SHORT REPORT

Association between T follicular helper cells and T peripheral helper cells with B-cell biomarkers and disease activity in primary Sjögren syndrome

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INTRODUCTION

Primary Sjögren syndrome (pSS) is a systemic autoimmune disease, characterised by an infiltration of the exocrine glands, leading to sicca syndrome. Extraluminal systemic involvements (such as pulmonary, renal or neurological involvement) occur in about 30% of the patients. One of the most severe complications is the development of B cell lymphoma.3 pSS is characterised by chronic B cell activation, as evidenced by the presence of anti-SSA (Sjögren syndrome A antigen), anti-SSB (Sjögren syndrome B antigen) antibodies, rheumatoid factor (RF) and hypergammaglobulinaemia.4 Using mass cytometry (CyTOF), we have shown an expansion of plasma cells in minor salivary gland and an expansion of circulating plasmablasts in pSS patients, compared with controls.3 Ectopic germinal centres (EGC) in minor salivary glands are present in about one-quarter of the patients and could enhance local production of autoantibodies. T cells also participate to the pathophysiology of pSS, as suggested by the presence of a T lymphocyte infiltrate within the patients’ minor salivary gland biopsies,4 as well as the association of pSS with several HLA class II alleles.5 In addition, there is an association between pSS and a single-nucleotide polymorphism located within CXCR5 locus that codes for a key chemokine expressed by T follicular helper (Tfh) cells.6

Tfh are a subset of T lymphocytes specialised in providing help to B cells, and are essential for EGC formation, recruitment (via CXCL13) and activation (via ICOS) of B cells, affinity maturation and development of memory B cells and plasmablasts (via secretion of interleukin 21 (IL-21)). They are CXCR5+, PD-1+ and ICOS+, the latter being considered as an activation marker.6 Several studies supported their involvement in pSS: (1) increased levels of Tfh in blood and within minor salivary glands in pSS compared with controls,7–9 (2) correlation between activated Tfh and disease activity (ESSDAI (EULAR Sjögren’s syndrome disease activity index),9–10 clinESSDAI10), (3) correlation between IL-21 and disease activity and autoantibodies status7,11,12 and (4) ability of the epithelial cells to induce Tfh.12 Another T cell subset has been recently described in inflamed tissues such as joint, but also in the blood of patients with pSS: Tfh and Tph might promote B-cell biomarkers and disease activity in primary Sjögren syndrome.

What is already known about this subject?

► T follicular helper cells (Tfh) are elevated in the blood of patients with primary Sjögren syndrome (pSS) and activated Tfh correlate with disease activity.

What does this study add?

► T peripheral helper (Tph) cells are a newly described subtype of T lymphocytes. They are elevated in the blood of patients with pSS and correlate with circulating plasmablasts.

How might this impact on clinical practice?

► As Tfh and Tph might promote B-cells activity in pSS, they could be a potential therapeutic target in this disease.
Given the role of B cell activation in pSS, we thought it would be relevant to study these cells’ subtypes in pSS. Thus, in this study, we aimed to assess Tfh and Tph in pSS, to look at their activation profile and their association with disease characteristics.

**PATIENTS AND METHODS**

**Patients and controls**

Patients were referred to the Department of Rheumatology of Hôpitaux Universitaires Paris-Sud (France), a tertiary centre, reference centre for systemic autoimmune diseases. The inclusion criteria were: age >18 years, diagnosis of pSS according to the American European Consensus criteria or the 2016 ACR (American College of Rheumatology) /EULAR criteria. Patients who received an anti-CD20 therapy or any immunosuppressive drug in the last 6 months or were treated with steroids >10 mg of prednisone per day were excluded. Clinical (sex, age, treatment, ESSDAI, lymphoma, cryoglobulinemic vasculitis), biological (anti-SSA or SSB antibodies, gammaglobulins level, RF) and pathological (result of the minor salivary gland biopsy) characteristics were available in the patients’ medical file. Hypergammaglobulinaemia was defined as a level of gammaglobulins higher than 12.5 g/L.

