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Prevalence, microbiology, and outcome of peritonitis in peritoneal dialysis patients in vietnam: a multicenter study

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Abstract

Background Chronic kidney disease (CKD) is a substantial contributor to global mortality, requiring interventions like kidney transplantation and dialysis. Peritoneal dialysis (PD) has emerged as an effective dialytic modality despite the susceptibility to peritonitis. The study aimed to determine the prevalence of peritonitis among PD patients, elucidating pivotal factors affecting its occurrence, causative bacterial agents, and treatment outcomes (mortality rates, removal of the Tenckhoff catheter, and switch to hemodialysis).

Methods A retrospective cohort study was conducted, which included patients who underwent PD between January 2019 and December 2021 at nine dialysis centers in Vietnam. The prevalence rate of peritonitis was estimated as the quotient of total peritonitis episodes and cumulative patient-years. The association of peritonitis with factors such as age, care (self-care or helper-assisted PD), comorbidities, education level was analyzed using regression analysis. Peritonitis outcomes including mortality rate, Tenckhoff catheter removal, and transitions to hemodialysis were evaluated. PD-related infections were assessed. Additionally, the causative bacterial agents and the negative culture rate were determined.

Results A total of 691 PD patients from nine centers from the south of Vietnam were recruited for the study. Peritonitis was reported in 32.42% of the patients during the study period of 2019–2021. An increase in the number of patients reporting peritonitis was observed over the years. A significant association ($p=0.01$) between peritonitis rate and level of literacy was found. The mortality rate among patients who underwent PD was 2.68%. About 16.18% of patients with peritonitis had to have the Tenckhoff catheter removed and needed to be switched to hemodialysis. Around 46.98% of the peritonitis cases were culture-positive.

Conclusion The prevalence of peritonitis among PD patients in Vietnam increased from 2019 to 2021. Lower literacy positively correlated with peritonitis, regardless of the type of PD. The high prevalence of culture-negative peritonitis cases indicated gaps in diagnostic procedures or the presence of unusual pathogens. These outcomes highlight the need for improved education, diagnostic practices, and interventions to reduce peritonitis risks and enhance patient care in PD programs in Vietnam.

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Keywords Peritonitis, Peritoneal dialysis, Continuous ambulatory peritoneal dialysis, Automated peritoneal dialysis

Background

Chronic kidney disease (CKD) is characterized by kidney damage or an estimated glomerular filtration rate (eGFR) below 60 mL/min/1.73 m^2, persisting for a duration of 3 months or longer [1]. It is highly prevalent globally. In 2017, CKD affected an estimated 843.60 million people worldwide with more than 10% of people globally living with this condition [2]. End-stage renal disease (ESRD) is the final stage of CKD in which the kidneys lose most of their function. It is a serious and irreversible condition, and typically requires ongoing kidney replacement therapy, such as dialysis or a kidney transplant, to sustain life [3]. The number of individuals with CKD needing dialysis was estimated to be more than 108,000 in 2018 [4]. Kidney health services in Vietnam are available to approximately 36,000 patients every year; however, this is only sufficient to treat a third of the ESRD population requiring dialysis nationwide [4]. The three types of renal replacement therapies include hemodialysis (HD), peritoneal dialysis (PD), and kidney transplantation [4].

PD is a renal replacement therapy for ESRD, using the peritoneum as a natural filter to remove waste and excess fluids [5]. A study in Vietnam reported that while 6% of patients needing dialysis used PD, 90% opted for HD [6]. Only 5–6% of ESRD patients choose PD, despite full reimbursement, due to concerns about peritonitis, limited education, trained personnel, and trust in PD [6]. PD is performed via continuous ambulatory (CAPD) or automated (APD) methods.

The risk of peritonitis, a debilitating infection associated with PD, has been a concern as it may result in technique failure (transitioning to HD for ≥30 days, excluding or encompassing deaths) during the first year of PD [7]. Single or multiple episodes of peritonitis can lead to progressive degenerative changes in the permeability of the peritoneum, leading to technique failure, decreased peritoneal ultrafiltration, and a high likelihood of transitioning to long-term HD [8, 9]. The prevalence of PD-associated peritonitis is reported as 12–26%, and it is a major contributing factor to mortality in 15–16% of patients undergoing PD [8–11]. In a single-center, retrospective, observational study on a cohort of older adults (≥65 years) with kidney failure and undergoing CAPD ($N=65$) in Vietnam, peritonitis resulted in the death of almost one-third of the study population (31.30%) [12].

