Human Immunology 80 (2019) 191–194

Contents lists available at ScienceDirect

Human Immunology

journal homepage: www.elsevier.com/locate/humimm

$CD3^+CD20^+$ T cells and their roles in human diseases

Qin Chen[a,1], Shunling Yuan[b,1], Hongwu Sun[c,*], Liusheng Peng[c,*]

[a] Department of Dermatology, Southwest Hospital, Third Military Medical University, Chongqing 400038, China
[b] East China Military Material Purchasing Bureau, Shanghai 200433, China
[c] National Engineering Research Center of Immunological Products, Department of Microbiology and Biochemical Pharmacy, College of Pharmacy, Third Military Medical University, Chongqing 400038, China

ARTICLE INFO

Keywords:
$CD3^+CD20^+$ T cells
Autoimmune diseases
Cancer
Infectious diseases

ABSTRACT

$CD3^+CD20^+$ T cells are a population of $CD3^+$ T cells co-expressing CD20 that make up to ~3–5% of the $CD3^+$ T-cell compartment in the peripheral blood of human beings. In healthy individuals, $CD3^+CD20^+$ T cells are heterogeneous for containing a lower proportion of $CD4^+$ cells, but produce higher levels of IL-17A and/or IFN-γ than those of $CD3^+CD20^-$ T cells. Recently, emerging studies have shown a pathogenic behavior of $CD3^+CD20^+$ T cells in autoimmune diseases and $CD20^+$ T-cell malignancies, and patients with the diseases may benefit from anti-CD20 immunotherapy to deplete these cells. However, $CD3^+CD20^+$ T cells may also play a protective role in ovarian cancer and HIV infection for their strong propensity to IFN-γ production. In this review, we will describe the current knowledge about $CD3^+CD20^+$ T-cell biology, and discuss their functional roles in autoimmune diseases as well as cancer and infectious diseases.

1. Introduction

In immunology, CD20 is a putative B-cell antigen for its expression on the surface of B cells but not other cell lineages, and it presents from late pro-B cells to memory cells except early pro-B cells or plasmablasts and plasma cells, while CD3 is acknowledged as the marker of T cells for its indispensable to constitute T-cell complex with T-cell receptor and ζ-chain to generate an activation signal. Traditionally, CD20 and CD3 are expressed on different immune cells, and accurately used to distinguish between $CD20^+$ B cells and $CD3^+$ T cells. However, increasing evidence has shown that a subset of $CD3^+$ T cells co-expressing CD20 is observed in the peripheral blood of healthy individuals and patients with autoimmune diseases and cancer [1–3]. These cells totally belong to $CD3^+$ T cells, for they express CD3 molecule at a similar level to conventional T cells, whereas the expression of classical B-cell markers such as CD19 and immunoglobulin molecules are lacked. So this subpopulation is justified to name CD20 expressing $CD3^+$ T cells ($CD3^+CD20^+$ T cells). In recent years, $CD3^+CD20^+$ T cells have been found to display similar but unique biological characteristics compared to conventional $CD3^+$ T cells, and studies to be discussed below show that $CD3^+CD20^+$ T cells may play an important role in human diseases. Here, the review will focus on the current understanding of the characteristics and functional roles of $CD3^+CD20^+$ T cells in autoimmune diseases, cancer and infectious diseases (Table 1).

2. Distribution and source of $CD3^+CD20^+$ T cells

The first report of $CD3^+CD20^+$ T cells dated back to 1990, where a small fraction of $CD3^+$ T cells co-expressing CD20 were described in the peripheral blood of patients with HIV infection [4]. Subsequently, with the use of CD20 monoclonal antibodies, circulating $CD3^+CD20^+$ T cells were also found in healthy individuals and patients with T-acute lymphoblastic leukemia [5,6]. Later, studies confirmed that this subpopulation pervaded thymus, bone marrow, secondary lymphatic organs, cerebrospinal fluid, brain and liver tissues [1,7,8]. In non-human primates, CD20 expression was also detectable on monkey lymph node $CD3^+$ T cells [9]. However, no murine $CD3^+CD20^+$ T cells were identified, although a CD20 homolog, MS4aB1, was reported to be expressed on murine $CD3^+$ T cells [10,11].

