Moncrief-Popovich Catheter and Implantation Technique: The AV Fistula of Peritoneal Dialysis

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Despite the decrease in peritonitis rate from touch contamination caused by the use of disconnect systems, technique failure in peritoneal dialysis (PD) from pericatheter and exit-site infections in PD remains unchanged. This indicates a failure of current PD catheters to prevent bacterial transfer from exit site to the peritoneal cavity. In 1991, Moncrief and Popovich introduced a new catheter design and implantation technique to address this problem. The catheter is made of silastic, has a coiled tip with 2 cuffs, and an arcuate bend between the cuffs. This would prevent catheter malfunction and leakage of PD fluid. The implantation technique involves embedding of the external segment of the catheter in the subcutaneous tunnel at insertion. The catheter segment is kept embedded for 4 to 6 weeks before externalization. This procedure will allow time for tissue ingrowth on into the external cuff and catheter surfaces between the 2 cuffs, preventing bacterial colonization of the catheter surfaces from the exit wound and thereby reducing pericatheter infections. Thus, the new technique will establish a more effective bacteriologic barrier between the exit wound and the peritoneal cavity than the conventional catheters. Ten years after validation of the catheter design and implantation technique by Moncrief and Popovich, various clinical studies confirm that this new technique of catheter implantation increases catheter life expectancy and reduces pericatheter infections in PD. Like the arteriovenous fistula of haemodialysis, this new catheter remains embedded in subcutaneous tunnel, is exteriorized electively when patient needs to be started on dialysis, and reduces pericatheter and exit-site infections in PD. The new technique, therefore, is widely accepted as a simple, safe, and cost-effective procedure for quality care of PD patients around the world.

Index Words: Peritoneal dialysis; Moncrief-Popovich catheter; peritonitis; exit-site infections; catheter-related infections.

Peritonitis rate from touch contamination in various peritoneal dialysis (PD) populations is continuously decreasing from 1983 because of the use of disconnect systems and flush before fill techniques.[1,2] Despite a decrease in the overall peritonitis rate, dropout rates to haemodialysis from PD caused by peritonitis remains steady.[3,4] This is predominately from the unchanged prevalence of exit-site and catheter-related infections leading to recurrent peritonitis.[5] This fact indicates that the current peritoneal dialysis catheters provide no true microbiologic barrier between the exit site of the PD catheter and the peritoneal cavity. The development and maintenance of a bacteriologic barrier between the exit site and the peritoneal cavity is essential for a permanent access in patients undergoing peritoneal dialysis. Transfer of bacteria from the abdominal wall into the peritoneal cavity occurs through the following mechanisms: (1) touch contamination with hand objects at the time of a PD exchange, which is minimized by the use of disconnect systems, (2) bowel-related organisms (eg, diverticulitis in elderly patients), and (3) pericatheter spread of bacteria from the skin wound at the exit site and subcutaneous tunnel which is associated with exit-site infection and recurrent peritonitis.[5] When Tenckhoff and Schecter[6] designed the standard peritoneal catheter, the most important step they took was the introduction of a Dacron cuff. The cuff is to act as a strong barrier against penetration of infection into the abdominal cavity via the exit site and subcutaneous tunnel.[6] Insertion of Tenchkoff catheter, however, violates a fundamental premise of wound healing. The presence of the foreign body (the catheter) in the immediate postoperative implantation procedure and

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the exit site through the skin form a passage for rapid and permanent colonization of the catheter tunnel and cuff(s) by skin bacteria. This colonization has been documented by electron microscopy as bacterial growth covered with exopolysaccharides (biofilm) on most of the surfaces of catheters studied shortly after implantation.[7] Recurrent episodes of peritonitis with the same organisms cultured at the catheter exit site suggest that colonization is associated with transfer of these organisms through the catheter tunnel directly from the skin into the peritoneal cavity.[8,9] When this occurs, there is no bacteriologic barrier between the abdominal wall and the peritoneal cavity. Thus, the Tenckhoff catheter has failed its fundamental design to establish and maintain the barrier.[5]