The 2022 ISPD guidelines recommend antibiotic prophylaxis for PD-related peritonitis, with most cases caused by Staphylococcus aureus or coagulase-negative staphylococci from skin contamination [11, 13]. Tunnel and exit-site infections occur when microorganisms from the catheter tunnel or exit site cause localized or peritoneal infection. Gram staining is usually performed on samples from purulent drainage from the exit site, and the results of the culture tests guide antibiotic treatment [11].

To develop robust strategies for preventing PD-associated peritonitis, it is necessary to thoroughly understand its prevalence and its association with the reported risk factors. In Asian countries, peritonitis remains more common and severe, continuing to be the main cause of morbidity among PD patients. South Asian countries, in particular, face unique challenges due to climatic and socio-economic factors, with higher peritonitis rates observed in hot, humid climates, especially in rural areas [14]. Additionally, literature reports the risk factors such as age, gender, cause of ESRD, type of PD, type of PD care, comorbidities, and level of education for peritonitis [15, 16]. This study aimed to update the estimates for the prevalence and mortality rates of peritonitis in PD patients in Vietnam and evaluate the associations between the rate of occurrence of peritonitis and age, self-care or helper-assisted PD, type of dialysis solution used, history of diabetes mellitus or other comorbidities, use of CAPD versus APD, and level of patients' education.

Given the emergence of antibiotic-resistant bacterial species causing PD-related peritonitis, the study also assessed the causative bacterial agents and negative culture rates. It also evaluated peritonitis treatment outcomes and the rate of removal of Tenckhoff catheters when patients switched to hemodialysis.

Methods

Study design and population

This retrospective cohort study was conducted on adult (≥18 years) patients diagnosed with ESRD (International Classification of Diseases, 10th revision, code: N18) and undergoing PD (prevalent PD patients) between January 2019 and December 2021 at nine dialysis centers in Vietnam (Thong Nhat Hospital, Ho Chi Minh UMC Hospital, Nguyen Trai Hospital, TN-Dong Nai Hospital, An Giang Hospital, Kien Giang Hospital, Can Tho City Hospital, Cu Chi Hospital, and Da Nang Hospital). Patients with a previous history of peritonitis were also included. Patients without complete demographic data were excluded from the study. Since this was a retrospective study, a waiver of consent was given by the ethics committee. Patient information was anonymized to ensure confidentiality. On average, there was one PD nurse for every 20–40 PD patients, with variations depending on the specific PD center. Training durations also varied across centers, lasting between 3 and 7 days for each new PD patient.

Additionally, each training session was approximately 30–40 min long. All clinical investigations were carried out following the principles and guidelines outlined in the Declaration of Helsinki 2008. Figure 1 details the study selection process and the cohort information of the present study.

The progress of the participants was monitored until December 2021, unless there was a censoring event such as renal transplantation, transition to HD, transfer to a different center, absence of follow-up, withdrawal from treatment, or death of the patient (due to peritonitis or non-peritonitis causes such as cancer, coronavirus disease-2019 (COVID-19), or other unknown reasons), or the completion of the study's designated follow-up.

Clinical data collection

Medical records were used to gather data on patients' demographic characteristics and medical histories. Demographic characteristics included age, sex, education level, primary cause of ESRD, history of peritonitis, type of PD (CAPD, APD, or APD with additional day dwell), type of care being rendered (self-care or assisted), type of dialysate solution used, history of diabetes mellitus, and the presence of concurrent comorbidities such as cardiovascular diseases (atherosclerosis, cerebrovascular accident, congestive heart failure, and myocardial infarction [MI]). The mortality outcome was analyzed for the period from 2019 to 2021, encompassing overall mortality as well as year-specific morality rates for 2019, 2020, and 2021.

Patients with peritonitis were identified based on the ISPD 2022 criteria [13]:

(1) Presence of symptoms such as fever, abdominal pain, cloudy fluid during drainage, nausea, and vomiting.

(2) Observation of white blood cells (WBCs) in the peritoneal effluent under microscopy, with a count exceeding 100/mm^3 along with a neutrophil count exceeding 50%.

