Treatment of chronic urinary tract infections with gentamicin

A. A. LINDBERG, H. BUCHT, AND L. O. KALLINGS

From the National Bacteriological Laboratory, Stockholm, and the Renal Clinic, St. Erik’s Hospital, Stockholm

SYNOPSIS Gentamicin was of value in the treatment of chronic urinary tract infections caused by multiresistant bacterial strains for which no atoxic antibiotic was available. The treatment was carried out after alkalinization of the patient’s urine. With the dosage given, gentamicin gave a low serum and a relatively high urine concentration. Excretion of active gentamicin in the urine was high even in patients with impaired renal function. The results of treatment of complicated chronic urinary tract infections with initial gentamicin and following long-term therapy showed negative urinary cultures in 12 out of 24 patients within one to 14 months of follow-up time. To reduce the risk of toxic side effects the dosage was adjusted according to the patient’s kidney function. No development of resistance was demonstrated in the bacteria.

Chronic urinary tract infections caused by various Gram-negative bacteria pose an ever-increasing problem from the point of view of treatment. These bacteria are often naturally resistant to many antibiotics or have developed resistance against sulphonamides, penicillins, streptomycin, tetracyclines, chloramphenicol, and nitrofurantoin. The antibiotics which remain for treatment are, for example, kanamycin, neomycin, polymyxin B, and colistin. However, these antibiotics are potentially neuro-, oto-, or nephrotoxic, particularly when not given in reduced doses to patients with an underlying kidney disease. This report describes our experience in the treatment of chronic urinary tract infections with a new antibiotic, gentamicin. The drug had not been used in Sweden before.

Gentamicin is a mixture of antibiotics which are obtained from *Micromonospora purpurea* (Luedemann and Brodsky, 1963). Gentamicin is related in its activity to streptomycin, kanamycin, and neomycin (Rosselet, Marquez, Meseck, Murawski, Hamdan, Joyner, Schmidt, Migliore, and Herzog, 1963; Weinstein, Luedemann, Oden, and Wagman, 1963a; Weinstein, Luedemann, Oden, Wagman, Rosselet, Marquez, Coniglio, Charney, Herzog, and Black, 1963b). The absorption from the gastrointestinal tract is poor and therefore it must be administered parenterally; 25% to 30% is bound to serum albumin (Black, Calesnick, Williams, and Weinstein, 1963; Bulger, Sidell, and Kirby, 1963). In vitro investigations showed that gentamicin had a bactericidal effect against various Gram-negative bacteria and *Staphylococcus aureus* (Black et al., 1963; Rubenisi, Kozij, and Jackson, 1963; Weinstein et al., 1963a, b). Clinical investigations showed that gentamicin was effective in the treatment of urinary tract infections caused by a number of different Gram-negative bacteria (Bulger et al., 1963; Jao and Jackson, 1963; Klein, Eickhoff, and Finland, 1964). Toxic side effects on the vestibular function with permanent labyrinth injury was observed when relatively large doses were used for the treatment of patients with reduced kidney function (Bulger et al., 1963; Jao and Jackson, 1963).

In this study the results of the treatment of 25 patients with varying degrees of impaired kidney function are reported where gentamicin was used in a reduced dosage. In addition to these clinical tests its in vitro activity against 338 bacterial strains was investigated.

MATERIAL AND METHODS

ANTIBACTERIAL ACTIVITY Minimal inhibitory concentrations (M.I.C.) and minimal bactericidal concentrations (M.B.C.) were determined by the tube dilution method against newly isolated strains of pathogenic bacteria. Of a 10⁻⁴ dilution of an 18-hour culture, 0.5 ml., representing 1·2 x 10⁹ bacteria, was pipetted into a series of tubes with 0·5 ml. gentamicin in phosphate-buffered brain...
Treatment of chronic urinary tract infections with gentamicin

heart infusion broth (Difco), pH 8.0, in two-fold dilutions from 0.3 µg/ml to 40 µg/ml. The tubes were incubated at 37°C, read after 18 hours, shaken, and read again after 24 hours. The lowest concentration of gentamicin which gave inhibition of bacterial growth was determined as the M.I.C. The M.B.C. was determined by subcultivation from the tubes showing no bacterial growth to blood agar plates and reading the lowest concentration of gentamicin from which no bacteria could grow after incubation overnight.

