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Urinary pH and the Indwelling Catheter

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ABSTRACT

The pH of the urine within a blocked indwelling catheter was significantly higher than the pH of the first urine portion from the new catheter. This observation suggests that the urinary pH was changed in an alkaline direction within the indwelling catheter, probably due to the production of ammonia induced by urease from Proteus strains. This pH gradient could only be demonstrated under conditions where the circadian pH variations of the urine within the individual could be neglected.

INTRODUCTION

Patients with dementia often develop urinary incontinence, which sometimes has to be treated with indwelling catheters(3). Catheterized patients always develop bacteriuria, which leads to cloudy urine, odour, catheter blockage and urine leakage(2). The frequent catheter blockages are, at least in part, thought to be due to the following mechanisms:

1. Urease is produced from some bacteria strains, especially Proteus, with formation of ammonia from urea(1,4,7).
2. The ammonia-induced alkalization of the urine promotes the precipitation of salts on the catheter, a foreign body in the urinary tract(cf.7).

Catheter encrustation may thus be regarded as a model for stone formation in the urinary tract(cf. 1,4).

Some clinical observations made us suspect that the catheter encrustations affect the urinary pH. During removal of blocked catheters, the smell of ammonia from the encrustated catheter irritated the nose and the eyes. The bulk of precipitated salts on the blocked catheter was localized to the proximal part of the catheter. It was noted by some nurses that the longer the catheter had been in use, the higher the urine pH. The aim of the present study was to elucidate the complicated interrelation between catheter life, i.e. the interval between two catheter changes, urinary bacteriology and urinary pH in patients with dementia and indwelling catheters.

MATERIAL AND METHODS

The patients were 16 long-stay inpatients at the somatogeriatric wards of Saint Lars Hospital with varying degrees of dementia, high-degree urinary incontinence and indwelling catheters(Table 1). One of these patients drew out all her catheters during the period of study(Table 2, Fig. 1). The dementia was of the senile or multi-infarction type in most patients. A few patients with presenile dementia of the Alzheimer or Pick type were also included. One patient, aged 46, suffered from post-traumatic dementia. The desired catheter life of the catheters of the type used was approximately 30 days. The studied patients had short catheter lives due to catheter blockage or to the patient wrenching the catheter out(cf. Table 1).

Table 1. The ages, weights and catheter lives of the 16 patients studied, 14 women and 2 men. Q_1-Q_3: interquartile range.

	Age(years)	Weight(kg)	Catheter life(days)
Median	84	52	11
Q_1-Q_3	79-88	47-58	4-16
Range	46-98	38-75	1-21

Table 2. Paired comparisons(n=19) of the pH in the urine of the distal part of a blocked catheter and in the first urine from the new catheter of 16 patients. The pH difference was highly significant($p<0.001$), as evaluated by the Wilcoxon matched-pairs signed-ranks test.

	pH blocked catheter	pH new catheter
Median	8.4	6.8
Q_1-Q_3	7.4 - 8.9	6.5 - 7.0
Range	6.5 - 10.0	5.3 - 7.9

The fluid intake of the patients, the catheterization, the nursing and the urine sampling were standardized as described in a previous study(9). The urinary pH was measured with an indicator strip(Spezialindikator Merck, Darmstadt, FRG, Tables 2,3) or with a digital pH-meter CG 818, reproducibility ± 0.01(Schott Geräte, Hofheim a.Ts., FRG, Tables 4,5). All patients had a closed drainage system with continuous flow of the urine into a bag with backflow valve. Latex catheters No. 12 and 14 Charrière(silicone-treated two-way Foley balloon catheters, Folimatic[R], Euromedical Industries Ltd., Rustington, West Sussex, England) were used in the initial studies(Tables 2,3). In an attempt to reduce the catheter complications, the latex catheters were replaced by silicone catheters(silicone Foley catheter Dover[R], J.G. Franklin & Sons Ltd., High Wycombe, England). The pH of the bag urine and of the catheter urine were checked by the pH-meter 2-3 weeks later(Tables 4,5).

Table 3. Paired comparisons(n=15) of the pH of the urine collected in the bag and the pH of the urine collected directly from the catheter and intraindividual differences between these pH values. 15 patients with latex catheters were studied. The pH was measured with indicator strips. The pH difference between bag urine and catheter urine was not significant, as evaluated by the Wilcoxon matched-pairs signed-ranks test(p=0.042).

	pH of the urine from the bag	pH of the urine from the catheter	Intraindividual differences in pH
Median	7.4	6.8	0
Q_1-Q_3	6.5 - 7.8	6.5 - 7.8	-0.4 - +0.9
Range	5.7 - 8.9	5.3 - 9.5	-1.3 - +2.3

