Glucocorticosteroid dependent decrease in the activity of calcineurin in the peripheral blood mononuclear cells of patients with systemic lupus erythematosus

S Sipka, K Szucs, S Szántó, I Kovács, G Lakos, E Kiss, P Antal-Szalmás, G Szegedi, P Gergely

Abstract

Objectives—To compare the activity of calcineurin in the peripheral blood mononuclear cells (PBMC) of patients with SLE not taking glucocorticosteroids (GCS) with that of healthy controls. Methods—The activity of calcineurin was assayed in the supernatants of sonicated mononuclear cells. Results—There was no significant difference in the calcineurin activity of patients with SLE not taking glucocorticosteroids (GCS) compared with the healthy controls. On the other hand, the activity of calcineurin was reduced in patients with SLE taking GCS, correlating negatively with the dose of GCS. The stimulation of PBMC by phorbol ester and calcium ionophore decreased the calcineurin activity both in patients with SLE and in healthy controls. GCS could also reduce calcineurin activity in the mononuclear cells of healthy subjects in vitro. Conclusions—In patients with SLE the decrease in the calcineurin activity of PBMC depended on the dose of GCS used for treatment, and it was not a disease specific alteration. The higher the dose of GCS, the greater the inhibition of calcineurin activity. The reduction of calcineurin activity is a new element in the immunosuppressive effects of GCS during the treatment of patients with SLE.

Large scale defects of the intracellular signal transduction processes were seen in the mononuclear cells of patients with systemic lupus erythematosus (SLE). Various forms of T cell defects were found, including decreased protein kinase C activity, diminished levels of protein kinase A RIα and RIβ transcripts, and proteins leading to disturbance of cAMP metabolism. Abnormal NF-κB and decreased p65-RelA protein expression. The abnormalities described in the monocytes can affect both the function of the release of mediators. Recently, oestrogen dependent, increased expression of calcineurin mRNA was found in the T cells of female patients with SLE. Calcineurin is a Ca²⁺/calmodulin dependent protein phosphatase, decreasing the level of phosphorylation in the transcriptional factor NF-AT (nuclear factor of activated T cells) required for the production of a series of cytokines (interleukin 2 (IL2), IL4, etc.), cell surface molecules (CD40, ICAM, etc.), and Fas ligand.

In this study we show that in patients with SLE not taking any glucocorticosteroids (GCS) the calcineurin activity of peripheral blood mononuclear cells (PBMC) does not differ from that of healthy controls. On the other hand, in patients with SLE taking various doses of GCS, decreased calcineurin activity can be measured. The higher the concentration of GCS, the greater the decrease in calcineurin activity. The in vitro stimulation of PBMC by phorbol ester and Ca²⁺ ionophore (A23187) results in a pronounced decrease in the calcineurin activity of cells derived from patients with SLE or from healthy controls. GCS can reduce the calcineurin activity also in the mononuclear cells of healthy subjects in vitro.

Patients and methods

PATIENTS, CLINICAL DATA, AND CONTROL GROUP

The SLE study group comprised 32 patients, 29 women and three men, with a median age of 36 years (range 18–68). The mean SLE disease activity index (SLEDAI) was 4.1 (range 2–20). The average dose of GCS (methylprednisolone or equivalent of prednisolone) taken by the patients was 9.8 mg/day (range 0–32). These patients were free from any cytostatic drugs. The average duration of the disease was 8.5 years (range 0.5–35). Three subgroups of these patients were studied: (a) seven patients (six women, one man) not taking any GCS, median age 41 years (range 28–59), mean SLEDAI 2.43; (b) six patients (five women, one man) taking 8 mg of GCS/day, median age 39 years (range 19–52), mean SLEDAI 4.4; (c) six patients (five women, one man) taking 32 mg of GCS/day, median age 43 years (range 19–52), mean SLEDAI 11.5. Thirty five healthy white subjects (32 women, three men), median age 36 years (range 20–52), served as controls. Approval was given through the institutional review board, and informed consent was obtained from all participants. All patients with SLE fulfilled the diagnostic criteria of the American College of Rheumatology with at least four of the revised criteria for the diagnosis of SLE. Patients with a SLEDAI score ≥3 were considered to have inactive disease.
Controls were taken as 100%. The number of patients is given in parentheses.

between the basal calcineurin activities in the PBMC and the daily doses of GCS (0–32

and the doses of glucocorticosteroids (GCS) used for treatment. The coe-

sion rate of correlation between the basal activities of calcineurin in the peripheral

blood mononuclear cells (PBMC) of patients with systemic lupus erythematosus (SLE)

Figure 1 Negative correlation between the basal activities of calcineurin in the peripheral

PBMC and the daily doses of GCS (0–32 mg/day) taken by patients with SLE was calculated. The calcineurin activity of healthy controls was taken as 100%. The number of patients is given in parentheses.

