International Urology and Nephrology (2024) 56:2379–2389
https://doi.org/10.1007/s11255-024-03988-9

NEPHROLOGY - ORIGINAL PAPER

The effect of body mass index on mortality, peritonitis, technique proficiency and residual renal function in peritoneal dialysis patients

Murat Altunok[1] · Erdem Çankaya[1] · Hatice Gözübüyük Kaplan[1] · Enes Çınar[1] · Abdullah Uyanık[1] · Can Sevinç[1]

Received: 3 September 2023 / Accepted: 12 February 2024 / Published online: 2 March 2024

Abstract

Background The prevalence of obesity is increasing worldwide. Obesity is also increasing in the chronic kidney disease (CKD) population. There are conflicting data on complications such as mortality, peritonitis, and technique proficiency of peritoneal dialysis (PD) in underweight and obese patients according to body mass index (BMI). We aimed to present the data in our region to the literature by comparing the residual renal function (RRF), peritonitis, technique proficiency, and mortality rates of the patients we grouped according to BMI.

Methods The data of 404 patients who were started and followed up in our clinic between March 2005 and November 2021 were evaluated retrospectively. They were grouped as underweight, normal weight, overweight, and obese according to BMI. RRF, mortality, technique proficiency and peritonitis data of the groups were compared.

Results Of the 404 patients, 44 were underweight, 199 were normal weight, 110 were overweight, and 55 were obese. No difference was found between the groups in the technique survey and in the time to first peritonitis with Kaplan–Meier analysis (respectively; $p = 0.610$, $p = 0.445$). Multivariate Cox regression analysis showed that BMI did not affect mortality (HR 1.196 [95% CI 0.722–1.981] ($p = 0.488$)).

Conclusion In conclusion, we report that BMI has no effect on RRF, peritonitis, technique proficiency, and mortality in patients undergoing PD, and that mortality may depend on additional factors such as mean albumin, time to first peritonitis, and loss of RRF.

Keywords Peritoneal dialysis · Body mass index · Peritonitis · Technique survival · Mortality

Introduction

The prevalence of obesity is increasing worldwide. According to the predictions of the World Health Organization (WHO), by 2025, one in five adults worldwide will be obese. Obesity is also increasing in the chronic kidney disease (CKD) population. The prevalence of obesity among patients undergoing dialysis in the USA is > 30% [1]. Although obesity is a well-known risk factor for end-stage renal disease (ESRD) [2], it has historically been considered a relative contraindication for peritoneal dialysis (PD) [3]. Although recent studies have shown that this myth has been dispelled and PD can be successfully carried out in obese patients [4, 5], observational studies in the CKD population have reported conflicting evidence about the relationship between obesity and mortality. There are also publications showing that it can provide a survival advantage for this patient population [6]. However, those with a body mass index (BMI) < 20 kg/m^2 were associated with the highest mortality

✉ Murat Altunok
mrtalt@hotmail.com

Erdem Çankaya
dr25erdem@gmail.com

Hatice Gözübüyük Kaplan
htcgozubuyuk@gmail.com

Enes Çınar
enes.cinar.11@hotmail.com

Abdullah Uyanık
abdullahuyanik@hotmail.com

Can Sevinç
can.sevinc@atauni.edu.tr

[1] Department of Nephrology, Faculty of Medicine, Atatürk University, 25240 Erzurum, Turkey

[7]. While higher BMI is associated with improved survival in dialysis patients, a lower BMI was associated with higher mortality [8–11]. This phenomenon of obesity paradox has greatly contributed to the growing confusion among nephrologists about whether to treat obesity in dialysis patients. Especially in the first year of PD, a BMI < 18.5 kg/m^2 has been associated with mortality [12].

There are still conflicting reports about infectious complications such as peritonitis, which is known as one of the most important causes of morbidity and mortality for PD patients, and complications such as technique proficiency [13, 14]. In addition, obesity is considered among the modifiable risk factors for peritonitis [15]. Therefore, prospective data on these patients are insufficient, as PD is not recommended for many obese patients and patients with a BMI < 18.5 kg/m^2 [13]. Our aim in this study is to present the data in our region to the literature by comparing the RRF, peritonitis, technique proficiency, and mortality rates of the patients we grouped according to BMI.

Materials and methods

The data of 404 patients whose PD were started by our clinic and who were followed up for at least 3 months between March 2005 and November 2022 were evaluated retrospectively. Patients aged 18 and over were included in the study. Approval was obtained from the local ethics committee. Since it was a retrospective observational study, patient consent was not required. At the start of the RRT, everyone's BMI was calculated by dividing their weight in kilograms by the square of their height in meters, as recommended by the WHO. Patients were divided into 4 groups as Weak: BMI below 18.5 kg/m^2, Normal weight: BMI 18.5 to less than or equal to 24.9 kg/m^2, Overweight: BMI of 25 to less than or equal to 29.9 kg/m^2, and Obese: BMI of 30 kg/m^2 or greater. In addition, BMIs were recorded at the time of the patients' withdrawal from PD. For the diagnosis of peritonitis, at least 2 of the following criteria are required according to International Society for Peritoneal Dialysis (ISPD) 2016 guidelines: clinical features consistent with peritonitis, peritoneal fluid leukocytosis (at least 100/mm^3 white cell count, at least 50 polymorphonuclear neutrophilic cells) and positive culture of PD fluid. If the 24 h urine volume of the patients was less than 100 ml, it was considered as urinary cessation and was called complete loss RRF. In addition, demographic and clinical characteristics of the patients, echocardiography (ECHO) reports at 6-month periods, number of peritonitis, time to first peritonitis attack, Kt/V values, initial urine values, withdrawal urine values, and reasons for PD withdrawal were included in the analysis. Technique proficiency for PD patients was defined as failure to achieve the desired target in Kt/V (Kt/V < 1.7), catheter dysfunction, ultrafiltration failure, skin or genital leakage, and leakage into the third spaces outside the peritoneal cavity. The local institutional ethics committee approved this study (Local Ethics Committee. No: B.30.2.ATA.0.01.00/133).

PD modalities and selection

In our country, patients can choose the RRT method they want without any limiting factor except medical necessity. Patients make their choices after this educational model is applied. A predialysis education program (PDEP) is a specially prepared training kit that has been used in some centers in our country. Using visual and written cards, this training kit educates CKD patients and their relatives. It has 6 modules as summarized: Module 1: how do kidneys work? What is kidney failure? Which diseases cause kidney failure?; Module 2: why is diet important in kidney disease? The drugs used in kidney disease and the importance of exercise; Module 3: introduction to the treatment of renal failure and general information about RRT; Module 4: peritoneal dialysis; Module 5: hemodialysis; and Module 6: kidney transplantation.