The M.I.C. and M.B.C. values for kanamycin and colistin were determined in the same manner.

The gentamicin activity at varying pH was investigated by determining the M.I.C. and M.B.C. at pH 5.0, 6.0, 7.0, and 8.0.

**TABLE I**

<table>
<thead>
<tr>
<th>Organism</th>
<th>No. of Strains</th>
<th>Concentration of Gentamicin (µg/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Range</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Median</td>
</tr>
<tr>
<td><strong>M.I.C.</strong></td>
<td><strong>M.B.C.</strong></td>
<td></td>
</tr>
<tr>
<td>E. coli</td>
<td>56</td>
<td>0.3-10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.6-10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td>Klebsiella sp.</td>
<td>110</td>
<td>0.3-5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.6-20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.6</td>
</tr>
<tr>
<td>Proteus mirabilis</td>
<td>24</td>
<td>0.3-5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.6-40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.2</td>
</tr>
<tr>
<td>Proteus sp. indole-positive</td>
<td>8</td>
<td>1.25-2.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.25-10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.0</td>
</tr>
<tr>
<td>Ps. aeruginosa</td>
<td>106</td>
<td>0.3-5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.6-40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.8</td>
</tr>
<tr>
<td>Staphylococcus aureus</td>
<td>36</td>
<td>0.1-0.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.6-5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.0</td>
</tr>
</tbody>
</table>

**RESULTS**

**ANTIBACTERIAL ACTIVITY** The M.I.C. and M.B.C. values of gentamicin at pH 8.0 for 302 Gram-negative bacteria and 36 strains of *Staphylococcus aureus* are shown in Table I. A concentration of 1.2 µg gentamicin/ml inhibited 100% of *Staphylococcus aureus*, 96% of Klebsiella, 93% of Pseudomonas, 62% of *E. coli*, and 37% of *Proteus* species. Five µg gentamicin/ml had a bactericidal effect on 100% of *Staphylococcus aureus*, 86% of Klebsiella, 89% of Pseudomonas, 94% of *E. coli*, and on 73% of the strains of *Proteus* species.

**COMPARISON BETWEEN IN VITRO ACTIVITY OF GENTAMICIN, KANAMYCIN AND COLISTIN** Eighty-five Gram-negative strains were chosen from the above mentioned material for comparison of the antibacterial effect of gentamicin with kanamycin and colistin. All strains were isolated from patients with infections which were difficult to treat. Table II shows the M.I.C. and M.B.C. values obtained. Inhibition of bacterial growth occurred with lower concentrations of gentamicin than with kanamycin or colistin, with the exception that *E. coli* strains were inhibited by a lower concentration of colistin. Lower concentrations of kanamycin and colistin than of gentamicin were required to produce a bactericidal effect on Klebsiella strains. Gentamicin had the best in vitro bactericidal effect against Pseudomonas and Proteus species.

**EFFECT OF VARYING pH ON THE ANTIBACTERIAL ACTIVITY OF GENTAMICIN** The effect of different pH on the M.I.C. and M.B.C. values for gentamicin was determined on three strains—Klebsiella, *Proteus mirabilis*, and *Pseudomonas aeruginosa*. Figure 1 shows that the pH value was of decisive importance.

---

1By courtesy of the Schering Corp., Bloomfield, New Jersey.

