**Name of Journal: *World Journal of Nephrology***

**ESPS Manuscript NO: 31293**

**Manuscript Type: Original Article**

***Retrospective Study***

**Advanced wasting in peritoneal dialysis patients**

Xu Z *et al*. Wasting in PD patients

**Zhi Xu, Glen H Murata, Robert H Glew, Yijuan Sun, Darlene Vigil, Karen S Servilla, Antonios H Tzamaloukas**

**Zhi Xu**, Nephrology Division, Department of Medicine, University of New Mexico School of Medicine, Albuquerque, NM 87131, United States

**Glen H Murata**, Research Service, Raymond G. Murphy Veterans Affairs Medical Center, Albuquerque, NM 87108, United States

**Robert H Glew**, Department of Surgery, University of New Mexico School of Medicine, Albuquerque, NM 87131, United States

**Yijuan Sun**, **Darlene Vigil**, **Karen S Servilla,** Renal Section, Medicine Service, Raymond G. Murphy VA Medical Center, Albuquerque, NM 87108, United States

**Yijuan Sun**, **Darlene Vigil**, **Karen S Servilla,** **Antonios H Tzamaloukas**, Department of Medicine, University of New Mexico School of Medicine, Albuquerque, NM 87108, United States

**Antonios H Tzamaloukas**, Research Service and Renal Section, Raymond G. Murphy VA Medical Center, Albuquerque, NM 87108, United States

**Author contributions:** Xu Z composed the first draft of this report; Murata GH made the statistical analysis and critical changes in the report; Glew RH made critical changes in the report; Sun Y assisted in the collection of data and made critical changes in the report; Vigil D assisted in the collection of data and made critical changes in the report; Servilla KS assisted in the collection of data and made critical changes in the report; Tzamaloukas AH designed the study and assisted in the collection of the data and the writing of the report.

**Institutional review board statement:** This study was reviewed and approved by the Human Research Committee of the Raymond G. Murphy VA Medical Center.

**Informed consent statement:** Patients were not required to give informed consent to the study because the study used anonymous clinical data that were obtained to evaluate nutrition and adequacy of dialytic treatment to which each patient had agreed.

**Conflict-of-interest statement:** We have no financial relationships to disclose.

**Data sharing statement:** No additional data are available.

**Open-Access:** This article is an open-access article which was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>

**Manuscript source:** Invited manuscript

**Correspondence to: Antonios H Tzamaloukas, MD, MACP, Emeritus Professor** of Medicine, University of New Mexico School of Medicine, **Physician** (Raymond G. Murphy VA Medical Center), Renal Section (111C), Raymond G. Murphy VA Medical Center, 1501 San Pedro, SE, Albuquerque, NM 87108, United States. antonios.tzamaloukas@va.gov

**Telephone:** +1-505-2651711-4733

**Fax:** +1-505-2566441

**Received:** November 8, 2016

**Peer-review started:** November 10, 2016

**First decision:** December 1, 2016

**Revised:** February 17, 2017

**Accepted:** March 12, 2017

**Article in press:**

**Published online:**

**Abstract**

***AIM***

To identify patients with end-stage renal disease (ESRD) treated by peritoneal dialysis (PD) who had zero body fat (BF) as determined by analysis of body composition using anthropometric formulas estimating body water (V) and to compare nutritional parameters between these patients and PD patients whose BF was above zero.

***METHODS***

Body weight (W) consists of fat-free mass (FFM) and BF. Anthropometric formulas for calculating V allow the calculation of FFM as V/0.73, where 0.73 is the water fraction of FFM at normal hydration. Wasting from loss of BF has adverse survival outcomes in PD. Advanced wasting was defined as zero BF when V/0.73 is equal to or exceeds W. This study, which analyzed 439 PD patients at their first clearance study, used the Watson formulas estimating V to identify patients with VWatson/0.73 ≥ W and compared their nutritional indices with those of PD patients with VWatson/0.73 < W.

***RESULTS***

The study identified at the first clearance study two male patients with VWatson/0.73 ≥ W among 439 patients on PD. Compared to 260 other male patients on PD, the two subjects with advanced wasting had exceptionally low body mass index and serum albumin concentration. The first of the two subjects also had very low values for serum creatinine concentration and total (in urine and spent peritoneal dialysate) creatinine excretion rate while the second subject had an elevated serum creatinine concentration and high creatinine excretion rate due, most probably, to non-compliance with the PD prescription.

***CONCLUSION***

Advanced wasting (zero BF) in PD patients, identified by the anthropometric formulas that estimate V, while rare, is associated with indices of poor somatic and visceral nutrition.

**Key words:** Wasting; Weight deficit; Fat-free mass; Nutrition; Body water; Anthropometry; Peritoneal dialysis; Watson formulas

**© The Author(s) 2017.** Published by Baishideng Publishing Group Inc. All rights reserved.

**Core tip:** This retrospective study of patients with end-stage renal disease treated by peritoneal dialysis (PD) analyzed the relationship between advanced wasting and other indicators of nutritional status, including body weight and serum albumin concentration. Advanced wasting was defined as zero body fat based on estimates of body water obtained from formulas based on gender, age, height and weight. Only two male patients, both young, were identified as having advanced wasting among the 439 patients (262 men and 177 women) on PD we studied. Both of these patients with advanced wasting had poor nutrition as evidenced by their remarkably low body weights and serum albumin levels. We conclude that advanced wasting, as defined in this study, is rare in patients on PD, but when present is strongly indicative of an exceedingly poor overall state of nutrition.

