Peritoneal dialysis (PD)–associated peritonitis contributes significantly to morbidity and modality failure. The number of patients on PD is declining in Western countries, and peritonitis is a potential deterrent to the therapy. Here, we present a clinically significant decline in the rate of peritonitis at a single center over a 28-year period, with current rates significantly lower than the national average, and we review several factors that have contributed to those outcomes.

Peritonitis and duration of follow-up have been recorded for all patients followed in our program since 1977. Introduction of important technological changes into the program were also recorded. All peritonitis rates are expressed as episodes/patient–year or episodes/patient–months. Data are summarized for each calendar year since 1977.

We followed 682 patients for a total follow-up duration of 15,435 patient–months. Glass bottles were changed to plastic bags in 1978. Straight connecting tubes were replaced by Y-sets in 1988. The presternal dialysis catheter was introduced in 1991 and has been the primary PD access since 1995. The peritonitis rate in 1977 was 5.8 episodes/patient-year, and that rate has progressively declined over the past 27 years to 0.35 episodes/patient–year in 2004.

Technical improvements that contributed to the decline in overall peritonitis rates have been adopted nationwide. The largest improvement occurred with the switch from glass bottles to plastic bags, and to the closed-system Y-set that incorporated the flush-before-fill principle. Advances in catheter technology have also played a key role. Quality improvement in the program and long years of experience in overall care of PD patients are significant factors that cannot be measured quantitatively. Improvements have been made to exit-site care protocols, to exit-site evaluation and diagnosis, and to treatment strategies. Patient education and training in catheter care remain the important factor in a PD program.

Many factors have contributed to the reduction of PD-associated peritonitis rates at our center. Improved connectology, catheter care, and patient education play key roles in the reduction of peritonitis.

**Key words**
Peritonitis rate, CAPD, CAPD-associated peritonitis, Missouri swan-neck catheter, presternal catheter

**Introduction**
Peritoneal dialysis (PD) is an important modality in the treatment of end-stage renal disease, but reports from the United States Renal Data System (USRDS) document a decline in the number of patients on PD. One of the deterrents to choosing PD is the higher morbidity and mortality associated with infection (1). The focus in recent years in the field of PD has been to find new technologies to reduce the incidence of infections and to prolong survival of the access, thus prolonging the lifespan of the patient on PD. Our center has put much thought into exit-site care and treatment protocols and into the development of new catheter technology, and has thus developed a tremendous amount of in-center experience in the management of PD (2,3). The present retrospective analysis reports the rates and trends of peritonitis at our institution from 1977 to 2004.

**Patients and methods**
We carried out a retrospective chart review of all PD patients followed over 28 years at the University of
Missouri and Dialysis Clinics, Inc., in Columbia, MO, U.S.A. We prospectively recorded peritonitis episodes in a peritonitis log that was tabulated annually for all patients based on PD patient–years. For each patient, time on PD was defined as the time from catheter insertion to the end of the annual period being tabulated. The rate was then determined for all episodes of peritonitis. The peritonitis rate was calculated as total patient–years divided by the total number of episodes of peritonitis and was reported as either episodes/patient–year or episodes/patient–months. The rate was determined for each year in the study.

**Results**

From 1977 to 2004, our center followed 682 patients. The total duration of follow-up was 15,435 patient–months (1,286 patient–years). The initial rate of peritonitis in 1977 was 5.8 episodes/patient–year. That rate gradually declined, so that by 2004, the annual rate was 0.35 episodes/patient–year (Figure 1). That rate, 1 episode for every 34.3 patient–months, is lower than the recently reported national average of 1 episode for every 25 patient–months (4,5).

**Discussion**

The peritoneal dialysis modality offers an effective alternative to hemodialysis. Patients who are unable to undergo—or to tolerate—hemodialysis can choose to perform PD. However, concern over the use of the PD modality has arisen because USRDS data show a decline in the rate of PD use since 1995. That decline has been attributed to a study that analyzed USRDS data and found higher mortality rates among patients on PD than among those on hemodialysis, largely due to infection (1). The most common infection associated with PD is peritonitis.