2Kindly supplied by Dr. K. Lincoln, Göteborg.
TABLE II
SUSCEPTIBILITY OF PATHOGENIC BACTERIA TO GENTAMICIN, KANAMYCIN, AND COLIMYCIN IN VITRO

<table>
<thead>
<tr>
<th>Organism</th>
<th>No. of Strains</th>
<th>Gentamicin</th>
<th>Kanamycin</th>
<th>Colimycin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M.I.C.</td>
<td>M.B.C.</td>
<td>M.I.C.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22</td>
<td>25-20</td>
<td>2-5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60</td>
<td>6-20</td>
<td>6-20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>3-2</td>
<td>3-3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>10-2</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-5</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0-6-20</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0-6-25</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

TABLE III
RELEVANT DATA IN 25 PATIENTS WITH PYELONEPHRITIS TREATED WITH GENTAMICIN

| Case No. | Diagnosis | Age and Sex | Endogenous Creatinine Clearance (ml./min.) | Infecting Organism | M.I.C. | M.B.C. | Gentamicin | Total Dose (g.) | Long-term Therapy | Follow-up (mth) | Relapse of Bacteriuria 
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>56 M C. calc.</td>
<td>62</td>
<td>Klebsiella 1-25</td>
<td>10</td>
<td>0-8</td>
<td>0-57</td>
<td>S</td>
<td>18</td>
<td>Three days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>69 F C. uroemia</td>
<td>8</td>
<td>Klebsiella 0-3</td>
<td>10</td>
<td>0-42</td>
<td>0-24</td>
<td>F</td>
<td>14</td>
<td>No relapse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>47 F C. calc.</td>
<td>39</td>
<td>Klebsiella 0-6</td>
<td>5-0</td>
<td>0-80</td>
<td>0-44</td>
<td>S</td>
<td>14</td>
<td>Eight mth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>60 F</td>
<td>77</td>
<td>Klebsiella 0-3</td>
<td>5-0</td>
<td>1-20</td>
<td>0-48</td>
<td>E</td>
<td>12</td>
<td>Four mth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>68 F</td>
<td>30</td>
<td>Klebsiella 0-3</td>
<td>2-5</td>
<td>0-85</td>
<td>0-48</td>
<td>E</td>
<td>13</td>
<td>Eight days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>56 F C. calc.</td>
<td>19</td>
<td>Proteus 1-25</td>
<td>10</td>
<td>0-52</td>
<td>0-24</td>
<td>S</td>
<td>13</td>
<td>Two mth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>56 M C. calc.</td>
<td>59</td>
<td>Klebsiella 0-3</td>
<td>10</td>
<td>0-82</td>
<td>0-40</td>
<td>A</td>
<td>12</td>
<td>Three mth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>39 F C. septicaemia</td>
<td>2</td>
<td>Klebsiella 0-3</td>
<td>1-25</td>
<td>1-20</td>
<td>0-25</td>
<td>F</td>
<td>9</td>
<td>No relapse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>59 F C. diab. mell.</td>
<td>22</td>
<td>Klebsiella 0-3</td>
<td>5-0</td>
<td>0-40</td>
<td>0-24</td>
<td>F</td>
<td>9</td>
<td>No relapse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>45 M</td>
<td>32</td>
<td>Klebsiella 0-6</td>
<td>2-5</td>
<td>0-59</td>
<td>0-24</td>
<td>F</td>
<td>9</td>
<td>No relapse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>51 F</td>
<td>19</td>
<td>Klebsiella 0-3</td>
<td>2-5</td>
<td>0-59</td>
<td>0-24</td>
<td>F</td>
<td>9</td>
<td>No relapse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>40 F</td>
<td>31</td>
<td>Klebsiella 0-6</td>
<td>20</td>
<td>0-44</td>
<td>0-16</td>
<td>F</td>
<td>9</td>
<td>No relapse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>44 F C. calc.</td>
<td>59</td>
<td>Klebsiella 0-6</td>
<td>1-25</td>
<td>0-61</td>
<td>0-32</td>
<td>A</td>
<td>8</td>
<td>Three wk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>56 M C. calc.</td>
<td>55</td>
<td>Klebsiella 0-3</td>
<td>5-0</td>
<td>0-82</td>
<td>0-40</td>
<td>S</td>
<td>9</td>
<td>Two mth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>76 M C. calc.</td>
<td>23</td>
<td>Klebsiella 0-6</td>
<td>2-5</td>
<td>0-47</td>
<td>0-24</td>
<td>F</td>
<td>3</td>
<td>Two wk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>32 F C. calc.</td>
<td>125</td>
<td>Prot. mir. 0-6</td>
<td>5-0</td>
<td>0-72</td>
<td>0-32</td>
<td>F</td>
<td>5</td>
<td>Three days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>36 F C. calc.</td>
<td>45</td>
<td>Prot. mir. 0-6</td>
<td>5-0</td>
<td>0-60</td>
<td>0-32</td>
<td>A</td>
<td>5</td>
<td>No relapse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>47 F C. Acute pyelonephritis</td>
<td>46</td>
<td>Klebsiella 1-25</td>
<td>5-0</td>
<td>0-57</td>
<td>0-28</td>
<td>S</td>
<td>1</td>
<td>No relapse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>66 M</td>
<td>33</td>
<td>Klebsiella 0-3</td>
<td>0-6</td>
<td>0-62</td>
<td>0-32</td>
<td>F</td>
<td>5</td>
<td>No relapse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>47 F</td>
<td>42</td>
<td>E. coli 0-6</td>
<td>2-5</td>
<td>0-68</td>
<td>0-32</td>
<td>F</td>
<td>3</td>
<td>Seven days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>60 M C. calc.</td>
<td>109</td>
<td>Klebsiella 0-3</td>
<td>1-25</td>
<td>0-90</td>
<td>0-48</td>
<td>F</td>
<td>2</td>
<td>No relapse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>39 F C. hydronephr.</td>
<td>117</td>
<td>Klebsiella 0-6</td>
<td>0-67</td>
<td>0-32</td>
<td>S</td>
<td>2</td>
<td>No relapse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>52 F C. calc.</td>
<td>50</td>
<td>Prot. mir. 0-6</td>
<td>2-5</td>
<td>1-00</td>
<td>0-36</td>
<td>A</td>
<td>3</td>
<td>Four days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>70 M</td>
<td>10</td>
<td>Klebsiella 0-6</td>
<td>5-0</td>
<td>0-41</td>
<td>0-24</td>
<td>F + A</td>
<td>2</td>
<td>No relapse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>46 F</td>
<td>102</td>
<td>Klebsiella 0-6</td>
<td>0-86</td>
<td>0-40</td>
<td>S</td>
<td>1</td>
<td>No relapse</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 All patients except no. 18 had chronic pyelonephritis. In this column the complications are listed. C. calc. = calculus formation in one or both kidneys.
2 M.I.C. = minimum inhibiting concentration of gentamicin
3 M.B.C. = minimum bactericidal concentration of gentamicin
4 S = sulfonamides
5 F = nitrofurantoin
6 A = acidifying agents
7 E = erythromycin
8 Period before positive urine cultures were again detected.

