presented on the cell surface and its other interacting partners. Laplagne et al. report on the importance of the GTPase, RhoB, in regulating BTN3A1 presentation on the cell membrane. They observed that the differential susceptibility of lung tumor cell lines to V γ 9V δ 2 T-cell killing correlated with differential subcellular and plasma membrane distribution of RhoB. There are a few methods to increase V γ 9V δ 2 cell recognition of cancer cells, primarily *via* boosting the IPP-activated BTN3A1/BTN2A1 complex. Bisphosphonate drugs increase accumulation of IPP making cancer cells more susceptible to V γ 9V δ 2 cell killing, but these drugs also induce proliferation of V γ 9V δ 2 cells in culture. Okuno et al. report on a newly synthesized bisphosphonate drug, pivaloyloxymethyl 2-(thiazole-2-ylamino)ethylidene-1,1-

OPEN ACCESS

Edited by:

Alexandre M. Carmo,
University of Porto, Portugal

Reviewed by:

David L. Wiest,
Fox Chase Cancer Center,
United States

*Correspondence:

Seth B. Coffelt
seth.coffelt@glasgow.ac.uk
Dieter Kabelitz
dietrich.kabelitz@uksh.de
Bruno Silva-Santos
bssantos@medicina.ulisboa.pt
Jurgen Kuball
J.H.E.Kuball@umcutrecht.nl
Willi Born
bornw@njhealth.org
Ilan Bank
ibank@tauex.tau.ac.il

Specialty section:

This article was submitted to
T Cell Biology,
a section of the journal
Frontiers in Immunology

Received: 03 September 2020

Accepted: 28 October 2020

Published: 20 November 2020

Citation:

Coffelt SB, Kabelitz D, Silva-Santos B,
Kuball J, Born W and Bank I (2020)
Editorial: $\gamma\delta$ T Cells in Cancer.
Front. Immunol. 11:602411.
doi: 10.3389/fimmu.2020.602411

bisphosphonate (PTA), that both expands V γ 9V δ 2 cells and increases their ability to recognize cancer cells.

$\gamma\delta$ T cells are also being equipped with chimeric antigen receptors (CAR) for hematological and epithelial-derived malignancies. Most likely, $\gamma\delta$ CAR T cells will associate with a lower risk of cytokine release syndrome as reported for NK CAR cells. Whether $\gamma\delta$ CAR T cells will overcome the scarce infiltration of tumors by classical $\alpha\beta$ CAR T cells remains to be tested and might depend on the type of $\gamma\delta$ T cells (i.e. V δ 1 cells versus V δ 2 cells), which have naturally different homing tissues. Rozenbaum et al. describe a new expansion protocol that generates high numbers of pure (> 99%) $\gamma\delta$ T cells which could be efficiently transduced with CAR constructs. CD19-directed $\gamma\delta$ CAR T cells efficiently killed CD19+ leukemic cells *in vitro* and *in vivo*. To test these various strategies whose goal is to augment $\gamma\delta$ T cell cytotoxic function, a variety of pre-clinical models are used that evaluate killing efficacy, but these models come with their own challenges. Joalland and Scotet summarize the advantages and disadvantages of the most commonly used pre-clinical models in $\gamma\delta$ T cell immunotherapy. In addition to the use of immunodeficient mice transplanted with human tumor cells and $\gamma\delta$ T cells, they also discuss the urgent need for improved animal-free *in vitro* models such as spheroids and organoids.

Another outstanding question in the field is how $\gamma\delta$ T cell function may be suppressed by tumors. Siegers et al. show that an embryonic-associated molecule, called NODAL, expressed by breast cancer cells, impacts $\gamma\delta$ T cell function. In human breast tumors, $\gamma\delta$ T cells are found in close proximity to NODAL+ cancer cells. Through gain-of-function and loss-of-function experiments, the authors report that NODAL expression on breast cancer cell lines reduces $\gamma\delta$ T-cell cytotoxicity. Gonnermann et al. describe a novel immunosuppression pathway in pancreatic cancer, where Galectin-3 secreted by cancer cells inhibits $\gamma\delta$ T cell proliferation via α 3 β 1 integrin. Interestingly, the cytotoxic activity of $\gamma\delta$ T cells was not impaired by Galectin-3.

This Research Topic includes two clinical trials. One trial investigated the ability of β -adrenergic receptor activation to mobilize $\gamma\delta$ T cells into the peripheral blood of test subjects. Baker et al. found that drugs antagonizing the β -adrenergic receptor pathway not only prevent $\gamma\delta$ T cell accumulation in blood, but that this pathway is also important for $\gamma\delta$ T cell expansion *ex vivo*. These data suggest that β -adrenergic receptor agonists may improve expansion protocols or $\gamma\delta$ T cell cytotoxic function. The second clinical trial included 46 children with acute leukemia that received hematopoietic stem cell

transplantation of $\alpha\beta$ TCR/CD19-depleted haploidentical grafts. Merli et al. tested the ability of the bisphosphonate drug, zoledronic acid, to counteract graft-versus-host-disease in these patients, and they show that zoledronic acid is well tolerated. Moreover, the children that received more doses of zoledronic acid had a better outcome than the children receiving fewer doses.

Finally, two articles in this collection discuss the importance of $\gamma\delta$ T cell ligands in cancer immunotherapy. Bartish et al. summarize the role of immunosuppressive molecules that contain sugar residues as well as the relationship between these glyco-molecules and $\gamma\delta$ T cells, highlighting opportunities for intervention. Wang et al. wrote a meta-analysis on publications pertaining to the BTN family. In this review, the authors also provide prognostic data for several BTN family members in lung adenocarcinoma and lung squamous cell carcinoma.

