REVIEW ARTICLE

Infections in continuous ambulatory peritoneal dialysis

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Introduction

The concept that the peritoneal membrane could be used as a means of removing solutes from the blood originated in the 1890s (Starling and Tubby, 1894) and peritoneal dialysis was first used for the treatment of renal failure in man by Ganter (1923). In the past, access to the peritoneal cavity was through several techniques and devices which needed frequent changing. 1968 saw the introduction of the Tenckhoff indwelling peritoneal catheter which had an average lifespan of approximately 20 months (Tenckhoff and Schechter, 1968). This was the first permanent, relatively safe, silastic peritoneal access device. In 1976 a new technique was described—Continuous Ambulatory Peritoneal Dialysis (CAPD)—which allowed fluid to remain in the peritoneal cavity for 4–8 h instead of an exchange of dialysate every hour (Popovich *et al.*, 1976). Although the Tenckhoff catheter is considered to be a permanent device, during CAPD the giving sets are changed every month, with some centres leaving them for 2 months. Originally there was poor acceptance of this new method because the dialysate was only available in glass bottles, which necessitated frequent opening of the dialysis circuit accompanied by a high incidence of peritonitis. By the time the dialysate became available in plastic bags, the technique had been simplified to comprise a closed-circuit system, with a resultant reduction in peritonitis. CAPD was introduced into the United Kingdom in 1978 and has since become an accepted form of dialysis treatment for patients with end-stage renal disease. More than 40 renal units now practice CAPD, accounting for 26% of the dialysis population and 14% of all patients on long-term renal replacement therapy. By 1985 it was estimated that about 27 000 patients world wide, of whom 2450 were in the UK, were being treated by CAPD (Gokal, 1986). CAPD is more economical, allows greater patient mobility, does

not require vascular access or any fluid and electrolyte restriction, and results in higher haemoglobin levels and better control of blood pressure. The technique is especially suited to the elderly and to diabetic patients, though extra insulin is required. Young patients awaiting transplantation should, however, be offered haemodialysis. Of the infective complications which occur in CAPD, peritonitis is the most important one, though deaths from peritonitis remain relatively rare (Spencer and Fenton, 1984; Working Party of BSAC, 1987; Peterson *et al.*, 1987). Peritonitis remains the commonest cause of failure in CAPD treatment. Whilst this review will concentrate on peritonitis, the problems of exit site and tunnel infections will also be discussed.

Peritonitis

This does not have the classical clinical presentation of surgical peritonitis with rigid abdomen, toxic symptoms and septicaemia. Characteristically, CAPD peritonitis is a mild illness, the predominant feature of which is a “cloudy bag” caused by the presence of large numbers of white cells, usually in excess of 100 cells/mm³. This may be accompanied by mild fever, abdominal pain and tenderness, with occasional difficulty in draining the exchange fluid. Positive blood cultures are extremely rare. The incubation period of peritonitis is uncertain, probably only 1–2 days. Symptoms usually disappear within 48 h following the instigation of appropriate antimicrobial treatment. It is probable that only small numbers of micro-organisms are necessary to produce peritonitis, but that not all episodes of microbial contamination lead to peritonitis. The principal portal of entry for organisms (figure) is thought to be the lumen of the catheter. The commercial production of peritoneal dialysate under stringent quality control criteria makes this fluid an unlikely source of bacteria. The commonest cause of infection is touch contamina-

Figure. Portals of entry of micro-organisms.

