The anatomy and physiology of peritoneal transport

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SUMMARY

Presumably most solutes removed during peritoneal dialysis move by diffusion or convection. Solutes must cross: 1) Stagnant fluid films within the peritoneal capillaries. 2) Capillary endothelium. 3) Capillary basement membranes. 4) Peritoneal interstitium. 5) Mesothelium, and 6) Stagnant fluid films within the peritoneal cavity.

Peritoneal capillaries differ in many ways from those of a hollow fiber dialyzer. The number of capillaries perfused in nonvasodilated states is probably less than 50 % of those perfused with maximum vasodilatation.

Functional and morphological studies suggest that proximal capillaries are less permeable than distal capillaries. Proximal capillaries may be the major site of net ultrafiltration.

Passive diffusion of larger solutes may occur mainly from the distal capillary.

During a peritoneal exchange, intraperitoneal volume will increase until osmotic equilibrium is approached. Osmotic equilibrium can be delayed and net ultrafiltration increased by increasing the glucose concentration in dialysis solution, increasing the instilled volume or by reducing peritoneal permeability and slowing glucose absorption.

Key words: Peritoneal Dialysis, Peritoneal Transport.

RESUMEN

Presumiblemente la mayoría de los solutos extraídos por diálisis peritoneal (DP) se mueven por difusión y convección, superando 6 niveles de resistencia sucesivos: fluido «estancado» en los capilares peritoneales, endotelio capilar, membrana basal capilar, intersticio peritoneal, mesotelio, fluido «estancado» en la cavidad peritoneal.

La red capilar peritoneal, a diferencia de la de un dializador capilar, no es una estructura estable, siendo el número de capilares perfundidos en estado de vasodilatación el doble de los existentes en situación basal. Estudios morfológicos y funcionales sugieren que el sector capilar proximal es menos permeable que el distal (venular), aceptándose que en el primero tiene lugar predominantemente la ultrafiltración, siendo el territorio capilar venular responsable de la difusión de medianas y grandes moléculas.

Durante un intercambio peritoneal el proceso de ultrafiltración tiene lugar merced al gradiente osmótico, del cual es responsable la alta concentración de glucosa intraperitoneal. A medida que por la reabsorción de glucosa el gradiente disminuye, aproximándose al equilibrio osmótico, disminuye igualmente el ritmo de ultrafiltración, que se hace nulo al alcanzar dicho equilibrio.

Dicho punto de equilibrio puede retrasarse, aumentando la ultrafiltración neta, incrementándose la concentración de glucosa, aumentando el volumen instilado o reduciendo la permeabilidad a la glucosa.

Palabras clave: diálisis peritoneal, transporte peritoneal.

IMPORTANT ASPECTS OF THE ANATOMY AND PHYSIOLOGY OF PERITONEAL TRANSPORT

Resistances to Solute Movement

Presumably most solutes removed during peritoneal dialysis move by diffusion or convection from peritoneal capillaries into the peritoneal cavity. Solutes must cross, 1) stagnant fluid films within the peritoneal capillaries, 2) capillary endothelium, 3) capillary basement membranes, 4) the peritoneal interstitium, 5) mesothelium, and 6) stagnant fluid films within the peritoneal cavity. Contributions from peritoneal lymphatics are possible but at this time undetermined.

Characteristics of Peritoneal Capillaries (see Table I)

TABLE I

CHARACTERISTICS OF PERITONEAL CAPILLARIES

1. Wall thickness, 1-2 microns.
2. Lumen diameter, 5-10 microns.
3. Less than 50 % perfused in non-vasodilated states.
4. Commercial solutions are vasodilatory (acetate, lactate, osmolarity responsible).
5. Vasodilating drugs such as nitroprusside cause greater venodilation than do solutions.
6. Proximal capillaries are less permeable than venules.

Peritoneal capillaries differ in many ways from those of a hollow fiber dialyzer. The wall is only 1-2 microns thick and the internal lumen is 5-10 microns in diameter. The number of capillaries perfused in non-vasodilated states is probably less than 50 % of those perfused with maximum vasodilation. Endogenous or exogenous vasodilators may increase the number of capillaries perfused. Vasodilatation may alter capillary permeability by perfusing more permeable capillaries and by altering permeability characteristics of capillaries in general. Capillaries form a network of interconnected vessels. Functional and morphological studies suggest that proximal capillaries are less permeable than distal capillaries. Proximal capillaries may be the major site of net ultrafiltration during peritoneal dialysis because of higher hydraulic pressure and a greater effect of glucose as an osmotic agent at this site where it is poorly absorbed. In the distal capillary, and particularly in the venules, net ultrafiltration may be much less. Passive diffusion of larger solutes from capillaries may occur mainly from the distal capillary; venules may be the main sites for protein loss. Capillaries are more permeable than man-made hollow fibers, but the number participating in the dialysis process is relatively low. Many portions of the mesentery are almost avascular.