Two different cohorts were used. Patients included in the cohort I were assessed using CyTOF based on a previous study performed by our group. Control subjects were either blood donors (from the French Blood Establishment) or patients with sicca syndrome without any pSS or other immune or infectious disease. Clinical evaluation confirmed that the latter had neither autoimmune nor a positive biopsy result. To validate the first findings obtained with cohort I, we used an independent cohort of replication (cohort II) with assessment of Tph and Tfh by flow CyTOF and adding ICOS as a marker of activation. Controls in the cohort II were exclusively blood donors. Informed consent was obtained from all patients and controls. Blood samples were collected in heparinised tubes.

**Mass CyTOF analysis**

Peripheral blood mononuclear cells (PBMCs) were isolated by Ficoll gradient and then frozen stored at −80°C as previously described. Samples were stained and prepared for CyTOF analysis, by using an optimised cocktail of 34 metal-conjugated antibodies designed to identify 40 major and minor human blood cell subsets. After acquisition on a CyTOF II (Fluidigm, South San Francisco, California, USA), data were normalised to internal bead standards. Tfh were defined as CD4+CXCR5+PD1hi, Tph as CD4+CXCR5+PD1hiICOS+, activated Tfh as CD4+CXCR5+PD1hiICOShi, and plasmablasts as CD19+CD27+CD38hi. Unfortunately, we encountered a technical issue with the CD38 staining (high amount of false positive staining) and thus plasmablasts could not be analysed by flow CyTOF. Detail of fluorochrome-conjugated antibodies used is provided in supplementary. Gating strategy is presented in online supplemental figure S1.

**Flow CyTOF analysis**

PBMCs were isolated by Ficoll gradient and freshly stained. Cells were analysed on a BD FACScanto II flow cytometer. Data were analysed using Flow Jo, version 10. Tfh were defined as CD4+CXCR5+PD1+, Tph as CD4+CXCR5+PD1hi, activated Tfh as CD4+CXCR5+PD1hiICOShi, activated Tph as CD4+CXCR5+PD1hiICOShi. Plasmablasts were defined as CD19+CD27+CD38hi. We found a positive moderate correlation between the percentage of Tfh (r=0.59, p<0.05) with disease activity assessed by ESSDAI in flow CyTOF. We next studied whether these subsets were associated with disease activity assessed by ESSDAI in flow CyTOF. We found a positive moderate correlation between ESSDAI and the percentage of Tfh (r=0.59, p<0.05).

**RESULTS**

**Patients’ characteristics**

We included 29 patients and 23 healthy controls (HC) for mass CyTOF analysis (cohort I). A second cohort including 15 patients and 19 HC was used for flow CyTOF analysis (cohort II). Controls in cohort I were mostly women (n=21, 91.3%) and their median age (IQR) was 54 (29) years. Controls in cohort II were mostly women (n=15, 79.0%) and their median age (IQR) was 39 (14.5) years. Patients’ characteristics are presented in table 1.

**Expansion of Tfh and Tph in blood of pSS patients**

We analysed circulating Tfh (CD4+CXCR5+PD1hi) and Tph (CD4+CXCR5+PD1hi) in cohort I using mass CyTOF. The median (IQR) percentage of Tfh among CD4+ T cells was significantly higher in pSS patients compared with controls: 5.9 (4.8) % vs 2.9 (1.9) % (p<0.001) (figure 1A), as well as the median percentage of Tph among CD4+ T cells: 4.7 (4.3) % vs 3.2 (3.2) % (p<0.01) (figure 1B). We confirmed these results in cohort II using flow CyTOF. The median percentage of circulating Tfh and circulating Tph was increased in pSS patients compared with HC, respectively: 9.7 (7.2) % vs 4.1 (4.8) % (p<0.001) for Tfh (figure 1C) and 4.5 (3.1) % vs 1.8 (4.1) % (p<0.01) for Tph (figure 1D).

Then, we evaluated in cohort II the activation status of these subsets, by defining activated Tfh as CD4+CXCR5-PD1hiICOShi and activated Tph as CD4+CXCR5+PD1hiICOShi. Activated Tfh were increased in patients with pSS compared with HC: 3.9 (2.4) % vs 1.2 (1.7) % (p<0.01) (figure 1E), as well as activated Tph: 1.0 (1.7) % vs 0.4 (0.5) % (p<0.001) (figure 1F).