Host defences

Phagocytic cells play very important roles in defence of the human host against microbial pathogens. In the peritoneal cavity, bacteria can be removed via the lymphatics to the reticuloendothelial system where they are phagocytosed and killed by macrophages. Peritoneal macrophages are also able to phagocytose and kill opsonised bacteria. The contribution of opsonic molecules is well recognised and a quantitative deficiency of opsonins can seriously compromise the bactericidal function of phagocytic cells. When these defence mechanisms are overcome, peritonitis develops with the characteristic exudation of polymorphs following the release of chemotaxins such as C5a arising from bacterial activation of serum complement. The number of phagocytic cells in peritoneal fluid is usually low ($c. 10^4$ cells/ml) and at these concentrations infecting bacteria are not sufficiently controlled. Verbrugh *et al.* (1984) found that 10^6 cells/ml were the minimum required to achieve bacteriostasis. The function of peritoneal macrophages can also be compromised by the commercial dialysis solutions themselves which have a low pH (5.5) and a high osmolality. Both of these properties have been shown to have adverse effects on peritoneal macrophage function (Harvey *et al.*, 1987). After instillation of large volumes of dialysate there is marked reduction in opsonic activity reflecting the low IgG and C3 concentrations (Verbrugh *et al.*, 1983; Keane and Peterson, 1984). These low concentrations are roughly equivalent to those found in 0.5% normal human serum (Clarke and Easmon, 1986). Keane and Peterson (1984) identified a relationship between the level of opsonic activity and the incidence of peritonitis. They found that patients with "low" opsonic activity had an approximately 7-fold greater incidence of peritonitis with *S. epidermidis* than those with a "high" opsonic activity. No heat stable opsonin specific for *Escherichia coli* is present in peritoneal effluent due to the low levels of C3. Even when opsonised, *E. coli* is phagocytosed less efficiently by macrophages than by polymorphonuclear leucocytes, which could explain the protracted course of peritonitis caused by enterobacteria. In Keane and Peterson's series, one-third of the patients with "high" opsonic activity were diabetics who have an increase in macromolecular permeability of the microvascular beds leading to higher IgG levels. It is worth noting that diabetics do not have an increased incidence of peritonitis. Peritoneal effluents capable of efficient opsonisation of staphylococci have been found, but only in those associated

tion during connecting or disconnecting a fresh dialysate bag. Horsman *et al.* (1986) found that isolates of coagulase-negative staphylococci (CNS) from the patient's skin were often identical to those strains causing subsequent peritonitis. Moreover, they found that most second infective episodes were caused by bacteria with plasmid profiles identical to those isolated in the initial infection. However, they were unable to determine whether recurrent infections were due to relapse after inadequate initial antibiotic treatment, or to reinfection with the same strain from the patient's own skin flora. A similar situation has been noted with infections caused by *Staphylococcus aureus*. However, in a subsequent paper, Eisenberg *et al.* (1987) found that in a series of 30 patients studied over 9 months most cases of peritonitis were not due to persistently colonising strains of CNS. The silastic Tenckhoff catheter never forms a completely sealed junction with the skin or subcutaneous tissues. The purpose of the single or double catheter cuffs is to prevent the penetration of bacteria around the catheter. Sometimes periluminal infection of the peritoneum does occur, usually in association with tunnel or exit-site infections (to be discussed later). Other portals of entry of micro-organisms into the peritoneal cavity are: intestinal—diverticular disease is a major cause and CAPD patients should never be allowed to become constipated; haematogenous—peritonitis due to *Mycobacterium tuberculosis*, *Streptococcus pneumoniae* and viridans streptococci have been reported; ascending—candida peritonitis due to vaginal candidosis; and environmental—*M. chelonae* traced to tap water and pseudomonads from swimming baths.

with dialysate dwell times of 6–10 h (Verbrugh *et al.*, 1984). Current CAPD techniques require a more frequent exchange of peritoneal effluent, containing phagocytes, immunoglobulins and complement, for fresh commercial dialysate which is completely devoid of such antimicrobial activity and which adversely effects the phagocytic and bactericidal capacities of polymorphonuclear leucocytes and macrophages. It has been suggested that peritonitis could be managed more effectively by augmentation of local phagocytic defences (Keane and Peterson, 1984) by the addition of purified immunoglobulins to the dialysis fluid. By so doing the opsonic activity against *S. epidermidis* was increased. Clarke and Easmon (1986) demonstrated that an intravenous immunoglobulin preparation with no inherent opsonic activity displayed good opsonisation of *S. epidermidis* when combined with peritoneal effluent. Therefore immunoglobulin preparations could be considered as useful agents to boost peritoneal defences in those CAPD patients who suffer from repeated attacks of peritonitis.

