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Comparison of the effects of recombinant interleukin 6 and recombinant interleukin 1 on nonspecific resistance to infection

Interleukin 1 (IL1) is a potent enhancer of nonspecific resistance to infection in mice. Since IL1 also induces interleukin 6 (IL6), we tested the hypothesis that IL6 mediates the effect of IL1 on nonspecific resistance. In a lethal Pseudomonas aeruginosa infection in granulocytopenic mice, in which 80 ng of recombinant human IL1α protects against death, IL6 appeared to be much less effective. Dosages of 8 ng, 80 ng and 320 ng IL6 did not differ from the control, whereas 800 ng had a marginal protective effect (0.05 < p < 0.1). IL1 and IL6 did not potentiate each other in animals treated with suboptimal dosages of both cytokines. Numbers of bacteria cultured from the blood, thigh muscle, liver, spleen, and kidney were similar in animals treated with 800 ng IL6 and in control animals, arguing against activation of microbicidal mechanisms. The serum concentration profile of IL6 after an i.p. injection of 80 ng IL1 was similar to that after 80 ng IL6 i.p. Only minute amounts of IL1 were detected in serum after an i.p. injection of IL6. Taken these data together, it appears that increased resistance to infection induced by IL1 is not mediated by IL6.

1 Introduction

Recently, we have reported the beneficial effect of recombinant interleukin 1 (rIL1) on survival of granulocytopenic mice with a lethal Pseudomonas aeruginosa infection [1]. In this study, we found protection with a single low dosage of IL1β. Although we could demonstrate that protection was not due to a direct antimicrobial effect of IL1, to granulocytes or to activation of macrophages, we were unable to elucidate the mechanisms of protection against lethal P. aeruginosa infection. One hypothesis was that treatment with IL1 protected against the lethal effects of the lipopolysaccharide (LPS) or other toxins of P. aeruginosa. In a subsequent study, in which the effect of IL1 on a candidal infection in neutropenic mice was investigated, we could demonstrate that the effect of IL1 on survival is not limited to Gram-negative infection [2].

IL6 is a 26-kDa cytokine, which is produced by mononuclear phagocytes, fibroblasts and a variety of other types of cells [3–5]. This factor has been described as interferon-β2 [6], hybridoma (plasmocytoma) growth factor [7–9], B cell-stimulating factor 2 (BSF-2) [10] and hepatocyte-stimulating factor [11]. Since IL1 is a potent inducer of IL6, the latter could be responsible for the enhanced survival of animals treated with IL1, e.g., by inducing a hepatic acute-phase protein. Therefore, we have compared the effects of IL6 and IL1 on survival of lethally infected mice. In addition, we have investigated the kinetics of injected IL6 and IL1, and the mutual induction of these cytokines in vivo.

2 Materials and methods

2.1 Mice

Female, 25 g Swiss Webster mice (Broekman, Someren, The Netherlands), were fed standard laboratory chow and water ad libitum.

2.2 IL

Human recombinant IL1α (rIL1α), which was kindly provided by Dr. Peter Lomedico, Hoffmann-La Roche, Nutley, NJ, was used in the majority of the experiments. rIL1β (kindly provided by Dr. Alan Shaw, Biogen/Glaxo, Geneva, Switzerland) was also used. These IL1 preparations contained <30 pg lipopolysaccharide (LPS) per mg of protein. Human rIL6, containing <3 pg LPS/μg of protein was produced as published elsewhere [8].

IL1 and IL6 were given as a single i.p. injection in 2% (v/v) normal mouse serum in 0.1 ml pyrogen-free saline. Control mice received heat-inactivated IL1 (100°C for 20 min).

2.3 Infection model

Mice were rendered granulocytopenic (<0.5 × 10⁷ granulocytes per liter) by means of two i.p. injections of cyclophosphamide (Bristol Myers, Syracuse, NY), 150 and 100 mg/kg of body weight, respectively, 4 days and 1 day before the inoculation of the microorganism. Approximately 2 × 10⁷ Pseudomonas aeruginosa (27853, ATCC, Rockville, MD) were injected into the left thigh muscle. Two doses of gentamycin (Lyomed Inc., Rosemont, IL), 120 mg/kg, were given s.c., 6 and 23 h post infection [1]. The mice in each cage were randomized to receive either IL1, IL6 or heat-inactivated IL1, 24 h before the inoculation of bacteria. Survival was
over a period of at least 48 h. Survival curves were analyzed using the Kaplan Meier log rank test [12].