Table 4. Paired comparisons(n=12) of the pH of the urine collected in the bag and the urine collected directly from the catheter and intraindividual differences between these pH values. 12 patients with silicone catheters were studied. The pH was measured with a pH-meter. The pH differences were not significant, as evaluated by the Wilcoxon matched-pairs signed-ranks test(p=0.172).

	pH of the urine from the bag	pH of the urine from the catheter	Intraindividual differences in pH
Median	7.73	7.64	0.40
Q_1-Q_3	6.36 -8.88	6.94 - 8.46	-0.38 - +0.73
Range	6.12 - 8.99	5.28 - 9.13	-1.34 - +1.29

The organisms of the catheter encrustations were determined by scraping off approximately 0.2 ml of the encrustation from the proximal part of the lumen of a blocked catheter, suspending it in physiological saline and performing a conventional quantitative bacteriological culture(Fig. 1). A parallel quantitative bacterial culture was made from the first urine portion from the new catheter.

The statistical calculations were performed according to Siegel (11), one-tailed distributions.

RESULTS

Urinary pH in the bladder and in the blocked catheter

The possible correlation between catheter life and urinary pH was studied in 16 patients with silicone-coated latex catheters and catheter complications manifested by short catheter lives due to blockages and wrenches(Table 1).

The catheter blockage provides a unique situation - the urine in the blocked catheter and the urine collecting in the bladder after blockage were produced within a narrow time range. It is thus reasonable to assume, that the shifts in urinary pH due to circadian variation within the individual can be neglected within this time range. Measurements showed, however, that the pH was higher in the urine from the blocked catheter than in the first urine from the new catheter, i.e. the urine within the blocked catheter was alkalized(Table 2).

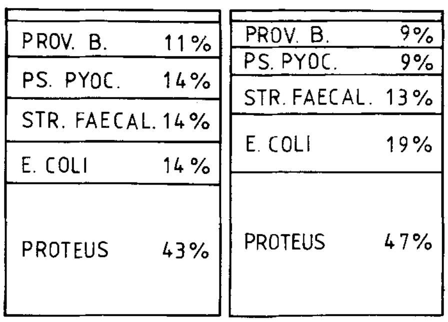

Fig. 1

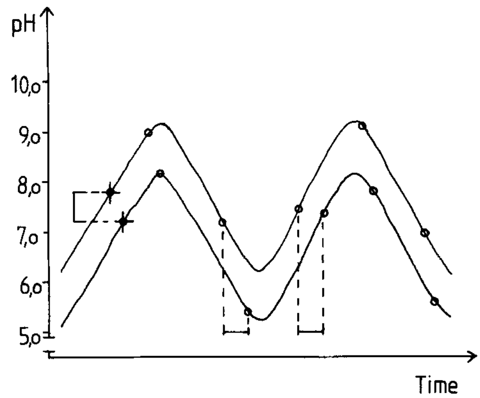

Fig. 2

Fig. 1 The distribution of bacteria in the encrustation within the blocked catheter(left) and in the first urine from the new catheter(right). Left: 35 strains from 15 patients. Right: 32 strains from 15 patients.

Fig. 2 Upper curve: a hypothetical circadian variation of the pH of the urine within an individual. Lower curve: the effect of an acidifying agent which lowers the urinary pH of the same individual by one pH unit over time. It is evident that this acidifying effect will easily be lost in isolated measurements. The difference between median values(I) of repeated measurements under standardized conditions is, however, expected to reflect the difference between the two curves. Likewise, the difference between the two curves is expected to be discernible within a restricted time range(I——I), cf. Table 2.

The bacteriology of urine and catheter

The catheter blockages and wrenches could be due to bacterial growth in the urine or in the incrustated catheter. Blocked catheters were therefore sent for bacterial culture together with a sample of fresh urine from the new catheter(Fig. 1). The bacterial growth in the encrustation within the blocked catheter was closely correlated to the bacterial growth in the first urine from the new catheter. Proteus strains were found in 13 out of 15 patients with short catheter lives due to blocked catheters.

Urinary pH in the bag and in the catheter

The pH of the night urine collected in the bag was compared with the pH of the urine from the catheter in 15 patients with silicone-coated latex catheters by means of indicator strips (Table 3). The pH difference between bag urine and catheter urine was not significant, as measured by the Wilcoxon matched-pairs signed-ranks test($p=0.042$). There were, however, great differences in the pH of the urine from the bag and the pH of the"fresh"urine from the catheter in individual patients, but in both directions. The correlation between the pH of the bag urine and the pH of the catheter urine was weak($r_s=0.508$, $p=0.025$, the Spearman rank correlation).

