

# The Effect of Hypokalemia on Early-onset Peritoneal Dialysis-related Peritonitis

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## Abstract

**Background:** Early-onset peritoneal dialysis-related peritonitis (EOP) increased technique failure and mortality among peritoneal dialysis (PD) patients. However, whether hypokalemia is the risk of EOP remains unclear.

**Objective:** This retrospective cohort study aimed to identify the association between hypokalemia within the first 3 months after PD initiation and EOP.

**Method:** A total of 947 PD patients registered at the Kidney Unit in Chaiyaphum regional hospital from January 2011 to December 2018 were recruited and followed up. The first EOP episode within 6 months after the initiation of PD was a primary outcome. Logistic regression was used to identify the association.

**Results:** Of the total, 485 experienced hypokalemia. 90 patients, developed EOP, 61 were from the hypokalemic group (12.6%). Hypokalemia was a significant risk factor of EOP (OR, 2.36; 95% CI, 1.42 to 3.94; P=0.01), as well as decreased serum bicarbonate level (OR, 0.90; 95% CI, 0.82 to 0.99; P=0.026) and decreased hemoglobin level (OR, 0.72; 95% CI, 0.57 to 0.90; P=0.004) and elevated sodium (OR, 1.07; 95% CI, 1.00 to 1.15; P=0.046) while controlling other covariates.

**Conclusions:** Hypokalemia within the first three months after PD initiation was a significant risk factor of EOP.

**Keyword:** First episode of peritonitis, hypokalemia, EOP.

## Introduction

PD-related peritonitis and malnutrition are serious complications among peritoneal dialysis (PD) patients<sup>(1)</sup>. PD-related peritonitis has impact on both patient survival and technique failure<sup>(2-4)</sup>. In addition,

early-onset PD-related peritonitis (EOP) was identified as an important risk factor for mortality and technique failure in peritoneal dialysis patients<sup>(2,5)</sup>.

A recent observational multicenter study reported that EOP was more likely predictor of technique failure<sup>(6)</sup>. Risk factors of PD-related peritonitis are the main focus of the PD community because reducing the risks indicates improvement of quality of care. Many modifiable medical factors were identified as risks for PD-related peritonitis such as hypoalbuminemia, hypokalemia, obesity, depression, absence of vitamin D supplementation, and invasive intervention<sup>(7)</sup>. The known

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risk factors of EOP are early use of PD catheter, male, hypoalbuminemia, and higher Charlson Comorbidity Index score<sup>(7-9)</sup>. The influence of hypokalemia on EOP has not been observed in these studies<sup>(6,8,9)</sup>.

PD situations in Thailand, nutritional indicators which are serum albumin and hypokalemia were found the poorest in the Peritoneal Dialysis Outcomes and Practice Patterns Study (PDOPPS)<sup>(10)</sup>. Eventhough the facility peritonitis rate was comparable with those in the UK and AUS/NZ<sup>(11)</sup>, we wonder whether these nutritional factors might contribute to peritonitis rate in our population. In PD patients, hypokalemia is a common electrolytes disorder. Hypokalemia caused by a variety of factors, including poor nutritional status, low potassium intake, intracellular shift and loss into the dialysate<sup>(12, 13)</sup>. The association between peritonitis rate and hypokalemia was not clear and inconclusive<sup>(14-17)</sup>.

Thus, we retrieved the data from the retrospective observational study to evaluate whether hypokalemic episode within the first three months of PD initiation increased the odds of EOP.

## Materials and Method

**Inclusion and exclusion criteria:** Adult PD patients who survived after 90 days of PD initiation in the Universal Health Coverage scheme of Chaiyaphum Hospital were enrolled from January 2011–December 2018. The Exclusion criteria were aged younger than 15 and had incomplete laboratory data. The patients who experienced hypokalemic episode within three months after PD commencing was grouped to compare the odds of having EOP with another group by using multiple logistic regressions to adjust the effect of potential confounders.

The prescription PD dose was three bags of 2 liters 1.5% dextrose solution perday. We titrated dosing to 4 bags per day in some patients depending on clinical conditions. Blood chemistry was tested before PD catheter placement, 1-2 weeks after PD initiation (titrated to achieve maximum dose), at four weeks later and then every eight weeks until reaching six months. Blood chemistry was performed by colorimetric method.