At PD initiation, participants were assigned to one of the PD modalities; CAPD with a twin-bagged system or instrumented peritoneal dialysis (IPD). The prescription of CAPD was 4× 1.5−2.5 L (body surface area, RRF determined) exchanges if no sign of inadequate dialysis was observed. Dialysate fluids containing (i) 1.36%, 2.27%, or 3.86% glucose; (ii) amino acids; or (iii) icodextrin were used according to the clinical needs of patients. The prescription of IPD was to give 6–15 L of exchange fluid within 6–8 h.

Statistical analysis

SPSS 20.0 (IBM Cor., Chicago, IL, USA) program was used for data analysis. In the statistical analysis of the study, mean, standard deviation, frequency, and percentage values were defined. The findings in the data were analyzed by the Kolmogorov–Smirnov (K–S) test. The general characteristics and demographic characteristics of the groups were determined by frequency (descriptive analysis: frequency analysis for a single variable) analysis. The Pearson Chi-square test was used to determine the relationship between categorical variables. Kruskal–Wallis *H* test was used for the mean comparison of non-parametric values of multiple independent groups, and Tamhane's T2 test was used for post-hoc analysis. One-way ANOVA (one-way analysis of variance) was used for the mean comparison of parametric values of multiple independent groups, and Duncan test was used for post-hoc analysis. In bilateral comparisons, paired sample *t*-test for parametric values and Wilcoxon test for

non-parametric values was used to compare the single variable for 2 different situations.

The endpoint for the analysis of patient survival was death. The endpoint for the patients in peritoneal dialysis was conversion to hemodialysis or transplantation. Conversion to hemodialysis and transplantation were censored for patient survival, and mortality curves were generated using the Kaplan–Meier log-rank method. The endpoint of the patients' RRF loss was a decrease in the amount of urine below 100 mL/day. The patient's lack of RRF loss was censored, and graphs showing RRF loss were generated using the Kaplan–Meier log-rank method. The patients' endpoint for the first peritonitis episode analysis was experiencing the first peritonitis episode. The patient's absence of a peritonitis episode was censored, and graphs showing the peritonitis episode were generated using the Kaplan–Meier log-rank method. In the analysis of the survival of the technique, transition to hemodialysis and death were considered final events; functional dialysis and loss of follow-up data were censored. In the analysis of the survival of the technique, kidney transplant patients were not included in the analysis. Univariate and multivariate Cox regression analyses were performed to determine risk factors for mortality in patients. A $p \leq 0.05$ value was considered statistically significant in the entire study.

Results

A total of 404 patients were identified as 44 underweight, 199 normal weight, 110 overweight, and 55 obese. The mean BMI at the beginning of PD was determined as 17.09 ± 1.29, 21.92 ± 1.73, 26.74 ± 1.29, and 33.92 ± 3.33, respectively. The ratio of female was high in the underweight and obese patient group. Among the groups, the underweight group had the lowest mean age and the highest mean age was in the overweight and obese group (Table 1). In terms of ESKD etiology, the rate of diabetes was high in overweight and obese patients (Table 1). Hypertension (HT) rate increased significantly as BMI increased. Other demographic and laboratory follow-up data are given in Table 1.

In the Kaplan–Meier analysis technique survey, no difference was found between the groups ($p = 0.610$, Fig. 1). Duration to the first peritonitis of the patients was determined as 23.79 ± 21.31 months in Underweight patients, 22.86 ± 22.582 months in Normal Weight patients, 19.45 ± 19.4 months in Overweight patients and 24.89 ± 23.61 months in Obese patients, and there was no significant difference between them ($p = 0.445$, Table 1). Peritonitis-free survival of the groups was similar in Kaplan–Meier analysis ($p = 0.840$) (Fig. 2). In addition, according to BMI, Methicillin-sensitive coagulase-negative staphylococci (MSCNS) were the most common peritonitis agent in the first peritonitis attack in all groups. The most common agents reproduced in tunnel infections were MSCNS and Methicillin-sensitive staphylococcus aureus (Table 1). There was no difference in urinary volume loss (residual renal function loss) between the patient groups undergoing PD ($p = 0.896$) (Fig. 3).

Of the 404 patients, 270 died. Their mean survey was $56{,}837 \pm 2929$ months. Among the groups, the underweight patients had the lowest mortality and overweight group had the highest mortality. Among the patient groups, the best survival by years was in the underweight patient group. Annual mortality rates are given in Table 2. In Kaplan–Meier analysis, the mortality of the overweight group was high ($p = 0.029$) (Fig. 4). Multivariate Cox regression analysis demonstrated that BMI did not affect mortality (HR 1.196 [95% CI 0.722–1.981] ($p = 0.488$)). Factors affecting mortality were loss of RRF, duration to the first episode of peritonitis, and mean albumin values (respectively, (HR 0.551) [95% CI 0.352–0.865] ($p = 0.010$); (HR 0.982) [95% CI 0.973–0.990] ($p < 0.001$); (HR 0.205) [95% CI 0.126–0.334] ($p < 0.001$)) (Table 3).

The BMI of the patients at the time of PD withdrawal was significantly increased compared to the baseline BMI, except for the obese patients (Table 4). In the Kaplan–Meier Analysis performed according to the PD withdrawal BMI of the patients, no significant difference was found between the groups in the patient surveys (Fig. 5) ($p = 0.292$).

Discussion

This study is one of the rare studies that evaluated not only the mortality of PD patients grouped according to BMI, but also peritonitis, the agents of the first peritonitis episode, tunnel infection, RRF, technique proficiency, and mortality according to withdrawal BMI. It has been shown that having a high BMI in hemodialysis has a protective effect on mortality [16]. This condition has conflicting data in PD patients. Although having a high BMI in PD patients had better mortality in the first year, this could not be demonstrated throughout the other years [17]. In addition, there are studies indicating that having a low BMI is a higher risk for death in PD patients [14]. On the contrary, high BMI was found to be associated with high mortality in some publications [4, 18]. The proportion of adipose tissue for the same BMI varies by ethnicity. The World Health Organization has proposed different BMI criteria to reflect obesity for Caucasians and Asians [19]. These data from different study regions suggest that ethnicity may influence mortality according to BMI. In addition, differences in mortality may be due to the fact that BMI does not distinguish between central obesity and generalized obesity. It has been reported that weight loss after the onset of PD increases mortality,

Table 1 Comparison of demographic, clinical, RRF and peritonitis rates of peritoneal dialysis patients according to BMI

