

PERITONEAL TRANSPORT: UNDERSTANDING THE NUMEROUS TESTING METHODS

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In peritoneal dialysis (PD) patient's treatment success is dependent on the functional and morphological integrity of the peritoneal membrane. Besides functional failure of the peritoneum, long-term PD may lead to anatomic changes in the peritoneal tissues such as neoangiogenesis, vasculopathy and fibrosis, sometimes causing peritoneal sclerosis. Because of these changes peritoneal permeability varies widely between patients and can change significantly over time within an individual. The peritoneal membrane changes and as a consequence the peritoneal transport status have been reported to play a major role in determining patients' morbidity and mortality¹.



In order to find an appropriate PD modality and prescription it is crucial to assess patient's actual peritoneal membrane transport status as accurately as possible. Peritoneal membrane transport does not only refer to transport of solutes, e.g. uremic toxins and electrolytes, but also fluid transport. Since both elimination of uremic toxins and ultrafiltration account for adequacy, it is important that a test method reliably assess both parameters.

Numerous techniques for measuring peritoneal transport are available (see table), of which the most prominent and widely used is the PET (**peritoneal equilibration test**), developed by Twardowski, et al². The PET was the first standardized method to quantify individual peritoneal membrane characteristics and to compare with larger populations. The results of the PET have been found to be relatively stable and highly reproducible.

After an overnight exchange of an 8 to 12 hour dwell:

- 2 liters of 2.5% (2.3% anhydrous) glucose concentration solution is instilled and allowed to dwell for 4 hours
- Several times during the dwell the patient is requested to roll from side to side
- Dialysate urea, glucose, sodium and creatinine are measured at 0, 2 and 4 hours
- A blood sample is taken after 2 hours
- The drain bag is measured to assess both drain and net ultrafiltration volume
- Dialysate to plasma ratios (D/P) are calculated for creatinine, urea and sodium at 0, 2 and 4 hours
- The ratio of glucose at drain time to the dialysate glucose concentration at time 0 (D_t/D_0) is measured

Based on population studies, patients are categorized as low, low-average, high-average or high transporters.

Since the PET is very labor intensive, the *fast* PET³ provides a simpler alternative by requiring only one dialysate sample. After draining the overnight dwell, the patient starts an exchange at home and arrives at the center in time for drainage of this 4-hour dwell. A blood sample is taken at the end of the exchange. The analysis of the *fast* PET is identical to that for the standard PET. However, only two reliable measures of peritoneal membrane permeability are determined, D/P creatinine and dialysate glucose after 4 hours. If these 2 measures give contradictory results, it may be difficult to accurately interpret the test. The original PET was standardized for a long overnight exchange since almost all patients were on CAPD and this was the most convenient approach. Recent studies confirmed the minimal impact of the prior long exchange on small solute equilibration. Thus, for clinical purposes, Twardowski, et al. have introduced the *short* PET⁴ accepting any dwell time between 3 and 12 hours for the prior exchange and even permit the test to be performed with either a 2 or 4 hour dwell. Gotch, et al. have suggested that the procedural steps in the PET may actually overestimate peritoneal membrane transport and underestimate the variation in peritoneal transport that may occur under actual clinical conditions⁵. Moreover, it is imperative to be aware that the PET alone does not give an assessment of total solute removal (adequacy).

Continued on page 2

Contents



Peritoneal Transport: Understanding the Numerous Testing Methods
Page 1, 2, & 3

Medical Professional Education and PD Serve® in Hong Kong and Taiwan
Page 6



GEMS
Peritoneal dialysis: Myths, barriers, and achieving optimum outcomes
Page 3 & 6

International calendar of events
Page 5

Thus, the PET should be combined with a 24-hour collection for renal and peritoneal solute clearance.

The Peritoneal Function Test (PFT), developed by Gotch, et al. has been extensively used and validated in multicenter studies^{6,7}. It measures the peritoneal mass transfer area coefficient during routine exchanges instead of under highly controlled conditions required for the PET. In addition to peritoneal transport and fluid balance, this test allows the clinician to assess total delivered dose for urea and creatinine and to collect information on protein and calorie nutrition.



The PFT requires:

- Sampling of each exchange
- A written record of exchange, inflow and outflow volume and glucose concentration
- Duration of dwell for each exchange in the 24-hours before a clinic visit
- A urine collection and blood sample are required at the end of the collection
- An exchange drained in the clinic at the time of the visit (QA, quality assurance exchange) as control

The dialysate exchange samples or aliquots are analyzed for urea, creatinine, glucose and total protein. The urine is analyzed for urea, creatinine and volume and the blood sample is tested for urea, creatinine, glucose, total protein and albumin. The results can be entered into a computerized kinetic modeling program (Pack-PD® or Patient on-line [POL]) to determine the mean mass transfer area coefficient (MTAC), which is displayed as Pt_{50} , (the time required for the dialysate concentration to reach 50% of plasma concentration for urea and creatinine).