The origin of $CD3^+CD20^+$ T cells in human beings is controversial. One study showed that $CD3^+$ T cells in the cord blood was largely lack of expressing CD20, and the existence of $CD3^+CD20^+$ T cells in the adult blood might arise by trogocytosis. Because when peripheral blood mononuclear cells were co-cultured with B-cell lines, or primary T cells were co-cultured with primary HLA-mismatched B cells *in vitro*, both CD20 and HLA-DR could be concomitantly transferred to T cells [12]. Since HLA-DR transfer to T cells is referred to as trogocytosis [13], CD20 trogocytosis may be a source of $CD3^+CD20^+$ T cells. However, the expression of HLA-DR on circulating $CD3^+CD20^+$ T cells was very

* Corresponding authors.
E-mail addresses: sunhongwu2001@163.com (H. Sun), pengliusheng06@163.com (L. Peng).
[1] Q. Chen and S. Yuan contributed equally to this work.

https://doi.org/10.1016/j.humimm.2019.01.001
Received 29 November 2018; Received in revised form 30 December 2018; Accepted 10 January 2019
Available online 11 January 2019

Table 1
$CD3^+CD20^+$ T cells and human diseases.

Human disease type	Presence of $CD3^+CD20^+$ T cells	Function of $CD3^+CD20^+$ T cells	References
Rheumatoid arthritis	Blood	low proliferative capacity, high activation state, enhanced susceptibility to apoptosis, constitutive cytokine production (i.e., IL-1β and TNF-α), Increased IL-17 production	7, 24
Multiple sclerosis	Blood, Brain tissues	Increased frequency and production of IL-17 and IFN-γ in blood	1, 8, 31
Primary sjögren's syndrome	Blood, Glandular	Production of IL-17	32
Psariosis	Blood	Increased production of IL-17, TNF-α and IL-21	33
$CD20^+$ T-cell leukemia/ lymphoma	Blood, Nodal biopsy	Unknown	34–37
Ovarian cancer	Blood, Ascitic fluid, Tumor tissues	Increased frequency and production of IFN-γ in ascitic fluid	12
HIV infection	Blood, Bone marrow	Unknown	4, 38, 39

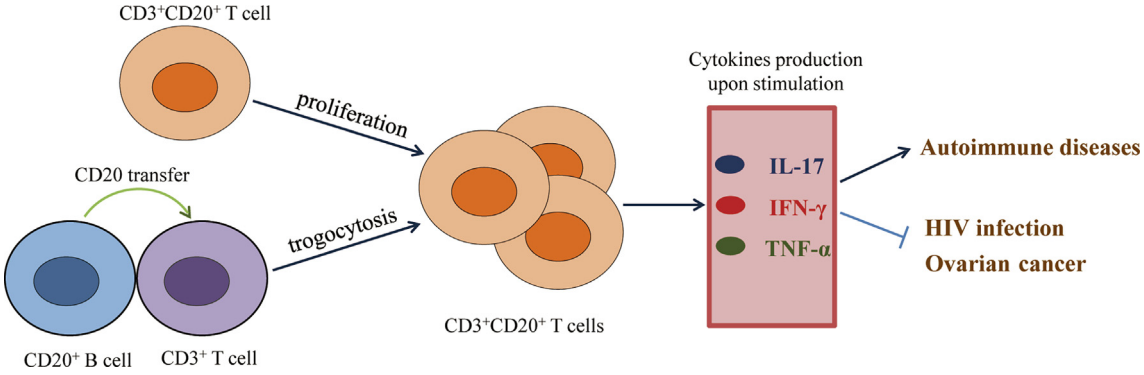

Fig. 1. The source and function of $CD3^+CD20^+$ T cells. $CD3^+CD20^+$ T cells experience clonal proliferation in the process of T-cell activation. $CD3^+CD20^+$ T cells are from the trogocytosis that CD20 of B cells is transferred to T cells during B/T-cell interaction. After stimulation, $CD3^+CD20^+$ T cells produce high levels of cytokines (IL-17, IFN-γ and TNF-α) to contribute to the pathogenesis of autoimmune diseases but play the protective role in HIV infection and ovarian cancer.