In spite of the most rigorous adherence of aseptic technique, microorganisms can be found in the operative field at the close of virtually all surgical procedures.[10] Creation of an exit through which bacteria can invade the fresh wound produce a scenario in which tissue in growth into the subcutaneous cuffs occurs in competition with bacterial invasion from the exit site. This invasion would retard or prevent healing and allow permanent colonization. It would also explain the presence of the biofilm on the external surface of the catheters even in patients whose catheters had never been used for dialysis.[7,8] Moncrief and Popovich designed a new catheter and implantation technique in 1991 to address this failure of current PD catheters to prevent pericatheter transfer of bacteria from the skin through the exit site and along the subcutaneous tunnel to induce infections in PD.[11]

Design of the Moncrief-Popovich Catheter: Difference from Tenckhoff Catheter

Moncrief -Popovich Catheter

Moncrief and Popovich designed their new catheter, made of silastic, with several important structural changes that differ from Tenckhoff catheter.[11] The changes and the reasons for the changes are as follows: (1) a coiled internal segment and (2) an arcuate bend in the subcutaneous segment (similar to the swan neck Missouri catheter designed by Twardowski et al,[12] and (3) 2 Dacron cuffs. The external Dacron cuff is elongated to 2.5 cm, and the ends of the cuff are tapered (longer than the internal one).

The changes in a coiled internal segment and an acruate bend in the subcutaneous segment are done to ensure that the new catheter will cause the least amount of mechanical complications because coiled catheters with swan neck bends induce less problems with catheter malpositions, catheter malfunctions, and/or pericatheter leakage.[12,13]

The changes in external cuff are done to increase the amount of surface on the cuff for more tissue ingrowth and to decrease the exposure of the cuff material to the skin bacteria that contaminate the exit site and catheter surfaces in the subcutaneous tunnel.

Moncrief- Popovich Catheter Implantation Technique

Moncrief and Popovich described a new implantation technique that significantly differs from conventional techniques of catheter implantation.[11] The intra-abdominal segment of the Moncrief-Popvich catheter (MPC) is implanted by using a surgical or subcutaneous puncture approach as in the conventional procedure for a double-cuffed, curled catheter; the subcutaneous tunnel segment with 2 Dacron cuffs and a swan neck bend is then implanted as described by Twardowski et al[12] except the external segment that would ordinarily be brought out through the skin in the standard implantation technique is completely buried under the skin in a subcutaneous tunnel. The entire wound is then closed with no exit site (Fig 1). Thus, the external segment remains buried for 4 to 6 weeks under the skin. The novel idea of complete wound closure during the postoperative period with subcutaneous embedding of the external part of the MPC allows healing of the exit tunnel with the tissue cells and prevents bacteria to colonize the catheter surfaces between the 2 cuffs. This, as per the objectives of this new procedure, ensures the provision of a bacterial barrier from the exit site to the abdominal cavity.

At a subsequent date, 4 to 6 weeks postoperatively, the distal segment of the catheter is