For follow up, a simplified PFT (SPFT) can be used. For the SPFT:

- The patient records the percent of glucose concentration used
- Fill and drain volumes and duration for each exchange over 24 hours
- An aliquot of a single 2 to 3 hour exchange, timed so that it can be drained in the clinic (the QA exchange),
- A blood sample and a 24 hour urine collection

A new Pt_{50} is calculated from previous three D/Ps of a standard PFT and the current D/P of the SPFT QA exchange. Reading the results of a PFT may take a little time, however it gives a clearer picture of the actual regimen as performed by the patient and problems with nutrition, compliance and water balance can be detected earlier.

The 24-hour batch dialysate test in combination with a simultaneous

urine collection and a blood sample can provide a good measure of delivered dialysis dose^{8,9}. The main disadvantage is the required collection of individual drains and their measurement. Unless the patient is well trained and reliable, it is best to perform the measurements and sampling at the clinic. According to one study, the 24-hr D/P creatinine correlates well with the PET transport information.

The peritoneal dialysis capacity (PDC) program is based on the three-pore-model from Rippe, et al^{10,11}. The PDC program describes the peritoneal membrane characteristics by means of three parameters: 1) the area parameter $A_0/\Delta X$, which determines the diffusion of small solutes; 2) the final reabsorption rate of fluid from the abdominal cavity to blood when the glucose gradient has dissipated ($J_{V_{AR}}$); and 3) the large pore fluid flux (J_{V_L}) which determines the loss of protein to the PD fluid. In brief, patients are asked to perform five exchanges. The day starts with a short PD dwell (2-3 h), followed by two intermediate dwells (4-6 h), and another short exchange (2-3 h), and finally a long overnight dwell. The glucose concentrations are also varied so that one of the short dwells is performed with a different glucose concentration than the others. This variation is applied to obtain as much information as possible about the characteristics of the peritoneal membrane.

Patients are asked to:

- Weigh the bags
- Take samples from all drained bags
- Note the exact weight of the bag before and after instillation of the fluid
- Note the time of instillation and drainage
- Collect 24 hour urine

The dialysate samples are analyzed for urea, creatinine, glucose and albumin (protein). Urine concentrations of urea, creatinine and protein are analyzed. Blood samples are taken at the beginning and the end of the test for determination of sodium, urea, creatinine, glucose and albumin (or protein). All this information is then combined with a computerized mathematical approach employing the three-pore model to estimate the parameters of membrane function. This test was also designed to mimic ordinary PD events. Not only can it enhance understanding the peritoneal membrane physiology, but it allows more accurate analysis of transport characteristics and ultrafiltration, as well as the underlying mechanisms¹².

In an attempt to develop an easier test for classifying peritoneal transport type, the dialysis adequacy and transport test (DAT) was introduced by Rocco et al^{13,14}. For this test, the patients are asked to perform their exchanges as usual. Only a serum sample and a 10 ml aliquot from a pooled, well-mixed 24-hour dialysate are required and the 24-hour D/P is calculated. Since the DAT has only been validated for patients on a fixed CAPD schedule of 4 two-liter exchanges, this test should only be used for patients on this prescription and should not be used for patients on cyclical therapy¹⁵.

The accelerated peritoneal examination (APEX) test follows the regime of the PET, but summarizes in a single number the peritoneal permeability for both glucose and urea¹⁶. It represents the time at which glucose and urea equilibration curves cross. Generally, the APEX may be shorter than a PET since most patients exhibit a crossing of the curves before 2 hours. The shorter the APEX time, the higher the peritoneal permeability and, conversely, the longer the time, the lower the peritoneal permeability. The APEX time may help to find out the optimum contact time between the functional peritoneal membrane surface area and the dialysate for the individual patient. If UF is the major goal, short dwell times should be used. If solute clearance is the major goal, longer dwell times should be used.

The standard peritoneal permeability analysis (SPA) is a more sophisticated way to assess peritoneal function¹⁷. It uses intraperitoneally administered dextran 70 to study fluid kinetics during a 4-hour dwell. The test was originally developed using the lowest glucose concentration. In the SPA, MTAC of small solutes, the percent of glucose absorbed and the peritoneal clearances of serum protein are calculated. The PET parameters can be calculated from the SPA parameters. Conversely, the D/P creatinine and the D_t/D_0 glucose can be used with the drained volume to calculate MTAC of creatinine and the percentage of glucose absorbed. Using SPA with the highest glucose concentration provides

better information on ultrafiltration because the larger drained volume makes the result less subject to measurement errors and the sodium sieving phenomenon associated with a hypertonic glucose solution provides an assessment of aquaporin-mediated water transport. The magnitude of the dip in D/P sodium is a rough estimate of the water channel function.