Xu Z, Murata GH, Glew RH, Sun Y, Vigil D, Servilla KS, Tzamaloukas AH. Advanced wasting in peritoneal dialysis patients. *World J Nephrol* 2017; In press

**INTRODUCTION**

The overall prognosis and survival of patients with chronic diseases, including those whose end-stage renal disease (ESRD) is treated by dialysis, is strongly linked to their nutritional status. The nutritional status of patients on chronic peritoneal dialysis (PD) has been assessed by anthropometry[1-3], biochemical parameters including serum albumin[4,5] and pre-albumin[5,6], and evaluation of body composition by bioelectrical impedance[7-9], dual energy X-ray absorptiometry[10,11], and measurement of total body potassium by stable isotopic methods[10].

In addition to the aforementioned direct analytical methods, indices estimated from the excretion of nitrogenous products in urine and in spent dialysate have also been applied to evaluate nutrition in patients receiving PD. These nutritional indices include the protein nitrogen appearance (PNA), which is derived from the excretion of urea nitrogen and provides an estimate of dietary protein intake[12], and lean body mass (LBM) which is estimated from the excretion of creatinine and provides an estimate of muscle mass[13]. A composite nutritional index derived by combining findings from history, physical examination and clinical laboratory analyses has been applied in PD patients[14,15].

This report addresses the identification and overall nutritional status of an advanced degree of weight deficit in PD patients. Weight deficit is encountered in approximately 7.5% of the patients on PD[2] and may result from muscle loss (sarcopenia) or from grossly diminished body fat (BF)[16]. Under several circumstances sarcopenia is associated with obesity rather than weight loss. In contrast, loss of BF is always associated with weight deficit. Low BF is defined as BF < 20% of body weight in women and < 12% of body weight in men[17]. BF can be assessed by anthropometry (skin-fold thickness), dual energy absorptiometry, bioelectrical impedance, and other methods usually restricted to research studies. Measurement of body water by radioisotope dilution is one of the standard research methods for assessing BF and has been applied in PD studies[10]. In PD patients, body water (V), which is needed for the calculation of fractional urea clearance (Kt/V urea) for assessing the adequacy of PD, is routinely estimated by anthropometric formulas. Estimates of V from anthropometric formulas can also be used to estimate BF[18,19].

Wasting in PD patients has been associated with adverse outcomes. This study had two aims: The first aim was to provide a definition of advanced wasting in PD patients by estimating BF calculated from V obtained from anthropometric formulas; the second was to identify PD patients with advanced wasting and to evaluate the association of advanced wasting with other traditional indices of nutritional status.

**MATERIALS AND METHODS**

***Definition of advanced wasting***

Table 1 defines the abbreviations used in this report. Advanced wasting has been defined as zero BF calculated using an anthropometric formula to estimate V[18]. This calculation is based on the assumption that body weight (W) consists of fat-free body mass (FFM) and BF. When hydration abnormalities are absent, the water content of FFM, which essentially represents all the water in the body because fat contains miniscule amounts of water, is constant at 73% (FFM = V/0.73)[20]. The fraction of body weight represented by water (V/W) is low in obese subjects in whom BF is a large component of W and, conversely, high in patients with weight deficit in whom BF is a small fraction of W. Thus, the V/W ratio increases progressively as body weight decreases due to loss of BF. Accordingly, this increase in the ratio V/W becomes evident when V is calculated by means of anthropometric formulas[21]. The value V/0.73 approaches W with progressive weight loss and becomes equal to W at a specific weight and larger than W below this weight[18]. Subjects with FFM calculated as V/0.73 equal to or larger than W have zero BF. Therefore, it is reasonable to define advanced wasting as V/0.73 ≥ W.

***Patients and nutrition indices***

Using the Watson formulas[22] to calculate V (VWatson), we computed FFM as VWatson/0.73 and compared it to W in 439 patients (262 men and 177 women) on PD. This comparison was performed at the time of the first determination of urea and creatinine clearances for assessment of the adequacy of PD. We compared nutrition indices between PD patients with VWatson/0.73 ≥ W and those with VWatson/0.73 < W.

Ideal weight (IW) was calculated by the method of Hamwi[23,24]. PNA was calculated by the method of Bergstrom[12] and normalized to both actual weight (nPNA/W) and ideal weight (nPNA/IW)[25]. LBM estimated from creatinine kinetics was computed according to the method of Keshaviah[13] and normalized to both actual weight (LBM/W) and ideal weight (LBM/IW). Measured creatinine excretion in dialysate plus urine was normalized to actual weight [(MCr Ex)/W], ideal weight [(MCr Ex)/IW], and predicted creatinine excretion (M/P Cr Ex). Predicted creatinine excretion was calculated using the formula: Cr Ex, mg/24-h = 302.150 – 4.380 × Age, years + 171.234 × Gender (women: 0; men: 1) – 39.041 × Diabetes (no: 0; yes: 1) + 11.730 × Weight, kg[26]. Measured and computed nutrition indices were compared between patients with VWatson/0.73 ≥ W and their respective 95%CIs in patients with VWatson/0.73 < W (the control group). Statistical analysis was performed using SYSTAT version 13.1.

