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Adequacy of peritoneal dialysis: Kt/V revisited

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Abstract. – OBJECTIVE: Kt/V urea has been used to assess adequacy of peritoneal dialysis. However, Kt/V urea only reflects the clearance of solute without taking into consideration the effects of dietary protein intake (DPI). The objective of this study is to evaluate the value of Kt/V based on nitrogen balance and to observe if it is the best adequacy index.

METHODS: On the premise that nitrogen balance is obtained, we calculated the minimal adequate dialysate volume and dialysis index (DI), Kt/V and solute removal index (SRI). We compared the values of DI, Kt/V and SRI to evaluate the adequacy of peritoneal dialysis.

RESULTS: Kt/V was changed with DPI and body weight of continuous ambulatory peritoneal dialysis (CAPD) patients. We cannot define adequate dialysis with a single value while DPI and body weight are different since CAPD, SRI and Kt/V are numerically equal. However, dialysis index (DI) can reflect the minimal adequate dialysate volume when DPI and body weight are different and, thus, reflects the adequacy of dialysis.

CONCLUSIONS: DI reflects the balance between DPI and solute clearance; thus, it is more useful to evaluate dialysis adequacy than Kt/V and SRI in clinically stable peritoneal dialysis patients.

Key Words:
Kt/V, Dialysis index (DI), Solute removal index (SRI), Peritoneal dialysis.

Introduction

Adequate dialysis is a key factor for healthy living in long-term dialysis patients. Although there is no precise definition of adequate dialysis at present, many researchers believe that adequate dialysis should refer to: comparable with certain dialysis doses (adequate dialysis dose), and mortality rate among patients does not decrease with increased dialysis dose, but increases if lower dose is used[1]. Clinical evaluation of dialysis adequacy on one hand is based on the remission of symptoms of uremia and on the other hand is judged on the solute clearance angle, such as, Kt/V and creatinine clearance (Ccr), to determine whether the peritoneal dialysis achieved its effect[2-5]. The current Kidney Disease Outcomes Quality Initiative (K/DOQI) guidelines recommend the value of weekly Kt/V in patients with peritoneal dialysis should be at least 2.0[2]. However, a substantial proportion of peritoneal dialysis patients cannot achieve this goal[6-8]. This index is not easy to achieve especially for patients with loss of residual renal function[9]. In fact, many patients with anuria follow the same health survival even if the index of KT/V is less than 2.0 during peritoneal dialysis. Therefore, many scholars have questioned the index recommended by DOQI. Moreover, large sample randomized controlled study (ADEMEX), recently, found that compared with peritoneal dialysis patients with Kt/V < 2.0, survival and technique survival rate of patient in weekly Kt/V > 2.0 show no difference[10]. This research has caused intense controversy related to the Kt/V target value in the peritoneal dialysis treatment. Recently, Lo et al[11] argued that the minimum value of Kt/V should be 1.7 in peritoneal dialysis patients. In theory, adequate dialysis is an equilibrium based on a certain amount of solute clearance, so that the body's internal environment maintains a steady state. This concept of steady-state (nitrogen balance) is the foundation of CAPD. It proved that by using clearance rate to evaluate the adequacy of dialysis is sort of one-sided as only the solute clearance is taken into consideration but not the dietary intake of patients.

Therefore, we constructed urea kinetic model to evaluate the indicator to judge the adequacy of dialysis based on nitrogen balance in order to reflect patient's condition more precisely, which can further guide the treatment.

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Methods

Premise Conditions

First, it is assumed that the patients are in the nitrogen balance and daily protein intake is 0.6-1.2 g/kg/day. The loss of nitrogen in non-urea forms is about 3.3 g/day. The protein loss through peritoneal dialysis fluid is about 6 g/day (the actual test results data from 106 patients with CAPD at the Renal Department of First Hospital of Peking University Dialysis Center), which is equivalent to 0.96 g/d nitrogen. Loss from amino acid nitrogen and non-urea nitrogen as reported in the literature is 0.51 + 0.12 g/d and 31 mg/kg/d respectively[12]. Total nitrogen intake is mainly from dietary protein, and total nitrogen discharge is equal to the total nitrogen intake.

Second, assuming target BUN value is 70 mg/dl (25 mmol/l)[12], third, suppose Kt/V = 0, and fourth, CAPD is presumed to have a balanced process, subsequently the amount of urea clearance will be equal to the exchange fluid of daily dialysate.