For each test mentioned above it has to be considered that peritoneal transport characteristics change significantly within the first month of PD. Peritoneal function tests performed during this time should be seen as preliminary and should be confirmed by an additional test 4 weeks later¹⁸. It is also important to recognize that peritoneal membrane function measurement - no matter if solute clearance or UF - is subject to error. Therefore, one should be cautious with the interpretation of a single reading. This problem can be overcome by including several exchanges within 24 hours for the analysis, as with the PFT or PDC. Furthermore, because most creatinine assays based on the Jaffé method are also sensitive to glucose, dialysate creatinine concentrations are falsely high and need to be corrected for high dialysate glucose concentrations.

Possible differences in peritoneal transport between children and adults have been discussed by many authors. A recent study from Bouts, et al did not confirm these concerns¹⁹. The results suggest that the peritoneal membrane in children may not be different from that in adults. Principally all the tests mentioned above are also applicable in children, the highest experience existing with the PET.

It is unclear how often peritoneal function should be assessed. The K/DOQI guidelines (National Kidney Foundation Dialysis Outcomes Quality Initiatives) recommend a measurement every 4 months²⁰. However, the tests are time-consuming for both patients and nurses. Facility personnel may have their own protocol for when to perform a test and some may assess patient's peritoneal function solely in cases of clinical irregularity. Ideally, one standard test used worldwide would be advisable, but since each test presently applied has its pros and cons, it is up to the Medical Director, which test best fits their needs.

Various tests existing to measure peritoneal membrane transport and other parameters

	PET	PFT	PDC	24 hour batch dialysate	DATT	APEX	SPA
Peritoneal membrane transport	●	●	●	●	●	●	●
Total peritoneal clearance		●	●	●			
Residual renal function		●	●	●			
Ultrafiltration	●	●	●	●			●
Nutritional status		●	●	●			

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PERITONEAL DIALYSIS: MYTHS, BARRIERS, AND ACHIEVING OPTIMUM OUTCOMES

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A recent article entitled “Peritoneal dialysis: Myths, barriers, and achieving optimum outcomes” suggests that peritoneal dialysis programs are often “plagued by myths and misinformation”. Bernardini attempts to disprove some of these beliefs with a review of up-to-date literature and show that to achieve optimum outcomes, an active continuous quality improvement team is a necessity.

The article was divided into three sections: Myths, Barriers and Outcomes. The first section discusses such myths as: peritoneal dialysis (PD) has high infection rates, noncompliant patients

should not be on PD, patients with a high body mass index (BMI) are not appropriate for PD, PD requires totally independent patients and PD has a poorer survival rate than hemodialysis (HD). Excellent tables and graphs are provided to dispel the high risks of infection and the survival advantage of HD. This report updates the reader to recent studies regarding these topics.

Among the barriers to using PD over HD, is the limited exposure and training of new nephrologists to PD, particularly in the United States. These facts may materially affect the choice of modality.

MEDICAL PROFESSIONAL EDUCATION AND PDSERVE® IN HONG KONG AND TAIWAN

Dora Chan, Regional Marketing Manager - Greater China
Fresenius Medical Care Asia Pacific

Peritoneal dialysis has been available in Greater China for approximately a decade. During that time, Fresenius Medical Care's Hong Kong and Taiwan teams have been very involved in supporting this treatment mode with state-of-art products and quality services. To continue this support and expand our services, we launched PDServe® in Hong Kong and Taiwan in late 2003. Throughout 2004, several new or improved contributions were made to the professional education program organized as part of our PDServe® offerings (Table 1).



In Hong Kong, a large-scale workshop was held, while in Taiwan, three regional workshops and a number of center-based mini-workshops, including topics such as exit site classification and infection control in PD were provided. We have trained more than 440 doctors and nurses during these PDServe® sessions. Follow up with several attendees revealed that many centers have incorporated the exit site classification into their routine checks and are effectively using the flipcharts and other exit site tools provided by PDServe®.