**Hypokalemia and EOP definitions:** The serum potassium level within three months of PD commencing was used to define hypokalemic status if the level was less than 3.5 mEq/L. The patients who had a hypokalemic episode at least once were classified into a hypokalemic

group. Therefore, misclassification that might occur if using mean serum potassium can be avoided. In order to explore the nature of serum potassium in our patients, we calculated the mean value of potassium of every visit within the first three months of PD commencing, as well as the median value of potassium.

Peritonitis episodes were recorded in local data registry system by fulfilling at least 2 out of 3 criteria: 1) clinical features consistent with peritonitis, i.e. abdominal pain, and/or cloudy dialysate effluent; 2) dialysis effluent white cell count > 100/uL or > 109/L (after dwell at least 2 hours), with > 50% polymorphonuclear; and 3) positive dialysis effluent culture. Relapsing peritonitis case (an episode that occurs within four weeks of completion of therapy of a prior episode with the same organism or one sterile episode) was excluded. According to the previous literature, the early-onset PD-related peritonitis is PD-related peritonitis occurring within the first six months of PD commencing.

**Data Collection:** Demographic, clinical characteristics, laboratory data, peritonitis, diabetic status, body mass index (BMI), date of start and stop PD, and peritonitis date were retrieved from the Peritoneal Dialysis Registry of the hospital. All laboratory data were electronically transferred from the Hospital Information System in order to lessen human error. Baseline data were collected at the first date of PD commencing included age, gender, body weight and height for BMI and diabetic status. Pre-dialysis baseline serum creatinine was collected for eGFR calculation using CKD-EPI formula<sup>(18)</sup>. Laboratory data collected within 1- 6 months of PD commencing included bicarbonate, serum sodium, BUN, uric acid, serum phosphate, calcium, albumin, haemoglobin, and total lymphocyte count. Due to its multiple measurement conditions, we used the mean value of these biochemical parameters from the PD at the start date until the day before EOP episode for the patients who had experienced EOP, and the mean of all 6-months measurements of the patients who had never experienced EOP.

In the study period, 947 from 1,215 PD patients had been enrolled for analysis. Of these patients, 268 patients were excluded due to being younger than 15 years (12 patients), had no laboratory data (140 patients), and withdraw from PD before 90 days (116 patients). 485 experienced hypokalemia, while 462 were not. Total EOP were 90 patients, 61 were in the hypokalemic group (12.6%).

## Results

**Sample Characteristics:** Patient characteristics are shown in Table 1. Per the study design, the hypokalemic group was similar to the normokalemic group regarding age, BMI, pre-dialysis eGFR, TLC, bicarbonate, hemoglobin, calcium, phosphate, BUN, uric acid, and sodium but was more predominate of female, more diabetes, and lower serum albumin. The median (min:

max) of mean serum potassium level of the hypokalemic group and the normokalemic group was 3.45 (2:5.44) and 4.3 (3.5:6) meq/L, respectively. Noticed that some patients in the hypokalemic group had mean serum potassium higher than 3.5 meq/L. However, they had experienced a hypokalemic episode at least once within the first three months. That is why they were classified.