2.4 Clearance of bacteria

Twenty-four hours after the injection of P. aeruginosa, six mice treated with IL6 and six control mice were killed by CO2 asphyxia. Immediately after death, blood cultures were taken by cardiac puncture, and the muscles of the left thigh (the site of inoculation of the bacteria), the spleen, the kidney and the liver were removed aseptically, weighed and homogenized in sterile saline in a tissue grinder. To bring the counts into the optimal range for reading, samples of thigh muscle were diluted 1:10⁶ and other samples were diluted 1:10 in sterile saline. The suspensions were then plated on sterile DST agar (Oxoid, Ltd., Basingstoke, GB) in tenfold dilutions. After overnight incubation at 37°C the number of colonies was counted.

2.5 Pharmacokinetics of rIL6 and rIL1, and induction of IL6 by IL1

At various time points after an i.p. injection of 80 ng of IL6, three mice were killed by CO2 asphyxia. Immediately after death blood was taken by cardiac puncture. The IL6 concentrations in the sera obtained were measured using the B-9 cell line [5], and IL1 concentrations were measured using D10.G4.1 cells [13], the D10(N4)M subclone; both assays have been described in detail [14]. Similarly, serum concentrations of IL6 and IL1 were measured after an i.p. injection of 80 ng IL1α in mice.

3 Results

3.1 Survival of mice

Human rIL1α, given as a single i.p. injection of 80 ng (≈ 3 μg/kg) 24 h before infection, improved the survival of neutropenic mice with a lethal P. aeruginosa infection significantly ($\chi^2 = 6.8, p < 0.01$) compared to control mice that received heat-inactivated IL1 (Fig. 1). rIL6 was much less effective than IL1 in these protection experiments (Fig. 1). Even the effect of 800 ng IL6 was not significantly different from the control ($\chi^2 = 3.0, 0.05 < p < 0.1$); dosages of 320 ng, 80 ng and 8 ng did not differ from the control.

To investigate whether IL1 and IL6 would potentiate each other, suboptimal dosages of both cytokines (8 ng and 80 ng, respectively) were injected either alone or in combination (Fig. 2). No potentiation was detected; if anything, there was slight, albeit not significant antagonism between IL1 and IL6.

3.2 Clearance of P. aeruginosa

No differences in the numbers of bacteria in blood and tissues were found between mice treated with 800 ng IL6 or control mice 24 h after an i.m. injection of $2 \times 10^7$ P. aeruginosa (Fig. 3). When the data were expressed as number of microorganisms per gram of tissue rather than per organ, the data from two groups also did not differ.

Figure 1. The effect of IL1α and of IL6 treatment on the survival of granulocytopenic mice with a P. aeruginosa infection. The cytokines were given as single i.p. injections 24 h before infection. Control mice received heat-inactivated IL1 (100°C for 20 min). Only the difference in survival between animals treated with IL1 is significant ($p < 0.01$). Each group consisted of 20 mice.

3.3 Pharmacokinetics of rIL6 and induction of IL6 by IL1

The kinetics of 80 ng rIL6 injected i.p. into mice (Fig. 4A) is remarkably similar to that of IL6 induced by an i.p. injection of 80 ng rIL1α (Fig. 4B), although the maximal IL6 concentration after the IL6 injection precedes that induced by IL1. In contrast, the serum concentrations of IL1 after injection of IL6 are barely measurable (Fig. 4A), whereas IL1 is readily measurable after injection of IL1 (Fig. 4B).
The actual mechanism responsible for increase in survival induced by IL1, IL6 and TNF remains unclear. In our previous studies direct antimicrobial effects of IL1 were ruled out in vitro [1,2]. Since the mice were profoundly granulocytopenic in those studies, an effect of IL1 on the neutrophils was considered unlikely. Also, the beneficial effects of IL1 on hematopoiesis [17] were not demonstrated in our short-term experiments [1,2]. In the IL1 studies, no effect of IL1 on macrophages could be demonstrated [1]. The most convincing argument against an effect on microbial function of macrophages, however, came from the microbial clearance data, which failed to demonstrate a difference between IL1-treated and control mice [1,2,15]. In the present study, we have obtained similar results with IL6, i.e., the numbers of bacteria in the blood and the various organs were similar in IL1-treated mice and control mice.

It is assumed that cytokines like TNF and IL1 contribute to death from infection [18-20]. It could well be that early treatment with IL1, and to a much lesser extent with IL6, reduces the lethal effects of these cytokines. This protection could be produced by down-regulation of receptors for these cytokines in the lethal phase. The down-regulation of TNF receptors by IL1 treatment, which has recently been described to occur in vitro, is in agreement with this concept [21].

In conclusion, whatever the mechanisms of IL1-induced protection against death due to lethal infection may be, IL6 does not appear to be a critical intermediate cytokine.

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5 References
Announcements

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