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The Bacteriuria in Long-stay Geriatric Inpatients with an Indwelling Catheter

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A copper-coated urinary catheter

ABSTRACT

Long-stay geriatric inpatients with an indwelling urinary catheter are harassed by foul-smelling urine, urine leakage, and frequent catheter blockages. It is reasonable to assume that catheter-induced bacteriuria plays an essential role in the catheter problems of these patients. An attempt to reduce the catheter-induced bacteriuria was made by the introduction of a latex catheter coated with a layer of copper metal. The antibacterial properties of the copper-coated catheters studied were, however, insufficient, probably due to too small amount of copper on the catheter. The copper layer was dissolved from the catheter in a few days. The effective time of copper treatment thus became too short.

INTRODUCTION

All patients with an indwelling catheter develop bacteriuria within 7-10 days(18). The bacteria from the intestinal tract appear to invade the urinary tract through the mucus layer between the urethral mucosa and the exterior surface of the catheter(7,10). When the bladder urine is infected, the milieu favours rapid growth of the bacteria. Back-flow in some catheter systems may make the situation still worse(Fig. 1).

Most catheters on the market have their top holes above the balloon(Fig.1). A few millilitres of residual urine thus collects below the level of the holes. It is reasonable to assume that this residual urine provides the source of persistent bacteriuria. The final result is a massive bacteriuria, in the range of 1-500 x 10^5 bacteria per ml urine. Some bacterial strains, especially Proteus, produce urease, which splits urea into ammonia, resulting in an alkalization of the urine. The increased pH favours the precipitation of most urine salts with encrustation and blockage of the catheter, distress to the patient, and change of the catheter(2,3,14,15,17).

It is desirable that the nursing of patients with an indwelling catheter is improved by cutting off the route of bacterial invasion, reduction of residual urine towards zero, eradication of bacterial strains already present, and widening of the catheter lumen. The present study reports an attempt to make the indwelling catheters bactericidal in order to cut off the route of bacterial invasion into the bladder. Copper metal was chosen to be precipi-

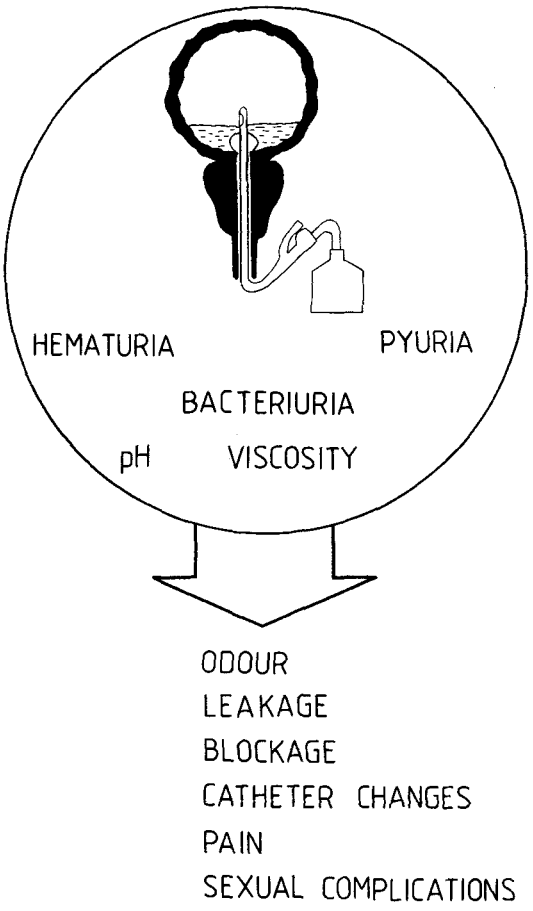

Figure 1
The indwelling catheter system. The indwelling catheter provides a foreign body in the urinary tract. Bacteria invade the bladder along the mucus layer between the urethral mucosa and the catheter. Persistent bacteriuria is due to continuous re-infection along the catheter and a bacterial reservoir in the residual urine below the top holes of the catheter.

tated as a bactericidal coat on the external surface of the latex catheters.

MATERIAL AND METHODS

Patients

Twenty-four long-stay inpatients from four somatogeriatric wards at Saint Lars Hospital, Lund, entered the study. They suffered from traumatic(one), presenile, senile or multi-infarction dementia. Four patients died in the pre-trial control period. One patient was excluded due to non-adherence to the protocol. The median age of the remaining 19 patients, 2 men and 17 women, was 85 years, interquartile range 79-89, extreme values 47-99. All patients had indwelling catheters for several months. All patients selected for the study had catheter problems, manifested by odour, leakage, and frequent catheter changes due to blockage or wrenching.