**Table 1: Clinical characteristics of total population separated by serum potassium level < 3.5 meq/L**

Demographic	Hypokalemia	No hypokalemia	Total
Number of patients	485(51.2)	462(48.8)	947
<b>Gender—no(%)</b>			
Female	288(57.3)	215(42.7)	503(53.1)
Male	197(40.6)	247(53.5)	444(46.9)
<b>Diabetes Mellitus—no(%)</b>			
No	203(41.9)	251(54.3)	454(47.9)
Yes	282(57.2)	211(42.8)	493(52.0)
<b>Age</b>			
Mean(SD)	57.8(12.2)	54.4(13.2)	56.1(12.8)
Median (min: max)	59.2(17.5:87.4)	55.5(15.9: 87.2)	57.3(15.9: 87.4)
<b>BMI</b>			
Mean(SD)	22.7(3.6)	22.87(3.9)	22.8(3.7)
Median(min: max)	22.6(14.2: 33.8)	22.3(14.5: 35.6)	22.5(14.2: 35.6)
<b>Potassium</b>			
Mean (SD)	3.5(0.5)	4.4(0.5)	3.8(0.6)
Median (min: max)	3.5(2: 5.4)	4.3(3.5: 6)	3.7 (2: 6)
<b>Albumin before EOP</b>			
Mean(SD)	3.1(0.5)	3.4(0.5)	3.2(0.5)
Median(min: max)	3.1(0.9: 4.7)	3.4(1.8: 4.7)	3.3(0.9: 4.7)
<b>eGFR at baseline</b>			
Mean (SD)	3.9(2.3)	3.7(2.1)	3.8(2.1)
Median(min: max)	3.00(1: 19)	3.00(1: 16)	3.00(1: 19)
<b>TLC before EOP</b>			
Mean(SD)	1,600(557)	1,619(549)	1,610(553)
Median (min: max)	1,520(478: 3,719)	1,537(537: 4,810)	1,530(478: 4,810)
<b>Bicarbonate before EOP</b>			
Mean(SD)	24.5(3.00)	24.0(3.2)	24.3(3.1)
Median(min: max)	24.3(15.5: 34.2)	23.9(13.5: 34.4)	24.1(13.5: 34.4)
<b>Hemoglobin before EOP</b>			
Mean(SD)	8.6(1.2)	8.7(1.2)	8.7 (1.2)
Median(min: max)	8.6(5.4: 13.2)	8.7(4.5: 12.1)	8.7(4.5: 13.2)

Demographic	Hypokalemia	No hypokalemia	Total
<b>Calcium before EOP</b>			
Mean (SD)	8.4(0.9)	8.4(0.8)	8.4(0.8)
Median (min: max)	8.4(5.0: 13.2)	8.4(5.4: 11.7)	8.4(5.0: 13.2)
<b>Phosphate before EOP</b>			
Mean(SD)	4.7(1.2)	5.0(1.4)	4.8(1.3)
Median(min: max)	4.5(2.0: 10.5)	4.8(1.7: 11.7)	4.6(1.7: 11.7)
<b>BUN before EOP</b>			
Mean (SD)	62.9(18.7)	68.3(20.8)	65.6(19.9)
Median(min: max)	60.3(19.9: 157.0)	65.2(22.4: 164.6)	62.5(19.9: 164.6)
<b>Uric acid before EOP</b>			
Mean (SD)	8.1(1.7)	8.4(1.5)	8.2(1.6)
Median (min: max)	7.9(4.1: 14)	8.3(5.0: 14.7)	8.1(4.1: 14.7)
<b>Sodium before EOP</b>			
Mean (SD)	134.2(4.0)	135.6(3.4)	134.9(3.8)
Median (min: max)	134.8(120.4: 142.8)	136.0(124.1: 144)	135.5(120.4:144.0)

**Remark:** BMI=body mass index; EOP=early-onset peritoneal-related peritonitis; eGFR= estimated glomerular filtration rate; TLC= total lymphocyte count; BUN=blood urea nitrogen

In the bivariate analysis (Table 2), hypokalemia, low serum albumin, serum bicarbonate, hemoglobin, and BUN were associated with EOP.

**Table 2: Explanatory variables for early-onset peritoneal dialysis-related peritonitis**

Characteristics	Crude OR	95%CI	P-Value
<b>Hypokalemia</b>			
No	Reference	Reference	Reference
Yes	2.15	1.35 to 3.41	0.01
<b>DM</b>			
No	Reference	Reference	Reference
Yes	0.87	0.56 to 1.34	0.527
<b>Gender</b>			
Female	Reference	Reference	Reference
Male	1.54	0.10 to 2.39	0.052
Age	1.01	1.00 to 1.03	0.128
Albumin	0.53	0.36 to 0.79	0.002
eGFR	0.97	0.87 to 1.08	0.543
TLC	1.00	1.00 to 1.00	0.034
CO <sub>2</sub>	0.87	0.81 to 0.94	0.000
BMI	0.99	0.93 to 1.05	0.631
Hemoglobin	0.65	0.54 to 0.79	0.000
Calcium	0.88	0.68 to 1.14	0.324
Phosphate	1.14	0.98 to 1.33	0.093
BUN	1.02	1.01 to 1.03	0.001
Uric acid	0.90	0.78 to 1.04	0.154
Sodium	1.02	0.97 to 1.09	0.421