for the activity of gentamicin. The concentration of gentamicin required to inhibit or kill the Klebsiella and Pseudomonas strains at pH 5 was 15 to 30 times higher than at pH 8, and 30 times higher to inhibit the Proteus mirabilis strains at pH 6 than at pH 8.

CONCENTRATION OF GENTAMICIN IN SERUM The 25 patients (Table III) were divided into three groups with regard to kidney function measured by endogenous creatinine clearance. Group I comprised patients with an endogenous creatinine clearance greater than 60 ml./min., representing a normal or moderately reduced kidney function. Patients in group II had clearance values of 20 to 60 ml./min.,
representing a marked reduction of kidney function (the majority of patients were within this group). Group III represented patients with serious kidney insufficiency having an endogenous creatinine clearance of less than 20 ml./min. The dose of gentamicin was chosen individually with regard to the patient's kidney function. Patients in group I received 0-7-1-2 mg. gentamicin/kg. bodyweight per day, patients in group II received 0-4-1-0 mg., and patients in group III received 0-4-0-5 mg. with one exception (case 8). The gentamicin dose was doubled during the first day of treatment.

The highest concentration in serum was obtained in the one-hour specimens, and the maximum concentration found was 6-4 μg./ml. (case 24). However, the majority of the one-hour values were approximately 2-3 μg./ml. (Fig. 2). Four hours after injection the patients in group III had the highest values of 3-8 and 2-9 μg./ml. while the patients in group I with the best kidney function reached a value of only 1-5 μg./ml. in spite of a larger dose. The same tendency was apparent in the eight- and 12-hour values, the maximum concentration measured was 3-6 and 2-5 μg./ml., respectively. With the majority of patients the eight- and 12-hour values of gentamicin were very low, approximately 1 μg./ml. serum.