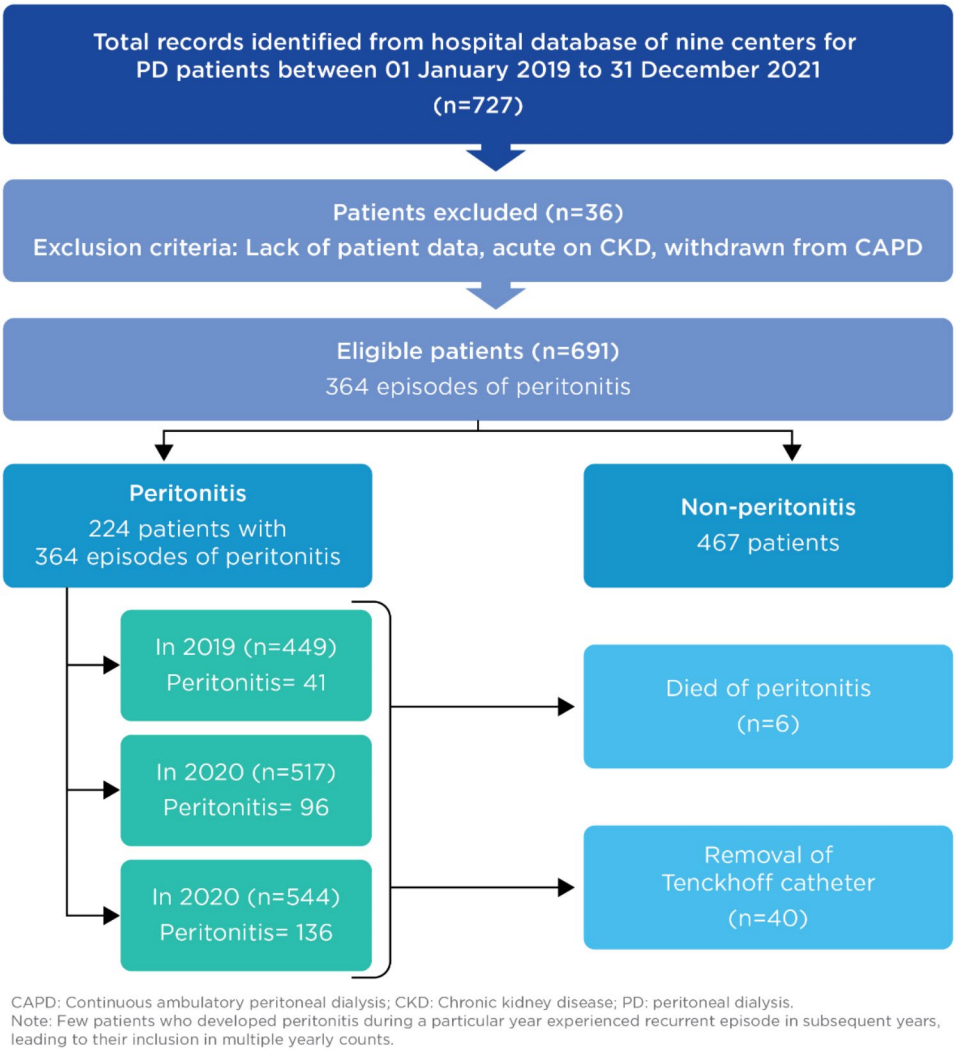

Fig. 1 Flow diagram representing cohort information and study outcomes

(3) Confirmation of bacterial presence in the peritoneal effluent through culture or by Gram staining.

Peritonitis was presented in both percentage and in episodes per patient-year. The peritonitis rate in percentage was calculated by dividing the total number of patients with peritonitis by the total number of patients with ESRD for the respective year. The rate of peritonitis occurrence was estimated by dividing the total number of peritonitis episodes by the total patient-years and reported as episodes per patient-year [8].