Theoretical Calculation of Dialysis Dose

If urea nitrogen is not progressively increasing, namely high catabolic state, then urea nitrogen produced by protein decomposition is completely cleared through the exchange of dialysate. Daily dialysate volume (DV_{UREA} N, ML) is:

DV_{UREA} N = [DPI × IBW × 16% – (1.47 + 0.031 × IBW)]/0.7 (1)

The DPI × IBW represents total daily protein intake (unit: G/d).

IBW is the ideal body weight (kg).

1.47 is for daily loss of protein in the form of amino acid and peritoneal dialysis fluid (unit: G/d).

Calculation of Dialysis Index (DI)

The DI is the ratio of discharge amount of actual dialysate fluid to the amount of required dialysis fluid, calculation is based on the formula (DI_{UREA} = DVact / DVrx) [13]. DI > 1 means excess dialysis.

DI < 1 represents dialysis insufficiency.

Kt/V Formula Based on Nitrogen Balance

Kt/V = Kd × T/V.

Kd is peritoneal urea nitrogen removal rate.

T is the time (unit: min).

V represents the urea distribution volume (weight × 0.58).

When the dialysate urea nitrogen concentration is equal to BUN concentration, the formula will be: KT/V = DV_{UREA} / V.

DV_{UREA} as shown in formula (1)

Then weekly Kt/V = (0.23DPI ↔ IBW-0.044 ↔ IBW-2.1) ↔ 7 / V (2)

Calculation of Solute Transport Index (SRI)

Solute transport index (SRI) is equal to Kt/V in CAPD treatment. When the residual renal is zero, SRI = (Vd × Cd) / (Vb × Cb) = (Vd × Cd / Cb) / Vb = Kt/V), where V and C represent the volume and concentration respectively, and the subscript d and b on behalf of dialysate and plasma separately[14].

Results

We can conclude from Figures 1 and 2 (Figure 1, patient weight was 60 kg) that Kt/V is affected by dietary protein intake and body weight. When the body weight is constant, Kt/V increases with an increase in DPI. Similarly, when dietary protein intake is unchanged (Figure 2, diet protein intake of patient was 0.9 g/kg/d), Kt/V changes correspondingly along with the change in the weight (as shown in Figure 1). Therefore, dialysis status of CAPD patients in different conditions cannot to be assessed by the same Kt/V standard value.

In the state of CAPD, solute transport index (SRI) and the Kt/V data mean the same and reflect the removal of solution from the body and its total content ratio.

Dialysis index (DI) relates to three aspects including DPI, body weight and blood urea nitrogen level which can reflect the dialysis dose

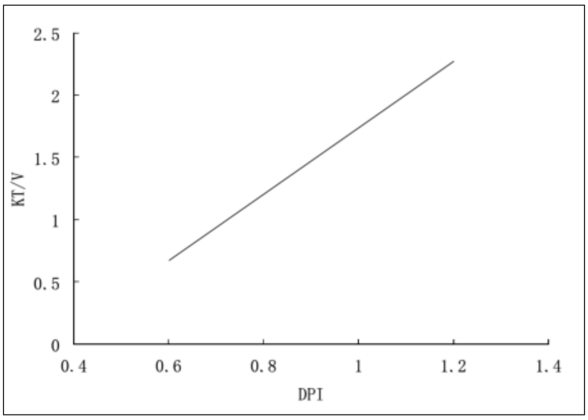

Figure 1. The relationship between Kt/V and dietary protein intake of the patient. When the residual renal function equals to zero, the Kt/V increased with protein intake (DPI) in 60 kg CAPD patients.

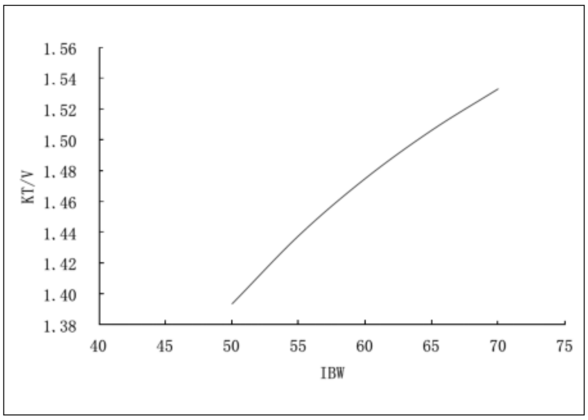

Figure 2. The relationship between Kt/V and weight of the patient, when DPI = 0.9 g/kg/d. Kt/V increased with the weight.

needed when nitrogen balance is achieved in patients with different weight and DPI. When there is no trouble in protein intake, the effect of dialysis can be revealed from the nitrogen balance. When the patient is not malnourished and in the status of nitrogen balance, DI=1 indicating the balance of the dietary nitrogen intake and elimination which means sufficient dialysis. DI > 1 represents that the actual dialysis volume is more than the body needs to discharge nitrogen, suggesting excess dialysis. DI < 1 indicates lack of dialysis dose to discharge nitrogenous waste, implying inadequate dialysis.

