ADAPTED AUTOMATED PERITONEAL DIALYSIS: IMPORTANCE OF VARYING DWELL TIME AND FILL VOLUME

ADAPTUOTA AUTOMATINĖ PERITONINĖ DIALIZĖ: UŽPYLIMO TŪRIO IR EKSP زيICOJOS LAIKO VARIJAVIMO SVARBA

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ABSTRACT
Key words: Adapted automated peritoneal dialysis, peritoneal membrane, fill volume, dwell time.

Peritoneal dialysis (PD) is one of the renal replacement methods which use peritoneal membrane as a semi-permeable membrane for blood purification and ultrafiltration (UF). To decrease morbidity and mortality rates optimal treatment regiments must be selected. Adapted automated PD (APD-A) is two phase prescription treatment: small intraperitoneal volume (IPV) with short dwell time and large volumes with long dwell time. Larger IPV increase the peritoneal surface area available for the exchange and enable to achieve greater uremic toxins clearance. To avoid the consequences of large IPV intraperitoneal pressure (IPP) should be measured. Short dwell time maintain adequate UF and urea purification. Though UF, blood purification and dialysate reabsorption capacities are still individual for every patient so peritoneal equilibration test needs to be performed. APD-A is well tolerated PD modification which potentially has greater long term outcomes for a patient resulting from increased volume control, improved blood pressure, enhanced removal of nitrogenous waste products and reduced loss of protein stores.

SANTRAUKA
Reikšminiai žodžiai: adaptuota automatine peritoninė dializė, pilvaplėvės membrana, pripildymo tūris, ekspozicijos trukmė.

Peritoninė dializė (PD) yra vienas inšturų paskaitinės terapijos metodų, kurio metu ultrafiltracija (UF) ir kraują valymas vyksta per pusiau pralaidžią membraną – pilvaplėvę. Turi būti parinkti optimalūs gydymo režimai, siekiant sumažinti pacientų sergamumą ir mirtingumą. Adaptauda automatine PD (APD-A) yra dviejų dalų procedūra, susidedanti iš mažo intraperitoneinio tūrio (IPT) su trumpu ekspozicijos laiku bei didelio IPT su ilgu ekspozicijos laiku etapų. Didelis IPT padidina pilvaplėvės paviršiaus plotą pasikeitimu ir sudaro geresnį toksinių medžiagų kliūtį. Kiekvienā pacientų IPT, kraują valymo, dializato reabsorbcijos galimybės yra individualios, reikalingi atskirti pilvaplėvės ekvilibraicijos testą. APD-A yra gerai toleruojamas PD metodas, kuris turi geresnį ilgalaikio gydymo rezultatus, nes jis yra užtikrino skystų pusiausvyrą ir pagerinamą krają spaudimo kontrolę, suintensyvėja azotinių produktų šalini-mas, sumažinama baltymų atsargų netekst.

INTRODUCTION
Peritoneal dialysis (PD) is one of the renal replacement methods which use peritoneal membrane as a semi-permeable membrane for blood purification and ultrafiltration (UF). Automated PD (APD) is the main PD modality used in children not only because it is well tolerated but also because it ensures freedom for school and social activities during the day [1]. It is well known that the main targets of PD are removal of nitrogenous waist products, correction of electrolyte

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and acid-base imbalance, and fluid removal [2]. Maintaining normal body fluid status (euvolemia) is an ongoing challenge for many PD patients because hypervolemia causes hypertension, fluid overload, and cardiovascular complications and increases mortality [2, 3, 4, 5]. To decrease morbidity and mortality rates we have to understand properties of peritoneal membrane and then select the optimal treatment regiments [6]. It means that selecting reasonable duration of dwell and fill volume can improve the effectiveness of PD [7].

The objectives of the present review are to present physiology of peritoneal membrane fluids and solutes transport, dwell time and fill volume influence to UF and blood purification, and acquaint with “adapted” APD benefits.

**CHARACTERISTICS OF PERITONEAL MEMBRANE**

Peritoneum is a biological membrane consisting of different structures where the main barrier for fluid transport is endothelial cells [5]. According to the generally accepted three-pore theory [5, 8] fluid and solutes transport is going through ultrasmall transcellular pores (aquaporins), small and large interendothelial pores. Large pores are few so their impact to fluid transport can be neglected [5]. Free water transport from the capillaries to the dialysate through the aquaporins occurs because of strong osmotic gradient over them in the first part of the dwell [6]. It forms about 50% of sodium-free UF [9]. Small pores are responsible for water and small solutes (coupled water) filtration and compose other 50% of UF. Coupled water transport effectiveness through small pores later in dwell is dependent on concentration and pressure gradients [9].

Also there occurs sodium sieving phenomenon which is observed in the first phase of PD dwell when sodium concentration decreases because aquaporins allow only free water transport resulting in dialysate dilution [6].

So in the first hour of a dialysis dwell UF rates are high because of high crystalloid osmotic pressure. Later when this gradient decreases diffusion of sodium and lymphatic absorption starts [10]. Peritoneal absorption of glucose and fluid essentially decreases the effectiveness of dialysis and this process may result UF failure [11]. For this reason modifying duration of the dwell and fill volume can increase efficiency of PD [7].

**IMPORTANCE OF FILL VOLUME**

PD efficiency varies with prescribed fill volume but it is well known that optimal fill volume is a patient’s individual parameter [12, 13] which should be adapted to the patient’s body surface area [1, 6]. If the dialysis target is to remove more uremic toxins we should use larger intraperitoneal volumes (IPV) because they increase the peritoneal surface area available for the exchange and enable to achieve greater solutes clearance [7, 12, 14, 15]. Therefore if we need to stimulate UF it is better to use small IPV because of potentially low intraperitoneal pressure (IPP) [7]. There exists a linear correlation between IPV and IPP [16]. Elevated IPP is associated with clinical signs of large fill volume intolerance [12], increased incidence of enteral peritonitis [16] and sleep disorders such as severe apneas [17], also with higher risk of hernia formation [16]. Besides extremely raised IPP enhance a risk of UF failure [7] as a consequence of excessive distention of the peritoneal cavity [6], modification of transcapillary UF rates and increased lymphatic absorption of fluids [16].