Table 1. Summary of services offered

Education:

- Exit site seminars
- Balance and biocompatibility workshops
- Educating hospital staff about PD
- Demonstrations on CAPD and APD procedures
- Basic and advanced PD training for nurses
- Physician's training on PD

Support tools:

- Videos, flipcharts, posters, pocket references
- PDServe® Connection newsletter

Support services:

- Home visits for patients
- PDServe® Information Centre

Research:

- Fresenius Medical Care Asia Pacific product clinical trials

Development:

- Provide assistance with PD centre setup and design

The Greater China region of Fresenius Medical Care Asia Pacific will continue our PDServe® offerings in 2005 and look forward to providing our customers with ongoing support through medical education workshops and tools.

Continued from page 3

The article concludes with a discussion about achieving optimal outcomes. A successful PD program is characterized by high patient retention. Continuous Quality Improvement (CQI) is instrumental to reaching this goal. The CQI team can improve outcomes by decreasing infection rates as has been done at the University of Pittsburgh program.

It is clear from this article that: 1) PD does not mean higher infection rates, 2) PD does not necessarily imply lower survival rates, 3) PD may be a choice for patients who are not totally independent but have excellent support systems, 4) Education of new nephrologists in both PD and HD is very important, 5) Pre-dialysis patient education, and ongoing patient monitoring CQI can markedly improve outcomes, including patient survival.



Article Review:

(This article is based on Bernardini, J. Peritoneal dialysis: myths, barriers, and achieving optimum outcomes. *Nephrology Nursing Journal* 31:494-498)

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INTERNATIONAL CALENDAR OF EVENTS

April 29-May 1, 2005 1st North American Chapter Meeting of the International Society for Peritoneal Dialysis (ISPD). Chicago, IL USA. Contact: Events International Meeting Planner Inc. Telephone: 514-286-0855; Fax: 514-286-6066; E-mail: info@eventsintl.com; or visit their website at <http://www.ispd.org>

May 4-8, 2005 National Kidney Foundation 2005 Spring Clinical Meetings Washington, D.C. Contact: National Kidney Foundation; 30 East 33rd Street New York, NY 10016 - Ph: (800) 622-9010 or (212) 889-2210; Fax: (212) 689-9261 or visit their website at <http://www.kidney.org>

May 24-27, 2005 14th International Vicenza Course on Hemodialysis. Vicenza, Italy. Congress Center of Ente Fiera, Via dell'Oreficeria, 36100 Vicenza. For more information please visit their website at www.vicenzanephrocourses.com or www.nefrologiavicenza.it

June 4-7, 2005 European Renal Association/ European Dialysis and Transplant Association XLII Congress. Istanbul, Turkey. Telephone: +39-0521-989078; Fax: +39-0521-959242; Email: congress@euromeetings.it or visit their website at <http://www.eraedta2005.org>

June 9-11, 2005 American Society for Artificial Internal Organs (ASAIO) 51st Annual Conference, Washington, D.C. Theme of conference - "Enabling The Future Through Discovery & Innovation". Contact: Patricia Stolack; Telephone: 561-391-8589; Fax: (561) 368-9153; Email: info@asaio.com or visit their website at <http://www.asaio.com/> for more information.

June 26-30, 2005 3rd World Congress of Nephrology; 18th Congress of the International Society of Nephrology; 10th Asian-Pacific Congress of Nephrology; 15th Renal Update of the Singapore Society of Nephrology. Singapore. Contact: 3rd World Congress of Nephrology - Congress Secretariat & Housing Bureau - C/o Ace: Daytons Direct (International) Pte Ltd - 2 Leng Kee Road #04-02 Thye Hong Centre Singapore 159086 - Website: www.wcn2005.org/home.htm; Email: admin@wcn2005.org; Phone: (65) 6379 5261; Fax: (65) 6475 2077

September 10-13, 2005 34th International Conference of the European Dialysis and Transplant Nurses Association/European Renal Care Association (EDTNA/ERCA) Vienna, Austria. Theme of conference - "Bridging the Gap between Patient and Technology". Contact: EDTNA/ERCA Head Office at Pilatusstrasse 35 Postfach 3052 - CH-6002 Luzern, Switzerland. Telephone: +41 41 766 05 80; Fax: +41 41 766 05 85 or visit their website at <http://www.edtna-erca.org/> for more information.

September 23-24, 2005 4th Annual Conference on Prevention in Renal Disease. Toronto, Canada. Contact: Prevention in Renal Disease, 399 Bathurst Street, ON M5T2S8 Canada, Telephone: (416) 603-7974 or visit their website at <http://www.nephrorevention.com>.

October 15-18, 2005 7th European Peritoneal Dialysis Meeting. Prague, Austria. Contact: EuroPD Congress Secretariat c/o In Conference Ltd., 10b Broughton St. Lane Edinburgh, EH1 3LY, UK; Email: margaret@in-conference.org.uk; or visit their website at <http://www.europd.com/> for more information.