Bacteriolytic and Bactericidal Activity in Monocytic and Myelomonocytic Leukemia with Hyperlysozymemia

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SUMMARY

Twenty-two sera of patients with monocytic and myelomonocytic leukemia with a high level of lysozyme were found to have higher bacteriolytic and bactericidal activity toward Escherichia coli strain “Lilly” and toward other microorganisms than sera of healthy individuals. The difference was most pronounced in the early stages of lysis and was related in part to the levels of lysozyme and complement. The most active sera were those with normal complement and elevated lysozyme. No relationship to the levels of immunoglobulins or transferrin was detected. Patients in remission and whose serum lysozyme level was normal had lower bacteriolytic activity than sera in the acute stage of the disease when the serum lysozyme level was high.

It seems, therefore, that leukemic patients with high serum lysozyme may have higher than normal bacteriolytic and bactericidal activity against some microorganisms. This observation correlates well with the finding that patients with high-lysozyme leukemia suffer less from infections than those with normal or low lysozyme.

The addition of pure human lysozyme to normal sera enhanced their bacteriolytic and bactericidal activity. The addition of various chemotherapeutic agents to normal human serum did not influence antibacterial activity against E. coli Lilly.

INTRODUCTION

Infection is one of the most frequent and often fatal complications in patients with leukemia. Two types of defense mechanisms protect against infection—cellular and humoral. The former has been studied in patients with leukemia (3, 10, 14, 15, 17, 21, 25, 27, 28), but little attention has been paid to the latter (2, 26). In recent years, it has become apparent that at least 3 serum components play an important role in the killing and lysis of microorganisms by the serum, namely, complement, lysozyme, and antibodies. Other factors such as transferrin (9) and β-lysin (7) have also been found to participate in antibacterial reactions in vitro.

Patients with monocytic and myelomonocytic leukemia usually have a high blood level of lysozyme (12, 20, 23), an enzyme produced mainly by monocytic and by polymorphonuclear blood cells (30), both normal and leukemic (31). It has recently been reported that leukemic patients with high serum lysozyme have a lower incidence of bacterial infections than those with normal or low lysozyme (6). We present herewith the results of investigation of the bacteriolytic and bactericidal activity in sera of patients with monocytic and myelomonocytic leukemia and in sera of healthy individuals supplemented with a pure human lysozyme. An attempt has been made to relate the ability of killing and lysing bacteria to the level of serum lysozyme, complement, transferrin, and immunoglobulins. The results show that the majority of hyperlysozymemic leukemic sera and sera of healthy individuals supplemented by human lysozyme have higher bacteriolytic and bactericidal activity than sera of healthy individuals.

MATERIALS AND METHODS

Material. Twenty-two sera from 16 patients with monocytic or myelomonocytic leukemia and high serum lysozyme were tested. Sera from 4 of these patients in drug-induced remission, with normal lysozyme, and 22 sera of healthy individuals matched by sex and age served as controls.

Venous blood was withdrawn in sterile conditions and allowed to clot, and the serum was separated. The blood was always taken in the morning, at least 12 hr after the last dose of chemotherapeutic agent was administered. The serum was either tested immediately or frozen in small aliquots at −70°C. Usually, the frozen sera were tested in less than 4 weeks after freezing and thawed only once, just before the start of the experiment. All sera tested for bactericidal activity and the majority of those tested for bacteriolytic activity were checked for bacteriological sterility. All of them were found to be sterile.

Immunoquantitation. The concentrations of IgG, IgA, IgM, and transferrin in the sera were estimated by radial immunodiffusion with immunoplates from Hyland Laboratories, Los Angeles, Calif., and the concentration of IgD was estimated on plates from Meloy Laboratories, Springfield, Va. Normal values were calculated in 100 sera from healthy individuals, 50 men and 50 women.

Assay of Complement. Total hemolytic complement was assayed according to the method of Kabat and Mayer (13). Normal values were estimated in sera of 40 adults, 20 men and 20 women.

