Synthesis of IgM, IgG, and IgA in rheumatoid arthritis

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SUMMARY We studied the production of immunoglobulins by lymphocytes separated from the blood of 15 rheumatoid arthritis (RA) patients, of 12 patients suffering from other connective tissue diseases (CTD), and of 18 healthy controls. The production of IgM, IgG, and IgA in pokeweed-mitogen-stimulated cultures was measured by counting the number of plaque-forming cells (PFC) and by determining the concentration of secreted immunoglobulins by means of an enzyme immunoassay. Synthesis of immunoglobulins, particularly IgM and IgG, was lower than in other CTD patients or controls. The IgM response of RA patients was 20% and 29% (PFC and Ig concentration) that of the controls. The respective figures for IgG were 33% and 53% and for IgA 61% and 72%.

The formation of antibodies against immunoglobulins is typical of rheumatoid arthritis (RA). These antibodies are known as the rheumatoid factors. With respect to responses in vivo against various antigens and observed levels of serum immunoglobulins there is controversy about antibody formation in RA. However, the majority of studies have demonstrated elevated levels of IgG, IgM, and IgA.

Although in-vitro methods for studying antibody response at the cellular level have been used in laboratory animals for several years, only recently has it been possible to apply the same methodology to human cells. A major advance in this respect has been the development of plaque assays, in which the number of cells secreting various classes of immunoglobulins after stimulation with a mitogen is determined. Using this plaque technique and an enzyme-linked immunosorbent assay (ELISA) we studied the synthesis of IgG, IgM, and IgA in patients suffering from RA.

Materials and methods

Subjects. Fifteen patients with active, definite rheumatoid arthritis according to the ARA criteria were selected for study (Table 1). Ten of the patients were seropositive and five seronegative. None had received systemic corticosteroid therapy before testing. Administration of nonsteroidal anti-inflammatory agents was not stopped because of the study. A control patient group consisted of 12 patients with reactive arthritis, scleroderma, polymyositis, or fibrositis (Table 1). Normal controls were 18 healthy subjects from the laboratory staff.

Cell isolation. Mononuclear cells were separated from 30 ml heparinised venous blood by centrifugation on Ficoll-Isopaque gradient. Cells from patients and paired normal donors were separated in parallel. Separated cells were washed 3 times in Hank's balanced salt solution (HBSS) and resuspended in culture medium. The cell concentration was adjusted to 1 × 10⁶ cells/ml.

Cell cultures. Cultures were prepared in 15 × 100 mm round-bottomed plastic tubes (Sterilin, Teddington Middlesex, England) in a final volume of 2 ml. The culture medium was RPMI-1640 (Flow Laboratories Ltd., Irvine, Scotland) supplemented with heat inactivated fetal calf serum (FCS, Flow Laboratories Ltd.), gentamicin (15 µg/ml, Schering Corporation, Kenilworth, USA), and L-glutamine (3...
mg/ml). Cells were cultured with (stimulated cultures) or without (unstimulated cultures) pokeweed mitogen (PWM, Gibco, New York, USA) at a final dilution of 1:100. Cultures were incubated for 5 days in a humid atmosphere of 5% CO₂ and 95% air at 37°C. At the end of this period the cells were washed twice with 2 ml HBSS and resuspended in 1 ml of culture medium without FCS. The culture supernatants were stored at −20°C for Ig determination.

Coupling protein-A to SRBC. Protein-A of *Staphylococcus aureus* (Pharmacia Fine Chemicals, Uppsala, Sweden) was coupled to SRBC with chromic chloride.⁴ One volume of protein-A (0.5 mg/ml) was mixed with 10 volumes of chromic chloride solution (2.5 × 10⁻⁴ M) and one volume of packed, washed SRBC and incubated at 30°C for 1 h. All reagents were prepared in 0.9% NaCl. After incubation the cells were washed 3 times in 0.9% NaCl and resuspended in HBSS.