Table 1 Demographic, clinical characteristics, and details of the PD procedure

Characteristic and PD details	Patients with ESRD and undergoing PD during 2019–2021 (*N* = 691)
Age, years, mean ± SD	48.90 ± 15.40
Sex, n (%)	
Male	381 (55.14)
Female	310 (44.86)
Level of education, n (%)	
University	96 (13.89)
Primary, secondary, or high school	545 (78.89)
Did not attend school/primary schooling not completed	50 (7.24)
Cause of ESRD, n (%)	
Hypertension	379 (54.85)
Diabetes mellitus	144 (20.84)
Chronic glomerulitis nephropathy	11 (1.59)
Lupus nephritis	4 (0.58)
Urinary stone	6 (0.87)
Polycystic kidney disease	5 (0.72)
Unknown	142 (20.55)
Comorbidities, n (%)	
Cardiovascular diseases (heart failure, valve disease, coronary artery disease, acute myocardial infarction, atrial filtration)	336 (48.63)
Others[a]	35 (5.07)
Type of PD[b], n (%)	
CAPD only	609 (88.13)
APD only	70 (10.13)
APD with additional day dwell	12 (1.74)
Dialysate concentration, n (%)	
1.50% only	167 (24.17)
2.50% only	91 (13.17)
Combined (1.50% and/or 2.50% and/or 4.25%)	433 (62.66)
Type of PD care[b], n (%)	
Self-care	431 (62.37)
Assisted	245 (35.46)
Self-care and assisted	15 (2.17)

[a] Other comorbidities included arthritis, birth defects, bone cancer, gastritis, gout, hemorrhoids, hepatitis, lupus, malnutrition, menorrhagia, Parkinson's disease, polyarthritis, primary thrombocytopenia, stomach cancer, and stroke

[b]Selfcare: PD patients exchange bag by themselves; Assisted care: Helper-assisted PD, where patients (usually elderly) require assistance to perform bag exchange

Statistical analysis

Data were analyzed using IBM SPSS version 23.00 software (Armonk, New York). Descriptive statistics such as mean ± standard deviation were used for continuous variables with a normal distribution and percentages for categorical variables. Chi-square test was used to assess the association between categorical variables. Regression analyses were used to determine the factors affecting the rate of peritonitis occurrence. The parameters for regression model were selected based on the risk factors reported in the literature. Statistical significance was determined using a two-tailed test; results with a p-value < 0.05 were deemed to be statistically significant.

Results

Demographic and clinical characteristics

A total of 691 ESRD patients undergoing dialysis during 2019–2021 in nine centers across Vietnam were included (449 patients in the year 2019, 517 patients in the year 2020, and 544 patients in the year 2021). Every year after 2019 included new patients who initiated PD and excluded those who discontinued PD. The rate of history of peritonitis in the study sample was 17.95% (124 of 691). Demographic and clinical characteristics of the patients are shown in Table 1. The mean age of the patients was 48.90 ± 15.40 years; 55.14% (381 of 691) of the patients were male and 78.89% (545 of 691) had primary, secondary, or high school-level education. Hypertension, reported in 54.85% (379 of 691) of patients, was the most common cause of ESRD. Around 48.63% (336 of 691) of the study population had cardiovascular comorbidities.

ESRD: End-stage renal disease; PD: Peritoneal dialysis; SD: Standard deviation

All the centers followed the prescribing practices of PD. For CAPD, patients received 4 bags of dialysate, each containing 2 L, with glucose concentrations of 1.50%, 2.50%, or 4.25%, adjusted according to the clinical status of the patient. For APD, patients were prescribed 2 bags of dialysate, each containing 5 L, with glucose concentrations of 1.50% or 2.50%. For some anuric PD patients where APD alone resulted in inadequate dialysis, an additional 2-liter bag of dialysate with glucose concentrations of 1.50%, 2.50%, or 4.25% was prescribed for daytime use, based on the clinical status of the patient. Thus, these patients received an APD with additional day dwell (an APD regimen, together with higher fill volumes and, combination with daytime CAPD).

CAPD was the preferred mode of PD in about 88.13% (609 of 691) of the patients. About 10.13% (70 of 691) of the patients underwent APD, while only 1.74% (12 of 691) underwent APD with additional day dwell (APD at night-time, one bag of 2 L added at day-time for the

Table 2 Causes of peritoneal dialysis discontinuation

Causes of peritoneal dialysis discontinuation, *n* (%)	Patients with ESRD and undergoing PD during 2019–2021 (*N* = 691)
Kidney transplantation	11 (1.59)
Hemodialysis because of peritonitis	60 (8.68)
Hemodialysis because of ultrafiltration failure	6 (0.68)
Hemodialysis because of catheter issues	2 (0.29)
Hemodialysis because of patient requirement	7 (1.01)
Death (non-peritonitis)	161 (23.30)
Death (peritonitis)	6 (0.87)
Others[a]	12 (1.74)

[a] Other reasons for ending PD included transfer to other hospitals for 9 (1.30%) patients, inguinal hernia in 1 (0.14%) patient, tunnel infection in 1 (0.14%) patient, and abdominal operation in 1 (0.14%) patient

