In Vitro Release of Interferon-gamma and Macrophage Migration Inhibition Factor in Drug-induced Urticaria and Angioedema

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T-cells are involved in the pathogenesis of cutaneous drug reactions. T-cell phenotype and cytokine release pattern in vivo and in vitro might correlate with the type of immune response involved in cutaneous drug reactions. In vitro release of interferon-γ and macrophage migration inhibition factor (MIF) from peripheral blood lymphocytes, following in vitro challenge with the suspected unmodified drugs, was studied in 12 patients with drug-induced urticaria and/or angioedema and in two group-matched controls. The occurrence of positive interferon-γ and MIF responses was significantly higher in patients with drug-induced urticaria and/or angioedema than in controls. The sensitivity and specificity of the interferon-γ test (50% and 92%, respectively) were similar to that of the MIF test (58% and 96%, respectively). Percentage agreement between both tests was 80.9 (kappa = 0.76). In vitro release of interferon-γ and MIF in drug-induced urticaria and/or angioedema suggests a drug-specific immune response, and may implicate the drug as a possible inducer of the reaction.

Key words: adverse drug reactions; cutaneous drug reactions; cytokine; in vitro test.

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Table I. Clinical data and distribution of IFN-γ and MIF responses for suspected drugs in 12 patients with drug-induced urticaria and angioedema

<table>
<thead>
<tr>
<th>Pat</th>
<th>Age/sex</th>
<th>Reaction</th>
<th>Suspected drug</th>
<th>IFN-γ response (% IFN-γ increase)</th>
<th>MIF response (migration index)</th>
<th>Drug withdrawal</th>
<th>Treatment</th>
<th>Remission</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40/F</td>
<td>Urticaria/angioedema (acute)</td>
<td>Dipyryme</td>
<td>negative (0)</td>
<td>negative (1.0)</td>
<td>+</td>
<td>A, AH, CS</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>30/F</td>
<td>Urticaria (acute)</td>
<td>Paracetamol</td>
<td>negative (0)</td>
<td>negative (0.91)</td>
<td>+</td>
<td>A, AH, CS</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>30/M</td>
<td>Urticaria (acute)</td>
<td>Oestradiol and oestriol</td>
<td>positive (1054)</td>
<td>positive (0.60)</td>
<td>+</td>
<td>A, AH, CS</td>
<td>+</td>
</tr>
<tr>
<td>4</td>
<td>2.5/M</td>
<td>Urticaria/angioedema (acute)</td>
<td>Paracetamol</td>
<td>negative (0)</td>
<td>negative (1.0)</td>
<td>+</td>
<td>A, AH, CS</td>
<td>+</td>
</tr>
<tr>
<td>5</td>
<td>63/F</td>
<td>Urticaria (acute)</td>
<td>Bezafibrate</td>
<td>negative (0)</td>
<td>negative (0.92)</td>
<td>–</td>
<td>CS</td>
<td>+</td>
</tr>
<tr>
<td>6</td>
<td>48/F</td>
<td>Urticaria (acute)</td>
<td>Enalapril maleate</td>
<td>negative (0)</td>
<td>positive (0.71)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>7</td>
<td>36/F</td>
<td>Urticaria (acute)</td>
<td>Oestriol</td>
<td>negative (0)</td>
<td>negative (0.96)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>8</td>
<td>52/M</td>
<td>Urticaria (acute)</td>
<td>Captopril</td>
<td>positive (34)</td>
<td>positive (0.63)</td>
<td>U</td>
<td>AH</td>
<td>U</td>
</tr>
<tr>
<td>9</td>
<td>59/F</td>
<td>Urticaria/angioedema (acute)</td>
<td>Acetylsalicylic acid</td>
<td>positive (150)</td>
<td>positive (0.77)</td>
<td>+ *</td>
<td>CS</td>
<td>±</td>
</tr>
<tr>
<td>10</td>
<td>15/M</td>
<td>Urticaria/angioedema (acute)</td>
<td>Acetylsalicylic acid</td>
<td>positive (180)</td>
<td>negative (0.96)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>11</td>
<td>43/F</td>
<td>Angioedema (acute, recurrent)</td>
<td>Alprazolam</td>
<td>negative (0)</td>
<td>negative (0.92)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>12</td>
<td>78/F</td>
<td>Angioedema (acute)</td>
<td>Doxepin</td>
<td>negative (0)</td>
<td>positive (0.74)</td>
<td>+</td>
<td>A, AH, CS</td>
<td>+</td>
</tr>
</tbody>
</table>

Total pos. 7/12 patients 7/21 tests

A = adrenalin; AH = oral anti-histamine preparations; CS = systemic corticosteroids; U = unknown.