Plaque assay. The number of Ig-secreting cells was determined before culture (spontaneous plaque-forming cells) and at the end of culture period by a haemolytic plaque assay.⁵ Noble agar (0.5% in HBSS containing 0.05% DEAE-dextran, Pharmacia Fine Chemicals) was heated to boiling and allowed to equilibrate at 46°C in a water bath. To 700 μl of agar was added 25 μl protein-A coupled SRBC (30% suspension), 25 μl rabbit antihuman immunoglobulin (μ-, δ-, or α-specific, diluted 1:30 in saline, Dako-immunoglobulins, Copenhagen, Denmark), 25 μl guinea-pig complement (diluted 1:3 in saline), and 100 μl cell suspension. This was then mixed and 3 separate 0.2 ml drops of the mixture were pipetted into a plastic Petri dish. A 22 × 32 mm glass coverslip was immediately placed over each drop, producing a thin layer of gel.

Plates were then incubated at 37°C for 4 to 6 hours. Plaques were counted using a stereo microscope. The number of antibody secreting cells was expressed as plaque forming cells (PFC)/10⁶ viable cells as determined by trypan blue exclusion at the time of harvesting.

Ig-determination by enzyme-linked immunosorbent assay (ELISA). A double sandwich ELISA method was used for IgM, IgG, and IgA in the culture supernatants.⁶ Microtitre plates (Dynatech Laboratories Ltd., Sussex, England) were coated with antihuman IgM, IgG, or IgA antisera (Orion Diagnostica, Helsinki, Finland). The antisera were diluted 1:5000–1:20 000 in 0.05 M carbonate buffer, pH 9.2, and 150 μl was added to each well. The plates were incubated at 4°C overnight and then washed 3 times with phosphate buffered saline (PBS), pH 7.4, containing 0.05% Tween 20. The supernatants from lymphocyte cultures were diluted 1:10–1:80 in culture medium, and 150 μl was added to each well. The plates were then incubated at 37°C for 1 hour, washed 3 times, and 150 μl of the alkaline phosphatase conjugated antihuman immunoglobulin serum (Orion Diagnostica), diluted 1:200 in PBS, was then added to each well.

After 1 h incubation at 37°C the plates were washed 3 times and 150 μl p-nitrophenylphosphate (1 mg/ml, Sigma Chemical Company, Saint Louis, USA) in 1 M diethanolamine-HCl buffer, pH 9.8, containing 0.5 × 10⁻³ M MgCl₂, was added to each well. The plates were then incubated at 37°C. After 1 h the enzymatic reaction was stopped by adding 50 μl 3 M NaOH, and absorbance at 405 nm was measured with a Titertek Multiscan plate reader (Flow Laboratories Ltd.).

The immunoglobulin content of the samples was calculated from standard curves obtained with standard sera (Behringwerke, Marburg, Germany).

Results

*IgM, IgG, and IgA producing cells after PWM stimulation.* Lymphocytes cultured in the presence of PWM for 5 days were harvested, and plaque assays were performed to determine the number of Ig-producing cells. The diagram in Fig. 1 shows the number of Ig-producing cells in 15 RA patients and 11 normal controls. The number of the controls used

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**Fig. 1** Immunoglobulin secreting cells in PWM-stimulated lymphocyte cultures. Results are expressed as plaque-forming cells (PFC)/10⁶ viable cells determined by trypan blue exclusion (at the moment of plating). Bars represent arithmetic mean. The values of RA patients are significantly different from the controls for IgM (*p*<0.001) and IgG (*p*<0.05) by Student's t test.
Table 2  Plaque-forming cells and Ig-concentrations in pokeweed-stimulated lymphocyte cultures

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>PFC/10⁶ cells</th>
<th>Ig concentration, ng/ml</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>IgM</td>
<td>IgG</td>
</tr>
<tr>
<td>RA patients</td>
<td>15</td>
<td>1381±7861**</td>
<td>1461±1867***</td>
</tr>
<tr>
<td>Other patients</td>
<td>12</td>
<td>5359±4796</td>
<td>5359±6612</td>
</tr>
<tr>
<td>Controls</td>
<td>18</td>
<td>7039±5440</td>
<td>4374±3362</td>
</tr>
</tbody>
</table>