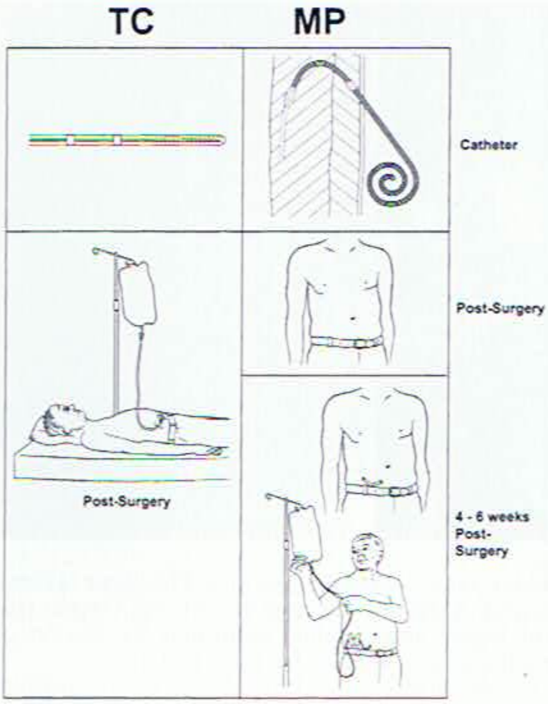

Figure 1. Line drawings representing the Tenckhoff catheter (TC) and Moncrief -Popovich catheter (MPC) and their respective implantation process. Top part of the figure shows the details of the external and internal segments of the silastic catheters, the position and configuration of the Dacron cuffs. The bottom part of the figure (second inset) represents immediate postimplantation phases of the respective catheters with patient. In the patient with TC, flushing, irrigation, and hospitalization are needed for 2 to 3 days. The patient with MPC, with embedded catheter, has no exit wound and does not require flushing, irrigation, and hospitalization after surgery. The patient is discharged on the same day. The third inset shows the step of exteriorization of the external segment of the MPC, a simple out-patient procedure, after 4 to 6 weeks after implantation with start of peritoneal dialysis.

then brought through the skin by a small incision, which is made 2 cm distal to the subcutaneous cuff perpendicular to the long axis of the catheter. The technique of delayed externalization facilitates tissue growth into the external cuff of a double-cuffed catheter. When the catheter is exteriorized, there are only 2 places to which bacteria can attach: the exit site and the catheter surfaces. However, the exit tunnel is well vascularized and patrolled by macrophages that can eradicate most bacteria, leaving the silicon surface as the only significant option for colonization. Because the new MPC implantation technique eliminates the second option, it should be very effective in preventing bacterial colonization of the catheter surfaces between the 2 cuffs and the exit site wound and provides maximum defense against any bacterial contamination from the exit site wound.[11]

Initial studies for Validation of the MPC and Implantation Technique

Moncrief and Popovich initiated various preliminary studies to validate their new catheter and implantation technique. They divided their studies in three parts. The first part was done in canine models of PD, the second part was done by clinical studies in PD patients, and the third part was done by electron microscopic examination of excised MPC. Moncrief and Popovich theorized that peritonitis episodes that led to catheter loss are the result of a failure of the standard technique of implantation to form an adequate bacteriologic barrier from the skin surface to the peritoneal cavity.[13] In an experimental model of PD, they showed in dogs that when catheter cuff material was implanted subcutaneously with a wick exposed to the skin surface, abscesses readily formed and tissue growth into the cuff was poor. However when the cuff material was implanted subcutaneously and the skin surface was closed for 6 weeks, a farm noninfected mass of scar growing into the cuff was achieved.[14] Moncrief and Popovich, therefore, hypothesized that if a double-cuffed catheter were embedded subcutaneously and allowed to heal, the externalization would have to be delayed for 3 to 5 weeks to improve tissue ingrowth into the catheter's external cuff, which would result in a more effective bacteriologic barrier.[14]

Exteriorization of the embedded MPC catheter without irrigation for 4 to 6 weeks may cause mechanical problems with blockage of catheter holes and omental adhesions, leading to catheter malfunctions. To examine this aspect of the problem, Moncrief and Popovich performed experiments again in a canine model of PD.[15] They compared the effect of catheter implantation with conventional and their new technique in relation to these mechanical problems. They noted that exteriorization of the catheter and irrigation with di-