PREPARATION OF HUMAN MONONUCLEAR CELLS

Human PBMC with an average of 88–95% lymphocytes and 5–12% monocytes were pre-
pared from heparinized blood of patients with SLE and controls according to Boyum’s method.21 The averages of the various subsets were detected by flow cytometry: CD3+ 69.4%, CD14+ 10.5%, CD56+ 1.8%, and CD14+ 8.3%. The suspensions of mononu-
clear cells (10^6 cells per sample) were labelled by saturating concentrations of anti-CD3-
FITC (T3, Coulter, Hialeah, USA), anti-CD14-RD1 (B4, Coulter), anti-CD19-RD1 (B4, Coulter), anti-CD56-PE

AND CHARACTERISATION BY FLOW CYTOMETRY

After staining and fixing, the cells were

PREDNISOLONE SODIUM SUCCEINATE

PBMC of five healthy controls were cultured for 72 hours in the absence and presence of 10^{-5} M prednisolone sodium succinate (Dipredon, Diadreson-F, Aquosum, Organon, The Netherlands) in RPMI medium with fetal calf serum (10%).

STATISTICAL ANALYSIS

Statistical means and SD values were calculated to compare the activity of calcineurin in the patients with SLE and in the healthy controls. The statistical significance of the differences was evaluated by Student’s paired t test. During measurements of the in vitro effects of GCS on calcineurin activity, each value was calculated as the mean of the data from five healthy control subjects. In these experiments the statistical significance was cal-
culated by Student’s paired $t$ test. The correla-
tion coefficient between the calcineurin activi-
ties and the doses of GCS was determined in the patients with SLE. In these studies the cal-
clineurin activities of the individual patients were expressed as a percentage of the activities measured in the healthy controls, which were considered to be 100%.

RESULTS

During the first phase of the experiment we compared the activity of calcineurin in the PBMC of patients with SLE and in healthy controls. As the calcineurin activities obtained from the patients with SLE were diverse, the daily doses of GCS taken by the subjects were considered when the data were analysed.

NEGATIVE CORRELATION BETWEEN THE BASAL

ACTIVITIES OF CALCINEURIN IN PBMC OF

PATIENTS WITH SLE AND THE Doses of GCS USED

FOR THE TREATMENT

The correlation between the basal calcineurin activities in the PBMC and the daily doses of GCS (0–32 mg/day) taken by the 32 patients

was statistically significant. The data were evaluated using Student’s paired t test. The correla-
tion coefficient between the basal calcineurin activities in the PBMC and the daily doses of GCS (0–32 mg/day) taken by the 32 patients

et al22 with slight modifications. The assay mix-
ture (30 µl) containing 50 mM Tris-HCl (pH 7.0), 0.3 mM dihydroethanol, 0.2 mM CaCl_2,
1 mM MnCl_2, 0.04 mg/ml calmodulin or 2 mM EGTA, an appropriate amount of extract
(0.5–1.5 mg/ml protein), and 3P labelled protein phosphatase inhibitor 1 (12–25 000

cpm/reaction mixture) was incubated at 30°C for 10 minutes. All mixtures contained 10 µg/ml aprotinin, 10 µg/ml leupeptin, 10 µg/ml trypsin inhibitor, 1 mM PMSF, 5 mM benzamidine as protease inhibitors, and 20 nM okadaic acid as a protein phosphatase 2A

inhibitor. The activity of protein phosphatase 1

was not assayed under the conditions given above, because 200 nM of okadaic acid did not

result in any inhibition. The reaction was

terminated by the addition of 100 µl of 10%
trichloroacetic acid. 3P of the supernatant

fraction was determined after centrifugation by

Cerenkov counting in a liquid scintillation

counter. The activity of calcineurin was calcu-

dated as the difference between 3P counts in

the absence and presence of Mn2+/Ca2+/
calmodulin.

CULTURING OF PBMC IN THE PRESENCE

OF PREDNISOLONE SODIUM SUCCEINATE

PBMC of five healthy controls were cultured for

72 hours in the absence and presence of 10^{-5} M
prednisolone sodium succinate (Dipredon,

Dipredon, Diadreson-F, Aquosum, Organon, The Netherlands) in

RPMI medium with fetal calf serum (10%).

PREPARATION OF HUMAN MONOCYTES

Cells were sonicated for 2 minutes with a

Branson sonifier in two volumes of homogeni-
sation buffer containing 50 mM Tris-HCl (pH

7.0), 0.5 M dihydroethanol, 10 µg/ml aprotinin,

10 µg/ml leupeptin, 10 µg/ml trypsin inhibitor,

1 mM phenylmethylsulphonyl fluoride

(PMSF), 5 mM benzamidine, and 0.3% Triton

X-100. The homogenate was centrifuged for

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with SLE was calculated. It was found to be highly significant: \( r_s = -0.52 \) \( (p<0.001) \). The inhibition of calcineurin activity in the PBMC of patients with SLE may be a new factor in the immunosuppression caused by GCS. There was no significant difference in the calcineurin activities of seven GCS-free patients with SLE and those of 35 healthy controls (fig 1).