Solute Pathways through the Capillary

There is evidence to suggest that solutes may move primarily through intercellular gaps between adjacent endothelial cells. Some transcellular movement may occur. Intracellular vesicles can be seen but their contributions to transport during peritoneal dialysis are unknown.

The Interstitium

The interstitium is probably a complex network of aqueous channels between clumps of collagenous and mucopolysaccharide gels. Peritoneal dialysis solution within the peritoneal cavity may dehydrate the interstitium to some extent.

The Mesothelium

The mesothelium over the rat diaphragm seems to be quite permeable, with very large intercellular gaps. In other sections of the peritoneum, particularly the rabbit visceral mesentery intercellular gaps between adjacent mesothelial cells are very narrow or occluded. The contributions of various portions of the peritoneum to transport, the importance of intercellular gaps and roles of other pathways need further clarification.

Intraperitoneal Stagnant Fluid Films

The stagnant fluid films within the peritoneal cavity are very substantial resistances. Even with rapid cycling, isolated pools of fluid between adjacent folds of mesentery are relatively immobile.

Limitations on Urea Clearances During Peritoneal Dialysis (see Table II)

TABLE II

LIMITATIONS ON PERITONEAL UREA CLEARANCES

1. Dialysate flow in CAPD - minimal effects when > 4 l/h.
2. Probably little or no blood flow limitation.
3. Total pore area (number of capillaries) very important.
4. Interstitial and fluid film resistances high.
5. Maximum urea clearance ≃ 40 ml/min. with rapid cycling.

Even with the most rapid cycling, urea clarance rarely exceeds 40 ml/min. This is primarily because of the limited number of capillaries participating in dialysis (a low total pore area) and the influences of the interstitium and stagnant fluid films. There is little evidence to suggest that urea clearances are blood flow limited. Gas diffusion studies in humans and rabbits suggest that effective peritoneal capillary flow may be three times maximum urea clearance. Dialysis solution flow rate is

limiting in continuous ambulatory peritoneal dialysis where urea clearances approach dialysis solution flow rates. However, with rapid cycling techniques (> 4 l/h.), urea clearance is 30 % or less of dialysis solution flow rate and is minimally limited by dialysate flow.

Understanding Ultrafiltration
(see Table III)

TABLE III

UNDERSTANDING ULTRAFILTRATION

1. Mainly from proximal capillary.
2. Net ultrafiltration maximum at osmotic equilibration - decreases earlier and thereafter.
3. Net ultrafiltration is greater with, a) higher glucose concentrations in solutions, b) larger instillation volumes, and c) reduced permeability slowing glucose absorption.

During a peritoneal exchange, intraperitoneal volume will increase until osmotic equilibrium is approached. Once osmotic equilibrium is approached, net reabsorption begins at rates usually near 40 ml/min. Osmotic equilibrium can be delayed and net ultrafiltration increased by increasing the glucose concentration in dialysis solution, increasing the instilled volume of dialysis solution, or by reducing peritoneal permeability and slowing glucose absorption. Net ultrafiltration will decrease if the glucose concentration is reduced, the instilled volume is reduced, or peritoneal permeability increases. In peritonitis, for example, it is likely that alterations of the mesothelium and/or effects of the local release of vasodilators, such as histamine or bradykinins, on blood vessels, increase peritoneal permeability. Distal capillaries may increase in permeability since an increase in protein loss is usually observed. Urea and creatinine clearances may be higher. Glucose absorption is more rapid. Osmotic equilibration is approached more rapidly and net reabsorption begins sooner. Thus, with prolonged exchanges, ultrafiltration is less in the presence of peritonitis. Better ultrafiltration rates can be achieved by shortening exchanges and draining before net reabsorption can obliterate ultrafiltration generated early in the exchange.

These points are highlights of concepts reviewed in previous publications. Suggested references follow which include detailed bibliographies.

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