low [1], implying that additional crucial ways were involved in the development of these cells. Actually, $CD3^+CD20^+$ T cells could inherit to daughter cells in the process of T-cell activation, for the proportion of $CD20^+$ T cells was significantly increased while purified T cells were cultured with mitogen and IL-2 [9]. The possibility of an inducible expression of CD20 on $CD3^+$ T cells was excluded, with CD20-negative being retained of cultured $CD20^-$ T cells *in vitro* [12]. In addition, neoplastic $CD20^+$ T-cell malignancies also represented neoplastic transformation of a normal subset of $CD20^+$ T cells rather than aberrant antigen expression [14], and then neoplastic cells could further experience clonal proliferation [15]. These data suggest that increased expression of CD20 on $CD3^+$ T cells may also originate from the clonal expansion of $CD3^+CD20^+$ T-cell themselves (Fig. 1).

3. Biological characteristics of $CD3^+CD20^+$ T cells

Although $CD3^+CD20^+$ T cells transcribed both CD3 and CD20, other typical B- cell molecules such as CD19, CD40, IgD and IgM were absent on these cells, whereas they expressed high levels of αβ T cell receptor, IL-7 receptor, CD28, CD27, CD49d and CD45RO, but low levels of γδ T cell receptor, CCR7, CD38 and CD69 [1,5,16]. Following treatment with anti-CD3 monoclonal antibody, a rapid rise in the intracellular calcium concentration (Ca^{2+}) of $CD3^+CD20^+$ T cells was observed [5]. After stimulation, this subpopulation also produced more of IL-17, IFN-γ and TNF-α than those of $CD3^+CD20^-$ T cells [1]. These data demonstrate that $CD3^+CD20^+$ T cells have a predominantly memory phenotypic feature and strong potential to cytokines production (Fig. 1). Additionally, $CD3^+CD20^+$ T cells contained more of $CD8^+$ cells than that of $CD3^+CD20^-$ T cells, and $CD8^+$ T cells could secrete a large number of cytotoxic granules such as perforin and granzyme [17]. Thus, it is speculated that $CD3^+CD20^+$ T cells may also secrete more of cytotoxic granules than those of $CD3^+CD20^-$ T cells.

4. $CD3^+CD20^+$ T cells in human diseases

4.1. *$CD3^+CD20^+$ T cells in rheumatoid arthritis*

Rheumatoid arthritis (RA) is one of chronic inflammatory autoimmune diseases, and a variety of immune cells and inflammatory factors have been involved in the pathogenesis of RA [18,19]. Rituximab (RTX), a monoclonal antibody against CD20 to deplete B cells, is clinically effective in the treatment of autoimmune diseases including RA [20,21]. However, the curative effect of RTX in RA could be not simply explained by the depletion of autoantibody-producing B cells, and an involvement of additional mechanisms such as B-cell functions as T-cell modulator and antigen-presenting cell may be also concerned [22,23]. Beyond these, Wilk and colleagues found a subset of $CD3^+CD20^+$ T cells in the peripheral blood of RA patients, and these cells as well as $CD20^+$ B cells could be simultaneously eliminated during RTX therapy. Functional analyses revealed that this subpopulation was in a state of high activation, low proliferative capacity, constitutive cytokines production (i.e. IL-1β and TNF-α) and enhanced susceptibility to apoptosis [7], suggesting that $CD3^+CD20^+$ T cells are likely to be involved in the pathological process of RA, and depletion of these cells may be an additional mechanism whereby RTX asserts its clinical benefit in RA. Recently, Eggleton and colleagues reported that the proportion of IL-17-producing $CD20^+$ T cells in the peripheral blood of RA patients was significantly higher than that in healthy individuals [24], which further confirmed the pathological role of $CD3^+CD20^+$ T cells in RA due to the harmful behavior of IL-17 in this disease. Thus, RA patients will benefit from RTX therapy to reduce the production of IL-17 by depleting $CD3^+CD20^+$ T cells.