**CONCENTRATION OF GENTAMICIN IN URINE** In most patients the maximum concentration of biologically...
active gentamicin in the urine was reached within one hour (Fig. 3). In group I the maximum value measured after one hour was 72 μg./ml., and the lowest value was 19 μg./ml. Four hours after injection the concentration varied between 24 and 32 μg./ml., after eight hours between 8 and 29 μg./ml., and after 12 hours between 4 and 26 μg./ml.

In group II a maximum value of 73 μg./ml. was reached after one hour; the lowest concentration was 14 μg./ml. After four hours the values varied between 5 and 66 μg./ml., after eight hours between 5 and 36 μg./ml., and after 12 hours between 1 and 36 μg./ml.

In group III the highest value of 46 μg./ml. was measured two hours after injection; the one-hour value varied between 7 and 14 μg./ml. After four hours the concentration was between 6 and 21 μg./ml. The corresponding value after eight hours was 6 and 20 μg./ml. and after 12 hours 4 and 15 μg./ml.

EXCRETION OF GENTAMICIN IN URINE RELATED TO KIDNEY FUNCTION The concentration of an antibiotic in the urine is, in addition to other factors, influenced by the volume of urine obtained from the patient, which therefore must be taken into consideration when estimating the amount of the given dose which is excreted in the urine. To eliminate this source of error the quantity of the given dose of gentamicin excreted in active form in the urine was plotted on the ordinate in Fig. 4 and the patient’s endogenous creatinine clearance on the abscissa. Between 43% and 98% of the given dose was excreted in the urine in the active form. In group I the excretion varied between 62% and 98%, in group II between 43% and 82%, and in group III between 48% and 77%.

CLINICAL RESULTS In 11 patients the pyelonephritis was complicated by either unilateral or bilateral calculus formation. Some of the relevant information concerning the patients is collected in Table III.

All the patients had negative urine cultures during treatment. Twelve of the 24 patients had negative urine cultures one to 14 months after the gentamicin treatment was stopped. The observation time for five of these patients (cases 18, 21, 22, 24, and 25) after the termination of treatment was only one to two months; the remaining seven patients had observation times exceeding five months. In one of these seven patients (case 3) positive urine cultures were found again after eight months; the patient’s original Klebsiella strain was replaced by an E. coli strain.

Twelve of the patients relapsed. The period of time before positive urine cultures were found again varied between two days and four months. In nine
of the patients the relapse was caused by the original strain, presumed only by a comparison of the anti-
biograms of the strains belonging to the same species isolated before gentamicin treatment and after
relapse. In one patient (case 5) the original Klebsiella strain was replaced by a mixed flora of E. coli and
Streptococcus faecalis; and in another patient (case 11) the Klebsiella strain was replaced by an
Alkaligenes faecalis strain.

According to the in vitro test the average serum levels after one hour did not exceed the concentration
necessary to inhibit the isolated bacteria at pH 7-4. The gentamicin concentration in the urine, however,
stayed above the M.I.C. value in all the patients during the entire period of treatment. The concentra-
tion exceeded the corresponding M.B.C. value in 17 of the 19 patients where the M.I.C. and M.B.C.
values had been determined. With the two patients (cases 2 and 12) in whom the M.B.C. concentration
in the urine was not reached the results of treatment were good nevertheless, since both patients still had
negative urine cultures after an observation time of 14 and nine months, respectively.

Case 8, who was treated by haemodialysis, developed a Klebsiella sepsis. Gentamicin treatment
was initiated in a dose high in proportion to the kidney function: 2-4 mg./kg. bodyweight per day for
the first day, then 1-2 mg./kg. bodyweight per day during the next three days. The general condition
of the patient improved dramatically by the first day and the blood cultures were negative.