**RESULTS**

Table 2 summarizes the clinical characteristics of the only two patients (Patient 1, Patient 2) with VWatson/0.73 ≥ W we identified among the 439 PD subjects analyzed. The frequency of advanced wasting was 0.5% in the population studied. Both subjects with advanced wasting were young (23 years or less), had renal failure due to primary glomerular diseases from childhood, were short and had a low body weight at the first clearance study. In both patients, body weight had changed by < 1 kg between initiation of PD and the first clearance study. Both Kt/V urea and creatinine clearance were inadequate in Patient 1 but adequate in Patient 2. Peritoneal transport characterized by a peritoneal equilibration test[27] was high in Patient 1 and low-average in Patient 2.

Table 3 compares the nutrition indices for Patients 1 and 2 with those of the control group of the remaining 260 male patients. Body mass index (BMI), the ratio of body weight to ideal weight (W/IW) and the serum albumin concentration were below the lower 95% confidence limit of the control group in both Patient 1 and Patient 2. In Patient 1, the serum urea nitrogen and creatinine levels were below the corresponding lower 95% confidence limits of the control group. In Patient 2 the serum urea nitrogen level was within the 95% confidence interval of the control group, while the serum creatinine level was above the upper 95% confidence limit of the control group.

In both Patient 1 and Patient 2 the nPNA/W and nPNA/IW values were within the 95% confidence interval of the control group. Normalized creatinine excretion values (MCr Ex)/W), (MCr Ex/IW) and the various indices derived from creatinine excretion (M/P Cr Ex, LBM/W, LBM/IW) were below the corresponding lower 95% confidence limits of the control group in Patient 1 and above the corresponding upper 95% confidence limits of the control group in Patient 2 (Table 3).

**DISCUSSION**

This report has two main findings: First, the incidence of advanced wasting defined as zero BF as determined using the Watson formula estimating body water was very low in patients on PD at the time of their first formal clearance study. Second, the two PD patients with advanced wasting defined by the use of the Watson formulas had very low body weight and serum albumin levels. However, several indices of nutritional status derived from urea nitrogen and creatinine excretion in these patients appeared to be normal or even elevated.

Weight excess and deficit are routinely evaluated in most populations by BMI, whereas deviation from ideal weight is used less frequently. The cut-off value for weight deficit is commonly set at a BMI of 18.5 kg/m2 in guidelines for the general population[28] or at a W/IW ratio of < 0.9 in PD patients[1,2]. The BMI values that correspond to a W/IW of 0.9 are 18.8 kg/m2 in women and 21.2 kg/m2 in men when ideal weight is estimated from the Hamwi formulas[29]. There is, in general, good agreement between BMI, W/IW and BF expressed as a fraction of body weight. However, there is substantial disagreement between BMI and W/IW estimates in the classification of individuals on PD as obese, normal weight or underweight[30]. In addition, there is substantial disagreement between BMI and lean body mass, and consequently between BMI and BF when estimated by DXA in PD patients[29].

In addition to the discrepancies between BMI and W/IW listed above, weight status classification on the basis of BMI or W/IW is subject to error because it does not take into account sarcopenia when it is associated with obesity or changing body composition as people age. Classification of weight deficit by BF content is subject to fewer errors[16], but may require expensive, sophisticated technology that is usually available only for research studies. Identification of patients with BF deficit is important because numerous studies support the assertion that low BF is associated with a poor outcome for PD patients.

The effect of weight deficit or obesity on the outcomes of chronic dialysis was first evaluated in hemodialysis patients in whom weight deficit was identified as a predictor of poor survival, while obesity was found to offer a survival advantage[31,32]. The effect of obesity on the outcome of patients receiving PD is less clear. A large retrospective study of United States Medicare PD patients found that obesity does offer a survival advantage[33]. Subsequent studies in the United States reported that the survival advantage of obesity was much weaker for PD patients compared to hemodialysis patients[34,35] and that obesity is a risk factor for peritonitis[36]. Kutner and Zhang[37] reported that the relationship between obesity and survival of PD patients is modified by race and gender, with obese white women on PD having a high risk of mortality. The influence of race on the outcomes of obesity in PD was confirmed by similar studies conducted in Asia[38] and in Australia and New Zealand[39]. Other studies reported either adverse effects[40,41] or no effect[42,43] of obesity on the survival of PD patients.

The focus of the present report is advanced weight deficit, not obesity. Unlike obesity where there is disagreement about its effect on the survival of patients treated by PD, the adverse effects of weight deficit on the outcomes of PD have been uniformly concordant[33,39-43]. Weight loss in the first year of PD is associated with an increased risk of death[44]. Finally, a recent meta-analysis confirmed the risk of mortality from low body weight of PD patients[45].