The extremely high rate of peritonitis in 1977 was in large part attributable to the PD exchange systems and technique. In the United States, dialysis solutions were available only in glass bottles. The bottles had to be spiked, and the administration tubing had to be connected and disconnected from the catheter for each exchange. That technique afforded many opportunities for contamination of the system.

The U.S. Food and Drug Administration approved dialysis solution in bags in 1978, a move that may have been associated with another significant decrease in peritonitis rates the following year. In 1979,
Buoncristiani introduced the Y-set, with the flush-before-fill technique (6) that washed any contamination of the spike away from the peritoneum by draining after introduction of the spike. This technique was the first important advance in continuous ambulatory peritoneal dialysis since the therapy was developed by Popovich and Moncrief in 1976. The flush-before-fill technique was tested in vitro and was shown to remove 100% of *Staphylococcus epidermidis*, 60% of *S. aureus*, and 30% of *Pseudomonas aeruginosa* from tubing when flushed with 100 mL of fluid immediately after inoculation (7). In a review of seven randomized trials with a total of 485 patients, Maiorca and Cancarini (6) reported a significantly lower risk of peritonitis with the Y-set than with standard spike systems [risk ratio (RR): 0.64; 95% confidence interval (CI): 0.53 to 0.77]. Those authors also reviewed eight randomized trials comprising 7,417 patient-months and found a significantly lower rate of peritonitis with the Y-set than with the standard spike (RR: 0.49; 95% CI: 0.40 to 0.61).

To reduce access-associated complications such as exit-site and tunnel infections, pericatheter leaks, catheter tip migration, outer cuff extrusion, and peritonitis, our center introduced the swan-neck Missouri catheter (8). The swan-neck design has a flange and bead just below the internal cuff of the catheter. Twardowski and colleagues developed a downward-directed exit site to reduce exit-site and tunnel infections. Locating the deep cuff in the rectus muscle was designed to minimize leaks. A caudally directed catheter tip, together with the introduction of a permanent bend between the cuffs was designed to reduce catheter tip migration and outer cuff extrusion respectively. Previous prospective and retrospective data comparing the Missouri swan-neck, the Tenckhoff, and the Toronto Western Hospital catheters demonstrated improved survival and overall reduction in complications with the swan-neck catheter (8,9).

The presternal catheter was subsequently introduced to further reduce exit-site infections relative to the conventional abdominal catheter (10,11). The chest wall is subject to less movement, reducing the risk of trauma and contamination. Wounds heal better on the chest wall because the subcutaneous tissue is also thinner than in the abdomen. The design proved to be particularly useful for obese patients; moreover, it allowed all patients to take baths or whirlpool treatments (10,11). Swan-neck presternal catheters have been reported to improve survival and peritonitis rates as compared with swan-neck abdominal catheters (9,12).

The presternal catheter is composed of two silicone tubes that are linked by a titanium connector during implantation; the exit-site is created on the chest (11,13). The implantation technique has been previously described in detail (10,11,13).

In the past decade, our center has also initiated exit-site protocols that have contributed much to the decline in peritonitis rates (Figure 1).

**Conclusions**

Early in the 1980s, the introduction of the Y-set and flush-before-fill was a large contributor to the decline in peritonitis rates nationwide. Since 1995, when our center switched to placing primarily presternal catheters, our peritonitis rates have declined even further. In addition, the introduction of exit-site care and treatment protocols has helped to further reduce rates. Technology advances have reduced the PD peritonitis rate to a near negligible level, but effective patient training in the care and maintenance of the peritoneal catheter is still paramount. We believe that this last point is critical in reducing rates of infection at our center and at others.

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Corresponding author:
Adam Whaley–Connell, DO, Post-doctoral Fellow, Division of Nephrology, Department of Internal Medicine, University of Missouri Health Sciences Center, MA436, DC043.0, Columbia, Missouri 65212 U.S.A.
E-mail: whaleyconnella@health.missouri.edu