Causative organisms

In CAPD patients the major causative organisms of peritonitis are coagulase-negative staphylococci (CNS) of which *S. epidermidis* is by far the commonest species found (Gruer *et al.*, 1984). In a recent survey of 750 isolates from episodes of peritonitis in the Royal Hallamshire Hospital, Sheffield, the commonest organisms were CNS (56%); the remainder of episodes were caused by *S. aureus* (11%), enterobacteria (11%), streptococci (8%), *Pseudomonas* spp. (6%), J-K diphtheroids (3%), enterococci (2%), *Candida* (<1%), and miscellaneous (2%). Of the 423 isolates of CNS, 317

Table I. Bacteria isolated from the peritoneal fluid of CAPD patients with peritonitis

Organism	Number (%)
Coagulase-negative staphylococci	423 (56)
Enterobacteriaceae	79 (11)
<i>S. aureus</i>	78 (11)
Streptococci	57 (8)
<i>Pseudomonas</i> spp.	48 (6)
J-K diphtheroids	24 (3)
Enterococci	17 (2)
<i>Candida</i> spp.	6 (<1)
Miscellaneous*	18 (2)
Total	750

*Miscellaneous: *Acinetobacter* spp. 9, *Achromobacter* spp. 3, *H. influenzae* 2, *Campylobacter* spp. 2, anaerobes 4.

Table II. Identity of isolates of coagulase negative staphylococci, Enterobacteriaceae, streptococci and pseudomonads

Group	Number	Species	Number
Coagulase-negative staphylococci	423	<i>S. epidermidis</i>	317
		<i>S. haemolyticus</i>	30
		<i>S. hominis</i>	26
		<i>S. warneri</i>	20
		<i>S. capitis</i>	7
		<i>S. saprophyticus</i>	5
		<i>Micrococcus</i>	18
Enterobacteriaceae	79	<i>E. coli</i>	25
		<i>Klebsiella</i> spp.	21
		<i>Enterobacter</i> spp.	18
		<i>Serratia</i> spp.	6
		<i>Proteus</i> spp.	6
		<i>Citrobacter</i> spp.	3
Streptococci	57	<i>Str. mitis</i>	22
		<i>Str. sanguis</i>	20
		<i>Str. salivarius</i>	5
		<i>Str. pneumoniae</i>	3
		<i>Str. agalactiae</i>	3
		<i>Str. bovis</i>	2
		<i>Str. milleri</i>	1
		<i>Str. mitior</i>	1
Pseudomonads	48	<i>P. aeruginosa</i>	27
		<i>P. maltophilia</i>	14
		<i>P. stutzeri</i>	4
		<i>P. cepacia</i>	2
		<i>P. putida</i>	1

(75%) were *S. epidermidis*. These findings are summarised in tables I and II.

S. epidermidis is regarded as an organism of low pathogenicity and yet is capable of causing peritonitis in patients on CAPD. Work has shown a defect in the effective opsonisation of *S. epidermidis* by peritoneal dialysis effluent (Verbrugh *et al.*, 1983). This combined with the relative scarcity of phagocytes in the effluent ($c.10^6/L$), may explain the ability of *S. epidermidis* to initiate infection from small numbers washed into the peritoneal cavity during an exchange. Much work has concentrated on the ability of *S. epidermidis* to produce "slime" and its effect on host defence mechanisms. "Slime-producing *S. epidermidis*" were described by Christensen *et al.* (1983) who found that 63% of clinically important strains grew as a "slimy film" on the walls of the culture tubes containing trypticase soya broth. Slime is not a true capsule, appears to be loosely bound to the cell surface and is easily removed by washing with water. Enhancement of slime production *in vitro* can be achieved by supplementing culture media with casamino acids and various sugars (Peters and Pulverer, 1984). Is slime involved with the adherence of staphylococci to the catheter? Ultrastructural studies by Peters *et*

al. (1982) showed that slime only appeared 12 h after exposure of catheter segments to *S. epidermidis*. The kinetics and mechanics of adherence of *S. epidermidis* probably involves at least two processes. The first is an initial nonspecific binding related to surface charge or hydrophobic interactions, or both, between the cell surface and the surface of the plastic devices (Dunne and Franson, 1986). The ability of micro-organisms to produce slime at this stage is not significant (Pascual *et al.*, 1986). The second is colonisation, as expressed as a function of slime production. The slime surrounds the micro-colonies of staphylococci and cements them firmly to the catheter surface.

