



Peter C. Farrell

PERITONEAL MASS TRANSFER

The most fundamental parameter of the human peritoneum, as it relates to solute transport, is the overall mass transfer coefficient (MTC). To some clinicians this term may sound as if it is not connected to clinical reality. In fact, it is of fundamental importance because it is the maximum achievable clearance, without the effect of ultrafiltration. Clearly, the latter can enhance clearance by solute-solvent coupling due to convection. However, to determine the capacity of a given peritoneum to remove solutes, be they drugs, waste metabolites or whatever, one would need to know the peritoneal MTC. Furthermore, serial measurements of the MTC provide the most accurate indicator of variations in the permeability of the peritoneum.

Even a rapid clearance measurement (45 minutes) would only provide a rough indication of changes in peritoneal permeability because even if adhesions were causing peritoneal area loss, or if fibrosis of the peritoneum was leading to peritoneal thickening, the reduction in diffusive capacity of the peritoneum is likely to be balanced by an improved convective removal of solute. The explanation is simple. A reduction in peritoneal MTC affects both outgoing (e.g. urea, creatinine) and ingoing (e.g. glucose) solutes in the same way. A reduction in the diffusive capacity for, say, urea means that the diffusion of glucose into the blood must also be compromised. As a consequence, for any given dialysate, there will be greater ultrafiltration due to the retention of glucose within the peritoneal cavity. The net result is improved convective solute removal overcoming, to a greater or lesser degree, the reduction in the peritoneum's diffusive mass transfer. In brief, the only way to be sure about subtle (as opposed to gross) changes in the peritoneum is to determine the mass transfer coefficient.

Various models of peritoneal mass transfer have been proposed (1-4) none of which are perfect but all of which, if correctly applied under appropriate exper

From the Center for Biomedical Engineering, The University of New South Wales, Sydney, Australia, 2033

imental conditions (4), can provide indications of any changes which may occur in the patient's dialysing surface.

Peter C. Farrell

We have used a model of the peritoneal mass transfer kinetics to follow patients' MTCs over periods of up to two years (4). Our initial observations (5) suggested that patients on intermittent peritoneal dialysis appeared to have a "tighter" membrane than patients who have been on CAPD for two weeks or more. In fact, the mean MTC for vitamin B12 (MW, 1355 Daltons) was 4.2 ± 1.5 ml/min in IPD patients compared to 7.4 ± 2.2 ml/min in CAPD patients. We could not readily explain these data except to suggest that perhaps the peritoneum, when bathed continuously in a hypertonic solution, became more solute permeable, whereas the peritoneum of patients on IPD is allowed to recover from the effects of lavage. As yet, this proposition is unproven but the observations are nonetheless of some interest (5). More recently, we have had an opportunity to follow variations in the MTCs of patients who have been on CAPD for periods up to two

years.

Briefly, the MTC is obtained from theoretical mass transfer models, which are applied to experimentally obtained data based on serial dialysate concentration measurements. For urea and creatinine a single-pool model of the body is used, whereas a two-pool (intra/extracellular) is necessary for accurate determination of vitamin B12 MTCs. A variable dialysate volume is used and parameters such as net solute generation, ultrafiltration, convective flux, characterised by a sieving coefficient, and residual kidney function are taken into account. Complete details of models, experimental approach and methods of solution are outlined elsewhere (4, 6).

We have examined urea, creatinine and B12 MTCs in 15 CAPD patients who have undergone from two to six evaluations for periods on CAPD ranging from six months to two years. Data on each patient were assessed by regression analysis and analysis of variance. There was good news and bad news. In three

patients there was a significant decrease in all solute MTCs. In two there was a steady decrease with time, in the third case there was a significant drop in MTCs between the first and second evaluations (five months apart) but no further deterioration over the next five months. The specific case reports are examined elsewhere in detail (6) but are summarized briefly below.

A 63-year-old woman with polycystic kidney disease had been on CAPD for 71 weeks before she ceased the treatment and died. She had had no previous dialysis and her MTCs were followed over the first year of her treatment. She had two episodes of peritonitis, which responded to treatment. Over the final six months of treatment her serum urea dropped from 23 to 8.4 mM/l, creatinine from 0.73 to 0.46 mM/l and albumin from 37 to 15 g/l, data indicating malnourishment and wasting. Concomitantly, her B₁₂ MTC fell from 4.9 to 2.7 ml/min and dietary protein intake (DPI) from 1.1 g/kg/24 h to 0.7 g/kg/24 h at the last evaluation, five months before she ceased CAPD. (DPI was assessed from net urea generation (7)) .No autopsy report on the peritoneum was available.