In the present report, we analyzed the nutritional status of PD patients identified as having advanced wasting based on the use of anthropometric formulas to estimate V. In the two PD patients identified as having advanced wasting using this method, the finding of very low BMI and serum albumin levels confirmed a poor nutritional status, whereas nutrition indices based on creatinine excretion provided conflicting findings. The potential pitfalls of creatinine excretion as a nutritional index in PD patients should be recognized.

An elevated serum creatinine value at the onset of PD[3], together with a high rate of creatinine excretion[46] is predictive of relatively long survival of PD patients. Creatinine production and excretion are directly related to muscle mass. High rates of creatinine excretion are indicative of preserved muscle mass and, therefore, good somatic nutrition[46]. However, high creatinine excretion rates are also encountered in clinical states causing muscle destruction, including certain disease states and drugs, and in unsteady states following rapid increases in creatinine clearance in patients with azotemia. Examples of clinical states causing rapid rise in creatinine clearance include elimination of the cause of urinary retention, correction of prerenal azotemia due to hypovolemia, hemodialysis sessions and resumption of the prescribed dose of PD by patients with previous poor compliance with the PD prescription. In this last case, calculating the M/P Cr in the unsteady state immediately following resumption of the prescribed PD dose has been proposed as an indicator of poor compliance with the prescribed dose of PD[47]. Creatinine excretion rates producing LBM/W values ≥ 0.9xW are strong indicators of non-compliance[48]. LBM/W computed from creatinine excretion data is, on average, about 10% lower than fat-free mass ((FFM) calculated as VWatson/0.73[49]. The higher value of LBM/W compared to VWatson/0.73 in Patient 2 (Table 3), who had no catabolic neuromuscular disease and was on no medications causing rhabdomyolysis, suggests that non-compliance was the reason for his very high creatinine excretion rate. Strong clinical evidence of non-compliance supports this conclusion.

The main limitations of the present report are the small number of patients categorized as having advanced wasting and especially the lack of information about survival, morbidity and overall quality of life in the two patients with advanced wasting and the control group. Further studies will be needed to evaluate the relationship between various nutrition indices in PD patients classified by anthropometric estimates of body water as having advanced wasting and the outcomes of these patients. Another limitation is that anthropometric formulas may not provide accurate estimates of body water at very low body weights, particularly in patients with sarcopenia and weight deficit. To test whether there are differences between various anthropometric formulas, we repeated the calculations using all formulas that estimate V[18] (data not shown). For all these calculations, both Patient 1 and Patient 2 exhibited a V/0.73 value that exceeded W. Thus, the characterization of advanced wasting in Patients 1 and 2 was consistent regardless of the anthropometric formula we used to estimate V. A third limitation of this report is that anthropometric V values systematically underestimate body water in patients with edema[50]. Edema is common in PD populations[51-53]. Values V/0.73 greater than W when V is estimated by anthropometric formulas may result in some cases from combined loss of BF and severe sarcopenia or from wasting with water excess. In this second instance the degree of wasting is even greater than the degree suggested by V/0.73. We suggest that a patient’s hydration status should be evaluated in patients when V/0.73 > W.

In conclusion, anthropometric formulas calculating V can accurately identify PD patients with advanced wasting. PD patients with advanced wasting identified by this method have poor nutrition indices. Special diagnostic and therapeutic efforts addressing the nutrition of these patients are required.

**ACKNOWLEDGEMENTS**

The authors express their thanks to the Research Service of the Raymond G. Murphy VA Medical Center for clerical and computer support of this study.

**COMMENTS**

***Background***

Weight deficit caused by loss of body fat (BF) has adverse effects on the state of health and survival of patients with end-stage renal disease. BF is estimated as the difference between body weight and fat-free body mass. At normal hydration, fat-free body mass can be calculated as the fraction body water over 0.73 fat-free body mass. Thus fat-free body mass and BF can be computed from body water. In this study, we computed BF using anthropometric body water estimates obtained at the first clearance study to evaluate adequacy of peritoneal dialysis (PD) and compared nutrition indices between the small number of patients with advanced body wasting (zero BF) and a large control group of patients with BF greater than zero.

***Research frontiers***

Because of the recognized effect of preservation of BF and fat-free body mass in patients on chronic dialysis, evaluation of body composition in these subjects has been an important focus of research. Various research methods have been applied in the study of body composition. These research methods require both costs for equipment and expertise. These requirements apply even to bioelectrical impedance analysis, which is the simplest method for evaluating body composition.

***Innovations and breakthroughs***

In contrast to research methods for evaluating body composition, the method proposed in this report utilizes only information and measurements necessary for evaluating the adequacy of PD and does not require any additional instruments or expertise. The method has no added cost.

***Applications***

Computation of BF using anthropometric body water estimates could allow simple and free of any costs monitoring of body composition in PD patients. Body composition estimates from this method could be compared to both indices of nutrition and results of research methods evaluating body composition. These comparisons will establish the place of the method presented in this report in the clinical monitoring of PD patients.

***Terminology***

The following symbols are essential for comprehending this method. W: Body weight; FFM: Fat-free mass; BF: Body fat; V: Body water. The following equations express the method: W = FFM + BF; FFM = V/073; BF = W – V/0.73.