*Self-administration of acetylsalicylic acid resulted in reappearance of the adverse reaction.

[percentage agreement in the results of IFN-γ and MIF responses: 80.9%; kappa = 0.76].
ium containing fetal calf serum (FCS). Drugs were used as antigens in three concentrations that did not inhibit free macrophage migration. Macrophage migration in the presence of the drug was compared with that in the absence of the drug, and the ratio was expressed as a migration index. A migration index of 0.80 or less at one of the drug concentrations was considered to be a positive MIF response.

The lymphocytes for the IFN-γ test were twice washed with M-199 Hank’s medium, containing antibiotics (penicillin – 100 u/ml, streptomycin – 100 µg/ml), and suspended in the same medium containing 15% FCS. The lymphocytes were cultured in test tubes, in concentrations of 2 x 10⁶ cells/ml of M-199 Hank’s medium (plus 15% FCS), containing Phytohemagglutinin P (purified – Difco Laboratories, Detroit, MI, USA) at the concentration of 40 µg/ml and each drug, or with medium alone. Incubation was done for 24 h in 37°C and 5% CO₂. Unmodified drugs dissolved in the appropriate solvents were used. The drug concentrations used were extrapolated from the known therapeutic doses. The viability of the lymphocytes incubated with these doses was tested with trypan blue. The two maximal drug concentrations, which were found to be non-toxic to the lymphocytes, were used. After incubation, the test tubes were centrifuged in 2500 rpm for 25 min at 5°C. The supernatants were collected and stored in –70°C until used. The ELISA for human IFN-γ in the supernatants was performed with the Quantikine kit (R&D Systems, USA) and according to the manufacturer’s instructions. The standards were diluted in the same medium of the samples. All standards and samples were performed in duplicate. IFN-γ release in the supernatants of peripheral blood lymphocytes was reflected by the percentage of IFN-γ increase calculated according to the following formula: % IFN-γ increase = 100 x (IFN-γ (pg/ml) with the drug IFN-γ with medium alone) / IFN-γ (pg/ml) with medium alone.

The results were based on the maximal IFN-γ release in one of the drug concentrations used. A positive IFN-γ test response to drugs was determined as the mean percentage increase of IFN-γ measured in the supernatants of controls +2 SD. A positive IFN-γ test response for 11 drugs, consisting of diclofenac sod., captopril, enalapril maleate, nife-dipine, atenolol, thyroxine sod., glibenclamide, quinidine bisulfate, ranitidine, paracetamol and allopurinol was determined as 27% IFN-γ increase. A positive IFN-γ test response to acetylsalicylic acid was determined as 88% IFN-γ increase.

Statistical analysis
The results of the IFN-γ and MIF tests obtained in patients and controls were compared and analysed using the chi-square test for the differences in proportions between the study groups. The kappa test was used on the percentage agreement of reaction between the two tests compared.

RESULTS
The occurrence of positive IFN-γ recorded in 6 of the 12 patients with drug-induced urticaria and/or angioedema was significantly higher than that recorded in 3 of 40 controls (p<0.005). Similarly, the occurrence of positive MIF responses recorded in 7 of the patients was significantly higher than that recorded in 4 of 95 controls (p<0.005). Considering the adverse drug reaction as the “gold standard”, the sensitivity and specificity of the IFN-γ test (50% and 92%, respectively) were similar to those of the MIF test (58% and 96%, respectively).

The distribution of IFN-γ and MIF responses for suspected drugs used by the 12 patients with drug-induced urticaria/angioedema (21 tests) is presented in Table I. Positive IFN-γ responses were recorded for 7/21 of the drug tests, whereas positive MIF responses were recorded for 9/21 of the drug tests. Coexistence of positive IFN-γ and positive MIF responses was observed in five patients (nos. 2, 6, 9, 10, 12) for five different drugs (acetylsalicylic acid, paracetamol, captopril, selegiline HCI and a combination of oestradiol and oestrol). Coexistence of negative IFN-γ and negative MIF responses was observed in eight patients (nos. 1, 3, 4, 5, 9, 10, 11, 12) for nine different drugs (dipyrone, paracetamol, indo-methacin, bezafibrate, captopril, oestrol, tyroxine sod., alprazolam and clobazam). Negative IFN-γ and MIF test results for drugs taken were observed in four patients (nos. 1, 3, 4, 11). Dissociation between IFN-γ and MIF test results was observed in four patients (nos. 5, 7, 8, 12) for 4 different drugs (enalapril maleate, progesterone, acetylsalicylic acid, doxepin). The kappa value calculated for the percent agreement in the results of IFN-γ and MIF responses was 0.76, a value which represents excellent agreement (80.9%), i.e. statistically significant. In two patients (nos. 10 and 12) positive IFN-γ and/or MIF responses were recorded for two different drugs. Possible clinical relevance, based on drug withdrawal and remission of the reaction, is presented in Table I.