Slime production has been suggested as a marker for pathogenicity of *S. epidermidis* in catheter-associated infection (Davenport *et al.*, 1986) and CAPD peritonitis (Kristinsson *et al.*, 1986a). In these studies, recurrent peritonitis was more likely to occur with slime-producing strains. However, West *et al.* (1986) could not link the presence of slime-producing staphylococci with complications in CAPD peritonitis. Other studies have examined the effect of slime on the activity of human neutrophils. Johnson *et al.* (1986) found that separated slime interfered with several polymorphonuclear leucocyte functions such as chemotaxis, degranulation and phagocytosis. Kristinsson *et al.* (1987) found that the presence of slime on the staphylococcal cell does not appear to interfere with opsonophagocytosis.

Infection with *S. aureus* is particularly difficult to treat and eradicate without resorting to removal of the peritoneal catheter. It produces a more severe form of peritonitis and tends to cause abscesses. The isolation of anaerobes from CAPD peritonitis may indicate underlying bowel pathology. *P. aeruginosa* infection is difficult to cure and 10 cases of peritonitis failed to respond to appropriate antibiotic treatment given up to 4 weeks (Krothapalli *et al.*, 1982). Removal of the Tenckhoff catheter in each patient was required because sinus tract infections developed. An equally gloomy picture pertains with fungal peritonitis, although this is a rare condition. In a review of the literature and their own experience with 11 cases, Eisenberg *et al.* (1986) found that prompt appropriate therapy was essential. The recommended therapy for most patients is removal of the catheter and systemic antifungal treatment with amphotericin B. Intra-peritoneal therapy with amphotericin B has been found to predispose to peritoneal fibrosis. However, in patients who are haemodynamically and metabolically stable, and for whom CAPD is desirable, a trial of antifungal chemotherapy is recommended

before any decision to remove the catheter is taken. In a case of peritonitis caused by *P. maltophilia* it was found that there was a significant difference in its susceptibility to aminoglycosides and polymyxin when incubated at 30°C (resistant) and 37°C (susceptible) (Wheat *et al.*, 1985). In view of the low initial temperature of peritoneal dialysate, this may have implications in selecting a suitable agent for treating cases of peritonitis caused by *P. maltophilia*. Other unusual causes of CAPD peritonitis have included *Campylobacter* spp. in two cases after gastroenteritis (Kristinsson *et al.*, 1986b).

Laboratory diagnosis of peritonitis

Rapid and accurate diagnosis of the aetiology of peritonitis is essential if the patient is to be given the most appropriate chemotherapy. Conventional microbiological methods have often given negative results despite the presence of inflammatory cells and clinical evidence of infection. These cases of "sterile peritonitis" probably reflect the inadequacy of the microbiological techniques used. The false negative results could be due to embedded organisms (Peters *et al.*, 1982) or to the poor survival of gram-positive organisms in peritoneal dialysate (Sheth *et al.*, 1986). Therapy directed against gram-positive cocci must always be considered in culture-negative peritonitis. Eosinophilic peritonitis (Gokal *et al.*, 1981) runs a somewhat benign course for several weeks, occurring early in CAPD treatment and probably represents a reaction to some component of the CAPD system.