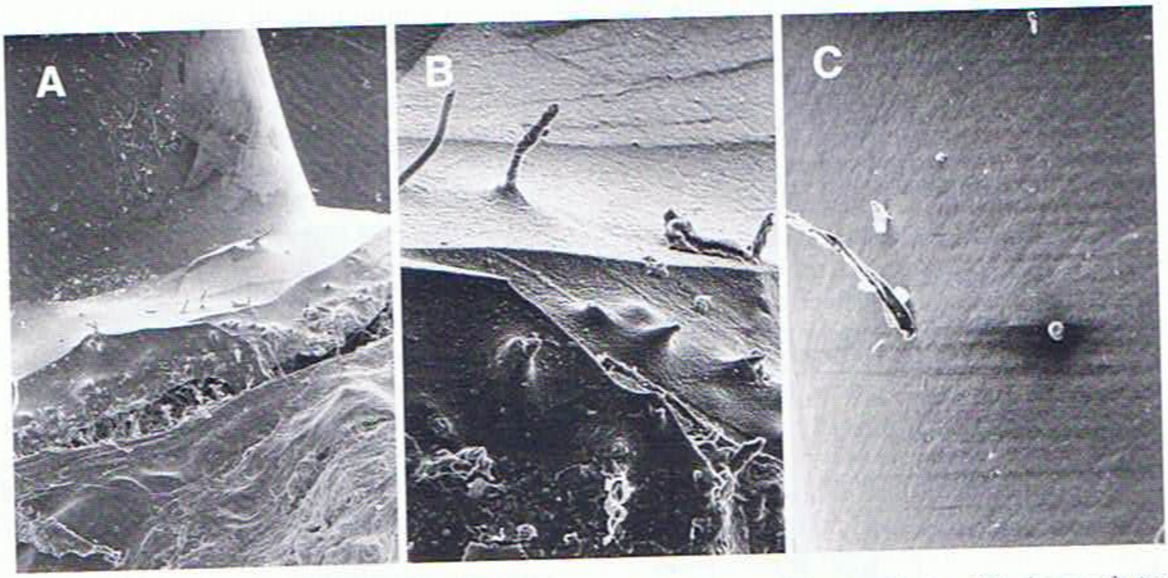

Figure 2. Scanning electron micrograph (SEM) picture of MPC removed from a patient on PD whose catheter was removed for renal trnsplantation. (A) Outer surface area of the catheter near the external Dacron cuff showing absence of bacterial biofilms. (B) Same field with higher magnification confirming the absence of biofilms. (C) Magnified view of the outer surface of the catheter area with no bacterial biofilms.

alysis fluids in canine experiments showed a higher degree of omental adhesion of the intra-abdominal segment of the catheters with conventional procedures, but with the MPC procedure (without irrigation with the dialysis solution), the incidence of omental adhesions was significantly lower. They concluded that catheter obstruction by omental adhesion is stimulated by immediate dialysis exposure; therefore, subcutaneously tunneled peritoneal catheters with delayed exteriorizations have an advantage.[15]

Encouraged by these experimental results, Moncrief and Popovich initiated clinical studies with their new catheter and implantation technique in PD patients in their center. In 1993, they reported results from 74 patients studied for a total of 201.2 patient months with the peritonitis rate of 1 episode every 28.7 patient months and the rate of ESI was 1 episode every 12.57 patient months.[16] In 1994, they reported further reduction of peritonitis rate in their patients with the combined use of MPC and disconnect systems to 1 episode every 32 months.[17]

In the third part of their study, Moncrief and Popovich initiated electron microscopic examination of bacterial growth on PD catheters that were removed from 12 patients for various clinical indications. The electron microscopic examinations were done blindly by 2 independent experts (JWC and MKD) in this field to verify the growth of bacterial biofilms on the surfaces of the 12 excised catheters; 3 were known to have contaminations. Nine of the 12 catheters were free or nearly free of bacterial biofilm growth on the catheter segment between the 2 cuffs, except the 3 that were known to have exit-site infection (Figs 2 and 3).[16] Moncrief and Popovich concluded from the results of their initial experimental clinical and electron microscopic studies[11,14-17] that the use of the new MPC and implantation technique creates an improved bacteriologic barrier between the exit site and the peritoneal cavity and reduce pericatheter infectious complications in PD. Further clinical studies with this new technique from other centers were needed to verify this claim.