4.2. *$CD3^+CD20^+$ T cells in multiple sclerosis*

Multiple sclerosis (MS) is primarily an inflammatory disorder of the

brain and spinal cord in which focal lymphocytic infiltration leads to damage of myelin and axons, both T and B cells are closely associated with the pathogenesis of MS [25]. In relapsing-remitting MS, IFN-γ- and IL-17-producing T cells are the main culprits within the T-cell compartment, and B cells within the central nervous system also secrete antibodies to cause the MS pathology [26,27]. Hence, RTX is rationally carried out to deplete $CD20^+$ B cells and dampen aberrant antibody production for reducing disease activity in MS [28]. However, during RTX therapy, T cells were unexpectedly decreased in cerebrospinal fluid of MS patients [29]. One explanation was that B cells could act as antigen-presenting cells and produce cytokines, B-cell depletion might attenuate T-cell activation and sequentially reduced T-cell trafficking into cerebrospinal fluid [30]. Until recently, $CD3^+CD20^+$ T cells were detected in the peripheral blood and cerebrospinal fluid of MS patients, and this subpopulation could be effectively depleted in RTX-treated MS patients [1,31], suggesting that $CD3^+CD20^+$ T-cell depletion may contribute to the decreased T-cell level of RTX therapy in MS. In addition, studies showed that $CD3^+CD20^+$ T cells in the peripheral blood of MS patients produced high levels of IFN-γ and IL-17 [1,8]. Given that INF-γ and IL-17 are the two proinflammatory cytokines involved in the pathogenesis of MS, we speculate that depletion of $CD3^+CD20^+$ T cells may also attenuate T-cell mediated inflammation and yield clinical benefit of MS patients.

4.3. $CD3^+CD20^+$ T cells in primary sjögren's syndrome and psoriasis

One group investigated the phenotypical and functional effects of RTX therapy on circulating and glandular IL-17-producing T cells in primary Sjögren's syndrome (pSS) [32], they found that RTX therapy depleted glandular $CD3^+CD4^-CD8^-IL\text{-}17^+$ and $CD4^+IL\text{-}17^+$ T cells as well as circulating $CD3^+CD4^-CD8^-IL\text{-}17^+$ T cells. Among them, a fraction of $IL\text{-}17^+$ T cells co-expressed CD20 on their surfaces, supporting the therapeutic effect of RTX in pSS that, besides its B-cell specificity, at least in part, is owning to directly hamper IL-17-producing $CD20^+$ T cells in the disease.

Recently, Niu and coworkers analyzed the level, phenotype, functional and clinical relevance of circulating $CD3^+CD20^+$ T cells in patients with psoriasis [33]. Although their levels were similar to those in healthy individuals, these cells in patients with psoriasis displayed an activated effector phenotype, and produced more of cytokines including IL-17 and TNF-α than those in healthy individuals. Interestingly, the proportion of IL-17 and TNF-α producing $CD3^+CD20^+$ T cells showed a significantly positive correlation with disease severity, suggesting that $CD3^+CD20^+$ T cells play a pathogenic role in psoriasis, and further study to elucidate their precise roles in psoriatic skin is warranted.

4.4. $CD3^+CD20^+$ T cells in cancer

Studies had confirmed that CD20 was aberrant expressed on $CD3^+$ T cells in some cases of patients with T-cell lymphocytic leukemia and lymphoma, which were easily misdiagnosed as B-cell leukemia/lymphoma [34–36]. During RTX therapy, patients with $CD20^+$ T-cell lymphoma had variable outcomes, for the response was good in cases with high expression of CD20, while it was poor in cases with variable staining of CD20 [37]. Thus, the efficacy of RTX may be associated with the intensity of CD20 expression on T-cell lymphoma. However, there is still not enough evidence to support the benefit of RTX therapy for this disease. On the contrary, $CD3^+CD20^+$ T cells were found to expand in ascitic fluid of patients with ovarian cancer and display a predominantly Tc1 effector memory phenotype [12], suggesting that $CD3^+CD20^+$ T cells may have a potential anti-tumor activity in ovarian cancer. Nevertheless, $CD3^+CD20^+$ T-cell level in ascitic fluid did not show any correlation with disease stage, therapy response or expected prognosis, and the secretion of cytotoxic granules in these cells were also not analyzed. Therefore, further studies should aim to elucidate whether $CD3^+CD20^+$ T cells are involved in anti-tumor immunity against ovarian cancer.