			BMI *(n = 404)*				
			Underweight (*n* = 40)	Normal weight (*n* = *199*)	Overweight (*n* = *110*)	Obese (*n* = *55*)	*p*
BMI	Mean ± SD		17.09 ± 1.29[d]	21.92 ± 1.73[c]	26.74 ± 1.29[b]	33.92 ± 3.33[a]	***< 0.001****
Withdrawal BMI	Mean ± SD		19.88 ± 4.20[d]	23.43 ± 3.16[c]	28.73 ± 4.04[b]	34.45 ± 5.30[a]	***< 0.001****
Gender	Female	*n* (%)	23 (57,5)	76 (38,2)	57 (51,8)	42 (76,4)	***< 0.001****
	Male	*n* (%)	17 (42,5)	123 (61,8)	53 (48,2)	13 (23,6)	
Age	Mean ± SD		34.35 ± 18.22[c]	50.58 ± 17.22[b]	58.35 ± 14.17[a]	63.13 ± 10.67[a]	***< 0.001****
Peritoneal technique	Surgery	*n* (%)	26 (65)	123 (61,8)	65 (59)	46 (83,6)	***0.013****
	Percutaneous	*n* (%)	14 (35)	76 (38,1)	45 (40,9)	9 (16,3)	
Method of peritoneal dialysis	IPD	*n* (%)	11 (27,5)	40 (20,1)	18 (16,3)	5 (9)	0.107
	CAPD	*n* (%)	29 (72,5)	159 (79,8)	92 (83,6)	50 (90,9)	
PET	HP	*n* (%)	12 (30)	65 (32,6)	32 (29)	12 (21,8)	0.581
	HM	*n* (%)	18 (45)	81 (40,7)	49 (44,5)	26 (47,2)	
	LM	*n* (%)	10 (25)	42 (21,1)	23 (20,9)	11 (20)	
	LP	*n* (%)	0 (0)	11 (5,5)	6 (5,4)	6 (10,9)	
Kt/V	Mean ± SD		2.779 ± 1.2897	2.575 ± 1.0966	2.725 ± 1.1866	2.622 ± 1.2897	0.617
Primary disease	DM	*n* (%)	2 (5)	50 (25,1)	40 (36,3)	20 (36,3)	***< 0.001****
	HT	*n* (%)	3 (7,5)	33 (16,5)	30 (27,2)	14 (25,4)	
	CGN	*n* (%)	16 (40)	43 (21,6)	21 (19)	11 (20)	
	Amyloidosis	*n* (%)	4 (10)	20 (10)	5 (4,5)	1 (1,8)	
	KIN	*n* (%)	6 (15)	25 (12,5)	7 (6,3)	5 (9)	
	Other	*n* (%)	9 (22,5)	28 (14)	7 (6,3)	4 (7,2)	
Status of DM	No	*n* (%)	38 (95)	150 (75,3)	69 (62,7)	33 (60)	***< 0.001****
	Yes	*n* (%)	2 (5)	49 (24,6)	41 (37,2)	22 (40)	
Status of HT	No	*n* (%)	22 (55)	67 (33,6)	24 (21,8)	11 (20)	***< 0.001****
	Yes	*n* (%)	18 (45)	132 (66,3)	86 (78,1)	44 (80)	
Status of CAD	No	*n* (%)	37 (92,5)	167 (83,9)	90 (81,8)	40 (72,7)	0.080
	Yes	*n* (%)	3 (7,5)	32 (16)	20 (18,1)	15 (27,2)	
EF Value	Mean ± SD		56.85 ± 4.97	54.80 ± 8.16	55.96 ± 7.50	53.55 ± 9.50	0.425
Complete loss RRF	No	*n* (%)	15 (41,6)	110 (62,1)	66 (66,6)	24 (48)	***0.018****
	Yes	*n* (%)	21 (58,3)	67 (37,8)	33 (33,3)	26 (52)	
Is there urine output?	No	*n* (%)	4 (10)	20 (10)	7 (6,3)	3 (5,4)	0.563
	Yes	*n* (%)	36 (90)	179 (89,9)	103 (93,6)	52 (94,5)	
Urine volume (mL/day)	Mean ± SD		940.00 ± 608.40	966.58 ± 64.61	1105.91 ± 644.83	990.91 ± 619.52	0.245
Is there urine at the withdrawal?	No	*n* (%)	23 (57,5)	69 (34,6)	37 (33,6)	27 (49)	***0.012****
	Yes	*n* (%)	17 (42,5)	130 (65,3)	73 (66,3)	28 (50,9)	
Volume of urine output (mL/day)	Mean ± SD		233.75 ± 464.83[b]	440.70 ± 540.55[a]	399.09 ± 476.36[ab]	272.73 ± 394.14[ab]	***0.030****
Is there a reduction in urine volume?	No	*n* (%)	3 (8,3)	29 (16,2)	14 (13,5)	4 (7,6)	0.328
	Yes	*n* (%)	33 (91,6)	150 (83,7)	89 (86,4)	48 (92,3)	
Urine reduction volume (mL/day)	Mean ± SD		812.50 ± 545.02[a]	610.34 ± 501.95[a]	763.11 ± 597.87[a]	759.62 ± 596.15[a]	***0.043****
Urine interruption time	Mean ± SD		39.35 ± 26.18	30.6 ± 20.21	42.48 ± 21.21	28.61 ± 23.13	0.461
PD duration	Mean ± SD		47.38 ± 29.125	41.74 ± 32.808	36.1 ± 28.448	44.95 ± 32.553	0.151
Cause of PD withdrawal	Exitus	*n* (%)	13 (32,5)	90 (45,2)	53 (48,1)	36 (65,4)	***0.013****
	Peritonitis	*n* (%)	8 (20)	36 (18)	26 (23,6)	8 (14,5)	
	Transplantation	*n* (%)	11 (27,5)	36 (18)	9 (8,1)	2 (3,6)	
	Technique problems	*n* (%)	6 (15)	30 (15)	20 (18,1)	9 (16,3)	
	Own will	*n* (%)	2 (5)	7 (3,5)	2 (1,8)	0 (0)	

Table 1 (continued)