***Peer-review***

This manuscript is clinically interesting.

**REFERENCES**

1 **Park YK**, Kim JH, Kim KJ, Seo AR, Kang EH, Kim SB, Park SK, Park JS. A cross-sectional study comparing the nutritional status of peritoneal dialysis and hemodialysis patients in Korea. *J Ren Nutr* 1999; **9**: 149-156 [PMID: 10431036 DOI: 10.1016/S1051-2276(99)90055-9]

2 **Tzamaloukas AH**, Murata GH, Servilla KS, Hoffman RM. Weight deficit in patients on continuous ambulatory peritoneal dialysis. *Am J Kidney Dis* 2002; **39**: 1068-1077 [PMID: 11979352 DOI: 10.1053/ajkd.2002.32791]

3 **Campbell R**, Augustine T, Hurst H, Pararajasingam R, van Dellen D, Armstrong S, Bartley C, Birtles L, Summers A. Anthropometrics Identify Wasting in Patients Undergoing Surgery for Encapsulating Peritoneal Sclerosis. *Perit Dial Int* 2015; **35**: 471-480 [PMID: 24584612 DOI: 10.3747/pdi.2013.00098]

4 **Avram MM**, Fein PA, Bonomini L, Mittman N, Loutoby R, Avram DK, Chattopadhyay J. Predictors of survival in continuous ambulatory peritoneal dialysis patients: a five-year prospective study. *Perit Dial Int* 1996; **16** Suppl 1: S190-S194 [PMID: 8728191]

5 **Dalrymple LS**, Johansen KL, Chertow GM, Grimes B, Anand S, McCulloch CE, Kaysen GA. Longitudinal measures of serum albumin and prealbumin concentrations in incident dialysis patients: the comprehensive dialysis study. *J Ren Nutr* 2013; **23**: 91-97 [PMID: 22633987 DOI: 10.1053/j.jrn.2012.03.001]

6 **Sreedhara R**, Avram MM, Blanco M, Batish R, Avram MM, Mittman N. Prealbumin is the best nutritional predictor of survival in hemodialysis and peritoneal dialysis. *Am J Kidney Dis* 1996; **28**: 937-942 [PMID: 8957050 DOI: 10.1016/S0272-6386(96)90398-4]

7 **Fein PA**, Gundumalla G, Jorden A, Matza B, Chattopadhyay J, Avram MM. Usefulness of bioelectrical impedance analysis in monitoring nutrition status and survival of peritoneal dialysis patients. *Adv Perit Dial* 2002; **18**: 195-199 [PMID: 12402618]

8 **Medici G**, Mussi C, Fantuzzi AL, Malavolti M, Albertazzi A, Bedogni G. Accuracy of eight-polar bioelectrical impedance analysis for the assessment of total and appendicular body composition in peritoneal dialysis patients. *Eur J Clin Nutr* 2005; **59**: 932-937 [PMID: 15928682 DOI: 10.1038/cj.ejcn.1602165]

9 **Koh KH**, Wong HS, Go KW, Morad Z. Normalized bioimpedance indices are better predictors of outcome in peritoneal dialysis patients. *Perit Dial Int* 2011; **31**: 574-582 [PMID: 20592100 DOI: 10.3747/pdi.2009.00140]

10 **Stall S**, Ginsberg NS, DeVita MV, Zabetakis PM, Lynn RI, Gleim GW, Wang J, Pierson RN, Michelis MF. Percentage body fat determination in hemodialysis and peritoneal dialysis patients: a comparison. *J Ren Nutr* 1998; **8**: 132-136 [PMID: 9724502 DOI: 10.1016/S1051-2276(98)90004-8]

11 **Pellicano R**, Strauss BJ, Polkinghorne KR, Kerr PG. Longitudinal body composition changes due to dialysis. *Clin J Am Soc Nephrol* 2011; **6**: 1668-1675 [PMID: 21734086 DOI: 10.2215/CJN.06790810]

12 **Bergström J**, Heimbürger O, Lindholm B. Calculation of the protein equivalent of total nitrogen appearance from urea appearance. Which formulas should be used? *Perit Dial Int* 1998; **18**: 467-473 [PMID: 9848623]

13 **Keshaviah PR**, Nolph KD, Moore HL, Prowant B, Emerson PF, Meyer M, Twardowski ZJ, Khanna R, Ponferrada L, Collins A. Lean body mass estimation by creatinine kinetics. *J Am Soc Nephrol* 1994; **4**: 1475-1485 [PMID: 8161729]

14 **Young GA**, Kopple JD, Lindholm B, Vonesh EF, De Vecchi A, Scalamogna A, Castelnova C, Oreopoulos DG, Anderson GH, Bergstrom J. Nutritional assessment of continuous ambulatory peritoneal dialysis patients: an international study. *Am J Kidney Dis* 1991; **17**: 462-471 [PMID: 1901197 DOI: 10.1016/S0272-6386(12)80642-1]

15 **Enia G**, Sicuso C, Alati G, Zoccali C. Subjective global assessment of nutrition in dialysis patients. *Nephrol Dial Transplant* 1993; **8**: 1094-1098 [PMID: 8272222]