Together, this Research Topic features new developments in $\gamma\delta$ T cell cancer immunotherapy, providing insight into mechanisms that both increase and suppress their effector functions. Finding the right patient population in which to manipulate these pathways and exploit this new information may be key to counteracting cancer.

AUTHOR CONTRIBUTIONS

SC, DK, BS-S, JK, WB, and IB wrote the editorial and invited authors to participate in the collection. All authors contributed to the article and approved the submitted version.

FUNDING

The authors acknowledge funding from the Cancer Research UK Glasgow Centre (A25142 to SBC), the Wellcome Trust (208990/Z/17/Z to SBC), the Medical Research Council (MR/R502327/1 to SBC), Breast Cancer Now (2018JulPR1101 and 2019DecPhD1349 to SBC), Tenovus Scotland (S17-17 to SBC), the Deutsche Forschungsgemeinschaft (Ka 502/19-2 to DK), the Wilhelm Sander Foundation (2018.045.1 to DK), “la Caixa” Banking Foundation (HR18-00069 to BS-S), the Dutch Research Council (NWO ZonMW 43400003 to JK), the Dutch Cancer Society (KWF UU 2014-6790, UU 2015-7601, UU 2018-11393, UU 2018-11979, UU 2019-12586, UU 2020-13043 to JK).

REFERENCES

- Saito H, Kranz DM, Takagaki Y, Hayday AC, Eisen HN, Tonegawa S. Complete primary structure of a heterodimeric T-cell receptor deduced from cDNA sequences. *Nature* (1984) 309(5971):757–62. doi: 10.1038/309757a0
- Bank I, DePinho RA, Brenner MB, Cassimeris J, Alt FW, Chess L. A functional T3 molecule associated with a novel heterodimer on the surface of immature human thymocytes. *Nature* (1986) 322(6075):179–81. doi: 10.1038/322179a0
- Brenner MB, McLean J, Dialynas DP, Strominger JL, Smith JA, Owen FL, et al. Identification of a putative second T-cell receptor. *Nature* (1986) 322(6075):145–9. doi: 10.1038/322145a0
- Borst J, van de Griend RJ, van Oostveen JW, Ang SL, Melief CJ, Seidman JG, et al. A T-cell receptor gamma/CD3 complex found on cloned functional lymphocytes. *Nature* (1987) 325(6106):683–8. doi: 10.1038/325683a0
- Born W, Miles C, White J, O'Brien R, Freed JH, Marrack P, et al. Peptide sequences of T-cell receptor delta and gamma chains are identical to predicted X and gamma proteins. *Nature* (1987) 330(6148):572–4. doi: 10.1038/330572a0

6. Chien YH, Iwashima M, Kaplan KB, Elliott JF, Davis MM. A new T-cell receptor gene located within the alpha locus and expressed early in T-cell differentiation. *Nature* (1987) 327(6124):677–82. doi: 10.1038/327677a0
7. Hayday AC. gammadelta T Cell Update: Adaptive Orchestrators of Immune Surveillance. *J Immunol* (2019) 203(2):311–20. doi: 10.4049/jimmunol.1800934
8. Willcox BE, Willcox CR. gammadelta TCR ligands: the quest to solve a 500-million-year-old mystery. *Nat Immunol* (2019) 20(2):121–8. doi: 10.1038/s41590-018-0304-y
9. Silva-Santos B, Mensurado S, Coffelt SB. gammadelta T cells: pleiotropic immune effectors with therapeutic potential in cancer. *Nat Rev Cancer* (2019) 19(7):392–404. doi: 10.1038/s41568-019-0153-5
10. Sebastyen Z, Prinz I, Dechanet-Merville J, Silva-Santos B, Kuball J. Translating gammadelta (gammadelta) T cells and their receptors into cancer cell therapies. *Nat Rev Drug Discov* (2020) 19(3):169–84. doi: 10.1038/s41573-019-0038-z
11. Kabelitz D, Serrano R, Kouakanou L, Peters C, Kalyan S. Cancer immunotherapy with gammadelta T cells: many paths ahead of us. *Cell Mol Immunol* (2020) 17:925–39. doi: 10.1038/s41423-020-0504-x
12. Harly C, Guillaume Y, Nedellec S, Peigne CM, Monkkonen H, Monkkonen J, et al. Key implication of CD277/butyrophilin-3 (BTN3A) in cellular stress sensing by a major human gammadelta T-cell subset. *Blood* (2012) 120(11):2269–79. doi: 10.1182/blood-2012-05-430470
13. Karunakaran MM, Willcox CR, Salim M, Paletta D, Fichtner AS, Noll A, et al. Butyrophilin-2A1 Directly Binds Germline-Encoded Regions of the Vgamma9Vdelta2 TCR and Is Essential for Phosphoantigen Sensing. *Immunity* (2020) 52(3):487–98.e6. doi: 10.1016/j.immuni.2020.02.014

Conflict of Interest: BS-S is a founder and share holder of Lymphact S.A., which has been acquired by GammaDelta Therapeutics (London, UK). JK is scientific co-founder and shareholder of Gadeta. JK received financial research support of Gadeta, Miltenyi Biotech and Novartis.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Copyright © 2020 Coffelt, Kabelitz, Silva-Santos, Kuball, Born and Bank. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.