Clincal Responses in 10 Years After the Introduction of MPC

A worldwide response occurred quickly to adopt the use of the new catheter and implantation technique as proposed by Moncrief and Popovich.[11,14] It was felt that although the use of MPC and embedding procedure may be beneficial for minimizing the risk of infections

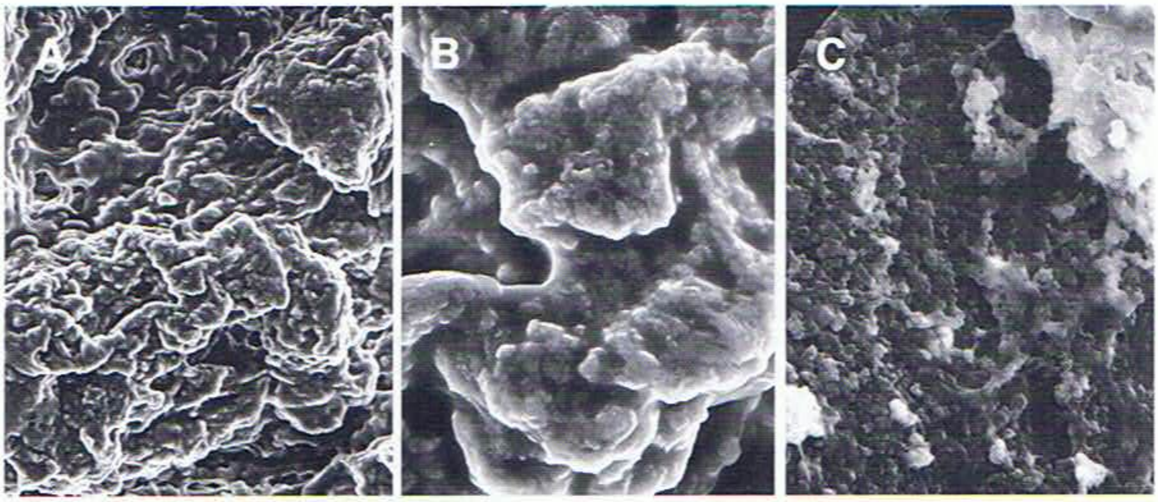

Figure 3. Scanning electron micrograph (SEM) of MPC removed from a patient on PD whose catheter was removed for recurrent peritonitis with Staph. aureus exit site infection. (A) Dacron cuff area near the external cuff. (B) Magnified view of an area in A and C, an area on the outer surface of the catheter near the external cuff. All 3 areas show diffuse and confluent formation of coccoid biofilm matrix with extensive adhesions.

complications in PD, but embedding of the catheter for 4 to 6 weeks without irrigation may cause catheter malfunctions from omental adhesions and/or from fibrin thrombus. Moreover, after the second operation for exteriorization of the embedded catheter, other problems like bleeding and haematoma formation at the exit site or pericatheter leakage of dialysis fluids may occur. These complications may lead to primary catheter failure, increase risk for infections, increase hospital expenses, and reduce patient acceptance. Therefore, before adopting to the new technique, most investigators initiated clinical studies in their respective centers to assess the clinical complications, infection rates, safety, and cost-effectiveness of the new subcutaneous embedding technique of the external segment of the catheter for 4 to 6 weeks in comparison to the conventional technique of catheter implantation with no embedding (Table 1). Because MPC was not universally available (or being expensive), most investigators used swan neck double-cuffed catheter with an arcuate bend in the middle.[18,19,21,22] The double-cuffed swan neck catheter was the