			BMI *(n = 404)*				
			Underweight (*n* = 40)	Normal weight (*n* = *199*)	Overweight (*n* = *110*)	Obese (*n* = *55*)	*p*
Technique proficiency	Insufficient dialysis	*n* (%)	3 (50.0)	15 (50.0)	11 (55.0)	7 (77.8)	0.739
	Insufficient UF	*n* (%)	1 (16.7)	1 (3.3)	1 (5.0)	0 (0.0)	
	Peritonitis	*n* (%)	0 (0.0)	3 (10.0)	1 (5.0)	0 (0.0)	
	Subcutaneous leakage	*n* (%)	0 (0.0)	2 (6.7)	3 (15.0)	2 (22.2)	
	Drainage problem	*n* (%)	1 (16.7)	6 (20.0)	2 (10.0)	0 (0.0)	
	Other	*n* (%)	1 (16.7)	3 (10.0)	2 (10.0)	0 (0.0)	
Did he/she have peritonitis?	No	*n* (%)	6 (15)	50 (25,1)	29 (26,3)	12 (21,8)	0.495
	Yes	*n* (%)	34 (85)	149 (74,8)	81 (73,6)	43 (78,1)	
Has he/she had a tunnel infection?	No	*n* (%)	36 (90.0)	172 (86.4)	98 (89.1)	51 (92.7)	0.593
	Yes	*n* (%)	4 (10.0)	27 (13.6)	12 (10.9)	4 (7.3)	
Duration for first tunnel infection	Mean ± SD		51.75 ± 20.13	24.37 ± 26.21	24.08 ± 15.59	14.75 ± 11.67	0.112
Peritonitis rates (episodes per patient/year)	Mean ± SD		0,91 ± 1,13	0,86 ± 1,17	0,88 ± 1,08	0,76 ± 0,82	0.901
Duration to the first peritonitis episode (month)	Mean ± SD		23.79 ± 21.31	22.86 ± 22.582	19.45 ± 19.4	24.89 ± 23.61	0.445
Agents of first peritonitis attack	Acinetobacter	*n* (%)	1 (2.9)	1 (0.7)	3 (3.7)	1 (2.3)	***0.041****
	Alpha hemolytic streptococcus	*n* (%)	2 (5.9)	10 (6.7)	6 (7.4)	2 (4.7)	
	Diphtheroid bacilli	*n* (%)	0 (0.0)	4 (2.7)	1 (1.2)	2 (4.7)	
	E. coli	*n* (%)	2 (5.9)	10 (6.7)	6 (7.4)	2 (4.7)	
	Enterobacter	*n* (%)	0 (0.0)	7 (4.7)	1 (1.2)	2 (4.7)	
	MRCNS	*n* (%)	7 (20.6)	20 (13.4)	17 (21.0)	4 (9.3)	
	MSCNS	*n* (%)	14 (41.2)	40 (26.8)	26 (32.1)	11 (25.6)	
	MSSA	*n* (%)	1 (2.9)	10 (6.7)	1 (1.2)	10 (23.3)	
	Other	*n* (%)	1 (2.9)	24 (16.1)	8 (9.9)	5 (11.6)	
	No reproduction	*n* (%)	6 (17.6)	23 (15.4)	12 (14.8)	4 (9.3)	
Total protein	Mean ± SD		6.54 ± 0.75^{ab}	6.34 ± 0.95^{b}	6.39 ± 0.70^{b}	6.79 ± 0.73^{a}	***0.005****
Baseline albumin	Mean ± SD		3.48 ± 0.65	3.24 ± 0.70	3.26 ± 0.54	3.39 ± 0.46	0.072
Mean albumin	Mean ± SD		3.45 ± 0.49	3.22 ± 0.60	3.2 ± 0.46	3.32 ± 0.51	0.061
Albumin output	Mean ± SD		3.33 ± 0.59	3.13 ± 0.68	3.07 ± 0.56	3.21 ± 0.53	0.140
Triglyceride	Mean ± SD		186.33 ± 111.22^{b}	162.55 ± 83.47^{b}	182.72 ± 96.14^{b}	235.73 ± 160.36^{a}	***< 0.001****
Cholesterol	Mean ± SD		206.45 ± 57.25	200.17 ± 48.74	213.55 ± 58.80	214.11 ± 64.71	0.139
HDL	Mean ± SD		44.8 ± 13.74	43.85 ± 12.64	44.05 ± 11.95	40.07 ± 10.25	0.0166
LDL	Mean ± SD		132.98 ± 43.39	142.19 ± 139.18	145.65 ± 52.45	140.51 ± 41.51	0.0929
Baseline uric acid	Mean ± SD		6.00 ± 1.27	6.20 ± 1.57	6.35 ± 1.54	6.59 ± 1.59	0.228
Uric acid output	Mean ± SD		5.72 ± 1.52^{ab}	5.46 ± 1.37^{b}	5.83 ± 1.36^{ab}	6.19 ± 1.35^{a}	***0.003****

Statistically significant values are in bold

a,b,c,d: means in the same column differ from each other ($p < 0.05$). Groups that do not have a common letter are different from each other

BMI body mass index, IPD instrumented peritoneal dialysis, CAPD continuous ambulatory peritoneal dialysis, PET Peritoneal equalization test, HP High permeable, HM High-moderate permeable, LM Low-moderate permeable, LP Low permeable, DM Diabetes mellitus, HT hypertension, CGN Chronic glomerulonephritis, CIN Chronic interstitial nephritis, CAD Coronary artery disease, EF Ejection Fraction, PAP Pulmonary artery pressure, RRF Residual Renal Function MSSA Methicillin-sensitive staphylococcus aureus, MRCNS Methicillin-resistant coagulase-negative staphylococci, MSCNS Methicillin-sensitive coagulase-negative staphylococci

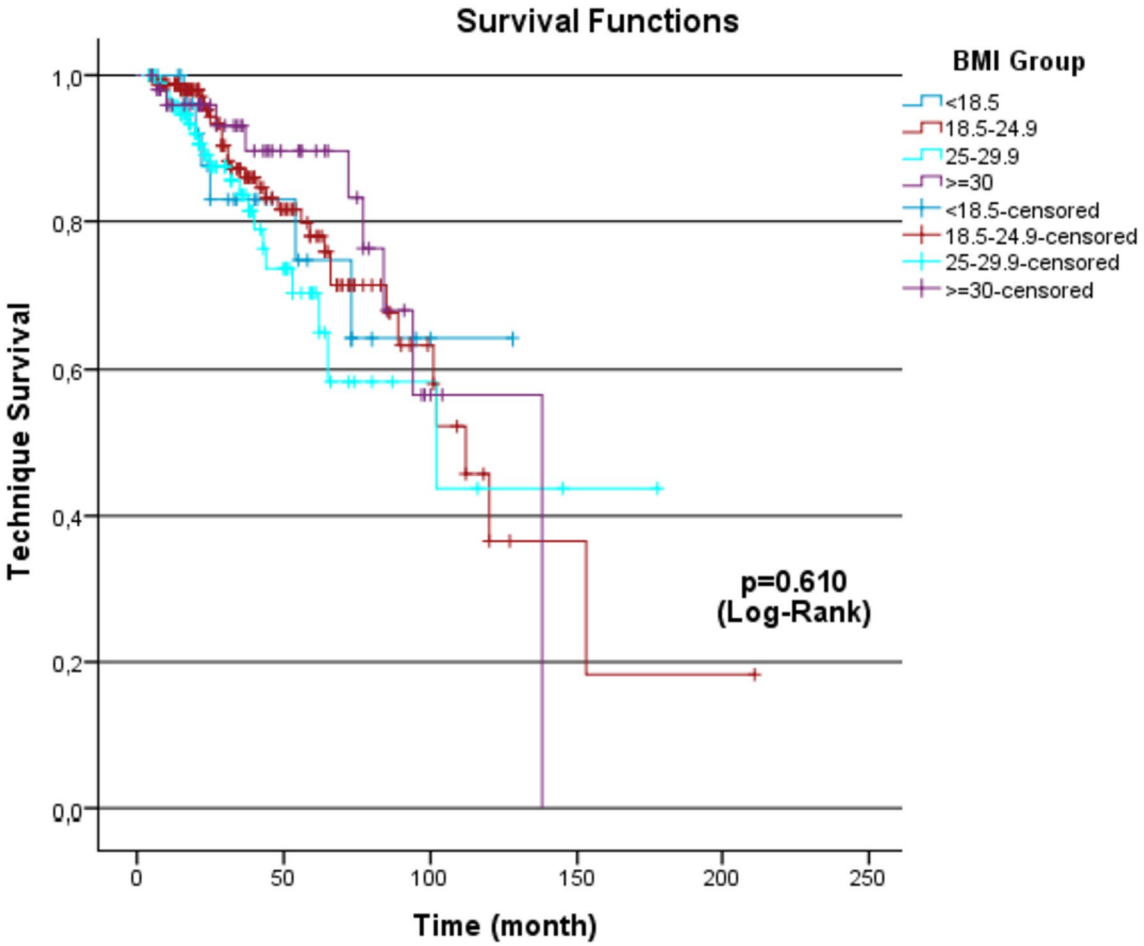

Fig. 1 Kaplan–Meier analysis of technique survival: comparison of patient groups according to BMI

