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The effect of acidic maintenance solutions on catheter longevity

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Long-term urinary catheterisation is rarely completely free of complications. Catheter blockage from mineral salt encrustation occurs in 40-50 per cent of patients. Recurrent blockage is distressing to patients and carers and costly to health services in both time and resources. Laboratory-based evidence shows acidic maintenance solutions can be effective in dissolving encrustations. This is supported by clinical experience but there are few clinical studies and no well-controlled clinical trials to date. This article examines the range of evidence for the effect of maintenance solutions on catheter longevity.

Long-term indwelling urinary catheterisation is common but is rarely completely trouble free. One of the most common problems is recurrent catheter blockage, caused by deposits of mineral salts encrusting the catheter surfaces coming into contact with urine (Okhawa et al, 1990; Cox and Hukins, 1989). Catheter blockage can be distressing for patients because it results either in bypassing and leakage, or in the discomfort of urinary retention. A build-up of encrustation on the external surfaces of the catheter around the tip and balloon can cause painful tissue abrasion or more severe trauma during catheter changes, such that patients are frequently apprehensive about being recatheterised.

Problems associated with encrustation

As many as 40-50 per cent of patients with long-term indwelling catheters suffer from recurrent encrustation leading to catheter blockage and can be identified as habitual 'blockers' (Getliffe, 1994a; Kunin et al, 1987). Managing such problems places increased demands on health care services in terms of time and other resources, including unscheduled visits to patients at home, frequent replacement of costly appliances, and/or time-consuming procedures.

Bacteriuria is an inevitable consequence of long-term catheterisation (Jewes et al, 1988) and causative organisms are frequently normal residents of the patient's own bowel flora. The bacteria colonise the surface of the catheter forming a living layer or biofilm, which becomes firmly 'cemented' in place by secretion of bacterial polysaccharides (Costerton et al, 1999). However, clinical symptoms of infection may not be present if there is no invasion of urinary tract tissue.

Encrustation is most likely to occur when the biofilm contains bacteria that produce the enzyme urease. These include *Proteus mirabilis*, some variants of *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Klebsiella* species. Urease breaks down urinary urea to release ammonia, which causes the urine to become alkaline - commonly with a pH in the range 7.0-9.5. Under these conditions minerals such as calcium phosphate and magnesium ammonium phosphate (struvite) are precipitated onto the catheter surface, causing encrustation (Fig 1).

Several studies have shown that both high pH and calcium content of urine are associated with a high frequency of encrustation (Choong et al, 1999).

Bacterial biofilms can form on all catheter materials currently in use (Morris and Stickler, 1998) and are extremely resistant to antimicrobial agents (Leidl, 2001; Stickler and Hewitt, 1991). Consequently there is no effective way of removing them except by removing the catheter, although efforts to find new materials that resist colonisation continue. There is no evidence that suprapubic insertions are less prone to blockage than urethral catheterisation (Evans and Feneley, 2000).

Proactive catheter changes at set intervals in accordance with the usual time the patient's catheter remains patent ('catheter life'), will remove both the biofilm and encrustation. This can be effective in preventing blockage but must be weighed against other risks accompanying frequent recatheterisation, including urinary tract infection, tissue trauma, patient discomfort, and cost. There are currently no published clinical studies on the risks and benefits, including direct and indirect costs, of managing encrustation by frequent catheter replacement.

Catheter maintenance solutions

A common procedure to reduce the build-up of encrustation and increase catheter life is to wash out the catheter with an acidic 'catheter maintenance solution' to dissolve the minerals which have been deposited. This procedure is sometimes referred to as a bladder washout (particularly in older literature) but this description is not accurate, as the aim is to wash out the catheter rather than the bladder (Getliffe, 1996).

This concept has important implications for the volume of solution introduced into the catheter because the excess will enter the bladder, with the risk of chemical irritation of the mucosa. Commonly available, generic, sterile solutions for catheter maintenance are listed in Table 1.