4.5. $CD3^+CD20^+$ T cells in HIV infection

$CD3^+CD20^+$ T cells have been identified for a long time in the peripheral blood and bone marrow of patients with HIV infection [4,38], but the relationship between these cells and HIV infection is unknown. Murayama and colleagues found that when monkeys were inoculated with simian immunodeficiency virus (SIV), a model mimicking HIV infection, $CD3^+CD20^+$ T cells of lymph node at the stage of lymphadenopathy were significantly increased and activated [9]. In addition, there was also a transiently increase of these cells during the acute phase of SIV infection [39]. However, the proportion of $CD3^+CD20^+$ T cells was significantly decreased in the peripheral blood of untreated HIV patients, which could be recovered with highly active antiretroviral therapy (HAART) [40]. Since $CD3^+CD20^+$ T cells have a strong potential to produce IFN-γ, it is conceived that these cells may be activated to experience clonal expansion and secrete IFN-γ to target SIV/HIV at early stage of infection. Afterwards, they will undergo activation induced cell death with time, which causes the decreased level of $CD20^+$ T cells at late stage of SIV/HIV infection, and ultimately contributes to attenuate SIV/HIV elimination.

5. Conclusion

Since the discovery of $CD3^+CD20^+$ T cells, their biological functions in human beings have been intermittently explored. Studies in RA and MS strongly foster the pathogenic behavior of $CD3^+CD20^+$ T cells in autoimmune diseases, whereas the protective role of these cells is supported in ovarian cancer and HIV infection. However, many outstanding questions regarding these cells and human diseases still exist. For example, Studies in these diseases are obviously hampered by the limitation to small sample size, and especially tissue samples are extremely scanty. Additionally, no available murine model has been already described to examine the biology of $CD3^+CD20^+$ T cells in these diseases. Moreover, the functional activity of $CD3^+CD20^+$ T cells in ovarian cancer and HIV infection remains obscured; especially their prevalent in other cancers as well as infectious diseases need to be largely investigated. Above all, there is no doubt that further studies on $CD3^+CD20^+$ T cells by using large samples and animal models will yield relevant data to deciphering their precise roles in human diseases.

Acknowledgements

This work was supported by grants from the National Natural Science Foundation of China (No. 81872331 and 81502457)

Disclosures

Conflict of interest disclosure: The authors declare that they have no conflict of interest.

References

[1] E. Schuh, K. Berer, M. Mulazzani, K. Feil, I. Meinl, H. Lahm, M. Krane, R. Lange, K. Pfannes, M. Subklewe, R. Gürkov, M. Bradl, R. Hohlfeld, T. Kümpfel, E. Meinl, M. Krumbholz, Features of Human CD3+CD20+ T Cells, J. Immunol. 197 (2016) 1111–1117.
[2] R. Schneider, CD20+ T cells in multiple sclerosis, Mult. Scler. Relat. Disord. 4 (2015) 58–59.
[3] N. Yokose, K. Ogata, Y. Sugisaki, S. Mori, T. Yamada, E. An, K. Dan, CD20-positive T cell leukemia/lymphoma: case report and review of the literature, Ann. Hematol. 80 (2001) 372–375.
[4] A. Landay, B. Ohlsson-Wilhelm, J.V. Giorgi, Application of flow cytometry to the study of HIV infection, AIDS 4 (1990) 479–497.
[5] L.E. Hultin, M.A. Hausner, P.M. Hultin, J.V. Giorgi, CD20 (pan-B cell) antigen is expressed at a low level on a subpopulation of human T lymphocytes, Cytometry 14 (1993) 196–204.
[6] M.J. Warzynski, D.M. Graham, R.A. Axtell, M.H. Zakem, R.K. Rotman, Low level