ESRD: End-stage renal disease; PD: Peritoneal dialysis

Table 3 Difference in the demographic and clinical characteristics of patients who experienced peritonitis and who did not experienced peritonitis

Characteristics		Peritonitis *N* (%)	Non-peritonitis *N* (%)	Significance (*p*)
Gender	Female	221 (47.32%)	89 (39.70%)	0.06
	Male	246 (52.68%)	135 (60.30%)	
Age	0–20 years	14 (3.02%)	4 (1.79%)	0.45
	21–35 years	93 (20.01%)	38 (17.01%)	
	36–50 years	141 (30.31%)	70 (31.31%)	
	50–65 years	148 (31.79%)	84 (37.50%)	
	> 65 years	69 (14.82%)	28 (12.50%)	
Level of education	Did not attend school/primary schooling not completed	26 (5.59%)	24 (10.71%)	**< 0.01**
	Primary, secondary, or high school	364 (77.88%)	181 (80.81%)	
	University	77 (16.50%)	19 (8.50%)	
Type of care	Assisted	167 (35.78%)	78 (34.78%)	0.49
	Self-care	292 (62.51%)	139 (62.12%)	
	Both	8 (1.71%)	7 (3.09%)	
Diabetes mellitus	No	372 (79.69%)	175 (78.06%)	0.64
	Yes	95 (20.31%)	49 (21.94%)	
Comorbidities	No	225 (48.19%)	110 (49.06%)	0.82
	Yes	242 (51.81%)	114 (50.94%)	
Type of PD	APD	57 (12.18%)	13 (5.82%)	**0.01**
	CAPD	10 (2.13%)	2 (0.90%)	
	APD with additional day dwell	400 (85.72%)	209 (93.31%)	

PD patients with oliguria). About 62.37% (431 of 691) of the patients relied only on self-care during their dialysis period (Table 1).

Death due to causes other than those directly related to peritonitis (23.30%) and switch to HD due to peritonitis occurrence (8.68%) were the top main causes of peritoneal dialysis discontinuation (Table 2).

Table 4 Prevalence of peritonitis in 2019, 2020, and 2021

Year	Peritonitis rate	Peritonitis episode per patient-year
2019	9.13%	1.05
2020	18.57%	1.13
2021	25%	0.71

Prevalence of peritonitis

Peritonitis during the 3-year period was reported in 32.42% (224 of 691) of the patients. The total episodes of peritonitis among 224 patients during the study period of 2019–2021 were 364. No significant difference was noted in the prevalence of peritonitis with respect to gender ($p = 0.06$), age ($p = 0.45$), type of care ($p = 0.49$), DM ($p = 0.64$), comorbidities ($p = 0.82$). A significant difference was noted in type of PD ($p = 0.01$) and education level ($p < 0.01$) (Table 3). Patients who underwent CAPD reported a higher peritonitis rate than those with APD or APD with additional day dwell. Peritonitis was more common in patients who did not attend school or in whom primary schooling was not completed, followed by those who had completed primary school.

APD: Automated peritoneal dialysis; CAPD: continuous ambulatory peritoneal dialysis; PD: peritoneal dialysis

A significant difference was observed in the prevalence of peritonitis across the centers (chi-square = 16.54, $p = 0.03$), with the An Giang center reporting 41.46% (68 of 164) and 2.75 episodes per patient-year, Can Tho center reporting 36.56% (34 of 93) and 1.06 episodes per patient-year, Cu Chi center reporting 34.88% (15 of 43) and 3.23 episodes per patient-year, Da Nang center reporting 24% (12 of 50) and 0.65 episodes per patient-year, Ho Chi Minh UMC center reporting 22.22% (16 of 72) and 0.87 episodes per patient-year, Kien Giang center reporting 26.19% (11 of 42) and 0.62 episodes per patient-year, Nguyen Trai center reporting 22.64% (12 of 53) and 1.27 episodes per patient-year, Thong Nhat center reporting 27.50% (22 of 80) and 2.14 episodes per patient-year, and TN-Dong Nai center reporting 36.17% (34 of 94) and 1.34 episodes per patient-year.

There was a general increase in the number of patients reporting peritonitis over the years. On a yearly basis, in 2019, about 9.13% (41 of 449) of the patients who had ESRD and underwent PD reported peritonitis; in 2020, about 18.57% (96 of 517) of the ESRD patients reported peritonitis; and in 2021, about 25% (136 of 544) of the ESRD patients reported peritonitis. The rate of peritonitis episode per patient-year was 1.05 in 2019, 1.13 in 2020, and 0.71 in 2021 (Table 4).