**Association of Tfh and Tph with disease activity**

We next studied whether these subsets were associated with disease activity assessed by ESSDAI in flow CyTOF. We found a positive moderate correlation between ESSDAI and the percentage of Tfh (r=0.59, p<0.05).

**Statistical analysis**

Data were expressed as median (IQR). Comparisons between groups were performed using Mann-Whitney U or Kruskal-Wallis test. Correlations were analysed using Spearman’s rank correlation coefficients. All analyses were performed using GraphPad Prism V.7.02 (GraphPad Software, San Diego, California, USA). A value of p<0.05 was considered as statistically significant.
(figure 2A), and between ESSDAI and the percentage of activated Tfh (ICOS⁺) (r=0.58, p<0.05) (figure 2B).

Conversely, no significant correlation was found between the percentage of Tph and ESSDAI (r=0.21, p=0.45) nor between the percentage of activated Tph and ESSDAI (r=0.28, p=0.33) (online supplemental figure S2, A and B). There was no correlation between clinESSDAI and Tfh, activated Tfh, Tph or activated Tph (online supplemental figure S2, C, D, E and F).

**Association of Tfh and Tph with B cell activation markers**

Then, we looked for an association between Tfh, Tph, activated Tfh, activated Tph and B-cell markers including plasmablasts (defined as CD19⁺CD27⁺CD38hi), hypergammaglobulinemia (defined as gammaglobulins >12.5 g/L), positivity for anti-SSA and RF. Using CyTOF, we found a positive moderate correlation between the percentage of plasmablasts and the percentage of Tfh (r=0.43, p<0.01) (figure 2C) and Tph (r=0.53, p<0.0001) (figure 2D), respectively. Plasmablasts characterisation was impossible in flow CyTOF for technical issues.

In flow CyTOF, median percentage of activated Tfh were significantly higher in patients with hypergammaglobulinemia, compared with patients without hypergammaglobulinemia: 4.0 (1.9) % vs 2.5 (1.5) % (p<0.05) (figure 2E). Using a threshold of 16 g/L to define

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**Table 1 Patients’ characteristics**

<table>
<thead>
<tr>
<th></th>
<th>Cohort I (n=29)</th>
<th>Cohort II (n=15)</th>
</tr>
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<tbody>
<tr>
<td>Sex (female)</td>
<td>29 (100%)</td>
<td>15 (100%)</td>
</tr>
<tr>
<td>Age (median±IQR), years</td>
<td>54.0±23</td>
<td>64±28</td>
</tr>
<tr>
<td>ESSDAI score (median, ranges)</td>
<td>2 (0–40)</td>
<td>4 (0–17)</td>
</tr>
<tr>
<td>Pulmonary involvement</td>
<td>0 (0%)</td>
<td>3 (20%)</td>
</tr>
<tr>
<td>Cutaneous involvement</td>
<td>2 (6.0%)</td>
<td>2 (13.3%)</td>
</tr>
<tr>
<td>Swelling of parotid glands</td>
<td>5 (17.2%)</td>
<td>2 (13.3%)</td>
</tr>
<tr>
<td>Lymphoma</td>
<td>NA</td>
<td>1 (6.7%)</td>
</tr>
<tr>
<td>Anti-SSA antibody</td>
<td>20/28 (71.4%)</td>
<td>11/15 (73.3%)</td>
</tr>
<tr>
<td>Anti-SSB antibody</td>
<td>10/28 (35.7%)</td>
<td>5/14 (35.7%)</td>
</tr>
<tr>
<td>Rheumatoid factor</td>
<td>9/17 (52.9%)</td>
<td>7/15 (46.7%)</td>
</tr>
<tr>
<td>Gammaglobulins levels (mean±SD)</td>
<td>15.3±6.3 g/L</td>
<td>14.0±4.4 g/L</td>
</tr>
<tr>
<td>Lymphocytes (mean±SD)</td>
<td>1.4±0.6x10⁹/L</td>
<td>1.7±0.7x10⁹/L</td>
</tr>
<tr>
<td>Biological cryoglobulinaemia</td>
<td>NA</td>
<td>1 (6.7%)</td>
</tr>
<tr>
<td>Current treatment</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Corticosteroids &lt;10 mg/day</td>
<td>1 (3.5%)</td>
<td>1 (6.7%)</td>
</tr>
<tr>
<td>Hydroxychloroquine</td>
<td>9 (31%)</td>
<td>1 (6.7%)</td>
</tr>
<tr>
<td>Rituximab (&gt;6 months before)</td>
<td>1 (3.5%)</td>
<td>4 (26.6%)</td>
</tr>
<tr>
<td>Belimumab (&gt;6 months before)</td>
<td>1 (3.5%)</td>
<td>0 (0%)</td>
</tr>
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</table>