16 **Lindholm B**, Bergström J. Nutritional aspects on peritoneal dialysis. *Kidney Int Suppl* 1992; **38**: S165-S171 [PMID: 1405370]

17 **Bray GA**, Bouchard C, James WPT. Definitions and proposed current classification of obesity. In: Bray JA, Bouchard C, James WPT, eds. Handbook of Obesity. New York: Marcel Dekker Inc., 1998: 31-40

18 **Tzamaloukas AH**, Murata GH, Vanderjagt DJ, Glew RH. Estimates of body water, fat-free mass, and body fat in patients on peritoneal dialysis by anthropometric formulas. *Kidney Int* 2003; **63**: 1605-1617 [PMID: 12675836 DOI: 10.1046/j.1523-1755.2003.009000.x]

19 **Tzamaloukas AH**, Murata GH, Vanderjagt DJ, Servilla KS, Glew RH. Body composition evaluation in peritoneal dialysis patients using anthropometric formulas estimating body water. *Adv Perit Dial* 2003; **19**: 212-216 [PMID: 14763065]

20 **Wang Z**, Deurenberg P, Wang W, Pietrobelli A, Baumgartner RN, Heymsfield SB. Hydration of fat-free body mass: new physiological modeling approach. *Am J Physiol* 1999; **276**: E995-E1003 [PMID: 10362610]

21 **Tzamaloukas AH**, Murata GH. Estimating urea volume in amputees on peritoneal dialysis by modified anthropometric formulas. *Adv Perit Dial* 1996; **12**: 143-146 [PMID: 8865889]

22 **Watson PE**, Watson ID, Batt RD. Total body water volumes for adult males and females estimated from simple anthropometric measurements. *Am J Clin Nutr* 1980; **33**: 27-39 [PMID: 6986753]

23 **Hamwi CT**. Therapy. In: Danowski TS, ed. Changing Concepts in Diabetes Mellitus: Diagnosis and Treatment. 2nd ed. New York, NY, American Diabetes Association, 1962: 73-78

24 **Harvey KS**. Methods for determining healthy body weight in end stage renal disease. *J Ren Nutr* 2006; **16**: 269-276 [PMID: 16825033 DOI: 10.1053/j/jrn.2006.01.008]

25 **Tzamaloukas AH**, Murata GH, Vanderjagt DJ, Servilla KS, Glew RH. Normalization of protein nitrogen appearance by various size indicators in patients on continuous peritoneal dialysis. *Adv Perit Dial* 2003; **19**: 207-211 [PMID: 14763064]

26 **Tzamaloukas AH**, Murata GH. A population-specific formula predicting creatinine excretion in continuous peritoneal dialysis. *Perit Dial Int* 2002; **22**: 67-72 [PMID: 11929147]

27 **Twardowski ZJ**, Nolph KD, Khanna R, Prowant BF, Ryan LP, Moore HL, Nielsen MP. Peritoneal equilibration test. *Perit Dial Bull* 1987; **7**: 138-147

28 **United States Department of Health and Human Services**. Public Health Service, National Institute of Health, National Heart, Lung and Blood Institute and National Institute of Diabetes and Digestive and Kidney Disease: Clinical Guidelines for Identification, Evaluation and Treatment of Obesity in Adults. The Evidence Report. NIH Publication No. 98-4083. Bethesda, Maryland, USPHHS, 1998

29 **Tzamaloukas AH**, Leger A, Hill J, Murata GH. Body mass index in patients with amputations on peritoneal dialysis: error of uncorrected estimates and proposed correction. *Adv Perit Dial* 2000; **16**: 138-142 [PMID: 11045279]

30 **Tzamaloukas AH**, Murata GH, Vanderjagt DJ, Servilla KS, Glew RH. Weight status classification of patients on continuous peritoneal dialysis. *Adv Perit Dial* 2003; **19**: 217-221 [PMID: 14763066]

31 **Leinig C**, Pecoits-Filho R, Nascimento MM, Gonçalves S, Riella MC, Martins C. Association between body mass index and body fat in chronic kidney disease stages 3 to 5, hemodialysis, and peritoneal dialysis patients. *J Ren Nutr* 2008; **18**: 424-429 [PMID: 18721737 DOI: 10.1053/j.jrn.2008.04.001]

32 **Kopple JD**, Zhu X, Lew NL, Lowrie EG. Body weight-for-height relationships predict mortality in maintenance hemodialysis patients. *Kidney Int* 1999; **56**: 1136-1148 [PMID: 10469384 DOI: 10.1046/j.1523-1755.1999.00615.x]

33 **Snyder JJ**, Foley RN, Gilbertson DT, Vonesh EF, Collins AJ. Body size and outcomes on peritoneal dialysis in the United States. *Kidney Int* 2003; **64**: 1838-1844 [PMID: 14531819 DOI: 10.1047/j.1523-1755.2003.00287.x]

34 **Abbott KC**, Glanton CW, Trespalacios FC, Oliver DK, Ortiz MI, Agodoa LY, Cruess DF, Kimmel PL. Body mass index, dialysis modality, and survival: analysis of the United States Renal Data System Dialysis Morbidity and Mortality Wave II Study. *Kidney Int* 2004; **65**: 597-605 [PMID: 14717930 DOI: 10.1111/j.1523-1755.2004.00385.x]