Drainage bags should be delivered intact, and without delay, to the laboratory, or stored at 4°C until this is possible. The fluid is removed aseptically. As the number of micro-organisms is low, as large a volume as possible should be sampled. Laboratories should aim for at least a 90% positive culture rate from infected i.e., cloudy, CAPD fluid (BSAC Working Party, 1987). Attempts to improve the rate of recovery of organisms have included: enrichment culture of the effluent with thioglycolate broth (Knight *et al.*, 1982); use of pour plates (Fenton, 1982); closed filtration system with a 0.45 µm filter through which 100 ml of effluent are passed; radiometric detection (Males *et al.*, 1986); and total volume culture (Dawson *et al.*, 1985). Problems with contamination and blockage of filters occur with some of these procedures. The culture plates should be incubated aerobically in a CO₂-enriched atmosphere and anaerobically, for 72 h, and examined at daily intervals. A direct gram-stained smear of the dialysate has proved unsuitable for demonstrating bacteria. However, a

positive result can be extremely useful and such an examination should always be performed, preferably by experienced operators. When organisms are detected microscopically they appear to be either adherent to or sequestered inside cells, usually polymorphonuclear leucocytes. Thus physical or chemical techniques capable of disrupting these cells could improve the rate of bacterial detection. This has proved to be the case with the use of lysis-centrifugation (Spencer and Ahmad, 1986) and ultra-sonics (Dabbs *et al.*, 1987). Of 90 samples from patients with peritonitis, 25 were found to have antibacterial activity. Of the remaining 65 samples, the detection rates of potential pathogens were: pour plates 48 (74%), centrifuge deposit 51 (78%), and lysis centrifugation 56 (86%). For the 25 samples in which antibacterial activity was detected, results were 7 (28%), 6 (24%) and 13 (52%) respectively. Fifty specimens of peritoneal fluid were tested by sonication, of which 42 (84%) yielded clinically significant isolates. Six of the eight negative cultures were from patients already on antimicrobial treatment. Pour-plate and centrifuge-deposit cultures without sonication were positive in 39 (78%) and 34 (68%) of cases respectively. This latter technique is now the standard laboratory method at the Royal Hallamshire Hospital, Sheffield, for culturing CAPD effluent.

Residual antibiotic activity can be removed with absorbent resin, thereby increasing the yield of positive cultures.

Treatment of peritonitis

Once the diagnosis of peritonitis has been made, empirical antibiotic treatment must commence as soon as possible, before the laboratory results are available. Therefore, it is essential that knowledge of any prevalent organisms and their antimicrobial susceptibilities are known. The choice of agent(s), route of administration, dosing schedules and length of treatment have recently been extensively and effectively reviewed in the UK and the USA (Working Party BSAC 1987; Keane *et al.*, 1987). A combination of an aminoglycoside and vancomycin appears to be the favoured empiric treatment. Once the organism is identified and its antibiotic susceptibility determined, one or other of these agents can be discontinued. Concern over the potential ototoxicity of an aminoglycoside + vancomycin combination has led some authors to propose alternative treatment regimens such as a combination of aztreonam plus teicoplanin, a glycopeptide antibiotic with little or no ototoxicity (Neville *et al.*, 1987). Use of the *Limulus* lysate assay has been

advocated as a rapid and sensitive measure of gram-negative peritonitis. An additional bonus would be that the majority of patients, who will have peritonitis caused by gram-positive bacteria (Clayman *et al.*, 1987), are thereby excluded from exposure to aminoglycoside therapy. Recently the emergence of vancomycin resistance in strains of CNS in a patient with peritonitis was described (Schwalbe *et al.*, 1987). All the isolates were *S. haemolyticus* which showed an increasing resistance to vancomycin during therapy. It is possible that *S. haemolyticus* is unique among CNS in being prone to develop resistance to vancomycin. Gruer *et al.* (1984) found that of 30 episodes of peritonitis caused by CNS, in only one was the organism (*S. haemolyticus*) not eradicated.