Assay of Lysozyme. The activity of lysozyme was tested by the lysoplate method of Osserman and Lawlor (20). Purified...
human lysozyme, isolated from the urine of a patient with monocytic leukemia by the method of Alderton et al. (1), served as a standard. The purity of lysozyme was verified by electrophoresis and immunoelectrophoresis, isoelectric focusing, and ultracentrifugation. Its lytic activity against Micrococcus lysodeikticus was compared to that of pure human lysozyme kindly provided by Dr. E. F. Osberman, New York, N. Y. The activity of the 2 was indistinguishable. With each set of estimations, solutions of pure lysozyme (5, 25, 100, 250, and 500 \(\mu g/ml\)) were tested and a semilogarithmic curve was plotted. The lysoplates were developed at 22–24° for 16 hr.

### Bacterial Strains

The microorganism used in all bacteriolytic and bactericidal tests was a rough strain of \(E. coli\) called Lilly, particularly susceptible to the lytic action of fresh human serum (32). Along with \(E. coli\) Lilly, other microorganisms were used. These included enteropathogenic \(E. coli\) (smooth) 055:B5, enteropathogenic \(E. coli\) (rough) 011:B4, Pseudomonas aeruginosa, Proteus mirabilis, Salmonella typhimurium, Streptococcus fecalis, and Staphylococcus aureus coagulase positive. \(E. coli\) Lilly was grown on TrypticaseTM soy broth obtained from BBL, Division of Bioquest, Cockeysville, Md. After 4 to 5 hr, the broth culture was diluted with sterile 0.9% NaCl solution and poured into the Roux culture bottles containing 2.3% Bacto nutrient agar obtained from Difco Laboratories, Detroit, Mich. These cultures were incubated for 18 hr, and then harvested. The bacteria were washed twice in sterile 0.9% NaCl solution, resuspended in the same fluid, and held at 4° until use. The final concentration was adjusted in such a way as to give at 1:10 dilution an absorbance of 0.35 to 0.45 at 525 nm in a 12-x 100-mm test tube in the Coleman spectrophotometer.

### Bacteriolytic and Bactericidal Tests

Bacteriolytic activity was tested according to the method described by Wardlaw (32). Bactericidal activity was tested by the reduction in the colony count when the bacteria were incubated with serum. A freshly harvested culture of \(E. coli\) Lilly was washed twice and resuspended in sterile 0.9% NaCl solution in a volume sufficient to give an absorbance of 0.30 at a wavelength of 525 nm. The tubes with bacteria were placed in ice water and checked for lysability, with the use of fresh normal serum as above. For the bactericidal test, the suspension of bacteria was diluted in 0.9% NaCl solution to give a final concentration of 3000 to 7500 viable cells in 0.3 ml. The final test mixture consisted of serum diluted in 0.9% NaCl solution (prewarmed at 37°) to which 0.3 ml of \(E. coli\) Lilly was added to give a total volume of 3.0 ml. The mixtures were incubated at 37°, and the progress of the bactericidal reaction was monitored by taking out 0.1-ml samples into an empty sterile Petri dish and diluting with 15 ml of molten nutrient agar kept ready in a 44° water bath. Such samples were taken out at zero time (i.e., 5 to 15 sec) and at 2, 6, 10, and 30 min. The poured plates were swirled gently and left to congeal, and colonies were counted after incubation for 1 to 5 days. The number of colonies in control blanks and in zero time samples varied from 100 to 250. Each serum was tested in dilutions of 1:10, 1:30, and 1:100. Each experiment was performed in duplicate. With each set of tests, a control blank was run with the use of a mixture of 2.7 ml of sterile 0.9% NaCl solution and 0.3 ml of suspension of \(E. coli\) Lilly. Identical procedures were used while testing other microorganisms. Sera of healthy individuals were tested as controls with each set of experiments.

### Addition of Chemotherapeutic Agents to Sera of Healthy Individuals

Various chemotherapeutic agents were added to 2 sera of healthy individuals in the following final concentrations: Methotrexate (Methotrexate sodium; Lederle Laboratories, Pearl River, N. Y.), 0.05 \(\mu g/ml\); nitrogen mustard (Mustine HCl, Boots Pure Drug Co, Nottingham, England), 0.25 \(\mu g/ml\); vincristine (Oncovin, Eli Lilly and Co., Indianapolis, Ind.), 0.1 \(\mu g/ml\); Azathioprine (Imuran, Burroughs Wellcome and Co. (U. S. A.) Inc., Tuckahoe, N. Y.), 2 \(\mu g/ml\); busulfan (Myleran, Burroughs Wellcome and Co. (U. S. A.) Inc.), 1 \(\mu g/ml\); 6-mercaptopurine (Purinethol, Burroughs Wellcome and Co. (U. S. A.) Inc.), 2.5 \(\mu g/ml\).