NA, not available.
Our study demonstrates that Tfh and Tph, as well as activated Tfh and Tph are expanded in pSS patients. It shows a correlation between Tfh and activated Tfh and disease activity, and an association between activated Tph and Tfh and some B-cell markers.

Our results regarding activated Tfh in pSS are consistent with previous studies that have shown an expansion of circulating activated Tfh in patients with pSS, mostly in those with extraglandular manifestations and/or high disease activity and a correlation between activated Tfh and disease activity. On the opposite, in another study, pSS patients had a normal frequency of blood activated Tfh, but an increased level of T follicular regulatory (Tfr) cells and blood Tfr/Tfh ratio.

In addition, our study focuses on Tph in pSS. Indeed, Tph have now been studied in many autoimmune diseases, such as systemic erythematosus lupus, systemic sclerosis or rheumatoid arthritis, but only few data are available in pSS. We confirmed their expansion in the blood of pSS patients and our study is one of the first to describe their association with clinical and biological characteristics.

Our results might suggest a potential role of activated Tph and Tfh in activation and differentiation of B-cells, as suggested by the association between these cells and some B cells markers (gammaglobulins, RF, anti-SSB antibodies). Regarding these hypothesis, Verstappen et al have shown that Abatacept was able to reduce the percentage and the number of circulating Tfh in pSS patients and, interestingly, this reduction contributes to attenuated B cell biomarkers such as circulating plasmablasts, anti-SSA and anti-SSB.

One limitation of our study is the definition of Tph, which probably lacks of specificity, as this subset defined as CD4+CXCR5-PD1hi could include other types of activated helper CD4 or pre-Tfh (as Tfh express PD1 before expressing CXCR5). To limit this bias, we have focused on the PD1hi subset and not only on the whole PD1+ subset. Regarding Tfh, we defined them as CD4+CXCR5+PD1+ as previously described. However, in other studies, CD25, FOXP3 and CD45RO/RA are used to define this population and distinguish them from T follicular regulatory cells (Tfr). Thus, we cannot exclude a contamination of our defined Tfh population by Tfr that is nevertheless a minute population.

Our study focused on circulating Tfh and Tph but did not explore those cells in the salivary glands. It is interesting to note that PD1+ICOS+ T cells were found at an increased frequency in pSS salivary glands compared with controls. A recently published article from Pontarini et al described that both Tfh and Tph-cells were enriched in salivary glands with germinal centres from pSS patients.
Another limitation was the age difference between controls and patients in the cohort II. Tfh and Tph detected by CyTOF and flow CyTOF differ. This is due to the differences between these two techniques, and to a weak staining with CXCR5 and PD1 in CyTOF. However, we were able to detect the same difference between patients and controls using these two techniques which supports the validity of our results.

What’s more, it can be noted that, in our study, the proportion of Tfh and Tph detected by CyTOF and flow CyTOF differ. This is due to the differences between these two techniques, and to a weak staining with CXCR5 and PD1 in CyTOF. However, we were able to detect the same difference between patients and controls using these two techniques which supports the validity of our results.

In conclusion, our study demonstrates that Tfh and Tph are increased in the blood of patients with pSS and might promote B cells activation. Thus, they could be potential new therapeutic targets in this disease, by inhibiting the crosstalk between these cells and B cells.

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Contributors  AD, YM and GN contributed to the conception and design of the study. AD conducted experiments and acquired data. All authors contributed to the analysis and interpretation of data. All authors were involved in drafting the article or revising it critically for important intellectual content and approved the final manuscript to be submitted. Co-list authors: XM and GN.

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Competing interests  MM is employed by BIOGEN.

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