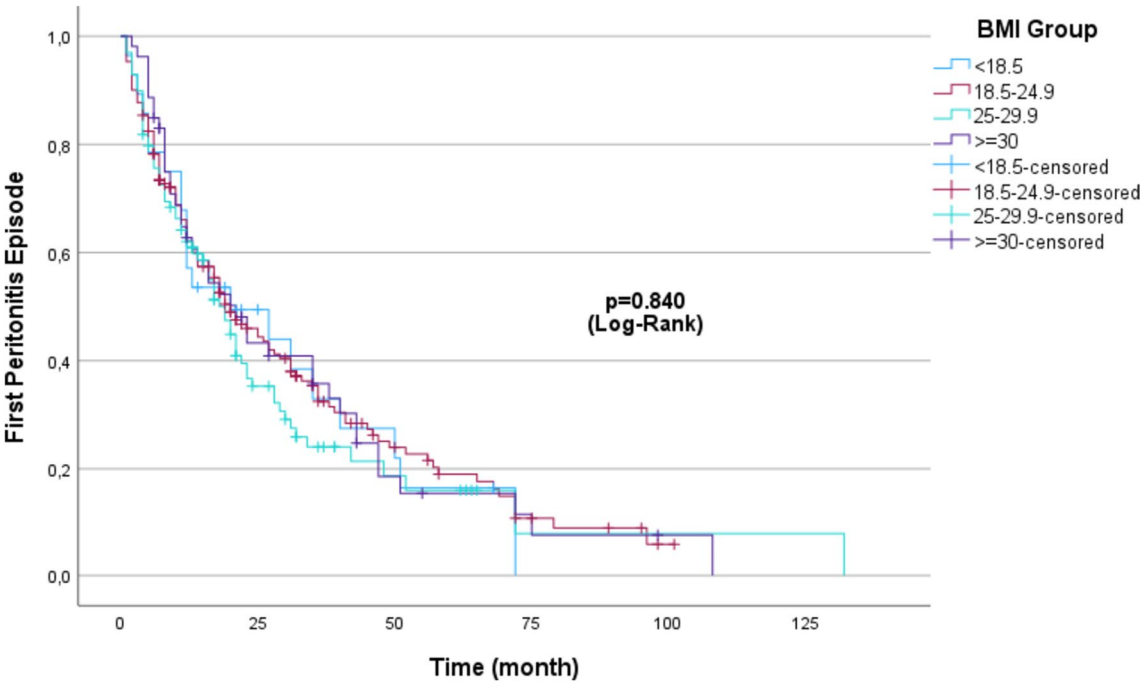

Fig. 2 Kaplan–Meier analysis of first peritonitis episode: comparison of patient groups according to BMI

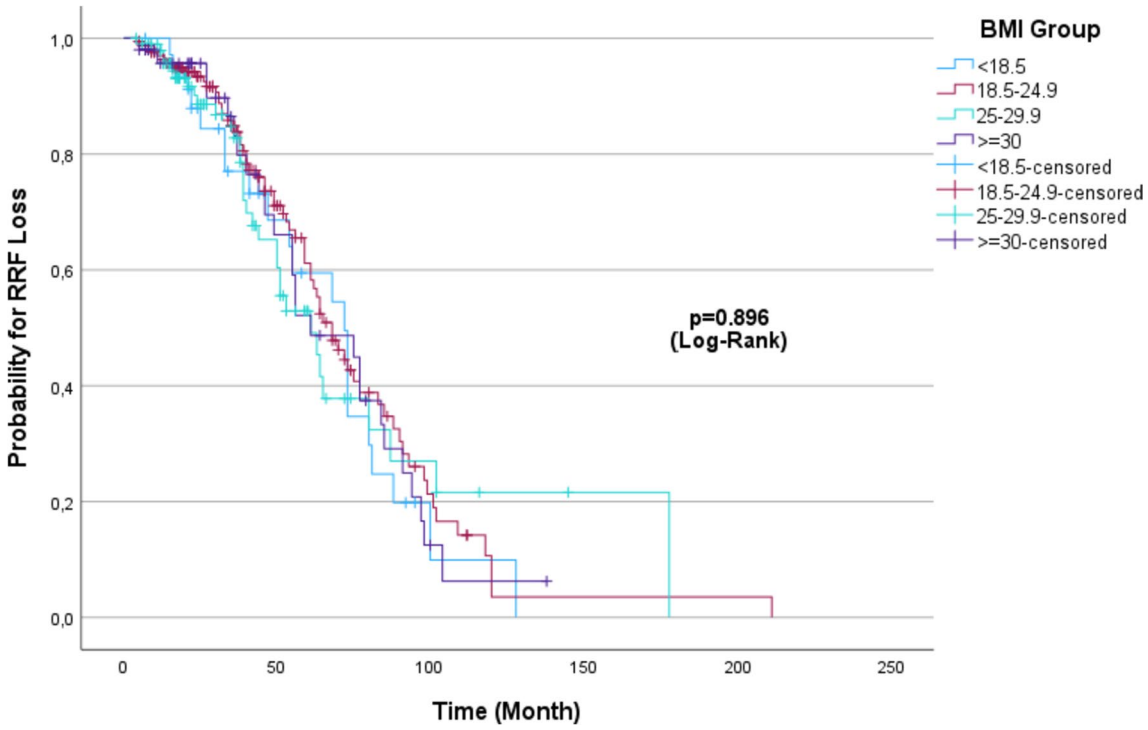

Fig. 3 Kaplan–Meier analysis of probability RRF loss: comparison of patient groups according to BMI