CD20 expression on T cell malignancie, Cytometry 18 (1994) 88–92.
[7] E. Wilk, T. Witte, N. Marquardt, T. Horvath, K. Kalippke, K. Scholz, N. Wilke, R.E. Schmidt, R. Jacobs, Depletion of functionally active CD20+ T cells by rituximab treatment, Arthritis Rheum. 60 (2009) 3563–3571.
[8] J.E. Holley, E. Bremer, A.C. Kendall, M. de Bruyn, W. Helfrich, J.M. Tarr, J. Newcombe, N.J. Gutowski, P. Eggleton, CD20+inflammatory T-cells are present in blood and brain of multiple sclerosis patients and can be selectively targeted for apoptotic elimination, Mult. Scler. Relat. Disord. 3 (2014) 650–658.
[9] Y. Murayama, R. Mukai, T. Sata, S. Matsunaga, A. Noguchi, Y. Yoshikawa, Transient expression of CD20 antigen (pan B cell marker) in activated lymph node T cells, Microbiol. Immunol. 40 (1996) 467–471.
[10] H. Xu, M.S. Williams, L.M. Spain, Patterns of expression, membrane localization, and effects of ectopic expression suggest a function for MS4a4B, a CD20 homolog in Th1 T cells, Blood 107 (2006) 2400–2408.
[11] Y. Yan, Z. Li, G.X. Zhang, M.S. Williams, G.B. Carey, J. Zhang, A. Rostami, H. Xu, Anti-MS4a4B treatment abrogates MS4a4B-mediated protection in T cells and ameliorates experimental autoimmune encephalomyelitis, Apoptosis 18 (2013) 1106–1119.
[12] M. de Bruyn, V.R. Wiersma, M.C. Wouters, D.F. Samplonius, H.G. Klip, W. Helfrich, H.W. Nijman, P. Eggleton, E. Bremer, CD20+ T cells have a predominantly Tc1 effector memory phenotype and are expanded in the ascites of patients with ovarian cancer, Oncoimmunology 4 (2015) e999536.
[13] N. Martínez-Martín, E. Fernández-Arenas, S. Cemerski, P. Delgado, M. Turner, J. Heuser, D.J. Irvine, B. Huang, X.R. Bustelo, A. Shaw, B. Alarcón, T cell receptor internalization from the immunological synapse is mediated by TC21 and RhoG GTPase-dependent phagocytosis, Immunity 35 (2011) 208–222.
[14] L. Quintanilla-Martinez, F. Preffer, D. Rubin, J.A. Ferry, N.L. Harris, CD20+ T-cell lymphoma. Neoplastic transformation of a normal T-cell subset, Am. J. Clin. Pathol. 102 (1994) 483–489.
[15] A. Takami, M. Saito, S. Nakao, H. Asakura, T. Nozue, Y. Onoe, A. Yachie, S. Shiobara, T. Matsuda, CD20-positive T-cell chronic lymphocytic leukaemia, Br. J. Haematol. 102 (1998) 1327–1329.
[16] I. Storie, G.A. Wilson, V. Granger, D. Barnett, J.T. Reilly, Circulating CD20dim T-lymphocytes increase with age: evidence for a memory cytotoxic phenotype, Clin. Lab. Haematol. 17 (1995) 323–328.
[17] I. Voskoboinik, J.C. Whisstock, J.A. Trapani, Perforin and granzymes: function, dysfunction and human pathology, Nat. Rev. Immunol. 15 (2015) 388–400.
[18] S. Venuturupalli, Immune Mechanisms and Novel Targets in Rheumatoid Arthritis, Immunol. Allergy Clin. North Am. 37 (2017) 301–313.
[19] E.Y. Kim, K.D. Moudgil, Immunomodulation of autoimmune arthritis by pro-inflammatory cytokines, Cytokine 98 (2017) 87–96.
[20] C.C. Mok, Rituximab for the treatment of rheumatoid arthritis: an update, Drug Des. Devel. Ther. 8 (2013) 87–100.
[21] M.D. Cohen, E. Keystone, Rituximab for Rheumatoid Arthritis, Rheumatol. Ther. 2 (2015) 99–111.
[22] A. Kessel, I. Rosner, E. Toubi, Rituximab: beyond simple B cell depletion, Clin. Rev. Allergy Immunol. 34 (2008) 74–79.
[23] G.J. Silverman, D.L. Boyle, Understanding the mechanistic basis in rheumatoid arthritis for clinical response to anti-CD20 therapy: the B-cell roadblock hypothesis, Immunol. Rev. 223 (2008) 175–185.