The final concentration of the chemotherapeutic agent was adjusted approximately according to the formula of Schabel et al. (29). Briefly, the theoretical maximal momentary body fluid drug level was estimated, assuming that the total unbound water is 70% of the total body weight. Then 70% of the total daily dose of the chemotherapeutic agent was expressed in \(\mu g/g\) of the fluid. Since this calculated concentration could be achieved only if the absorption of the given drug was quick and complete (if not administered i.v.), it represents hypothetical maximal instantaneous equilibrium. The real concentration that exists in the serum in vivo is always much lower.

### Addition of Lysozyme to Sera of Healthy Individuals

Various amounts of pure human lysozyme or of egg-white lysozyme were added to sera of healthy individuals and the bacteriolytic and bactericidal activity was estimated.

Statistical evaluation was performed with the help of the University of Toronto Central Computer. The level of immunoglobulins, transferrin, complement, and lysozyme was accepted as significantly increased or decreased only when it was higher or lower than the mean ± 2 S.D. Index of determination was estimated by the least-squares curve fit method. From it, \(t\) and finally \(p\) was estimated. Confidence limits of difference between means of 2 populations were estimated with the CONDIF program.

### RESULTS

#### Humoral Factors in Leukemia (Table 1)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Number of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute myelomonocytic</td>
<td>10</td>
</tr>
<tr>
<td>Acute monocytic-monoblastic</td>
<td>6</td>
</tr>
</tbody>
</table>

Ten patients who had acute myelomonocytic leukemia and 6 had acute monocytic-monoblastic leukemia. All of them suffered from a generalized active disease. Ten patients received chemotherapeutic agents; 6 patients received 6-mercaptopurine, 1 of them with cyclophosphamide and another with methotrexate; 3 patients received vincristine, 1 of them with cyclophosphamide; 1 patient received myleran. Patients with recent acute infection or any serious illness in addition to leukemia were excluded from the study. Similarly, no patients with hematological side effects of chemotherapy were included.

The most striking feature of the results was the markedly elevated lysozyme level in the leukemic patients. The
Bacteriolytic and Bactericidal Activity in Leukemia

Table 1
Humoral factors of immunity in patients with monocytic and myelomonocytic leukemia

<table>
<thead>
<tr>
<th>Group</th>
<th>Lysozyme (µg/ml)</th>
<th>Complement (HU₅₀/ml)</th>
<th>Transferrin (mg/ml)</th>
<th>IgG (mg/ml)</th>
<th>IgA (mg/ml)</th>
<th>IgM (mg/ml)</th>
<th>IgD (mg/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monocytic and myelomonocytic leukemia</td>
<td>44.8 ± 23.4</td>
<td>131 ± 50</td>
<td>1.62 ± 0.43</td>
<td>13.19 ± 5.15</td>
<td>3.47 ± 1.82</td>
<td>1.43 ± 0.90</td>
<td>0.072 ± 0.033</td>
</tr>
<tr>
<td>Healthy individuals</td>
<td>9.7 ± 1.8</td>
<td>167 ± 29</td>
<td>2.19 ± 0.37</td>
<td>11.54 ± 2.22</td>
<td>2.33 ± 0.79</td>
<td>1.19 ± 0.42</td>
<td>0.003 – 0.4a</td>
</tr>
</tbody>
</table>

* Range.

complement level was lower than normal in 9 instances. Transferrin was low in 9 estimations, being never higher than in healthy individuals. The serum level of IgG in leukemic patients was lower than normal in 3 instances and higher than normal in 6 estimations. IgA level was low in 1 instance and higher than normal in 8 others. IgM was low in 2 instances and higher than normal in 8 estimations. IgD level was generally normal.