The multivariable analysis (Table 3) confirmed that hypokalemia was a statistically significant risk factor of EOP (OR, 2.36; 95% CI, 1.42 to 3.94; P=0.01) after adjustment for age, gender, diabetes status, albumin, eGFR, TLC, BMI, calcium, phosphate, BUN, and sodium. EOP was also significantly associated with

decreased serum bicarbonate level (OR, 0.90; 95%CI, 0.82 to 0.99; P=0.026), decreased hemoglobin level (OR, 0.72; 95% CI, 0.57 to 0.90; P=0.004) and elevated sodium (OR, 1.07;95% CI, 1.00 to 1.15; P=0.046) while controlling other covariates.

**Table 3: Associations of early-onset peritoneal dialysis-related peritonitis and hypokalemic episode in the first three months**

Characteristic	Number	EOP(%)	Crude OR	Adjusted OR	95%CI	P-Value
<b>Hypokalemia</b>						
No	462	29(6.3)	Reference	Reference	Reference	Reference
Yes	485	61(12.6)	2.15	2.36	1.42 to 3.94	0.001
<b>DM</b>						
No	454	46(10.1)	Reference	Reference	Reference	Reference
Yes	493	44(8.9)	0.87	1.03	0.62 to 1.71	0.913
<b>Gender</b>						
Female	503	39(7.8)	Reference	Reference	Reference	Reference
Male	444	51(11.5)	1.54	1.31	0.79 to 2.17	0.297
Age			1.01	1.02	1.00 to 1.04	0.128
Albumin			0.53	0.74	0.45 to 1.22	0.242
eGFR			0.97	1.11	0.99 to 1.25	0.143
TLC			1.00	1.00	1.00 to 1.00	0.229
CO <sub>2</sub>			0.87	0.90	0.82 to 0.99	0.026
BMI			0.99	1.03	0.96 to 1.10	0.467
Hemoglobin			0.65	0.72	0.57 to 0.90	0.004
Calcium			0.88	1.22	0.91 to 1.65	0.183
Phosphate			1.14	1.05	0.84 to 1.31	0.676
BUN			1.02	1.01	1.00 to 1.03	0.057
Uric acid			0.90	0.87	0.73 to 1.03	0.114
Sodium			1.02	1.07	1.00 to 1.15	0.046

### Discussion

The result showed that hypokalemic episode within the first three months after PD commencing is a significant risk factor of EOP. Our finding was both similar and different from previous studies. The possible explanation might be the difference in defining hypokalemic status. In addition, the association in some studies were not adjusted for important confounders.

Firstly, the majority of studies identified hypokalemia based on time-average potassium levels,

measured repeatedly throughout the observational period, while some did not clearly define how it was classified hypokalemia<sup>(14,17)</sup>. Our study is the first analysis using the clearly defined process of hypokalemic episode identification. In the study, the patients who had a hypokalemic episode (less than 3.5 mEq/L.) at least once were classified into a hypokalemic group. We considered that the averaged serum potassium level might not reflect the actual status of hypokalemia because the hypokalemic status in some patients might be concealed by post-correction normokalemia, and

hypokalemia can recurrent even after being cured. As we can see in the table 1, some patients in the hypokalemic group might not be classified as hypokalemia if we used time-averaged serum potassium because their mean serum potassium level was higher or equal to 3.5 mEq/L.

Secondly, some literatures indicated the association between hypokalemia and PD-related peritonitis. However, some were more likely to insufficiently adjusted for confounding factors. Hypokalemia may relate with malnutrition and poor general conditions<sup>(19-21)</sup>. Besides serum albumin level, total lymphocyte count is one of the nutritional indexes that should be enrolled in the multivariable adjustment to lessen the influence of malnutrition and hypokalemia on PD-related peritonitis. We adjusted for the nutritional index such as total lymphocyte count which rarely considered in the same research question. These findings support the proposed mechanism of hypokalemia affecting intestinal dysmotility and increasing the risk of peritonitis<sup>(22, 23)</sup>.