[24] P. Eggleton, E. Bremer, J.M. Tarr, M. de Bruyn, W. Helfrich, A. Kendall, R.C. Haigh, N.J. Viner, P.G. Winyard, Frequency of Th17 CD20+ cells in the peripheral blood of rheumatoid arthritis patients is higher compared to healthy subjects, Arthritis Res. Ther. 13 (2011) R208.
[25] A. Compston, A. Coles, Multiple sclerosis, Lancet. 372 (2008) 1502–1517.
[26] J. Romme Christensen, L. Börnsen, D. Hesse, M. Krakauer, P.S. Sørensen, H.B. Søndergaard, F. Sellebjerg, Cellular sources of dysregulated cytokines in relapsing-remitting multiple sclerosis, J. Neuroinflammation 9 (2012) 215.
[27] G. Giovannoni, Cerebrospinal fluid analysis, Handb. Clin. Neurol. 122 (2014) 681–702.
[28] S.L. Hauser, E. Waubant, D.L. Arnold, T. Vollmer, J. Antel, R.J. Fox, A. Bar-Or, M. Panzara, N. Sarkar, S. Agarwal, A. Langer-Gould, C.H. Smith, HERMES Trial Group, B-cell depletion with rituximab in relapsing-remitting multiple sclerosis, N. Engl. J. Med. 358 (2008) 676–688.
[29] A.H. Cross, J.L. Stark, J. Lauber, M.J. Ramsbottom, J.A. Lyons, Rituximab reduces B cells and T cells in cerebrospinal fluid of multiple sclerosis patients, J. Neuroimmunol. 180 (2006) 63–70.
[30] M.C. Agahozo, L. Peferoen, D. Baker, S. Amor, CD20 therapies in multiple sclerosis and experimental autoimmune encephalomyelitis - Targeting T or B cells, Mult. Scler. Relat. Disord. 9 (2016) 110–117.
[31] A. Palanichamy, S. Jahn, D. Nickles, M. Derstine, A. Abounasr, S.L. Hauser, S.E. Baranzini, D. Leppert, H.C. von Büdingen, Rituximab Efficiently Depletes Increased CD20-Expressing T Cells in Multiple Sclerosis Patients, J. Immunol. 193 (2014) 580–586.
[32] A. Alunno, F. Carubbi, O. Bistoni, S. Caterbi, E. Bartoloni, P. Di Benedetto, P. Cipriani, R. Giacomelli, R. Gerli, Interleukin (IL)-17-producing pathogenic T lymphocytes co-express CD20 and are depleted by rituximab in primary Sjögren's syndrome: a pilot study, Clin. Exp. Immunol. 184 (2016) 284–292.
[33] J. Niu, Z. Zhai, F. Hao, Y. Zhang, Z. Song, H. Zhong, Dissection of a circulating CD3+ CD20+ T cell subpopulation in patients with psoriasis, Clin. Exp. Immunol. 192 (2018) 206–212.
[34] C.L. Buckner, L.R. Christiansen, D. Bourgeois, J.J. Lazarchick, J. Lazarchick, CD20 positive T-cell lymphoma/leukemia: a rare entity with potential diagnostic pitfalls, Ann. Clin. Lab. Sci. 37 (2007) 263–267.
[35] A. Rahemtullah, J.A. Longtine, N.L. Harris, M. Dorn, A. Zembowicz, L. Quintanilla-Fend, F.I. Preffer, J.A. Ferry, CD20+ T-cell lymphoma: clinicopathologic analysis of 9 cases and a review of the literature, Am. J. Surg. Pathol. 32 (2008) 1593–1607.
[36] B. Martin, C. Stefanato, S. Whittaker, A. Robson, Primary cutaneous CD20-positive T-cell lymphoma, J. Cutan. Pathol. 38 (2011) 663–669.
[37] Y. Kakinoki, J. Hashiguchi, T. Ishio, K. Chiba, D. Niino, K. Ohshima, CD20-positive primary gastric T-cell lymphoma poorly responding to initial treatment with rituximab plus CHOP, and a literature review, Int. J. Hematol. 102 (2015) 702–708.
[38] K.M. Algino, R.W. Thomason, D.E. King, M.M. Montiel, F.E. Craig, CD20 (pan-B cell antigen) expression on bone marrow-derived T cells, Am. J. Clin. Pathol. 106 (1996) 78–81.
[39] V.L. Hodara, L.M. Parodi, M.S. Keckler, L.D. Giavedoni, Increases in NKG2C Expression on T Cells and Higher Levels of Circulating CD8+ B Cells Are Associated with Sterilizing Immunity Provided by a Live Attenuated SIV Vaccine, AIDS. Res. Hum. Retroviruses 32 (2016) 1125–1134.
[40] F. Förster, A. Singla, S.K. Arora, R.E. Schmidt, R. Jacobs, CD20+ T cell numbers are decreased in untreated HIV-1 patients and recover after HAART, Immunol. Lett. 146 (2012) 74–78.