Discussion

In this study, we found that widespread clinical use of recommended target urea solute removal index (Kt/V) cannot objectively reflect the adequacy of dialysis. In CAPD patients, solute transport index (SRI) is equal to the numerical value of urea solute removal index (Kt/V). It shows that the ratio of the solute removal and total solutes in the body[14], thus, it cannot be the dialysis adequacy index. But when the patient is in nitrogen balance, dialysis index (DI) is fully reflective and good indicator of dialysis.

Dialysis index (DI) represents the ratio of actual dialysis dose to the theoretical dialysis dose[13], which can comprehensively reflect the dialysis adequacy taking dietary protein intake (DPI), IBW, and BUN into consideration. Several researchers take Kt/V as an evaluation index of dialysis adequacy in peritoneal dialysis patients. However, the value of Kt/V as an index has been controversial[10,11]. This study shows that Kt/V value which achieves the nitrogen balance varies with the patient's diet protein intake and body weight. If DPI and weight values are variable, Kt/V value may not be constant in order to achieve the dialysis adequacy. The recommended values of DOQI and traditional CAPD dialysis scheme are based on the patient protein intake of 1.2 g/kg/d. However, we observed that many patients can maintain good nutritional status with clinical DPI in 0.8-1.0 g/kg/d. Some researchers recently suggested that a DPI between 0.9-1.1g/kg/d is sufficient for patients undergoing peritoneal dialysis and, therefore, it is not necessary to achieve value of 1.2 g/kg/d, as recommended by DOQI [15]. As shown in Figure 1, Kt/V in the range of 1.32-1.9 is sufficient to achieve dialysis adequacy for patients with 60 kg bodyweight and DPI of 0.8-1.0 g/kg/d. We can evaluate the adequacy of dialysis in CAPD patients according to dialysis index (DI), protein intake, and blood BUN level in the clinic. Assuming DI = 0.85, BUN = 82 mg/dl, DPI = 1.2 g/kg/d, and if there is no excessive protein intake (protein intake reaches 1.2 g/kg/d in CAPD patients according to DOQI guidelines), then DI < 1 suggests that the inadequate dialysis is caused by lack of dialysis dose. Assuming DI > 1, BUN = 36 mg/dl, DPI = 1.2 g/kg/d, then we can assume that the excessive dialysis is based on the nitrogen balance. If the protein intake is 0.6 g/kg/d under the same circumstances, then, DI > 1 could be due to inadequate intake of protein but not dialysis excess, in which condition the body may be in a negative nitrogen balance. Similarly, there is also a possibility of positive nitrogen balance when DI < 1. Accordingly, adjusting only the dialysis prescription is not sufficient and understanding the nutritional status of patients through the analysis of dialysis index (DI) and protein intake is also important.

However, the use of dialysis index (DI) to reflect the adequacy of dialysis also has shortcomings to some extent. Calculating the value of DI has certain preconditions, which sometime may not be very objective. For example, it is assumed that the target BUN value of minimum tolerance level is 70 mg/dl in CAPD patients which is subjective provision. It is likely that CAPD patients can tolerate higher BUN concentration. The highest BUN level tolerated by CAPD patients still remains unclear but has been suggested to be 70 mg/dl concentration in CAPD patients. In addition, some hypotheses cannot be implemented for example, peritoneal clearance dysfunction and short time for abdominal peritoneal dialysis fluid storage, which cannot guarantee that D/P is close to 1. So it could be difficult to confirm that the removal of urea for CAPD is an equilibrium process and will consequently result in low dose of dialysis[16]. Moreover, if the non-urea nitrogen level is not accurately estimated, it could also affect the accuracy of dialysis index (DI). We hold the opinion that the concept of dialysis adequacy should take balance into consideration so as to maintain all aspects of the body balance through full dialysis. It will be more beneficial to improve the survival rate of patients with CAPD. Also, compared to the solute transport index (SRI) and urea solute removal index (Kt/V), the dialysis index (DI) is more rational to represent equilibrium as it is derived from the nitrogen balance.

Conclusions

DI is more objective and reliable to evaluate the comprehensive protein intake in dialysis adequacy than simple urea solute removal index (Kt/V) and solute transport index (SRI) for CAPD patients in clinical steady state.

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Conflict of Interest

The Authors declare that there are no conflicts of interest.

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