The averaged serum albumin level before EOP has not shown is a significant risk factor in our analysis. It might be that serum albumin at baseline might not be affected much at the early period but can be progressively declined after PD commencing because of peritoneal protein loss and long-term associated nutritional factors. On the other hand, low serum bicarbonate and decreased hemoglobin level were significantly associated with EOP. Therefore, the time-average serum bicarbonate before the day of EOP event is more likely to be the sign of systemic inflammation in individual patients<sup>(24)</sup> or an early sign of EOP. The mechanism is still unclear and needed to be further determined. Besides, the time-averaged hemoglobin might not be a real risk factor of EOP but rather a coincidentally correlated factor with malnutrition or inadequacy, which strongly associated with peritonitis.

To confirm that hypokalemia has an influence on PD-related peritonitis via intestinal dysmotility, Enterobacteriaceae should be the significant pathogens in our population. Unfortunately, we did not include the pathogen profile into the analysis. Moreover, the study cannot explore technique contamination which is one of the factors involving the PD-related peritonitis. Furthermore, it is the single center analysis which lacks information of dialysis adequacy, residual renal function, diuretic usage, angiotensin-converting enzyme (ACE) inhibitors and angiotensin receptor blockers (ARBs) usage in the analysis.

For advantages, the study applied electronically transferred data from HIS to analysis which help reducing human error. Additionally, the study included objective nutritional indexes in a routine lab for adjustment. Either applying 6-months averaged biochemical values, or at baseline values, hypokalemia still observed as a significant risk factor of EOP.

## Conclusion

Hypokalemia within the three months of PD commencing was a significant risk factor of EOP. It is a warning sign that should be seriously concerned. More frequent follow-up, exploring the causes, and continuous supplement administration in complicated cases.

**Ethical Considerations:** The Ethics Committee of KhonKaen University approved this study (reference number: HE632093). Chaiyaphum Hospital approved the authors to use the data (EC number: 4/63).

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## References

1. Kiebalo T, Holotka J, Habura I, Pawlaczyk K. Nutritional Status in Peritoneal Dialysis: Nutritional Guidelines, Adequacy and the Management of Malnutrition. *Nutrients*. 2020;12(6).
2. Feng S, Wang Y, Qiu B, Wang Z, Jiang L, Zhan Z, et al. Impact of early-onset peritonitis on mortality and technique survival in peritoneal dialysis patients. *Springerplus*. 2016;5(1):1676.
3. Munoz de Bustillo E, Borrás F, Gomez-Roldan C, Perez-Contreras FJ, Olivares J, Garcia R, et al. Impact of peritonitis on long-term survival of peritoneal dialysis patients. *Nefrologia : publicacion oficial de la Sociedad Espanola Nefrologia*. 2011;31(6):723-32.
4. Fourtounas C, Savidaki E, Dousdabanis P, Hardalias A, Kalliakmani P, Papachristou E, et al. Peritonitis during the first year after commencement of peritoneal dialysis has an impact on technique survival and patient morbidity. *Adv Perit Dial*. 2006;22:50-4.
5. Harel Z, Wald R, Bell C, Bargman JM. Outcome of patients who develop early-onset peritonitis. *Adv Perit Dial*. 2006;22:46-9.