Table 1. Clinical Outcomes of MPC Technique in Various Centers

Author/Year	*Place*	*Study Catheter*	*Controls/ Catheter*	*Mechanical problems*	*Peritonitis Incidence**	*Exit site/ Pericatheter infections**
Han[18] 1992	Korea	Swan neck	Historical/ Swan neck	Acceptable	Lower	Lower
de Alvaro[19] 1994	Spain	TC	TC	Acceptable	No change	Lower
Caruso[20] 1997	US	MPC	Quinton Updike	Acceptable	Lower	Lower
Park[21] 1998	Korea	Swan neck	Swan neck	Acceptable	Lower	Lower
Prischl[22] 1999	Austria	Swan neck	Historical/ Swan neck	Increased	Lower	Lower
Page[23] 2000	Canada	TC	—	Accepatble	—	—
Esson[24] 2000	US	Single cuff Quinton coiled	—	Increased	Increased	Increased
Ahlmein[25] 2001	Sweden	TC	TC	Acceptable	No change	No change

Abbreviations: TC, Tenckhoff catheter; MPC, Moncrief Popovich catheter.
*Compared with controls.

closest possible catheter that resembled MPC. Other centers used straight catheters with the new embedding technique.[23-25] Results from various single-center studies in the last 10 years (Table 1) confirmed that the subcutaneous embedding procedure is simple, safe, and increases the life expectancy of the catheters.[18-25] Infectious and mechanical complications (Table 1) were also reduced by the use of the new embedding procedure, but the best results were seen with the use of the double-cuffed swan neck catheters than with the use of straight catheters.

Mechanical Problems

The rate of mechanical complications, like pericatheter leaks, omental adhesions, and hernia, was mostly acceptable but was dependent on the type of catheters used and the center experience with the new technique (Table 1). Interestingly, the rates of mechanical complications were only higher in centers that used straight catheters without double cuffs (Table 1). Use of straight catheters with the embedding technique is a clear violation of the recommendations made by Moncrief and Popovich, who designed the MPC to incorporate an arcuate bend between the 2 cuffs similar to that of swan neck catheters.[11,14] The swan neck, double-cuffed catheters reduce mechanical complications over a straight catheter by the permanent bend in the catheter, which prevents the normal tendency of the internal and external segment of the catheter to straighten material memory.[12,13,24] Straightening of the internal segment may lead to malposition or by applying tension on the internal cuff to pericatheter leak or hernia. Straightening of the external segment may lead to external cuff extrusion and exit-site infection.[12,13,24]

Infectious Complications

In relation to infectious complications, most of the investigators reported reduction of the peritonitis rate and exit-site and pericatheter infections by the use of the new technique of subcutaneous embedding compared with the conventional catheters and implantation techniques (Table 1). Additionally, further reduction of peritonitis, exit-site infections (ESIS), and pericatheter infections were noted with combined use of the new subcutaneous embedding technique and disconnect systems.[16-18] These reports were based on single-center and nonrandomized studies. To confirm these claims, further prospective randomized studies were initiated. In 1998, Park et al[21] in a randomized study confirmed that the rates of peritonitis and ESI both are reduced in patients undergoing PD treatment with double-cuffed swan neck catheters implanted by the new embedding technique with delayed externalization compared with the rates peritonitis and ESI in patients with swan neck catheters implanted by the conventional techniques with immediate externalization.[21]

An international, multicenter, randomized study comparing the MPC (n = 60) versus regular catheters (n = 53) was also reported in 1998.[26] The results of this international study indicated no difference in peritonitis rates between the patients using the MPC catheters and the regular catheters (0.47 *v* 0.41 episodes/yr/patient, P = .66). But the rates of exit-site infections were reduced by the use of MPC in comparison to regular catheters (0.109 *v* 0.284 episodes/yr/patient, P = .04).[26]