In fact that most patients cannot accurately tell the difference in fill volume changes IPP measurement should be performed [18, 19]. It will provide objective assessment of fill volume prescription [18] and allow avoiding the consequences of enlarged IPP complications. According to Fischbach researches maximum tolerated IPP in children should be lower than 18 cm H₂O and IPV in prone position should be close to 1400 mL/m² [12, 20].

**INFLUENCE OF DWELL TIME**

The dwell time exchanges allow not only increase UF capacity but also enhance uremic toxins and phosphates clearance [21]. Short dwell time maintain adequate UF (transport sodium free water trough aquaporins) and urea purification [6, 21]. To avoid hyperhydration which is known as a risk factor for cardiovascular complications [2, 3, 5] we should use short time dwells. On the over hand such a choice is inappropriate for adequate purification of creatinine and phosphates [6, 21] and may induce positive sodium balance [22]. Long-dwell exchanges allow for more nitrogenous waist products that need longer diffusion time clearance [7, 22]. However too long-dwell is a risk factor for decreased UF and does not appreciably improve urea removal [7]. In a long dwell time there is a loss of glucose osmotic gradient which leads to UF failure and generates dialysate reabsorption. As UF, blood purification and dialysate reabsorption capacities are individual for every patient peritoneal equilibration test (PET) needs to be performed [5, 6, 7]. It allows determining individual permeability parameters (APEX time; phosphate purification time) and enables to adapt dwell time to the patient’s condition and treatment targets [1, 22].

**PRESCRIPTION OF ADAPTED APD**

APD is ordinarily prescribed as a series of repetitive exchanges with the same fill volume and same dwell time. A new modification of APD is called “adapted” APD (APD-A) and is composed from two phases (Fig.1). In the first phase there is used short dwell time with small fill volume...
to ensure adequate UF and subsequently there is used seri
of longer dwell time with larger fill volume to promote
uremic toxins removal (Fig. 2). The concept of short dwell
time with small IPV is to improve UF resulting in more
free water extraction and increasing diffusion gradient by
hemoconcentration [7, 9]. Subsequent long dwell and lar
ge fill volume phase enhance diffusion volume, time, and
peritoneal surface area recruitment allowing greater blood
purification.

**BENEFITS OF APD-A**

Comparison of APD-A and APD-C by measuring dialysis efficiency parameters shows a significant improvement in several parameters. There were no clinical signs of discomfort or indications of fill volume intolerance during APD-A sessions [7]. Adequate UF and blood purification are the main ongoing challenges of PD which can be achieved by APD-A. There was seen increased urea (7 %), creatinine (9 %) weekly clearances also enhanced phosphate dialytic re
moval (9 %) (7). These alterations were related to improved diffusion process resulting from extended dwell time, enlarged fill volume and convective mass transport. The mean UF achieved per session and dialytic sodium removal signifi
cantly increased because of low IPP and preserved glucose osmotic gradient in a short-dwell with small IPV.

Moreover these positive changes were achieved with lower metabolic cost [7] meaning that reduced absorption of glucose potentially retards loss of UF capacity resulting from neoangiogenesis and fibrosis [5, 11]. Also lower glucose absorption may positively contribute to various nutr
tional and metabolic disturbances [11]. Also improved water and sodium balance is potentially related to decrease loss of protein stores [6] because there were observed increased normalized protein catabolic rate (a potential marker of nutrition) [23]. Besides there was a tendency to gain lean body mass [7].

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**Fig. 1.** Comparison of “conventional” APD (APD-C) and APD-A modalities

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<th>APD-C</th>
<th>APD-A</th>
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<tr>
<td>Total amount of dialysate balance (120000 ml)</td>
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<td>Isoosmotic 1.5 % glucose dialysate</td>
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<td>Duration of dialysis session (9 hours)</td>
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<td>Dry peritoneal cavity during the day</td>
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<td>6 times same fill volume (2 000 ml)</td>
<td>2 times low fill volume (1 500 ml) with short dwell time (45 min)</td>
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<td>Same dwell time (90 min cycle)</td>
<td>3 times large fill volume (3 000 ml) with long dwell (150 min)</td>
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**Fig. 2.** Prescription of adapted APD. Fill volume is prescribed under intraperitoneal pressure control (IPP < 15–18 cm H₂O). Small IPV is 750 ml/m² and larger IPV is 1500 ml/m². Dwell time adapted according to APEX time: short dwell 30–60 min and longer dwell 90–240 min, repeated from 3 to 4 times.
Improved UF and sodium removal resulted in a meaningful blood UF reduction [7]. In the other words varying dwell time induces UF, avoids dialysate reabsorption [4] and prevents from hyperhydration which causes hypertension [2, 3, 4, 5].

All together these achievements gained by APD-A potentially reduces morbidity and positively influences patient’s survival rates without any additional financial cost.

CONCLUSIONS

Better understanding of the peritoneal membrane physiology, fill volume and dwell duration impact to dialysis process is essential for optimal treatment regiments prescription especially for children on APD. Varying the dwell duration and fill volume has beneficial influence on effectiveness of APD by achieving greater UF, sodium removal and blood purification. APD-A is well tolerated PD modification which potentially has greater long term outcomes for a patient resulting from increased volume control, enhanced removal of nitrogenous waste products and reduced loss of protein stores.

REFERENCES