The route of antimicrobial administration is normally intraperitoneal, with or without additional intravenous therapy. Normally the peritoneal cavity contains fibrinogen and fibrinolysin. In inflammation the fibrinolysin activity is impaired, with consequent increases in fibrinogen. Thereafter fibrin will not be broken down and formation of fibrin filaments and clots will occur. Intraperitoneal antibiotics are, therefore, always given together with heparin to inhibit the formation of these fibrin clots and reduce the incidence of post-infective adhesions of the peritoneal membrane. Peritoneal lavage has little to commend itself in the management of peritonitis. Treatment by oral antibiotics has been advocated (Neville *et al.*, 1987) and the new quinolone compounds have been studied as possible therapeutic agents. Early pharmacokinetic studies have suggested that therapeutic concentrations of ciprofloxacin may be achievable against bacterial isolates commonly associated with CAPD peritonitis (Fleming *et al.*, 1987). However amongst patients taking concurrent oral aluminium-containing antacids that also act as phosphate binders, a pronounced reduction in ciprofloxacin levels were found. Weissauer-Condon *et al.* (1987) concluded on the basis of in-vitro tests in peritoneal fluid that peritonitis due to staphylococci and pseudomonads cannot be treated effectively with the quinolones.

The choice of antibiotics is usually influenced by conventional susceptibility testing. However, it should be recognised that some antibiotics lose activity in peritoneal dialysis fluid (Sewell and Golper, 1982; Verbrugh *et al.*, 1984; Craddock *et al.*, 1987; Weissauer-Condon *et al.*, 1987). This decrease may result from the low pH, high osmolality or urea concentration in dialysis fluid. High concentrations of calcium and magnesium may also partly explain the reduced activity of the aminoglycosides. It is advocated that antibiotics

chosen for the treatment of peritonitis should be investigated first in dialysis effluent.

Relapses have been reported in patients adequately treated with vancomycin or cephalothin plus tobramycin (Buggy *et al.*, 1984). Sequestration of viable staphylococci within neutrophils in the peritoneal fluid was demonstrated. When rifampicin, an antibiotic known to readily penetrate and accumulate in leucocytes, was added to the treatment regimen resolution occurred and no relapses occurred. Similar results have followed the use of clindamycin, another antibiotic known to be taken up by leucocytes and macrophages (Cohen and Bailey, 1984).

Other causes of residual viability in the presence of antimicrobial agents have been proposed. Evans and Holmes (1987) suggested that *S. epidermidis* could retain viability, despite continuous exposure to vancomycin, due to the poor diffusion of the antibiotic through the dense aggregation of extracellular material (slime) in which the micro-colonies are embedded. Sheth *et al.* (1985) investigated the ability of slime-producing strains of CNS adherent to plastic catheters to survive exposure to bactericidal concentrations of nafcillin. They suggested that survival was due either to poor drug diffusion intracellularly, or avid binding of the drug by the slime matrix, or to an altered bacterial metabolic state which renders them less susceptible to the antibiotic.

The optimal length of treatment remains unresolved; gram-positive peritonitis usually resolves in 7–10 days, whereas gram-negative peritonitis can require 3 weeks or more of therapy. Measurement of serum C-reactive protein to monitor the effectiveness of antibiotic therapy has been proposed as a way of determining effective treatment schedules (MacD. Agar and Flett, 1984). There is no evidence that antibiotic prophylaxis prevents peritonitis.

Other infections

Peritonitis can be secondary to infection of the skin tunnel through the abdominal wall in which the Tenckhoff catheter lies. Pain and signs of inflammation along the site of the tunnel occur and these infections are extremely difficult to eradicate. Removal of the catheter may be necessary. Exit-site infections present with redness, skin induration and sometimes a purulent exudate. Aggressive antibiotic treatment is necessary for both these infections which are usually caused by *S. aureus*. If the cuff becomes a focus of infection, antibiotic treatment alone will not eradicate the infection. "Cuff-shaving" or removal of the external cuff have

been advocated in the management of exit site infections.