In our center , we used MPC catheters since 1992 and have observed its effect on ESI and peritonitis rate based on long-term use of the MPC from 1992 to 1998.[27] We used 2 different research designs: (1) a prospective nonrandomized study to compare the results of our experience on the use of MPC during the early period of 1992 to 1993 (Group A, n = 30) versus late period 1993 to 1994 (Group B, n = 35) and (2) a prospective randomized study to compare MPC (Group C, n = 22) versus Tenckhoff catheters (Group D, n = 19). Our result indicated that the rate of ESI improved over time (indicating center experience) and was significantly below the rate of ESI from the use of Tenckhoff catheters (randomized study, $P < .05$) (Fig 4). The peritonitis rate was no different between different time periods and between the use of MPC and Tenckhoff catheters.[27] In this respect, our results were similar to the multicenter randomized study.[26]

Thus, the results of the randomized studies[26,27] confirm the original hypothesis of

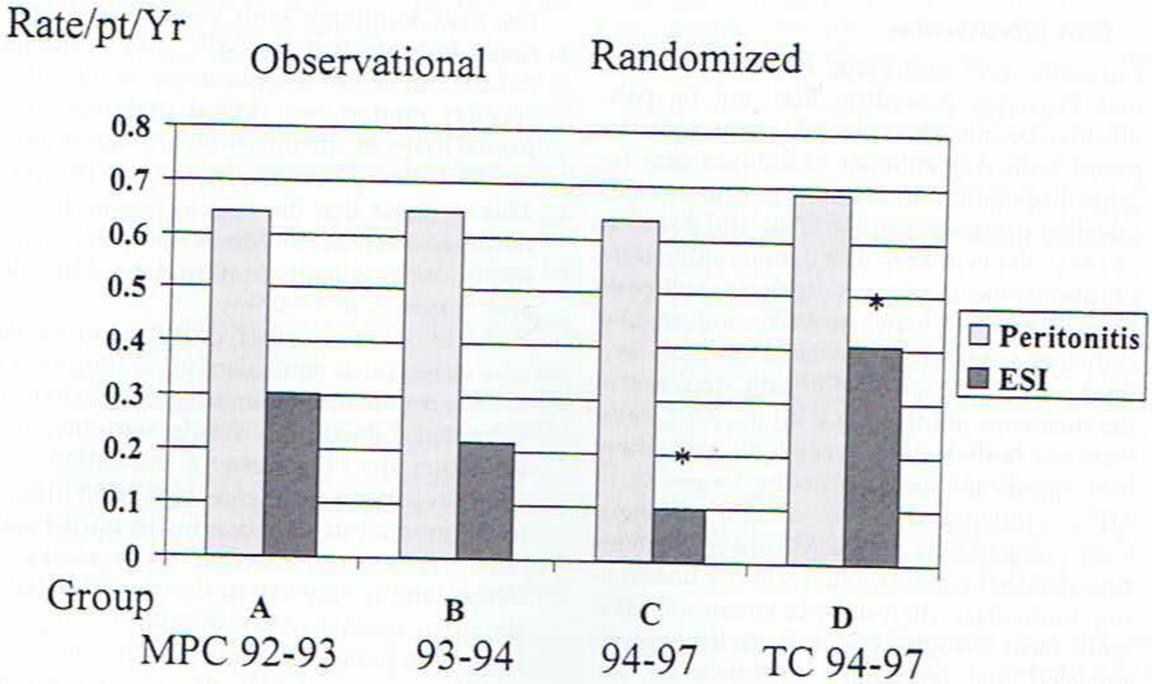

Figure 4. Comparison of incidence peritontis and exit-site infection with the use of MPC in our university center from 1992 to 1997. The period from 1992 to 1994 represents prospective but observational data, indicative of center experience with the new technique. Prospective data from 1994 to 1997 indicate results from a randomized trial of MPC in comparison to Tenckhoff catheter in the same center.[27]

Moncrief and Popovich that the use of the MPC and implantation technique can reduce exit-site and catheter-related infections in PD by preventing pericatheter spread of bacteria from the exit site to the subcutaneous tunnel. The new catheter implantation technique is not designed to affect peritonitis occurring from other avenues like touch contamination or bowel-related infections in PD.

