The electrified catheter
Role in sterilizing urine and decreasing bacteriuria

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Summary. A catheter was designed to decrease the incidence of catheter-induced urinary infections. A randomized, controlled study was performed to assess its safety and efficacy. The study comprised 24 patients subjected to hemorrhoidectomy. The criteria for entry were a preoperative urinary pathogen count below 10^5 colony-forming units/ml urine as well as postoperative urinary retention that did not respond to conservative measures. The 24 patients were randomly assigned to treatment using a Nelaton catheter in 12 patients and an electrified catheter in the remaining 12. The catheters were left in place for 3 days, during which cephalosporin was given parenterally. The electrified catheter (EC) carried two silver-silver chloride electrodes. During the 3 days of catheterization and for 4 days thereafter, daily urine samples were cultured. The criterion for catheter-induced urinary infection was a pathogen count above 10^5 colony-forming units/ml urine. No complication was encountered from catheterization. Electrodes were not broken. A bacterial count above 10^5 colony-forming units was found in 7 of 12 patients in the Nelaton catheter group, and a count below 10^5 units was determined in the 12 patients in the EC group. The study demonstrated that the EC can decrease the incidence of catheter-induced urinary infections. The EC is safe, cost-effective, and without complications.

The most common site of hospital-acquired infections is the urinary tract, where approximately 40% of all such infections occur [26]. The main predisposing factor for these infections is urethral instrumentation, including catheterization [11, 22]; 10% - 15% of all hospitalized patients have indwelling catheters [8, 26].

Catheter-associated infections cause significant morbidity [7]. The incidence of urinary infections after a single in-and-out urethral catheterization ranges from 1% in healthy young college women to 20% in hospitalized women on a medical ward [24]. In patients with indwelling catheters, the incidence is directly related to the duration of catheterization and to whether open or closed drainage systems are used [10, 13].

Antibacterial solutions left in the bladder after catheterization have minimized the incidence of catheter-induced urinary infections [1, 15]. The closed-catheter drainage system has also reduced the incidence of infection from about 90% at 4 days to 30% - 40% [22]. Other effective measures include periodic instillation of chemicals into the collecting bag [3, 13]. Prophylactic antibiotic irrigations of closed-catheter systems have thus far not decreased the incidence of infection but rather have made organisms more resistant [6]. To date, neither an antibiotic nor a method has been effective enough to eliminate catheter-associated infections [22]. Furthermore, the catheter that does not effect urinary tract infection does not yet exist.

The lethal effect of electric fields [14, 16, 17, 20] and iontophoresis [4, 5, 23] on bacteria and yeasts has been demonstrated by many investigators. Recent studies have shown that a reduction in bacterial growth and the destruction of bacteria are possible with a certain electrode combination [4, 5]. An electric field causes a bactericidal effect by damaging the cell membrane of the organisms, resulting in leakage of the intracellular contents and a loss of both the motility and the synthesis of enzyme β-galactosidase [14, 16, 17, 20]. It has been proposed that the electric field causes an irreversible loss of the membrane's function as the semipermeable barrier between the bacterial cell and its environment and that this action is the cause of death. The killing of the organisms was not due to heating or electrolysis and was independent of the current density and energy input [14, 16, 17, 20]; it was dependent on the field strength and the total time of the treatment.

Recently, a randomized controlled study involving 24 patients [21] showed that an electrified drain, applied to drain the surgical wounds of 12 patients, had a lethal ef-
fect on the bacterial count as compared with the effect on 12 patients whose wounds were drained with similar but nonelectrified drains; 4 of the latter 12 patients had high bacterial counts.

In view of these studies and considering the need for long-term catheterization without the risk of urinary tract infection, a specially prepared catheter is described that seems to satisfy these demands.