**Bacteriolytic Activity against E. coli Lilly.** Bacteriolytic activity of the leukemic sera was found usually to be significantly higher than that of healthy individuals, especially in the early stages of the bacteriolytic reaction. At the serum dilution of 1:20, the mean percentage lysis by the leukemic sera was 52.7 ± 19.9 in 10 min (Chart 1), 82.2 ± 6.6 at 30 min, and 84.8 ± 6.5 at 60 min. Corresponding results in the normal controls were 31.9 ± 5.0, 55.5 ± 5.6, and 66.0 ± 5.0. The difference in 10-min readings is significant at the level of p < 0.01. It was less significant at the 30- and 60-min readings. Similar differences were also detected at serum dilutions of 1:10 and 1:40.

When individual samples were compared, each with the matched normal serum simultaneously run as a control, it was found that, at 10-min readings, the leukemic sera exhibited significantly stronger bacteriolytic activity than the corresponding controls in 21 of 22 instances. But after longer incubation, this difference was less striking, for at 30 min 15 samples and at 60 min only 13 leukemic sera were more active than the corresponding controls.

In attempting to analyze the basis of the differences in bacteriolytic activity of the individual samples, 7 parameters were studied, namely, lysozyme, complement, transferrin, and 4 immunoglobulins. Charts 2 and 3 show that bacteriolytic activity was related in part to the levels of serum lysozyme and complement, especially in the early stages of the bacteriolytic reaction. In these figures the correlation of bacteriolytic activity with lysozyme level was significant at p = 0.025 and with complement at p < 0.01. Less striking correlations were noted at 30- and 60-min readings. The most active sera were those which had normal complement and high lysozyme. Since almost all samples had a normal or high level of immunoglobulins, no special consideration was given to this parameter. No relationship of bacteriolytic activity to the level of transferrin was detected.

Two pairs of sera from different patients had an identical level of lysozyme but differed in complement. In both pairs the bacteriolytic activity was higher in that sample which had the higher level of complement.

In 4 patients, bacteriolytic activity was estimated in the sera with high pretreatment levels of lysozyme and in the samples with normal lysozyme in chemotherapy-induced remission. No significant differences in the levels of complement, immunoglobulins, or transferrin were noted in the paired samples. In each, the pretreatment serum possessed higher bacteriolytic activity than the posttreatment sample.

**Bacteriolytic Activity of Leukemic Sera against Other Microorganisms.** Five leukemic sera were tested for bacteriolytic activity against E. coli (rough) 011:B4, E. coli (smooth) 055:B5, P. mirabilis, S. typhimurium, S. fecalis, and S. aureus. All 5 leukemic sera exhibited higher bacteriolytic activity than the sera of healthy individuals towards the first 3 microorganisms.
Bactericidal Activity of Leukemic Sera against E. coli Lilly. Considering the bactericidal rather than the bacteriolytic activity of serum, we tested 10 sera of patients with leukemia and 26 sera of healthy individuals against E. coli Lilly. In the former group, the mean levels of lysozyme and complement were 41.5 μg/ml and 184 HU50/ml. In the latter group the respective values were 8.5 μg/ml and 192 HU50/ml. No significant difference was found in the levels of immunoglobulins and transferrin. Five patients received various chemotherapy agents, such as 6-mercaptopurine, myleran, methotrexate, or vincristine. The bactericidal activity of leukemic sera was significantly higher than that of healthy individuals at all dilutions, especially when the bacteria were exposed to serum for very short periods, e.g., 2 min (Chart 5). Also, when the number of bacteria exposed to the same amount of serum (diluted 1:30) was increased up to 3 times, the leukemic serum was able to kill bacteria at the same rate regardless of their initial number. In leukemic sera there appeared to be some correlation between the bactericidal activity and the level of serum complement; however, the limited number of observations made statistical evaluation infeasible.

Bactericidal Activity of Leukemic Sera against Other Microorganisms. Three control sera and 3 leukemic sera killed E. coli (rough) 011:B4, to a much lesser extent than they killed E. coli Lilly. Longer exposure time was necessary to express bactericidal activity. The leukemic sera were more active than the sera of healthy individuals.