**Calcineurin activities in the PBMC of patients with SLE with or without GCS treatment and in healthy controls**

In four groups of subjects the calcineurin activities of PBMC were assayed and compared. The cells were either non-stimulated or stimulated by PMA and Ca\(^{2+}\) ionophore. In the non-stimulated cells of six patients with SLE taking 32 mg of GCS/day, there was a significant decrease in the calcineurin activity compared with the value of six healthy controls (9.7 mU/mg vs 15.1 mU/mg, \( p<0.05 \)). In the seven GCS-free patients or in the six patients taking 8 mg of GCS/day, the changes were not significant compared with the values of the healthy controls (14.6 mU/mg and 12.8 mU/mg vs 15.1 mU/mg). In the cells stimulated by PMA and Ca\(^{2+}\) ionophore for four hours there was a marked decrease in the calcineurin activities of all groups compared with their
Calcineurin in PBMC of patients with SLE

Calcineurin in PBMC of patients with SLE after 24 hours: 16.8 mU/mg. The drug had significantly inhibited calcineurin (PRED) for 72 hours. This non-toxic dose of the drug had no significant effects on the cells. These preparations could be induced also in a dose dependent manner in the PBMC of healthy subjects.

Discussion
The goal of these experiments was to measure the activity of calcineurin in the PBMC of patients with SLE. The major results are as follows. Firstly, there is no difference in the calcineurin activities of PBMC in the GCS-free cultures of the patients or in the cells of in vitro experiments treated with high doses of GCS, suggesting that the GCS induced inhibition of calcineurin activity was independent of the synthesis of the enzyme. However, in these cells an increased rate of apoptosis was detected at 24 and 48 hours of culturing compared with the GCS-free cells (data are not shown). This observation is in accordance with an earlier observation that the rate of apoptosis is increased in the T cells of patients with SLE treated with GCS. Therefore, we suppose that cabin 1, a newly endogenous inhibitor of calcineurin, might possibly be one of the key molecules playing a part in this phenomenon, coupling processes of receptor regulation, apoptosis, and calcineurin activity in the PBMC.

Furthermore, cabin 1 may also play a part in the reduced calcineurin activity seen in the cells stimulated by phorbol ester and Ca²⁺ ionophore in our experiments. Our results confirmed the observation of Rider et al., who found no difference in the amounts of calcineurin mRNA in patients with SLE and healthy controls. According to our data this similarity was also reflected in the calcineurin activities of the PBMC of patients with SLE and healthy subjects. The significantly decreased calcineurin activity of PBMC measured in patients with SLE treated with 32 mg GCS/day, however, is a new observation. In addition, a significant negative correlation was found between the doses of GCS used in the treatment and the calcineurin activity (fig 1). This effect of GCS may also be an element of the immunosuppression related to the inhibition of the production of NF-AT dependent cytokines (for example, IL2, IL4, IL6, and IL13) in patients with SLE, and this pathway may coexist with other, well known influences of GCS. Calcineurin is a Ca²⁺ dependent enzyme, and, therefore, the inhibition of Ca²⁺ influx by GCS may have an important role in the GCS dependent decrease of calcineurin activity. This fact may partly explain the earlier finding that GCS inhibit the calcineurin dependent activation of IL2 and IL4 genes. However, the inhibition of calcineurin by GCS is not a phenomenon that can be induced also in a dose dependent manner in the PBMC of healthy subjects in vitro.
The mononuclear cells of healthy controls cultured in vitro showed rather different patterns of calcineurin activity in the untreated and PRED treated series (fig 3). The gradually increasing calcineurin activities of control cultures could be attributed to the production of several cytokines (for example, TNF or IL1) derived from the mononuclear cells attached to the surface of plastic dishes used for the culturing. By increasing the intracellular levels of Ca2+, TNF and IL1 could significantly increase the calcineurin activity of cells cultured for longer than 24 hours. The significant inhibition of calcineurin seen in the cells cultured in the presence of PRED for 24 hours was described recently. However, the recovery of calcineurin activity in the PRED treated cells from its reduced level at 24 hours may be explained by the appearance of the cytokines (TNF and IL1) during the second day of culturing (48 hours). As PRED can also inhibit the cytokine production of cultured cells activated by the plastic surface, the calcineurin activity increased by the effect of cytokines could never reach the values seen in the GCS-free counterparts of these cells.

Our data show that the decreased calcineurin activity induced by high doses of GCS may represent a new element in the immunosuppressive treatment of patients with SLE.

The authors thank Mrs Julia Hunyadi for expert technical assistance.


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