DISCUSSION
The present study demonstrates in vitro drug-induced release of IFN-γ and MIF by peripheral blood lymphocytes, challenged in vitro with the suspected unmodified parent drug compounds, in patients with acute drug-induced urticaria and/or angioedema.

In vitro cytokine release may have a diagnostic role in CDRs (1). MIF release in adverse drug reactions and various types of CDRs was increased in patients compared to controls (6–12), and was increased in response to suspected drugs compared to non-suspected drugs (7, 8). Recent studies related to drug-specific T-cell clones derived from the peripheral blood mononuclear cells (PBMC) of patients with CDRs, revealed the release of Th1-type cytokines, including IFN-γ, in patients with beta-lactam-induced morbilliform exanthems (4) and in patients with acute drug allergy to carbamazepine, phenytoin, allopurinol, or paracetamol (manifested by exanthem) (17). The diagnostic role of in vitro IFN-γ release has recently been reported in a case of carbamazepine-induced erythroderma (18), in whom following incubation of the patient’s PBMC with unmodified carbamazepine, a significant high level of IFN-γ was detected in the supernatant, as compared to controls.

Release of MIF has also been reported in drug-induced IgE-mediated hypersensitivity reactions, such as IgE-mediated allergy induced by horse serum in mice (19) and immediate-type allergy to penicillin (20). In diclofenac sodium-induced urticaria (21) the positive MIF response recorded for the offending drug was associated with a positive rat mast cell degranulation test result, suggesting the coexistence of drug-induced CMI and immediate-type hypersensitivity reaction. Similarly, release of Th1-cytokines, including IFN-γ has been reported in penicillin allergy, manifested by urticaria, angioedema and exanthem (22). T-cell clones specific for penicillin G (CD4+ or CD8+) or penicillin G coupled to human serum albumin (CD4+) generated from the PBMC of the patients, produced a heterogeneous cytokine pattern, showing high amounts of IL-2, IFN-γ, TNF-α, and rather variable levels of IL-4 and IL-5.

Most commonly used drugs are simple compounds (haptons) and therefore are poor immunogens. Various mechanisms may account for the immunogenicity of the unmodified parent drug compounds in the present study (2, 4, 23–26). The underlying
mechanism responsible for the occurrence of a Th1-type cytokine release in drug-induced urticaria and/or angioedema, that primarily activates Th2 subsets, is not clear. It is suggested that polarization of T-cell responses into distinct Th1 and Th2 differentiation may depend on the immunogenicity of the antigen, antigen dose, its route of administration and the immunization protocol (27).

Accordingly, the relatively low sensitivity of IFN-γ and MIF tests recorded by us in patients with drug-induced urticaria and/or angioedema (50% and 58%, respectively) may reflect the balance between the preferential activation of Th2-type or Th1-type cells. The possible involvement of non-immunologic mechanisms in the generation of urticaria and angioedema induced by acetylsalicylic acid (aspirin) and angiotensin-converting enzyme inhibitors, such as enalapril and captopril, cannot be overlooked (28, 29). Negative IFN-γ and MIF responses may also reflect lack of antigenic metabolites in vitro, or non-drug etiologies involved the induction of urticaria and/or angioedema. The occurrence of positive IFN-γ and/or MIF responses for two different drugs recorded in two of the patients is not clear. Cross-reactivity between acetylsalicylic acid and paracetamol, reported in aspirin intolerance (28), may play a role in one of the patients (no. 10).

The increased IFN-γ release observed in the controls, following in vitro challenge of lymphocytes with the cyclooxygenase inhibitor, acetylsalicylic acid, may be related to modulatory effects of PGE2 on the cytokine secretion profile of T-cells (30).

In vitro drug-induced cytokine release from peripheral blood lymphocytes indicates immune sensitization to the drug and does not necessarily constitute definite proof that the patient’s clinical manifestations result from an immune sensitization elicited by that drug. Clinical relevance may be attributed to in vitro drug-induced IFN-γ and MIF release in patients with drug-induced urticaria and angioedema, based on the excellent agreement between IFN-γ and MIF test results, follow-up evaluation and previous reports (7, 8). However, as challenge tests were not performed, the usefulness of these in vitro tests as diagnostic tests needs further elucidation.

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