Design

The clinical trial of the copper-coated catheter was designed as an open study with a pre-trial control period for 3 months, a test period of the copper-coated catheter for 2 months, and a post-treatment control period for 2 months.

Catheter regimen

Catheter treatment and the fluid regimen were standardized within the department by a group decision of the nurses. The fluid intake was set at 1,800 ml/day. All patients had a closed drainage system with a back-flow valve and continuous flow of urine into a bag. Only catheters Nos. 12 and 14 Charrière were used (silicone-coated, two-way Foley balloon catheters, Folimatic^{R}, Euromedical Industries Ltd, Rustington, West Sussex, England). The copper-coated latex catheter of the test period is specified below. In the post-treatment control period, homogeneous silicone catheters were tried for some patients with the most urgent catheter problems (Bardex^{R}, C.R. Bard International Ltd, Pennywell Industrial Estate, Sunderland, England). Prior to catheterization, the periurethral area was cleansed with chlorhexidine solution, 0.05%, isotonic. Catheters were routinely changed after 30 days (two exceptions see Table 2) or when blocked or wrenched. Catheter rinsing was performed during impending blockage. As clinical parameter of catheter function catheter life was chosen, i.e. the time in days between two catheter changes. The nurses also noted clinical signs of local irritation, discharge from the urethra, the odour and appearance of the urine, and possible inconvenience to the patients.

Copper-coated catheters

Latex catheters without silicone coating were provided by Warne Surgical Products Ltd, Southway, Andover, Hampshire, Great Britain. These catheters were coated with pure coppear metal by precipitation, 300 µg/cm. The copper-coated latex catheters were then sterilized by means of ethylene oxide.

Analysis of copper content in used catheters

Fifteen consecutive copper-coated catheters, used for periods of varying length, were selected for the analysis (Fig. 3). The catheters were cut 5 cm and 15 cm from the distal tip. The 10 cm long segment was reduced to ashes, the ash was made red-hot for 15 minutes at +750^{o} C, the remnant was dissolved in 3 ml 10% H_2SO_4, and the copper content was determined by colorimetry.

Bacteriological examination

Bacterial culture was performed every week, starting the week before the patients received the copper-coated catheter. Bacteria were identified by conventional laboratory methods. Quantification was performed as plate counts on two dilutions from each sample.

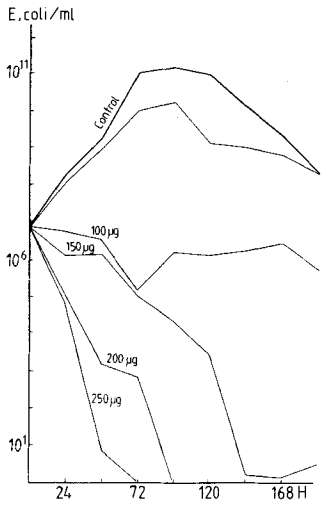

Fig. 2 The bactericidal activity of copper acetate (µg/ml) against E. coli. Soya broth 1%. Incubation at +37° C.

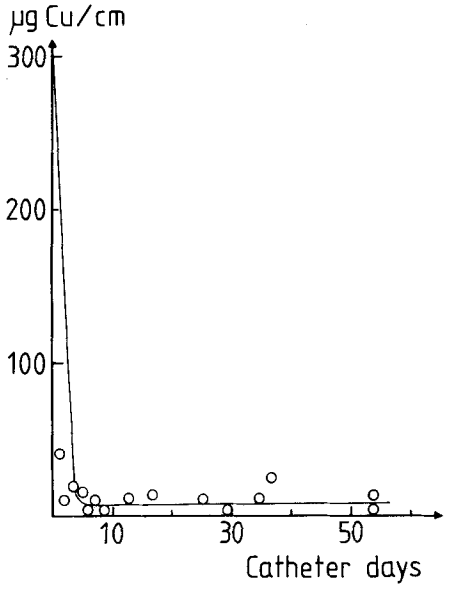

Fig. 3 The dissolution of copper acetate from latex catheters. Analysis of 15 catheters used for periods of varying length (catheter days). It is evident that the superficial copper acetate was dissolved and disappeared within the first days of catheter treatment.

Permanent quantitative urine sediment

A permanent quantitative urine sediment based on glutaraldehyde fixation and cytocentrifuge preparation was described in a previous study (16). The urine was collected in a sterile plastic tube and thoroughly shaken. Then 0.1 ml urine was pipetted into a glass tube with 0.9 ml 2% glutaraldehyde in 0.134 M phosphate buffer, pH 7.4. Slide preparations were obtained by means of a cytocentrifuge (Shandon-Elliot Cytospin^{R}), 1000 rpm, 10 minutes, 0.2 ml glutaraldehyde-suspended urine. The preparations were contrasted by the May-Grünwald-Giemsa stain. The cells and bacteria were counted in a Zeiss Photomicroscope at x1,000 magnification, 5 random visual fields, the median of which was converted to cells/µl urine.