Bacteriolytic and Bactericidal Activity of Normal Sera Mixed with Chemotherapeutic Agents. Samples of 2 normal sera were checked for bacteriolytic and bactericidal activity after admixture with each 1 of the following agents: methotrexate, nitrogen mustard, vincristine, 6-mercaptopurine, azathioprine, and myleran. The change in pH of the final mixture did not exceed 0.02. There was almost no influence on bacteriolytic activity of the sera. For example, sera in dilution 1:20 mixed with chemotherapeutic agents lysed at 15-min readings from 23.3 to 26.3% of the microorganisms as compared to 33% for the control. In another experiment the comparable values were 26.7 to 28.1% and, for the control, 27.9%. There was no remarkable influence on bactericidal activity of the sera. After 6 min of exposure, sera (1:100) mixed with chemotherapeutic agents killed from 50.5 to 60.4% of the microorganisms, whereas the control sera killed 59.4%.

Bacteriolytic and Bactericidal Activity of Normal Sera Supplemented with Human Lysozyme. Addition of pure human lysozyme or of egg-white lysozyme to the serum of healthy individuals enhanced significantly its bacteriolytic activity against E. coli Lilly (Chart 6). The influence of lysozyme was especially striking in the early stages of the bacteriolytic reaction. Human lysozyme also enhanced bacteriolytic activity against E. coli (rough) 011:B4, but not against E. coli (smooth) 055:B5 or against P. mirabilis. Human lysozyme was 1.5 to 2 times more active than egg-white

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The abbreviation used is: HU, hemolytic units.
lysozyme. Addition of pure human lysozyme enhanced significantly the bactericidal activity of the serum against E. coli Lilly and E. coli (rough) 011:B4, but not against E. coli (smooth) 055:B5.

Rate of Infections in High-Lysozyme and Normal (or Low)-Lysozyme Leukemias. A group of 46 leukemic patients with a normal or low level of serum lysozyme was compared to 59 patients with high serum lysozyme. The last group included all patients whose sera were used in the present study. In the former group lysozyme varied from 2.4 to 17.5 µg/ml (mean, 9.6 µg/ml); in the latter the range was 18.7 to 150 µg/ml (mean, 46 µg/ml). In each group the number of infections with a known bacterial agent was calculated per patient separately from the number of febrile episodes in which no etiological agent was found.

In the 1st group 89% of the patients suffered from at least 1 infectious episode and the number of infections/patient was 2.2. In the 2nd group the comparable numbers were 71% and 1.2, the difference being significant at p < 0.01. The number of febrile episodes without a pathogen was 0.7/patient in the 1st group and 0.3 in the 2nd (p < 0.01). Infection was found at death in 10 of 13 cases from the 1st group (77%) and in 12 of the 20 cases in the 2nd group (60%).

DISCUSSION

Bacterial and fungal infections are frequent and often fatal in patients with leukemia. However, the factors leading to the imbalance in host-parasite interaction in leukemic patients have not yet been elucidated. Although an impairment of phagocytic activity of polymorphonuclear cells has been reported (3, 10, 14, 15, 17, 21, 25, 27, 28), there is still no agreement on its importance in various types of leukemia (14, 25, 27). Normal phagocytic activity but an increase in the death rate of polymorphonuclears was found in acute myeloblastic leukemia (25). Normal phagocytosis was also observed in chronic myelogenous and chronic lymphocytic leukemia (14, 28). According to Sbarra et al. (27) there is most probably no failure in the phagocytic capability of white cells in monocytic and myelomonocytic leukemia, and any reduction in the antibacterial defence capabilities in these diseases is not due to decreased activity of the phagocytic system. These observations may imply that, at least in some leukemias, the impairment of antibacterial defence mechanisms is not, or not only, due to low numbers or malfunction of phagocytic cells.

Low resistance in leukemic patients may also be caused by an impaired ability of the serum to kill and lyse microorganisms. A significant decrease of serum bactericidal activity was reported in chronic myelogenous and chronic lymphatic leukemia (11). On the other hand, increased bactericidal activity of sera in the former but not in the latter was reported by others (18, 33). No relationship of serum bactericidal activity to the activity of the leukemic process, therapy, or intercurrent infections was detected. Libánský and Ježková (18) have stated that the patients with chronic myelogenous leukemia who had high serum bactericidal activity suffered less from infections than those with normal bactericidal activity. No investigation of the various humoral factors was undertaken by these authors. Furthermore, the different methods of investigation and the different microorganisms used make comparison of the results infeasible.