Twelve of the patients now received silicone catheters. The pH of the night urine in the bag and the pH of the "fresh" urine from the catheter were checked 2-3 weeks later by means of a pH-meter (Table 4). The pH difference was not significant, as measured by the Wilcoxon matched-pairs signed-ranks test($p=0.172$). There were in this experiment great individual differences in pH between bag urine and catheter urine, dispersed in both directions(Table 4). This accorded with the results in the previous experiment(Table 3). In the patient group with silicone catheters(Table 4), the correlation between the pH of the bag urine and the pH of the catheter urine was significant($r_s=0.726$, $p<0.01$, the Spearman rank correlation).

In summary, the pH of the bag urine and the pH of the catheter urine showed great variations in both directions within the group of patients(Tables 3,4). These variations were not due to the catheter material or to the method of pH measurement. Despite the great variation, there was a correlation between the pH of the bag urine and the pH of the catheter urine.

DISCUSSION

The main finding of the present study was that the pH of the urine within a blocked catheter was significantly higher than the pH of the first urine portion from the new catheter(Table 2). This observation suggests the presence of a rising pH gradient within the catheter from the bladder.

The studied patients were selected because of frequent catheter blockages. It is reasonable to assume that the pH rise in the blocked catheters was due to urea splitting with the release of ammonia, induced by urease-producing Proteus strains(cf. Fig. 1). This pH shift in an alkaline direction can be expected to favour catheter encrustation and blockage. The urine salts with the exception of uric acid are reported to be less soluble at alkaline pH(1,6,7).

The pH gradient within the catheter could be demonstrated only under conditions, where the circadian variations of the urinary pH within the individual could be neglected(Table 2). When the circadian variation of the urinary pH could not be neglected, this pH gradient could not be demonstrated(Tables 3,4).

The pH of the bag urine appears to provide a summation parameter of the pH of the urine produced during approximately 12 hours, the production of ammonia from urea and the production of carbon dioxide from the fermentation of sugar. In contrast, the pH of the "fresh" urine from the catheter appears to reflect the acid-base balance of the individual within a restricted time range and the modifications of urinary pH induced by bacteria during the flow of the urine from the kidneys to the catheter tip(Tables 3,4).

The observations shown in Tables 3,4 indicate that the intra-individual variation of the pH between bag urine and the catheter urine ranges between $\pm$1.3 pH units. It is reasonable to assume that the pH differences between bag urine and catheter urine reflect circadian variations of the urine within an individual.

There was some correlation between the pH of the bag urine and the pH of the catheter urine(Tables 3,4). The scatter of the individual pH differences between bag urine and catheter urine was great, approximately symmetrical and far in excess of the error of measurement involved, i.e. the differences were real but balanced each other in the statistical tests used.

The inability of the statistical tests to reject the null hypothesis does not imply that the bag urine can be taken to represent the catheter urine or vice versa, as proposed in a recent study (5). This would be to embrace the null hypothesis uncritically, which is demonstrated by the distribution of the pH differences between bag urine and catheter urine without regard to the sign (Table 5). These intraindividual differences(median 0.72 pH units) are far greater than the reproducibility of the pH-meter, $\pm$0.01 units.

Table 5. The same data as in Table 4, now listed independently of sign in order to demonstrate that the intraindividual pH differences between bag urine and catheter urine exceed the precision of the pH-meter ($\pm$0.01 units).

	Median	Q_1-Q_3	Range
Intraindividual pH difference	0.72	0.39 - 1.02	0.01 - 1.34

The urinary pH varies between 4.5 - 8.0 under physiological conditions(10). The influence of drugs, e.g. methenamine hippurate (8,9), or bacteria on the urinary pH - often comparatively slight changes - has to be studied against a background of great physiological alterations in response to the acid-base balance of the body(Fig. 2). This is the basic problem in the study of urinary pH. In a previous study, we circumvented this difficulty by using the median values of several independent measurements(9); this variable may be expected to reflect differences between close but different curves(Fig. 2). In the present study, we used pH differences of urine portions produced approximately within the same time range(Table 2), i.e. the physiological pH variation with time could be neglected(Fig. 2).

The present finding of Proteus strains in the urine and in the blocked catheters of 13 out of 15 patients with short catheter lives is in agreement with the general model of the interrelation between catheter life, urinary bacteriology and urinary pH suggested by previous authors(2). Many inpatients with indwelling catheters are invaded with Proteus strains which alkalize the urine(4,7,9). The pH rise favours catheter encrustation and blockage(1,7,9).

It is reasonable to assume that the increasing encrustation of the catheter with slowing of the urine flow, the increment of the inner surface of the catheter due to the encrustation and the localization of urease-producing Proteus strains in the precipitated salts within the catheter(Fig. 1) influenced the urine in an increasingly alkaline direction, the "older" the catheter became. This influence will, however, be difficult to demonstrate with the differences involved between patients, within patients and between catheters. Clinical problems of this type are complex and individual factors are not readily isolated and studied.

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