6. Ma X, Shi Y, Tao M, Jiang X, Wang Y, Zang X, et al. Analysis of risk factors and outcome in peritoneal dialysis patients with early-onset peritonitis: a multicentre, retrospective cohort study. *BMJ Open*. 2020;10(2):e029949.
7. Li PK, Szeto CC, Piraino B, de Arteaga J, Fan S, Figueiredo AE, et al. ISPD Peritonitis Recommendations: 2016 Update on Prevention and Treatment. *Peritoneal dialysis international : journal of the International Society for Peritoneal Dialysis*. 2016;36(5):481-508.
8. Keswani M, Redpath Mahon AC, Richardson T, Rodean J, Couloures O, Martin A, et al. Risk factors for early onset peritonitis: the SCOPE collaborative. *Pediatr Nephrol*. 2019;34(8):1387-94.
9. Tian Y, Xie X, Xiang S, Yang X, Lin J, Zhang X, et al. Risk Factors and Outcomes of Early-Onset Peritonitis in Chinese Peritoneal Dialysis Patients. *Kidney & blood pressure research*. 2017;42(6):1266-76.
10. Tentori F, Zhao J, Bieber B, Kanjanabuch T, Kawanishi H, Perl J, et al. SP498 INTERNATIONAL VARIABILITY IN THE PREVALENCE OF HYPOKALEMIA AMONG PATIENTS ON PERITONEAL DIALYSIS (PD): RESULTS FROM THE PDOPPS. *Nephrology Dialysis Transplantation*. 2017;32(suppl\_3):iii296-iii.
11. Perl J, Fuller DS, Bieber BA, Boudville N, Kanjanabuch T, Ito Y, et al. Peritoneal Dialysis-Related Infection Rates and Outcomes: Results From the Peritoneal Dialysis Outcomes and Practice Patterns Study (PDOPPS). *Am J Kidney Dis*. 2020;76(1):42-53.
12. Musso CG. Potassium metabolism in patients with chronic kidney disease. Part II: Patients on dialysis (stage 5). *International Urology and Nephrology*. 2004;36(3):469-72.
13. Port F, Young E. Fluids and electrolytes disorders in dialysis Kokko, J Tannen, R eds. *Fluids and Electrolytes* WB Saunders Philadelphia. 1996;541:544.
14. Liawnoraset W. Prevalence and factors affecting peritonitis in CAPD patients in Maharat Nakhon Ratchasima Hospital under universal coverage scheme during 2008-2010: a three-year experience. *J Med Assoc Thai*. 2011;94 Suppl 4:S19-24.
15. Chuang YW, Shu KH, Yu TM, Cheng CH, Chen CH. Hypokalaemia: an independent risk factor of Enterobacteriaceae peritonitis in CAPD patients. *Nephrol Dial Transplant*. 2009;24(5):1603-8.
16. Ribeiro SC, Figueiredo AE, Barretti P, Pecoits-Filho R, de Moraes TP, all centers that contributed to BIIs. Low Serum Potassium Levels Increase the Infectious-Caused Mortality in Peritoneal Dialysis Patients: A Propensity-Matched Score Study. *PLoS One*. 2015;10(6):e0127453.
17. Fan X, Huang R, Wang J, Ye H, Guo Q, Yi C, et al. Risk factors for the first episode of peritonitis in Southern Chinese continuous ambulatory peritoneal dialysis patients. *PLoS One*. 2014;9(9):e107485.
18. Levey AS, Stevens LA, Schmid CH, Zhang YL, Castro AF, 3rd, Feldman HI, et al. A new equation to estimate glomerular filtration rate. *Ann Intern Med*. 2009;150(9):604-12.
19. Liu Y, Cheng BC, Lee WC, Li LC, Lee CH, Chang WX, et al. Serum Potassium Profile and Associated Factors in Incident Peritoneal Dialysis Patients. *Kidney & blood pressure research*. 2016;41(5):545-51.
20. Szeto CC, Chow KM, Kwan BC, Leung CB, Chung KY, Law MC, et al. Hypokalemia in Chinese peritoneal dialysis patients: prevalence and prognostic implication. *Am J Kidney Dis*. 2005;46(1):128-35.
21. Vavruk AM, Martins C, Nascimento MM, Hayashi SY, Riella MC. [Association between hypokalemia, malnutrition and mortality in peritoneal dialysis patients]. *J Bras Nefrol*. 2012;34(4):349-54.
22. Shu KH, Chang CS, Chuang YW, Chen CH, Cheng CH, Wu MJ, et al. Intestinal bacterial overgrowth in CAPD patients with hypokalaemia. *Nephrol Dial Transplant*. 2009;24(4):1289-92.
23. Su CY, Pei J, Lu XH, Tang W, Wang T. Gastrointestinal symptoms predict peritonitis rates in CAPD patients. *Clin Nephrol*. 2012;77(4):267-74.
24. Chang TI, Oh HJ, Kang EW, Yoo TH, Shin SK, Kang SW, et al. A low serum bicarbonate concentration as a risk factor for mortality in peritoneal dialysis patients. *PLoS One*. 2013;8(12):e82912.