Results expressed as arithmetic mean ± SD.
*Significantly different from controls, p<0-001.
**Significantly different from other patients, p<0-01.
***Significantly different from other patients, p<0-05.

was only 11 because in some experiments the same control served for more than one patient sample. The number of IgM-producing cells among rheumatoid lymphocytes was highly significantly less (p<0-001) than for controls. The difference between rheumatoid and normal lymphocytes for numbers of IgG-producing cells and total plaque-forming cells was also significant (p<0-05). Numbers of IgA-forming cells were not statistically different.

For comparison we also collected samples from patients with other connective tissue diseases (Table 1). Table 2 shows the number of plaque-forming cells after PWM-stimulated culture of lymphocytes from RA patients, other CTD patients, and all the healthy controls. Fewer cells synthesising IgM or IgG were detected in rheumatoid blood than in blood from patients with other CTD or the controls. The IgM response of RA patients was 20% and 29% (PFC and Ig concentration) that of the controls. The figures for IgG were 33% and 53% and those for IgA 61% and 72%. The results cannot be explained by possible differences in cell survival, since cell viability counts after culture were similar in all groups (data not shown).

Concentration of immunoglobulins in culture supernatants. The sensitive ELISA method for detecting IgM, IgG, and IgA in the supernatants of 5-day lymphocyte cultures confirmed the above results (Fig. 2, Table 2).

Number of cells secreting IgM, IgG, or IgA spontaneously or in unstimulated cultures. Two kinds of control experiments were carried out to exclude some possible causes for the decreased synthesis of
The response of RA lymphocytes to mitogens or other polyclonal stimulants has been extensively studied by lymphocyte transformation, and decreased responses have been found. Of special relevance to the present study is the work done on stimulators thought to act mainly on B lymphocytes. Thus Lloyd and Panush and Highton et al. using PWM, and Haines and Hough using staphylococcal protein A reported depressed response of RA cells in transformation tests. Earlier Lance and Knight found a decreased response to PWM with RA lymphocytes, but almost as low a response was obtained with cells of osteoarthritis patients. However, activation of lymphocytes into antibody production or blast transformation as well as thymidine incorporation are different phenomena, which are separable. In a recent report on primary antibody response to an antigen, trinitrophenyl (TNP) hapten, depressed anti-TNP IgM secretion was found.

Several explanations of depressed production of antibodies may be envisaged, including defects in B cells, monocytes, or T helper cells, increased activity of T suppressor cells, and the operation of humoral factors. The data of Segond et al. suggest normal B cell function in RA. Concanavalin-A-induced suppressor activity as well as other tests for suppressor function are also reported to be normal in RA lymphocytes. Thus it remains to be discovered what mechanisms are responsible for the depressed antibody synthesis we have demonstrated.

There is an apparent contradiction between these results and the high levels of antibodies detected in rheumatoid sera. Decreased antibody production should result in low levels of immunoglobulins in serum. A similar discrepancy was reported in patients with SLE whose peripheral blood B cells showed impaired immunoglobulin synthesis after PWM stimulation. However, it should be kept in mind that in-vitro studies are performed on blood lymphocytes. It may well be that lymphocytes actively synthesising immunoglobulins are present in other sites such as synovial tissue. Furthermore, all the mechanisms regulating antibody response in vivo may not be present in cell cultures.

As already discussed, the explanation for the impairment of antibody synthesis in RA is not clear. We would like to think that in RA, possibly after polyclonal stimulation, a too vigorous antibody response takes place. The immune system thus has to use powerful mechanisms of regulation to avoid immunological exhaustion. What we see in vitro would be consistent with this state of affairs.

During this study Kari Poikonen was supported by a grant from Lääke Oy Tukinimus-ja Tiedesäätiö. We thank Mrs Pirjo Hänninen for technical assistance and Mrs Lea Holmalahti for secretarial help.
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