35 **Johansen KL**, Young B, Kaysen GA, Chertow GM. Association of body size with outcomes among patients beginning dialysis. *Am J Clin Nutr* 2004; **80**: 324-332 [PMID: 15277152]

36 **Pulliam J**, Li NC, Maddux F, Hakim R, Finkelstein FO, Lacson E. First-year outcomes of incident peritoneal dialysis patients in the United States. *Am J Kidney Dis* 2014; **64**: 761-769 [PMID: 24927898 DOI: 10.1053/j/ajkd.2014.04.025]

37 **Kutner NG**, Zhang R. Body mass index as a predictor of continued survival in older chronic dialysis patients. *Int Urol Nephrol* 2001; **32**: 441-448 [PMID: 11583369 DOI: 10.1023/A: 1017581726362]

38 **Nessim SJ**. Extremes of body mass index and mortality among Asian peritoneal dialysis patients. *Perit Dial Int* 2014; **34**: 338-341 [PMID: 24991049 DOI: 10.3747/pdi.2014.00031]

39 **McDonald SP**, Collins JF, Johnson DW. Obesity is associated with worse peritoneal dialysis outcomes in the Australia and New Zealand patient populations. *J Am Soc Nephrol* 2003; **14**: 2894-2901 [PMID: 14569099 DOI: 10.1097/01.ASN.0000091587.55159.SF]

40 **Zhou H**, Cui L, Zhu G, Jiang Y, Gao X, Zou Y, Yang M, Liu H, Di J, Zong Y, Pan J. Survival advantage of normal weight in peritoneal dialysis patients. *Ren Fail* 2011; **33**: 964-968 [PMID: 22013929 DOI: 10.3109/0886022X.2011.615968]

41 **Kiran VR**, Zhu TY, Yip T, Lui SL, Lo WK. Body mass index and mortality risk in Asian peritoneal dialysis patients in Hong Kong-impact of diabetes and cardiovascular disease status. *Perit Dial Int* 2014; **34**: 390-398 [PMID: 24497598 DOI: 10.3747/pdi.2013.00055]

42 **Kim YK**, Kim SH, Kim HW, Kim YO, Jin DC, Song HC, Choi EJ, Kim YL, Kim YS, Kang SW, Kim NH, Yang CW. The association between body mass index and mortality on peritoneal dialysis: a prospective cohort study. *Perit Dial Int* 2014; **34**: 383-389 [PMID: 24584607 DOI: 10.3747/pdi.2013.00008]

43 **Prasad N**, Sinha A, Gupta A, Sharma RK, Bhadauria D, Chandra A, Prasad KN, Kaul A. Effect of body mass index on outcomes of peritoneal dialysis patients in India. *Perit Dial Int* 2014; **34**: 399-408 [PMID: 24584600 DOI: 10.3747/pdi.2013.00056]

44 **Xiong L**, Cao S, Xu F, Zhou Q, Fan L, Xu Q, Yu X, Mao H. Association of Body Mass Index and Body Mass Index Change with Mortality in Incident Peritoneal Dialysis Patients. *Nutrients* 2015; **7**: 8444-8455 [PMID: 26473916 DOI: 10.3390/nu7105405]

45 **Ahmadi SF**, Zahmatkesh G, Streja E, Mehrotra R, Rhee CM, Kovesdy CP, Gillen DL, Ahmadi E, Fonarow GC, Kalantar-Zadeh K. Association of Body Mass Index With Mortality in Peritoneal Dialysis Patients: A Systematic Review and Meta-Analysis. *Perit Dial Int* 2016; **36**: 315-325 [PMID: 26475847 DOI: 10.3747/pdi.2015.00052]

46 **Perez RA**, Blake PG, Spanner E, Patel M, McMurray S, Heidenheim P, Lindsay RM. High creatinine excretion ratio predicts a good outcome in peritoneal dialysis patients. *Am J Kidney Dis* 2000; **36**: 362-367 [PMID: 10922315 DOI: 10.1053/ajkd.2000.8987]

47 **Keen M**, Lipps B, Gotch F. The measured creatinine generation rate in CAPD suggests only 78% of prescribed dialysis is delivered. *Adv Perit Dial* 1993; **9**: 73-75 [PMID: 8105967]

48 **Tzamaloukas AH**, Murata GH. Lean body mass calculation by creatinine kinetics in CAPD. Is it only a measure of somatic nutrition? *Perit Dial Int* 2000; **20**: 351-352 [PMID: 10898059]

49 **Tzamaloukas AH**, Murata GH, Piraino B, Raj DS, VanderJagt DJ, Bernardini J, Servilla KS, Sun Y, Glew RH, Oreopoulos DG. Sources of variation in estimates of lean body mass by creatinine kinetics and by methods based on body water or body mass index in patients on continuous peritoneal dialysis. *J Ren Nutr* 2010; **20**: 91-100 [PMID: 19853476 DOI: 10.1053/j.jrn.2009.08.004]