The second patient, who was 13 years of age and had renal disease secondary to reflux nephropathy, was on HD for 20 months followed by seven months of IPD and approximately 20 months of CAPD with a subsequent return to HD. We followed the patient for 70 weeks of CAPD and conducted five MTC evaluations. MTCs fell consistently for all solutes (B₁₂ from 7.5 to 2.5 ml/min over the 70 week period) with no accompanying increase in serum metabolites due to decreasing DPI, concomitant decreases in body weight, creatinine production and serum albumin level. After 20 months of CAPD, the patient had a laparotomy because of suspected subacute bowel obstruction. Both the large and small bowel were wrapped in a thick envelope of peritoneum which was resected. The patient was transferred to hemodialysis.

The third patient, a 47-year-old man, had chronic glomerulonephritis. Cardiovascular complications precluded HD and after four months of IPD the patient was

put on CAPD, which continued for 16 months before the patient was admitted to hospital with generalized peritonitis, hypotension, and mitral incompetence. He subsequently died in hospital of a cardiac arrest. Three MTC evaluations were conducted on this patient and the results are shown in Table I.

The autopsy report revealed dense fibrous adhesions enveloping the anterior surface of the stomach, duodenum, and most of the small and large intestines.

In contrast, the good news is that the remaining 12 patients, four of whom had completed two years of CAPD, showed no deterioration whatsoever in their MTCs; this demonstrates that viability of the peritoneum can be maintained during continuous lavage with hypertonic solutions. The relevant data are shown in Table II.

In summary, CAPD is capable of supporting ESRD patients for extended periods with acceptable waste metabolite removal. However, complications due to peritoneal fibrosis and adhesion formation can result in deterioration of peritoneal mass transfer. Observed pathological changes may be related to conventional peritonitis or perhaps even to chemical peritonitis, an issue raised at the recent Berlin meeting by Furman *et al* (8). However, our data are insufficient to implicate either factor. It should also be pointed out that serum urea and/or creatinine levels do not necessarily provide an acceptable indication of dialysance. The complications of anorexia and wasting, which are associated with inadequate dialysis, appear in patients adjusting to inadequate treatment, whether this be due to innate patient problems or insufficient daily lavage volume and may mask an increase in serum B₁₂ MTC and creatinine resulting from a decrease in dialysance. For this reason

TABLE I: MTC values for patient number three

PERIOD ON CAPD (WK)	9	30	47
Urea MTC (ml/min)	46.0	26.2	26.5
Creatinine MTC (ml/min)	31.6	12.4	13.2
Vitamin B ₁₂ MTC (ml/min)	23.1	4.8	5.5

TABLE II: Variations in MTC with time on CAPD

PERIOD ON CAPD* (n)	5±4 (12)	22±7 (12)	41±8 (7)	62±15 (6)	90±6 (4)
Urea, MTC (ml/min)	21.1±3.5	25.3±5.9	24.5±5.4	23.4±4.0	27.4±7.6
Creatinine MTC (ml/min)	11.1±3.0	14.0±5.1	14.7±2.4	14.7±3.1	19.8±5.1
Vitamin B ₁₂ MTC (ml/min)	4.8±2.4	5.2±3.3	4.7±0.7	5.8±3.1	7.4±1.9

*Mean ± SD (Weeks)

rapid clearance or, preferably, MTC measurements should be coupled with dietary assessment for complete definition of a patient's clinical status .



REFERENCES

1. Babb AL, Johansen PJ, Strand MJ *et al.* Bidirectional permeability of the human peritoneum to middle molecules. *Proc EDTA* 1973;10:247.
2. Villarroel F. Kinetics of intermittent and continuous peritoneal dialysis. *J. Dial* 1977;1:333.
3. Popovich RP, Pyle WK, Moncrief JW. Peritoneal dialysis. In: Villarroel F, Dedrick RL, eds. *Chronic replacement of kidney function*. AICHE Symp Series 187 1978;75:31.
4. Randerson DH, Farrell PC. Mass transfer properties of the human peritoneum. *ASAIOJ* 1980;3:140.
5. Farrell PC, Randerson DH. Membrane permeability changes in long-term CAPD. *Trans Am Soc Artif Intern Organs* 1980; 26: 197.
6. Randerson DH, Farrell PC. Long-term peritoneal clearances in CAPD. In: Atkins RC, Thomson NM, Farrell PC, eds. *Peritoneal dialysis*. Edinburgh:Churchill-Livingstone. 1981: 22-29.
7. Randerson DH, Farrell PC. Amino acid and dietary status in CAPD patients. In: Atkins RC, Thomson NM, Farrell PC, eds. *Peritoneal dialysis*. Edinburgh:Churchill-Livingstone. 1981 : 179-191.
8. Furman KI, Kundig H, Block JD. Reason for failure of saline-iodine flushes. *Advances in Peritoneal Dialysis*. Amsterdam:Excerpta Medica. 1981:281-286.