Among various antibacterial humoral factors, at least 3 play an important role, namely antibodies, complement, and lysozyme. Abnormalities in the level of immunoglobulins in various types of leukemia have been described, hypogammaglobulinemia in chronic lymphatic leukemia (4) or hypergammaglobulinemia in monocytic and myelomonocytic leukemia (23) being the best examples. Suppression of the formation of antibodies during therapy of leukemia (8) and anergy to some antigens (17) have also been recorded. The total hemolytic complement was normal in the majority of patients with chronic myelogenous leukemia (34), but its level was much more variable in acute leukemias (2, 34) and in chronic lymphatic leukemia (2) than in healthy individuals. The level of serum lysozyme in leukemia has recently been investigated by several workers (12, 20, 23, 24) and was generally high in patients with monocytic or myelomonocytic leukemia (20, 23), varying in chronic myelogenous leukemia (22), and lower than normal in chronic lymphatic leukemia (12, 24).

Since increased activity of lysozyme, a known bacteriolytic factor (32), was found in monocytic and myelomonocytic leukemia (20, 33), it was of interest to investigate whether there is any difference in the rate of infections in high-lysozyme versus low-lysozyme leukemia. Castro et al. (6) divided 68 patients into 2 such groups and found that patients with high serum lysozyme suffered less frequently from bacteremia and that bacterial and fungal infections were rarer at death than in the group of patients with low serum lysozyme. This observation correlates well with the in vitro study of bacteriolytic and bactericidal activity in our patients with monocytic and myelomonocytic leukemia, and with our clinical data.

Our results show that the bacteriolytic activity of leukemic sera is significantly higher than that of sera from healthy
individuals. The activity was especially high against rough strains of *E. coli* and was also higher against the smooth strain of *E. coli* and *P. mirabilis*. The difference was especially notable in the early stages of the bacteriolytic reaction, being then related to the levels of complement and lysozyme. Sera of patients in remission had much lower bacteriolytic activity than when the patients were acutely ill and had high serum lysozyme.

Bactericidal activity was also higher in leukemic sera, especially when the bacteria were exposed to sera for short periods of time. Even very diluted sera were more active than the normal sera, but longer exposure time was necessary to detect the differences.

Since several of our patients received chemotherapeutic agents, 2 sera of healthy individuals were preincubated with various chemotherapeutic agents and then tested for bacteriolytic and bactericidal activity. No enhancement of these activities was apparent. The main difficulty of testing the influence of chemotherapeutic agents on antibacterial activity of human serum arises from the fact that no accurate information about the blood level of these agents is known. In experimental animals these drugs disappear quickly from the serum, or at least their concentration rapidly diminishes (5). Since the blood samples in our patients were taken at least 12 hr after the last dose of chemotherapeutic agents was administered, it seems that the concentration of these agents in the sera tested was negligible.

In a further analysis of these reactions, several sera from healthy individuals were supplemented by pure human lysozyme in various concentrations. Such sera possessed very high bacteriolytic activity against various microorganisms even at high dilutions and when the complement level was not higher than 4 HU$_{50}$/ml. Human lysozyme enhanced bacteriolytic activity to a greater extent than egg-white lysozyme. The addition of pure human lysozyme enhances bactericidal activity, especially against *E. coli* Lilly and another rough strain of *E. coli*. Some enhancement was noted against *E. coli* (smooth) but not against other microorganisms.

These results are in discordance with the results of Neu et al. (19). These authors failed to detect any influence of human lysozyme incorporated into agar on the growth of various microorganisms and concluded that it is doubtful that lysozyme is beneficial in patients with monocytic leukemia. However, the authors worked with synthetic media and no source of complement was added to the system. In order for lysozyme to act on gram-negative bacteria, a "pretreatment" of the bacterial envelope with complement and possibly with antibody is required. Any chemical or physical agent that acts on the envelope in a fashion similar to complement may expose the bacterial wall to the action of lysozyme and reveal its activity (16). And indeed, when the authors exposed EDTA-treated bacteria to human lysozyme, they found that the human was 3 to 4 times more active than the egg-white lysozyme (19).

It seems, therefore, that sera of patients with monocytic or myelomonocytic leukemia and high lysozyme are more active in bacteriolytic and bactericidal reactions against some microorganisms than sera of healthy individuals. In order to correlate these results with the rate and type of infections in leukemic patients, a combined study of humoral factors and phagocytic activities is necessary and this is in progress in our laboratory.

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