50 **Tzamaloukas AH**, Saddler MC, Murata GH, Malhotra D, Sena P, Simon D, Hawkins KL, Morgan K, Nevarez M, Wood B. Symptomatic fluid retention in patients on continuous peritoneal dialysis. *J Am Soc Nephrol* 1995; **6**: 198-206 [PMID: 7579085]

51 **Fan S**, Sayed RH, Davenport A. Extracellular volume expansion in peritoneal dialysis patients. *Int J Artif Organs* 2012; **35**: 338-345 [PMID: 22466994 DOI: 10.5301/ijao.5000080]

52 **Henriques VT**, Martinez EZ, Divino-Filho JC, Pecoits-Filho R, da Costa JA. Increase in BMI over time is associated with fluid overload and signs of wasting in incident peritoneal dialysis patients. *J Ren Nutr* 2013; **23**: e51-e57 [PMID: 23046738 DOI: 10.1053/j.jrn.2012.08.008]

53 **Tzamaloukas AH**, Murata GH, Dimitriadis A, Voukiklari S, Antoniou S, Malhotra D, Kakavas J, Dombros NV, Nicolopoulou N, Balaskas EV. Fractional urea clearance in continuous ambulatory peritoneal dialysis: effects of volume disturbances. *Nephron* 1996; **74**: 567-571 [PMID: 8938682 DOI: 10.1159/000189453]

**P-Reviewer:** Friedman EA, Yorioka N **S-Editor:** Ji FF **L-Editor: E-Editor:**

**Table 1 Abbreviations used in this report**

|  |  |
| --- | --- |
| Abbreviation | Interpretation |
| V | Body water, L; VWatson = body water estimated by the Watson formula  |
| W | Body weight, kg |
| IW | Ideal body weight, kg |
| BF | Body fat, kg |
| FFM | Fat-free mass, kg |
| BMI | Body mass index, kg/m2 |
| PNA | Protein nitrogen appearance, g; nPNA/W = PNA normalized to W, g/kg; nPNA/IW = PNA/IW = PNA normalized to IW, g/kg  |
| Cr Ex | Creatinine excretion rate, mg/24-h; (MCr Ex)/W= measured Cr Ex normalized to W, (mg/kg)/24-h; (MCr Ex)/IW = Measured Cr Ex normalized to IW, (mg/kg)/24-h  |
| M/P Cr Ex | Measured/Predicted creatinine excretion rate |
| LBM | Lean body mass estimated from Cr Ex, kg; LBM/W = LBM normalized to W;LBM/IW = LBM normalized to IW  |

**Table 2 Clinical characteristics of peritoneal dialysis patients with advanced wasting**

|  |  |  |
| --- | --- | --- |
| Clinical characteristic | Patient 1 | Patient 2 |
| Sex | Male | Male |
| Cause of ESRD | Glomerulonephritis | Glomerulonephritis |
| Age, years | 21 | 23 |
| Height, cm | 149 | 155 |
| Weight, kg | 36.7 | 40.0 |
| Kt/V urea1, weekly | 1.34 | 2.92 |
| Creatinine clearance1, L/1.73 m2 weekly | 49 | 218 |
| Peritoneal transport (4-h D/P creatinine)2 | High (0.84) | Low-average (0.54) |

1Total (renal plus peritoneal) clearance; 2Characterized by the value of the 4-hour dialysate/plasma (D/P) creatinine concentration ratio in a peritoneal equilibration test (PET)[27]. ESRD: End-stage renal disease.

**Table 3 Nutrition indices in two males with advanced wasting (Patient 1, Patient 2) and a control group**

|  |  |  |  |
| --- | --- | --- | --- |
| Nutrition index | Patient 1 | Patent 2 | Control group1 |
| VWatson/0.73 | 1.036 | 1.030 | 0.744 (0.521-0.932) |
| BMI, kg/m2 | 16.5 | 16.6 | 25.5 (18.9-32.8) |
| W/IW | 0.778 | 0.816 | 1.151 (0.935-1.367) |
| Serum albumin, g/dL | 2.60 | 2.80 | 3.60 (3.15-4.05) |
| Serum urea nitrogen, mg/dL | 41.0 | 58.0 | 56.8 (43.2-70.4) |
| Serum creatinine, mg/dL | 2.02 | 13.55 | 7.38 (5.25-9.51) |
| nPNA/W, g/kg per 24 h | 0.94 | 1.21 | 0.86 (0.70-1.02) |
| nPNA/IW, g/kg per 24-h | 0.81 | 1.07 | 0.99 (0.75-1.13) |
| (MCr Ex)/W, mg/kg per 24-h  | 13.0 | 35.9 | 18.7 (13.9-23.5) |
| (MCr Ex)/IW, mg/kg per 24-h | 11.4 | 27.9 | 21.5 (17.5-25.5) |
| M/P Cr Ex | 0.51 | 1.680 | 0.97 (0.55-1.39) |
| LBM/W | 0.64 | 1.420 | 0.66 (0.55-0.77) |
| LBM/IW | 0.52 | 1.100 | 0.76 (0.66-0.86) |

1The control group consisted of 260 men on PD analyzed in their first clearance study. The values in the control group column indicate mean (95%CI). BMI: Body mass index; PNA: Protein nitrogen appearance; LBM: Lean body mass.