Table 2 Comparison of mortality according to BMI

	Median follow-up time	Case	Mean survival time	Median survival time	1st-year cumulative survival rate	2nd-year cumulative survival rate	3rd-year cumulative survival rate	5th-year cumulative survival rate	*p* (log-rank)
	Month (min–max)	*N* (events/total)	Month ± SD(95% CI)	Month ± SD(95% CI)	% ± SE	% ± SE	% ± SE	% ± SE	
Overall survival	32 (4–211)	270/404	56,837 ± 2,929 (51,095–62,578)	44 ± 3,033 (38,056–49,944)	90.8 ± 0.2	71.1 ± 0.2	58.8 ± 0.3	37.7 ± 0.3	
Under-weight	41 (7–128)	21/40	67,312 ± 7,551 (52,512–82,113)	73 ± 15,12 (43,365–102,635)	95.0 ± 0.3	81.8 ± 0.6	69.6 ± 0.7	50.9 ± 0.9	***0.029****
Normal weight	32 (4–211)	126/199	61,188 ± 5,004 (51,379–70,996)	46 ± 4,701 (36,787–55,213)	91.0 ± 0.2	71.7 ± 0.3	60.5 ± 0.3	41.4 ± 0.4	
Over-weight	27 (4–173)	79/110	47,441 ± 4,589 (38,448–56,435)	37 ± 3,282 (30,568–43,432)	91.7 ± 0.2	65.7 ± 0.4	51.1 ± 0.5	24.4 ± 0.5	
Obese	37 (5–138)	44/55	51,052 ± 5,024 (41,204–60,9)	44 ± 7,357 (29,58–58,42)	83.1 ± 0.5	67.1 ± 0.6	55.3 ± 0.6	34.4 ± 0.7	

Statistically significant values are in bold

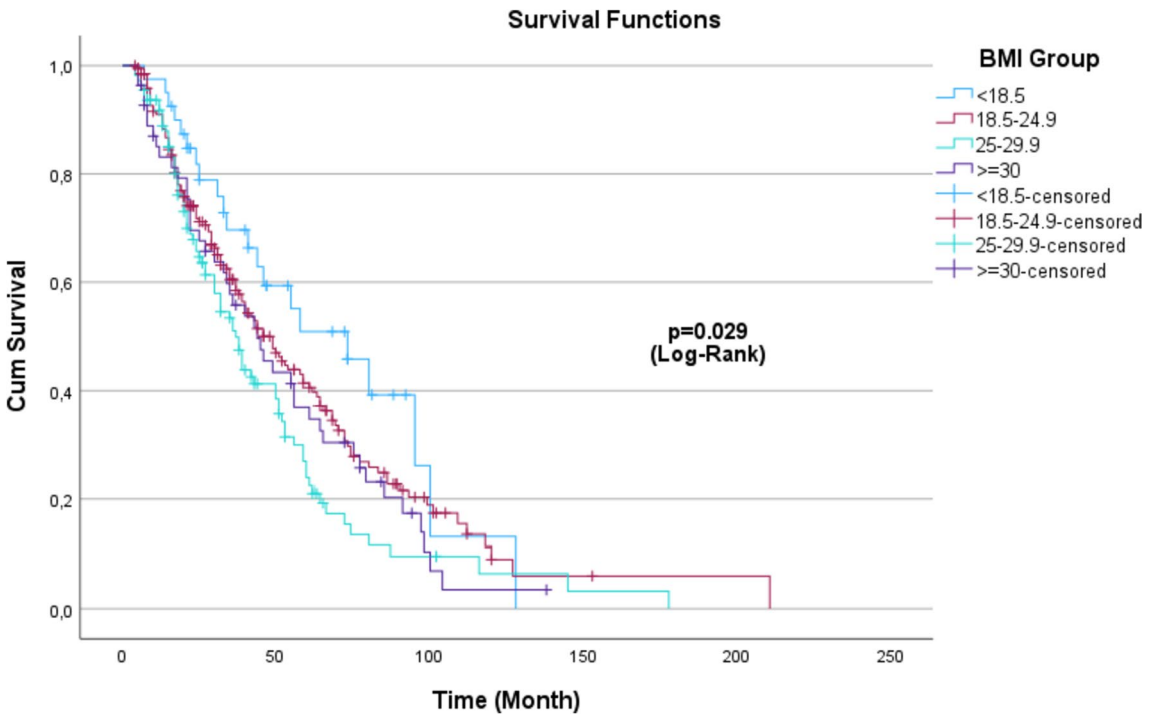

Fig. 4 Kaplan–Meier analysis of survival: comparison of patient groups according to BMI

and weight gain and maintaining a constant weight do not change mortality [20]. There are studies stating that weight gain with an increase in muscle mass improves mortality more than with an increase in adipose tissue [21]. It is difficult to determine this distinction in PD patients. The increase in BMI of the patients in our study after the onset of PD may have improved the mortality of the patients in the underweight patient group. Moreover, being underweight alone may not be an indicator of malnutrition. Therefore, the presence of conditions such as inflammation and arteriosclerosis together with low weight may increase mortality [22]. A neutral effect of BMI on survival has also been observed in several studies [23, 24]. In our study, we showed that BMI was not among the factors affecting mortality in the Cox regression analysis performed with baseline BMI and withdrawal BMI did not affect mortality. Hence, we think that BMI is not a determinant in the selection of PD.

There were limited studies comparing the relationship between BMI and peritonitis. Studies have reported that obesity increases the risk of peritonitis due to greater difficulties in exit site care and increased susceptibility to skin and soft tissue infection [14, 25]. There are previous data showing poor PD outcomes including poor solute clearance, higher risk of infectious complications, and early technique proficiency [4, 26, 27]. Recent data [28–32], like our results, report that there was no difference between BMI groups in PD patients in terms of complications such as technique proficiency, duration to first peritonitis attack, inadequate dialysis, and tunnel infection. In addition, we identified MSCNS as the most common peritonitis agent, similar to the other study [14].

In conclusion, we report that BMI alone is not an accurate parameter to predict mortality, peritonitis, RRF, and technique proficiency parameters in PD patients. In this respect, we believe that it is not appropriate for physicians and patients to evaluate BMI as a negative parameter in the selection of PD.

Table 3 Univariate and multivariate Cox regression analyses showing influencing factors on overall survival