Bonus Effects of the MPC and Implantation Procedure

Simple and Safe Procedure: Acceptable to Patients and Health Care Systems

The use of the new catheter and the implantation technique was originally adapted by various centers with the primary objective for reduction of pericatheter infections in PD. But it soon became apparent that this new embedding technique is safe, simple, and provides additional benefit for improving quality of patient care and cost savings to the health care systems.[18,19,21,23,25] Stable patients with end-stage renal disease, who will not require immediate dialysis and once get selected to undergo PD treatment from the predialysis clinics, are electively operated with this new catheter implantation procedure. The catheter remains embedded for 4 to 6 weeks or more until the patient requires starting on dialysis. The operative procedure for subcutaneous embedding is simple and requires no flushing of the catheter postoperatively (Fig 1). Patients are discharged from the hospital on the same day of surgery and thus reduce hospital and nursing costs significantly. Patients with embedded catheters, postoperatively, have no scar, no cosmetic problems, and can continue with their daily activities including swimming and bathing without any risk of infections at the exit wound (Fig 1). Keeping the catheters embedded for 4 to 6 weeks or longer produced no significant drawbacks with mechanical complications like omental adhesions or catheter malpositions.[20,21,23,25] The exteriorization of the catheter is done as a simple outpatient procedure, which takes a few minutes, and the dialysis is started at the same time in the patient.

Cost Effectiveness

Concerns were also made that the Moncrief and Popovich procedure may not be cost-effective because it involves 2 operations compared with conventional techniques that require 1 operation. In an effort to examine this question precisely, Caruso et al[20] did a review of 195 patients in 1997. The demographic complications, life expectancy analysis, and costs were compared between MPC and regular catheters. Comparison revealed clinically evident and statistically significant decrease in the incidence of infection with the MPC catheters. At both 1- and 2-year follow-up, there was significant increase in the longevity of MPC compared with the straight catheters. Cost comparisons between catheter systems revealed that patients who were not undergoing immediate dialysis, placement of MPC were most cost-effective. Sensitivity analysis revealed that temporary subcutaneous implantation of MPC significantly decreased the incidence of infectious complications, increased catheter life expectancy, and was the cost-effective choice for patients who will undergo peritoneal dialysis.[20]

Cost of the new catheters was also a factor. But it was soon realized that the technique of burying the distal segment of the PD catheter in a subcutaneous tunnel with delayed exteriorization can be used with various other type of peritoneal dialysis catheters with the same clinical and economic advantages of MPCs.[18,19,21-23,25] The advantages and convenience of the new technique made the procedure highly acceptable to patients and staff of the dialysis units. This new procedure is therefore widely used as a simple and effective way to improve patient outcomes in PD by various health care systems around the world.[18-25]

Conclusion

Moncrief and Popovich introduced a new catheter design and implantation technique to reduce infectious complications in PD occurring by bacterial colonization of catheters via the pericatheter routes. Since its introduction, 10 years have passed. Results from various nonrandomized clinical studies comparing the new technique with conventional technique indicate that the MPC and technique reduce infectious complications in PD. Prospective randomized clinical trials also confirmed that exit-site infections are significantly reduced than peritonitis by the use of MPC. This confirms that the new technique indeed reduces infections in PD by the pericatheter routes, as originally proposed by Moncrief and Popovich in 1990.[11,14]

Additionally, another contribution of the new technique is equivalent to creating an AV fistula in patients undergoing haemodialysis treatment. Like the AV fistula, with this new technique, the PD catheter is implanted electively in patients with end-stage renal disease in the predialysis period, remains buried subcutaneously after insertion for 5 weeks or longer, and is only exteriorized to start dialysis when needed. Also, infectious complications from pericatheter and exit-site infections in PD are reduced with the use of this new technique. Therefore, an unprecedented acceptance for this new technique of subcutaneous embedding with delayed exteriorization of the external end of the catheter has occurred by patients and health care authorities around the world to improve the quality of care of PD patients.

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