DISCUSSION

The in vitro investigations showed that gentamicin had a broad spectrum against the majority of Gram-
negative rods and Staphylococcus aureus. The average M.I.C. at pH 8-0 for the 338 cultures
investigated (Table I) was between 0-3 and 2-2
μg./ml.; none required more than 40 μg. gentamicin/mL. The concentration necessary for bactericidal
effects was about two to four times higher than that
required for the inhibition of bacterial growth. Against E. coli and Klebsiella, gentamicin showed
nearly the same in vitro activity as kanamycin and colistin (Table II). A comparison of the activity
of these three antibiotics against Proteus species and
Pseudomonas aeruginosa indicated that gentamicin
was an effective agent against both species, whereas
kanamycin was effective only against Proteus species
and colistin only against Pseudomonas. The results
obtained from the in vitro tests of the activity of
gentamicin are in agreement with earlier reports
(Black et al., 1963; Klein et al., 1964; Rubenis
et al., 1963; Weinstein et al., 1963a, b).

The in vitro activity of gentamicin was greater in an
alkaline than in an acid medium (Fig. 1). The
concentration required for a bacteriostatic effect at
pH 8 was from eight to 30 times less than that
required at pH values from 5 to 7. Similar results
were obtained by Rubenis et al. (1963). It may be
concluded from these facts that the treatment of
urinary tract infections with gentamicin should be
carried out with patients having an alkaline urine.

To eliminate the risk of toxic side effects, the
dosage of gentamicin was determined individually for
each patient with regard to kidney function (Table
III). The serum concentration did not exceed 6-3
μg./ml. in any patient even with the doubled dose of
gentamicin (Fig. 2). After 12 hours only 0-1 to
2.5 μg. gentamicin/ml. serum was found. The
maximum urine concentrations of gentamicin varied
between 21 and 72 μg./ml. urine (Fig. 3). The con-
centration decreased relatively fast and after 12
hours between 4 and 26 μg./ml. was found.

The excretion of active gentamicin in the urine
varied between 43% and 98% of the given dose
(Fig. 4). The highest excretion was reached in
patients with normal kidney function and the lowest
in a patient with renal insufficiency. No definite
correlation could be found in this material between
the patient's kidney function and the quantity of
active gentamicin which was excreted. Bulger et al.
(1963) reported 30% to 96% excretion of gentamicin
in the urine. The high excretion of gentamicin in the
urine also in patients with reduced renal function
is of great importance in the treatment of patients
with chronic urinary tract infections.

The first urine culture after initiation of the therapy
was negative in all patients and 12 of the 24 patients
still have negative cultures one to 14 months later
(Table III). The cause of the relapse in 12 of the
patients may be that this material consisted of patients
with chronic pyelonephritis often complicated by, e.g.,
calculus (Table III). Before gentamicin therapy was
initiated all the patients had been treated with a
number of antibiotics and chemotherapeutics with-
out lasting effects. Chronic urinary tract infections
often recur after cessation of treatment, and as a rule
only about 20% are cured (Kass, 1955; Grieble and
Jackson, 1958; Turck, Browder, Lindemeyer, Brown,
Anderson, and Petersdorf, 1962). In the report given
more than 50% of the patients were cured. This may
de be due to the fact that on the sixth day of gentamicin
therapy the patients were put on long-term treatment
with either sulphonamides, nitrofurantoin, or
acidifying agents (Table III).

No significant development of resistance to
gentamicin of the bacteria which caused a relapse
could be established. This observation differs from
the experiences reported by Jao and Jackson (1963)
who found a tendency towards increased resistance in vitro of the relapsing strain against gentamicin.

Serious toxic side effects in the form of irreversible labyrinth damage from gentamicin treatment were reported by Jao and Jackson (1963) and Bulger et al. (1963). Eleven of the patients in our study were carefully observed for ototoxic effects. One of them developed reversible labyrinthine damage after gentamicin treatment; this patient had a chronic pyelonephritis with an endogenous creatinine clearance of 17 ml./min. The dose of gentamicin was low, i.e., 0·4 mg./kg. bodyweight per day. No other toxic manifestations have been observed.

REFERENCES