Variables		Univariate analysis				Multivariate analysis			
		β	HR	95% CI	*p* value	*β*	HR	95% CI	*p* value
BMI	Underweight	0.330	0.719	0.453–1.142	0.163	0.717	2.049	0.912–4.602	0.082
	Normal weight	Reference							
	Overweight	0.314	1.369	1.032–1.818	***0.030****	0.179	1.196	0.722–1.981	0.488
	Obese	0.150	1.162	0.823–1.639	0.394	− 0.267	0.765	0.365–1.603	0.478
Gender	Female	Reference				**NA**			
	Male	0.143	1.154	0.907–1.468	0.245				
Age		0.018	1.019	1.011–1.026	***< 0.001****	0.001	1.001	0.987–1.015	0.930
Peritoneal technique	Surgery	Reference				**NA**			
	Percutaneous	0.145	1.156	0.898–1.488	0.259				
Method of peritoneal dialysis	IPD	Reference							
	CAPD	0.353	1.423	1.020–1.986	***0.038****	0.362	1.437	0.815–2.533	0.210
Status of DM	No	Reference							
	Yes	0.441	1.555	1.202–2.012	***< 0.001****	0.114	1.121	0.676–1.859	0.658
Status of HT	No	Reference				**NA**			
	Yes	− 0.096	0.908	0.699–1.180	0.471				
Status of CAD	No	Reference				**NA**			
	Yes	0.044	1.045	0.774–1.412	0.773				
EF value		− 0.027	0.973	0.953–0.994	***0.011****	− 0.007	0.933	0.966–1.021	0.635
Complete RRF loss	No	Reference							
	Yes	− 0.814	0.443	0.340–0.577	***< 0.001****	− 0.595	0.551	0.352–0.865	***0.010****
PET	HP	Reference				**NA**			
	HM	0.142	0.838	0.635–1.106	0.211				
	LM	0.176	1.282	0.908–1.812	0.158				
	LP	0.299	1.387	0.777–2.493	0.275				
Kt/V		− 0.073	0.929	0.818–1.056	0.261	**NA**			
Duration to the first peritonitis episode		− 0.022	0.978	0.973–0.984	***< 0.001****	− 0.019	0.982	0.973–0.990	***< 0.001****
Mean albumin		− 1.335	0.263	0.203–0.341	***< 0.001****	− 1.586	0.205	0.126–0.334	***< 0.001****
Triglyceride		− 0.001	0.999	0.998–1.000	0.199	**NA**			
Cholesterol		− 0.001	0.999	0.997–1.001	0.521	**NA**			
HDL		− 0.004	0.996	0.986–1.005	0.371	**NA**			
LDL		0.001	1.000	0.999–1.101	0.995	**NA**			
Baseline uric acid		0.068	1.070	0.981–1.168	0.129	**NA**			
Uric acid output		0.090	1.094	1.009–1.186	***0.029****	0.051	1.053	0.922–1.202	0.448

Statistically significant values are in bold

HR hazard ratio; *CI* confidence interval; *NA* not considered in the multivariable model

Table 4 BMI changes

		BMI *(n = 404)*		
		Onset	Withdrawal	*p*
All patients	Mean ± SD	24.39 ± 5.08	26.02 ± 5.79	***< 0.001****
Underweight	Mean ± SD	17.09 ± 1.29	19.88 ± 4.20	***< 0.001****
Normal weight	Mean ± SD	21.92 ± 1.73	23.43 ± 3.16	***< 0.001****
Overweight	Mean ± SD	26.75 ± 1.30	28.73 ± 4.05	***< 0.001****
Obese	Mean ± SD	33.93 ± 3.34	34.45 ± 5.31	0.191

Statistically significant values are in bold

Study limitations

There were some limitations in our study. Due to the relatively small size of our patient groups and the single-center experience, racial differences could not be revealed. In addition, the nutritional adequacy assessment of the patients was just limited to albumin and BMI. Bioimpedance data of the patients were not available. Since it was a retrospective

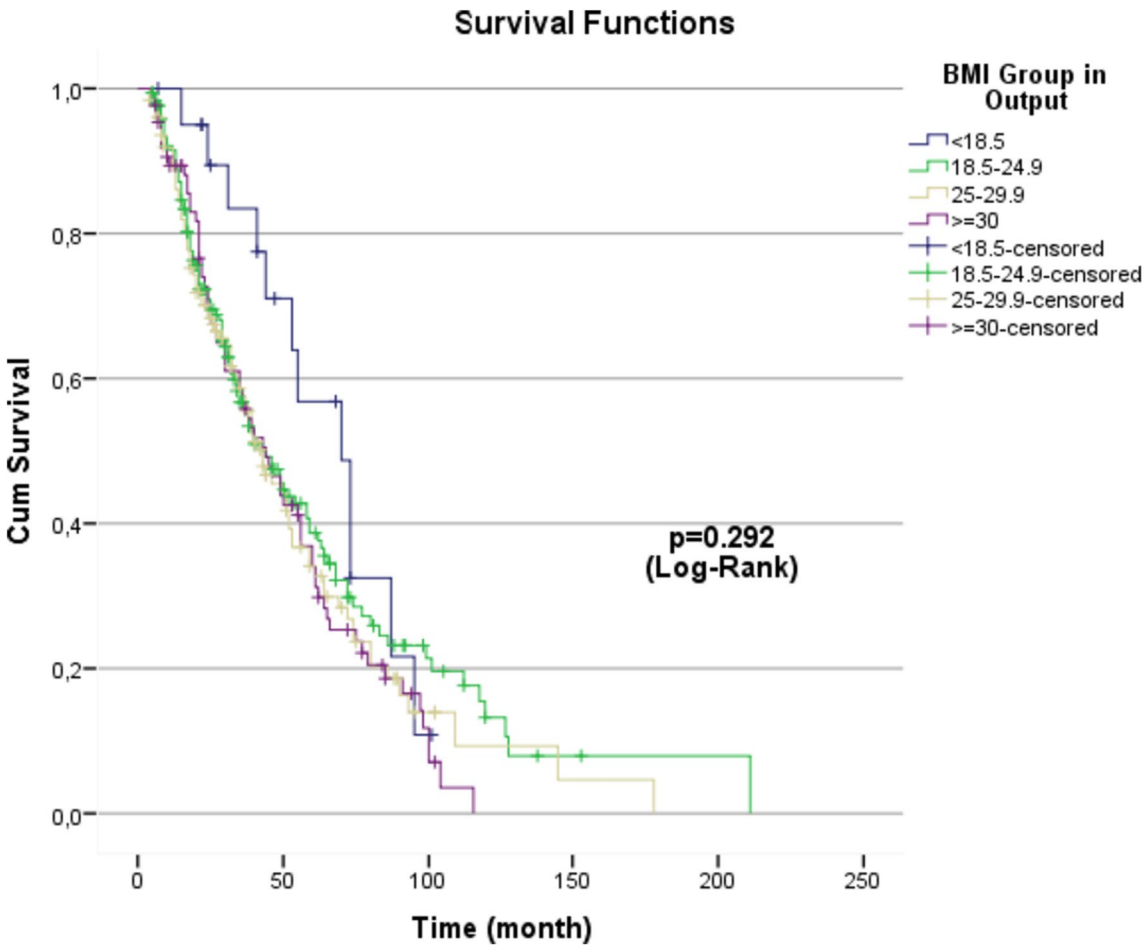

Fig. 5 Kaplan–Meier analysis of survival: comparison of patient groups according to BMI in output

study, the causes of death could not be stated. Despite these facts, our study is the first to compare mortality, peritonitis, technique proficiency, RRF, and mortality according to PD withdrawal BMI in PD patients according to BMIs.

Author contributions MA, EÇ: conceptualization, methodology, software. MA, EÇ, HGK, EÇ: data curation, writing—original draft preparation. MA, AU, CS, HGK, EÇ: patient and specimen collection. MA, EÇ: laboratory studies. MA, EÇ, AU: visualization, investigation. MA, EÇ: writing—reviewing and editing.

Funding Funding was not received for this study.