Prevention of infection

Because most episodes of peritonitis are due to accidental contamination, prevention has been studied extensively. Rigid adherence to aseptic procedures is most important and can be most effective. Despite careful training and supervision in hospitals whilst learning the procedures, many patients are discharged home without the benefit of home assessment or domiciliary nursing care. Regular home visits are essential to discourage the patients from taking various short-cuts which modify their techniques. Survival analysis shows that when other host, agent and environmental factors are controlled, age (younger patients), low patient motivation and minimal social support are significant risk factors for peritonitis. Microbial contamination can occur via lapses in "patient responsibility" such as the care of the connector or care of the exit site, and "centre responsibility" such as faulty insertion of Tenckhoff catheters into the peritoneal cavity (Spencer and Fenton, 1984).

It was hoped that the incidence of peritonitis would decrease with the introduction of more sophisticated and safer connection devices. The introduction of the titanium adaptor appears to have reduced peritonitis rates, though this has never been subjected to the scrutiny of properly controlled clinical trials. Additional measures have included an extra clamp on the catheter to prevent air entering the transfer set; a 0.2– μm membrane in-line filter; use of heat via microwaves and ultra-violet light. Connectors which make use of iodine antiseptics include the Oreopoulos-Zellermann connector, the beta-cap and the Bazzato double bag systems (Oreopoulos *et al.*, 1983). Sodium hypochlorite is used in the Buorocristiani system and the "Y" set in which the lumen is filled with sodium hypochlorite during the dwell period and this agent is also used to disinfect caps and ends of the tubing set during the exchange procedure (Fenton *et al.*, 1985).

It has been suggested that prophylactic use of chlorhexidine in the dialysis solution would prevent peritonitis. Junor *et al.* (1985) found that 11 of a group of 54 patients who sprayed connectors at each exchange with chlorhexidine 0.5% in 70% alcohol developed sclerosing peritonitis—an extremely serious complication of peritoneal dialysis. None of 108 patients who used povidone-iodine suffered from this problem which is thought to occur as a result of the leeching of plasticisers from the tubing and catheter.

Controlled clinical trials have not been performed on all the aforementioned new devices or techniques. In the few that have been done, some have failed to show any significant differences between the control and study groups. Uncontrolled studies have shown only small reductions in the overall rate of peritonitis. The improvements usually occur when the high-risk patients are studied separately. These patients, who are usually small in number, contribute most to the incidence of peritonitis. Perhaps we should attempt to define these patients in advance by measuring aspects of their host defences and concentrating our efforts in their augmentation.

To reduce still further the rates of peritonitis we will also have to concentrate on the other routes of infection such as the periluminal pathway. We still have to look for new approaches to produce an effective sealing of the skin-catheter interface. To minimise the risk of haematogenous seeding, serious thought must be given to the concept of antibiotic prophylaxis for all dental procedures in such patients to prevent infection with viridans streptococci. Apart from the use of povidone-iodine all the new systems, devices or techniques have the drawback of increasing the complexity of the system and of increasing costs.

The future

The genesis of catheter-related infections is principally related to catheter design and placement rather than the material of construction. Silicone

has a unique property of maintaining squamous epithelial surfaces, as demonstrated by the normal histological appearances of the peritoneum even after use of a peritoneal catheter for several years. New catheter designs are being proposed. The "Tenckhoff chronic straight" is the commonest catheter in use, easily inserted and easily removed. The column-disk (Lifecath) catheter is currently undergoing European trials. With this catheter it is reported that exit-site infections are rare; the lifespan is twice that of the Tenckhoff design, but peritonitis rates are similar (Ash, 1984). Other catheters under investigation include the Missouri-type swan neck, said to reduce the accumulation of sweat and decrease the incidence of exit-site infections, and the Toronto Western Hospital II which forms a good seal with the peritoneal cuff, and has silicone base disks to prevent dislodgement, but again no decrease in peritonitis rates have been reported.

Other future developments will examine constituents of the dialysate fluid, incorporation of antibiotics or disinfectants into catheter material, enhancement of host defences, possibly by the addition of immunoglobulins, and altering the charge on the catheter surface to prevent microbial attachment. As microbial adhesion to inanimate surfaces is a complex and multifaceted process, the role of the biofilm and strategies to inhibit its formation are being investigated (Holmes and Evans, 1986). The most appropriate antimicrobial treatment, duration and route of administration are still areas for further investigation.

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