The *British National Formulary* (British Medical Association and Royal Pharmaceutical Society of Great

TABLE 1. CATHETER MAINTENANCE SOLUTIONS**Suby G**

This is a 3.23% citric acid solution, with a pH of 3–4. It contains magnesium oxide to minimise tissue irritation and is aimed at reducing encrustation. Suby G is used where routine catheter maintenance is required to reduce the build-up of encrustation.

Solution R

This is a 6% citric acid solution, pH2, containing magnesium carbonate, aimed at dissolving encrustations. It is a stronger acid than Suby G and is therefore not recommended for frequent, regular use.

Mandelic acid, 1%

This is an acidic solution, pH2, aimed at inhibiting the growth of urease-producers. This stronger acid is not commonly used to reduce catheter encrustations.

Saline 0.9%

This neutral solution, pH7, is recommended for the flushing of debris and small blood clots. Neutral solutions will not dissolve encrustations.

Chlorhexidine 0.02%

This is an antiseptic solution aimed at preventing or reducing bacterial growth, in particular *Escherichia coli* and *Klebsiella* species, but it will not prevent biofilm formation on long-term catheters.

Britain, 2004) lists a number of catheter patency solutions based on citric acid formulations (Solutions G and R) and the introduction of nurse prescribing makes it imperative that nurses understand the evidence base for their use. The following sections review strategies to acidify patients' urine and examine evidence for acidic catheter maintenance solutions to promote catheter longevity.

Control of urinary pH

Attempts to acidify patients' urine through ingestion of acidic liquids such as cranberry juice, or acidifying agents such as ascorbic acid (vitamin C), have failed to produce clear evidence of effectiveness, although some studies have been poorly controlled. Avorn et al (1994) carried out a randomised, double-blind placebo-controlled trial on the effects of drinking cranberry juice on the incidence of bacteriuria and pyuria in 153 older women without catheters. There was a modest reduction in the rate of antibiotics prescribed for the cranberry group, which provides evidence of some bacteriostatic effect, but there was no significant difference in the pH of the urine in the two groups. Similarly there is no evidence that urine produced by volunteers who have consumed cranberry juice or ascorbic acid slows the swarming and speed of colonisation of *Proteus mirabilis* in laboratory studies (Stickler and Hughes, 1999).

Data from other laboratory-based studies also suggests that any attempt to reduce urinary pH to prevent catheter

encrustation, without the elimination of urease-producers, is unlikely to succeed (Bibby et al, 1995). Given the constant supply of urea in the urine, the presence of urease-producers as a biofilm on the catheter surface will continue to create an alkaline micro-environment within the catheter lumen.

Instilling acidic maintenance solutions

The application of an acidic solution to an encrusted catheter has a lengthy history. Over 200 years ago the surgeon John Hunter recommended that catheters prone to encrustation should be removed at regular intervals and soaked in vinegar prior to re-insertion (Quist, 1981). In, 1943 Suby and Albright reported that Solution G, a buffered mixture of four per cent citric acid, magnesium oxide and sodium bicarbonate, was effective at dissolving phosphatic calculi. More strongly acidic solutions such as solution R (six per cent citric acid) have been used successfully to dissolve fragments of struvite renal calculi following lithotripsy (Holden and Rao, 1991) and have also been used to treat catheter encrustation.

A recent literature search using the Cochrane Library, Medline, Embase, and CINAHL databases demonstrated that the strongest evidence to support the use of acidic catheter maintenance solutions comes from laboratory studies, using models of the catheterised bladder. The effectiveness of acidic solutions in reducing encrustation has been shown by increased concentrations of magnesium and calcium in drainage fluid following washouts and by measurement of the non-occluded luminal area of catheters receiving washouts compared with those which have not (Getliffe, et al, 2000; Getliffe, 1994b; Hesse et al, 1989). Neutral solutions such as saline and chlorhexidine are not effective.

Although mineral deposits dissolve in the acidic environment of catheter maintenance solutions, the effect is temporary as the urinary pH inside the catheter rises rapidly again once the acidic solution is withdrawn. Citric acid solutions G and R (and mandelic acid, Table 1) will dissolve encrusting material but researchers caution that the potential benefits of stronger acids may be outweighed by inflammatory tissue reactions that arise. They suggest a weaker acidic solution such as Suby G is likely to be more appropriate for regular use.