Statistics

The Wilcoxon matched-pairs signed-ranks test was calculated according to Siegel (21), two-tailed probabilities.

RESULTS

Pre-trial experiments suggested that copper acetate, 250 µg/ml, had a bactericidal effect (Fig. 2). Weaker concentrations had little or no bacterio-

Table 1 The pyuria, haematuria and bacteriuria in 18 patients with indwelling catheters in the pre-trial control period(C) with silicone-coated latex catheters and in the test period(T) with copper-coated latex catheters. Median values in cells per µl urine from three days in each period. All figures reduced to whole numbers, which explains some minor inconsistences in D(=C-T). Quantification by means of the glutaraldehyde-cytocentrifuge sediment. It is evident from the differences(D) between the values obtained in the control period and in the test period that no favourable effect could be demonstrated during treatment with copper-coated catheters under the conditions prevailing.

	Leukocytes			Erythrocytes			Bacteria		
Pat	C	T	D	C	T	D	C	T	D
1	139	76	63	101	20	81	13680	4650	9120
2	90	6	84	10	275	-265	4560	9120	-4560
3	115	213	-98	6	6	0	1368	4560	-3192
4	912	42	870	0	0	0	4560	5472	-912
5	88	61	26	5	16	-10	3648	10032	-6384
6	474	238	236	51	10	41	9120	1915	7204
7	39	17	22	4	2	2	5472	2736	2736
8	167	2736	-2569	4	27	-24	2736	13680	-10944
9	88	78	10	2	39	-37	27360	27360	0
10	59	37	22	46	4	42	2918	17	2901
11	30	113	-83	0	5	-5	1368	638	1302
12	365	1905	-1550	0	91	-91	13680	4560	912
13	40	370	-330	125	46	79	4560	11856	-7296
14	17	184	-166	0	8	-8	912	638	274
15	309	730	-420	59	182	-123	6840	5016	1824
16	294	88	206	10	5	5	365	1368	-1003
17	275	365	-89	27	0	27	18240	7296	10944
18	42	64	-22	18	2	16	1824	730	1094

static effect.

All patients had massive bacteriuria prior to the test period, as evaluated by quantitative bacterial culture. The bacteriuria persisted during the first three weeks of treatment with the copper-coated catheter. It was thus decided to eradicate the urine bacteria by appropriate antimicrobial therapy during the fourth test week. Sixteen patients delivered urine samples for bacteriological examination two weeks later(three drop-outs, one dead, two without catheters due to frequent wrenching). They all had re-assumed bacteriuria.

It still seemed reasonable to assume that a closer examination might reveal a reduction of bacteriuria, pyuria and haematuria during the test period. Eighteen patients had delivered permanent quantified urine sediments in the pre-trial control period and in the first three test weeks. It is, however, evident from Table 1 that the bacteria, leukocytes and erythrocytes were not reduced, when the silicone-coated latex catheters were replaced by copper-coated latex catheters.

In spite of the negative laboratory tests, the copper-coated catheter might have clinical advantages. The catheter life, i.e. the interval in days between two catheter changes, was chosen as parameter of the clinical properties of the copper-coated catheter. It is, however, evident from Table 2 that catheter life was not prolonged by copper coating. In addition, the reports of the

Table 2 Catheter life of 19 patients during pre-trial control period with silicone-coated latex catheters (Pre-C), during test period (T) with copper-coated latex catheters, and during post-trial control period (Post-C) with silicone-coated latex catheters or silicone catheters. Catheter life is interval in days from one catheter change to next catheter change. In the pre-trial control period, the median life of the 5 catheters preceding the test period is given. In the test period and in the post-trial control period, the median life of all catheters used is given. It is evident from the figures that treatment with a copper-coated latex catheter did not significantly increase the catheter life.
Pre-C: pre-trial control period.
T: test period
Post-C: post-trial control period.
Q_1-Q_3: interquartile range.

Pat	Pre-C	T	Post-C
1	20	73	3
2	8	4	6
3	17	9	10
4	10	12	13
5	10	11	3
6	25	25	16
7	8	13	15
8	10	20	64
9	12	13	12
10	3	3	3
11	9	33	9
12	30	31	31
13	13	17	31
14	4	7	2
15	6	3	9
16	8	2	1
17	22	8	3
18	4	3	3
19	4	12	10
Median	10	12	9
Q_1-Q_3	6-17	11-20	3-15
Range	3-30	2-73	1-64

nurses were not in favour of the copper-coated catheter, which was thought to induce local irritation and urethral discharge more than conventional silicone-coated latex catheters. There was, however, no increase of pyuria or haematuria during the test period (Table 1).