**Subjects and methods**

**Subjects**

A prospectively randomized, controlled study was performed to assess the safety and efficacy of an electrified versus a nonelectrified catheter. The study comprised 24 subjects who gave their informed consent to participate. They were selected from 73 patients in whom hemorrhoidectomy was to be done and who met the criteria for entry comprising a preoperative urinary pathogen count of less than $10^5$ colony-forming units/ml urine as well as postoperative urinary retention that failed to respond to conservative measures. Their age ranged from 45 to 66 years (mean, 56.6 ± 9.2 years). Of the 24 patients, 18 were men and 6 were women. The small number of women in the study reflected the criterion for a catheter-induced urinary infection is less common in women than in men. None of the subjects had a urinary complaint at the time of presentation or in the past. All 24 patients complained of third-degree hemorrhoids. The physical examination was normal. A mid-stream voiding culture was done preoperatively. The women voided in the lithotomy position and the nurse collected a midstream specimen after the perineum had first been cleaned with soap and water to prevent contamination [25].

Hemoglobin levels, complete blood counts, liver-function tests, and serum creatinine and electrolyte values were normal. Blood cultures were free of organisms. Urinary retention occurred in the afternoon of the day of hemorrhoidectomy. An indwelling catheter was applied after conservative measures of relieving the urinary retention had failed. Patients were randomly assigned to treatment in consecutive order. Of the 24 patients, 12 (9 men and 3 women) were in the electrified-catheter group and the other 12 (9 men and 3 women) were in the conventional-catheter group. The catheter was left in place for 72 h in both groups. During this period, a third-generation cephalosporin (Cefotaxime) was given parenterally; no antibiotic was given pre- or perioperatively. Cefotaxime covers a wide range of organisms and we commonly use it postoperatively.

**Catheters**

The electrified catheter consisted of a Nelaton catheter that carried two fine silver-silver chloride electrodes measuring 0.25 mm in diameter and placed 4 mm apart (Fig. 1). The distal parts of the electrodes were placed in the side opening situated close to the end of the catheter. The electrodes were connected to a small 9-V battery that was fixed to the abdomen by an adhesive strip. The silver-silver chloride electrodes were chosen because they did not break in urine at the amperage used. We tried stainless-steel and copper electrodes, but they broke. Amperage above that used may injure the vesical tissues or break the electrodes.

The catheters were removed after 72 h and were examined for any changes such as electrode breakage or alterations in the catheter material. During this period and 4 days thereafter, a urine sample was taken daily for culturing. During the postoperative period, clinical assessment was performed. The preoperative laboratory tests were repeated 1 week after the operation. The criterion for a catheter-induced urinary infection was a pathogen count of more than $10^5$ colony-forming units/ml urine in all urine cultures obtained within the 3 days of catheterization and the following 4 days.

**Statistical analysis**

The results were analyzed statistically using Student's t-test.

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**Results**

We did not encounter complications from catheter application in either group of patients. Examination of the catheter after its removal from the urinary bladder showed no changes. The silver-silver chloride electrodes were intact; none had been damaged during the 72 h of indwelling in the urinary bladder. A bacterial count above $10^5$ colony-forming units/ml urine was found postoperatively in 7 of the 12 patients drained with the conventional catheter (CC). The day on which the high count was detected as well as the type of organism involved are specified in Table 1.

The organisms encountered were *Escherichia coli*, *Proteus mirabilis*, *Klebsiella pneumoniae*, and *Staphylococcus epidermidis*. A high pathogen count started on the 2nd postoperative day in 2 patients, on the 3rd day in 3 subjects, and on the 4th day in 2 patients. The count of the 7 patients remained high through the last day of culturing. No clinical manifestation of infection was encountered. We considered as fever an oral temperature of 38°C or higher. On the 7th postoperative day, culture and sensitivity tests on the urine of the 7 patients with high pathogen counts were performed, and the appropriate antibiotic was given. The 12 patients with an EC had a bacterial count of less than $10^5$ colony-forming units/ml urine.

**Table 1. Clinical data and pathogens detected in urine in the conventional catheter (count, > $10^5$ colony-forming units/ml urine)**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Day number (postoperative)</th>
<th>Organism</th>
<th>Blood culture</th>
<th>Fever</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td><em>Escherichia coli</em></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td><em>Proteus mirabilis</em></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td><em>Escherichia coli</em></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td><em>Escherichia coli</em></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td><em>Staphylococcus epidermidis</em></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td><em>Escherichia coli</em></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td><em>Klebsiella pneumoniae</em></td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>