The bladder mucosa plays an important role in host defence against urinary tract infection, and in animal studies dilute acids have been shown to remove the protective layer of mucus – although it was regenerated within 24–48 hours (Donmez et al, 1990; Parsons et al, 1975).

Increased shedding of urothelial cells in the urine has been associated with disruption of the urothelium and there is evidence such increases occur after washouts with both acidic and neutral pH solutions (Kennedy et al, 1992; Elliott et al, 1989). This suggests both chemical irritation and the physical force of instillation can be potential risk factors. Manufacturers of prepacked catheter maintenance solutions therefore recommend that solutions should be instilled under the force of gravity only.

Prepacked solutions are usually available in 100ml and 50ml volumes. However, even large catheters such as 18

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Charriere hold only approximately 4ml, so after allowing for sufficient fluid to bathe the catheter balloon and tip as well as the lumen, a large amount of solution still enters the bladder, where it may cause chemical irritation.

A logical conclusion is that smaller volumes of catheter maintenance solution are likely to reduce the potential for mucosal irritation. This is supported by the observation that 100ml is no more effective than 50ml at reducing encrustations in laboratory models. Furthermore, two sequential washouts with 50ml may be more effective than a single washout with either 50ml or 100ml (Getliffe et al, 2000). This may be partly due to a cumulative effect in lowering the pH within the catheter lumen, thus promoting further dissolution. It is also possible that the small quantity of solution actually within the catheter rapidly becomes saturated with dissolved minerals and therefore, drainage of the first 50ml followed by the introduction of a further 50ml fresh solution would result in further dissolution. However, these regimens still need to be tested rigorously in clinical environments before conclusive guidance can be given.

There have been few clinically-based studies of the use of catheter maintenance solutions, at least in part because they are difficult to perform. Many patients are older and/or unwilling to change their usual care regimens. In addition, the existence of large variations among patients in the frequency with which their catheters block presents difficulties in comparing results between groups, as differences among individuals within a group may be greater than those between groups.

Mayes et al (2003) undertook a structured review of the literature, which aimed to identify systematic reviews or randomised clinical trials (RCTs) that addressed catheter blockage or patency, but were unable to find any RCTs. In the only randomised study identified Kennedy et al (1992) used a randomised crossover design of three bladder washout treatments (saline, Suby G, and Solution R) to examine crystal formation and catheter encrustation in 25 older women. Washouts were given twice a week for three weeks, then the catheter was removed

and examined (or changed earlier if necessary). Saline washouts were administered for one week to provide a neutral period between test solutions.

The order of administration of test solutions was decided using randomisation tables but there was no blinding to treatment allocation, so staff, researchers, and patients were all aware of which solution was being used. Each subject received all three test solutions but only 14 (56 per cent) completed the study.

While a significant reduction in struvite crystals was found in the returned acidic washout fluid, there was no significant reduction of crystals in the neutral (saline) washout following any of the three-week periods of treatment. Uric acid crystals appeared with Suby G and Solution R, and these solutions were associated with higher red-cell deposits in the urine. However, the interpretation of the results is not straightforward as there was no standard protocol for decision-making when a catheter was removed earlier than planned and no details on other control measures to ensure equality during different tests. Consequently, it is not possible to draw robust conclusions on the length of time catheters remained patent in relation to the treatment conditions.

Conclusion

The majority of evidence on the effect of maintenance solutions on catheter longevity is derived from in vitro, laboratory-based studies. While these provide important information, their outcomes need to be translated into the clinical environment in order to guide clinical practice.

There remains an urgent need to conduct well-designed clinical trials and/or cohort studies to provide clearer evidence of the effect of acidic solutions on catheter patency for patients susceptible to recurrent encrustation and blockage. Although such studies may be difficult to undertake with the patient group concerned, clear agreements on methodology and the outcome measures would allow comparisons of results even if sample sizes are small. Meanwhile, practitioners must keep using their clinical judgement to select the most appropriate catheter care regimen for each patient. ■

FIG 1. CAUSES OF CATHETER BLOCKAGE