After usage, the copper-coated catheters were light yellow-brown below the balloon, darkening to dark brown on the distal tip out-side the urethra. This colour change was suspected to indicate a dissolution of copper during usage, most marked in the balloon end. The copper content was analysed 5-15 cm from the distal tip. The analysis showed that most of the copper-coating was dissolved within the first days (Fig. 3).

It is concluded that the present coating of latex catheters with copper metal did not confer bactericidal properties to the catheters, probably due to inadequate concentrations of copper in the mucus layer around the catheter, and rapid dissolution of the copper coating.

DISCUSSION

The present experiments failed to produce an indwelling catheter with bactericidal or bacteria-reducing properties in clinical practice (cf. Tables 1,2). This failure was due to a comparably weak antibacterial activity of copper and rapid dissolution and disappearance of the copper from the exterior surface of the catheter (Figs. 2,3).

The care-workers felt that the copper-coated catheter was more irritating to the urethral mucosa than silicone-coated latex catheters. It is reasonable

to assume that an additional irritative effect of clinical significance would induce an increased pyuria and an increased microscopic haematuria. Pyuria and haematuria were, however, not influenced by the change from silicone-coated catheters to copper-coated latex catheters(Table 1).

The idea to reduce catheter complications by making the exterior surface of the catheter bactericidal is not new. Butler & Kunin tried to lubricate and impregnate the exterior surface of the catheter with polymyxine B(8). The antibiotic disappeared, however, from the catheter in a few hours, and this attempt to reduce the catheter-induced bacteriuria failed. Chlorhexidine-containing cream is now often used as an antimicrobial barrier to ascending urinary tract infection in patients with indwelling urinary catheters(19). The effect seems, however, to be limited.

Not even the idea to make the catheters bactericidal or bacteriostatic by means of physical agents is new. During the patent investigations of the present idea, we found a Japanese patent claim focussed on the use of gold, silver and copper as antimicrobial coating of catheters(1). The bactericidal efficiency of the Akiyama catheters is, however, unknown to us.

The bacteriuria of patients with indwelling catheters is distinguished by an order of magnitude greater than the bacteriuria found in non-catheterized patients, multiple bacterial strains, spontaneous changes of the bacterial flora, and differences of bacterial flora at different levels of the urinary tract(2,3,5,6,14,17). The massive multi-strain bacterial invasion into the bladder favours the selection of antibiotic-resistant strains during anti-microbial therapy(cf. 14,17). It seems unlikely that antibiotics will provide a solution to the problem of bacteriuria in patients with an indwelling catheter. Instead, it is reasonable to assume that the solution of the problem of catheter-induced bacteriuria will be found among physical agents, physical factors, and physical constructions(cf.9).

It is clarifying to list the desired properties of an ideal urinary catheter. It should be non-irritating. Its surface should be smooth, refusing encrustation and bacteria, and permanently bactericidal or at least bacterio-static. The bactericidal properties of the catheter should preferably be conferred to the mucous layer surrounding the catheter in the urethra. The drainage system of the catheter should reduce the residual urine in the bladd-er towards zero. The wall of the catheter should be thin, increasing the lumen but not the external diameter of the catheter. A valve should prevent back-flow of infected urine into the bladder(cf.4,8,11,12,13,19,20).

Some of the listed demands on an indwelling catheter are already met. Closed catheter-bag systems with a back-flow valve are common in geriatric wards in Sweden. The thin catheter wall is provided by catheters of homogen-eous silicone. Another interesting material is the chlorsulphonated poly-

ethene hypalone. It has, however, to our knowledge not yet been utilized for the production of urinary catheters. A few catheters on the Swedish market have their drainage holes below the balloon. This re-location is thought to eliminate the residual urine. It is, however, not known by us whether this theoretical improvement results in a corresponding practical improvement.

The problem of making the catheter bactericidal and yet non-irritating remains. The permanent bacteriuria of patients with an indwelling catheter provides extreme test conditions for a catheter with bactericidal properties. The failure of the present copper-coated catheters in the present patients does not exclude the possibility that later modifications of copper-coated catheters will be found to be valuable in e.g. short-term catheterization.

The indwelling catheter forms a complex entity with the lower urinary tract. It is difficult to evaluate a theoretical improvement of any one detail. It should be emphasized that the present failure to construct a bactericidal copper-coated catheter does not imply that the problem is non-soluble; the copper content can be increased, the copper dissolution can be slowed down, the possibly irritating surface of metallic copper can be veiled. Such experiments are in progress. It is, however, reasonable to assume that quantitative bacterial cultures, quantitative urine sediments, and measurement of catheter life will provide the cornerstone parameters in the clinical evaluation of new catheters.

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