Data availability The dataset used in the current study is available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval All participants gave informed consent and the local institutional ethics committee (Ataturk University School of Medicine Clinical Research Ethics Committee) approved the study methods (Acceptance number: B.30.2.ATA.0.01.00/133) 'Declarations Section'—'Ethics approval and consent to participate' sub-section.

References

1. Friedman AN (2013) Obesity in patients undergoing dialysis and kidney transplantation. Adv Chronic Kidney Dis 20:128–134
2. Balkau B, Charles MA (1999) Comment on the provisional report from the WHO consultation. European Group for the study of Insulin Resistance (EGIR). Diabet Med 16:442–443
3. Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (2001) Executive summary of the third report of The National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). JAMA 285:e2486–e2489
4. McDonald SP, Collins JF, Johnson DW (2003) Obesity Is associated with worse peritoneal dialysis outcomes in the Australia and New Zealand patient populations. J Am Soc Nephrol 14(11):2894–2901

5. Mehrotra R, Chiu YW, Kalantar-Zadeh K, Vonesh E (2009) The outcomes of continuous ambulatory and automated peritoneal dialysis are similar. Kidney Int 76(1):97–107
6. Ladhani M, Craig JC, Irving M, Clayton PA, Wong G (2017) Obesity and the risk of cardiovascular and all-cause mortality in chronic kidney disease: a systematic review and meta-analysis. Nephrol Dial Transplant 32(3):439–449
7. Leavey SF, McCullough K, Hecking E, Goodkin D, Port FK, Young EW (2001) Body mass index and mortality in healthier as compared with sicker haemodialysis patients: results from the Dialysis Outcomes and Practice and Patterns Study (DOPPS). Nephrol Dial Transplant 16:2386–2394
8. Kalantar-Zadeh K, Block G, Hymphreys MH, Kopple JD (2003) Reverse epidemiology of cardiovascular risk factors in maintenance dialysis patients. Kidney Int 63:793–808
9. Leavey SF, Strawderman RL, Jones CA, Port FK, Held PJ (1998) Simple nutritional indicators as independent predictors of mortality in hemodialysis patients. Am J Kidney Dis 31:997–1006
10. Fleischmann E, Teal N, Dudley J, May W, Bower JD, Salahudeen AK (1999) Influence of excess weight on mortality and hospital stay in 1346 hemodialysis patients. Kidney Int 55:1560–15667
11. Kopple JD, Zhu Z, Lew NL, Lowrie EG (1999) Body weight-for-height relationships predict mortality in maintenance hemodialysis patients. Kidney Int 56:1136–1148
12. Snyder JJF, Gilbertson DT, Vonesh EF, Collins AJ (2003) Body size and outcomes on peritoneal dialysis in the United States. Kidney Int 64(5):1838–1844
13. Prasad N, Sinha A, Gupta A et al (2014) Effect of body mass index on outcomes of peritoneal dialysis patients in India. Perit Dial Int 34(4):399–408
14. Pavey BS, Whaley-Connell A, Nichols WK, Negoi D, Khanna R (2008) A series of unusual complications of the presternal peritoneal dialysis catheter. Adv Perit Dial 24:113–116
15. Cho Y, Johnson W (2014) Peritoneal dialysis-related peritonitis: towards improving evidence, practices, and outcomes. Am J Kidney Dis 64(2):278–289
16. Kalantar-Zadeh K, Abott KC, Slahudeen AK, Kilpatrick RD, Horwich TB (2005) Survival advantages of obesity in dialysis patients. Am J Clin Nutr 81:e543–e554
17. Ahmadi SF, Zahmatkesh G, Streja E, Mehrotra R, Rhee CM, Kovesdyl CP et al (2015) Association of body mass index with mortality in peritoneal dialysis patients: a systematic review and meta-analysis. Perit Dial Int 36:315–325
18. Zhou H, Cui L, Zhu G, Jiang Y, Gao X, Yl Z et al (2011) Survival advantage of normal weight in peritoneal dialysis patients. Ren Fail 33:e964–e968
19. Lo WK (2016) Metabolic syndrome and obesity in peritoneal dialysis. Kidney Res Clin Pract 35:10–14
20. Fernandes NM, Bastos MG, Franco MR, Chaoubah A, Lima Mda G, Divino-Filho JC, Qureshi AR (2013) Brazilian Peritoneal Dialysis Multicenter Study (BRAZPD) Group: body size and longitudinal body weight changes do not increase mortality in incident peritoneal dialysis patients of the Brazilian peritoneal dialysis multicenter study. Clinics 68:51–58
21. Ramkumar N, Pappas LM, Beddhu S (2005) Effect of body size and body composition on survival in peritoneal dialysis patients. Perit Dial Int 25(5):461–469
22. Chan GC, Fung WW, Szeto CC, Ng JK (2023) From MIA to FIFA: the vicious matrix of frailty, inflammation, fluid overload and atherosclerosis in peritoneal dialysis. Nephrology (Carlton) 28(4):215–226
23. Aslam N, Bernardini J, Fried L, Piraino B (2002) Large body mass index does not predict short-term survival in peritoneal dialysis patients. Perit Dial Int 22:191–196
24. Fried L, Bernardini J, Piraino B (1996) Neither size nor weight predicts survival in peritoneal dialysis patients. Perit Dial Int 16:357–361
25. Shetty A (2011) Logistics of peritoneal dialysis in the obese population. Dial Transplant 40(8):364–366
26. Nolph KD, Jensen RA, Khanna R, Twardowski ZJ (1994) Weight limitations for weekly urea clearances using various exchange volumes in continuous ambulatory peritoneal dialysis. Perit Dial Int J Int Soc Perit Dial 14:261–264
27. National Kidney Foundation (1997) NKF-DOQI clinical practice guidelines for peritonealdialysis adequacy. Am J Kidney Dis 30:S67-136
28. Krezalek MA, Bonamici N, Kuchta K, Lapin B, Carbray J (2018) Denham W et all Peritoneal dialysis catheter function and survival are not adversely affected by obesity regardless of the operative technique used. Surg Endosc 32:1714–1723
29. Hsieh Y-P, Chang C-C, Wen Y-K, Chiu P-F (2014) Yang Y (2014) Predictors of peritonitis and the impact of peritonitis on clinical outcomes of continuous ambulatory peritoneal dialysis patients in Taiwan–10 years' experience in a single center. Perit Dial Int J Int Soc Perit Dial 34:85–94
30. Quero M, Comas J, Arcos E, Hueso M, Sandoval D, Montero N (2021) Impact of obesity on the evolution of outcomes in peritoneal dialysis patients. Clin Kidney J 14(3):969–982
31. Jin Yu, Zhu L, Ni J, Tong M, Wang H (2023) Technique failure in peritoneal dialysis-related peritonitis: risk factors and patient survival. Ren Fail 45:1
32. Liu D, Lin Y, Gong N, Xiao Z, Zhang F, Zhong X, Ai J (2021) Degree and duration of hypokalemia associated with peritonitis in patients undergoing peritoneal dialysis. Int J Clin Pract 75(8):e14188