Causative agents

Culture tests were done for all 364 episodes of peritonitis. The total number of peritonitis episodes over 3 years was 364. In 2019, there were 59 episodes, with 20 positive cultures; in 2020, there were 134 episodes with 73 positive cultures, and in 2021, there were 171 episodes with 78 positive cultures. The total number of positive culture episodes was 46.98% (171 of 364), and total negative cultures were 53.02% (193 of 364) (Table 5).

Outcomes of peritonitis

Mortality due to peritonitis

Overall, 2.68% (6 of 224) of patients died due to peritonitis. Mortality due to peritonitis increased from 2019 to 2021. There were no (0 of 41) deaths in 2019. In 2020 and 2021, there were 2.08% (2 of 96) and 2.94% (4 of 136) deaths due to peritonitis, respectively. No significant difference was observed in the mortality rate with respect to age ($p = 0.14$), gender ($p = 0.10$), type of care ($p = 0.05$), and type of PD ($p = 0.68$). The difference in mortality rate was also not significant across the study period 2019, 2020, and 2021 ($p = 0.53$).

Table 5 Microorganisms responsible for peritonitis infection ($n = 364$)

Category	Responsible microorganism	Episodes, *n* (%)
Culture positive (*n* = 171)		
Gram-positive	*Staphylococcus aureus* (excluding MRSA)	50 (29.24)
	MRSA	1 (0.58)
	Coagulase-negative *Staphylococcus*[a]	14 (8.19)
	Enterococcus spp[b]	6 (3.51)
	Streptococcus spp	1 (0.58)
Gram-negative	*Klebsiella spp*[c]	28 (16.37)
	Pseudomonas spp[d]	28 (16.37)
	Escherichia coli	26 (15.21)
	Acinetobacter baumannii	6 (3.51)
	Enterobacter spp[e]	2 (1.17)
	Moraxella catarrhalis	2 (1.17)
	Other gram-negative*	5 (2.93)
Fungus		2 (1.17)
Culture negative ($n = 193$)		193 (53.02)

MRSA: Methicillin-resistant *S. aureus*

[a]: *Staphylococcus epidermidis*, *Staphylococcus haemolyticus*, *Staphylococcus schleiferi*, *Staphylococcus carnosus*, *Staphylococcus hominis*

[b]: *Enterococcus faecalis*, *Enterococcus faecium*

[c]: *Klebsiella pneumoniae*, *Klebsiella ozaenae*

[d]: *Pseudomonas aeruginosa*, *Pseudomonas (unidentified)*

[e]: *Enterobacter SBL*, *Enterobacter cloacae*

*: *Burkholderia cepacia complex*, *Plesiomonas shigelloides*, *Cronobacter sakazakii*, *Pantoea agglomerans*, *and Stenotrophomonas (unidentified)*

Removal of tenckhoff catheter and switch to HD

By the end of 2019, 9.76% (4 of 41) of PD-associated peritonitis patients had to have the Tenckhoff catheter removed and needed to be switched to HD. The percentage increased in the subsequent years. In 2020 and 2021, 14.58% (14 of 96) and 16.18% (22 of 136) of the patients reported similar outcomes, respectively. However, no significant difference was found regarding the removal of Tenckhoff catheter and switching to HD across the study period 2019, 2020, and 2021 ($p = 0.60$).

PD-related infections

Overall, tunnel infections were reported in 7.59% (17 of 224) of patients with peritonitis, i.e., 7.32% (3 of 41) in 2019, 3.13% (3 of 96) in 2020, and 8.09% (11 of 136) in 2021. Exit site infections related to peritonitis treatments were reported in 8.04% (18 of 224) of patients with peritonitis, i.e., 7.32% (3 of 41) in 2019, 6.25% (6 of 96) in 2020, and 5.89% (8 of 136) in 2021. Nevertheless, the difference in infection rates was not significant across the study period 2019, 2020, and 2021 ($p = 0.29$).

Associations of PD-associated peritonitis prevalence with various risk factors

Regression analyses were conducted to determine the associations between PD-associated peritonitis prevalence and various risk factors, including age, sex, level of education, cause of ESRD, comorbidities, type of PD, and type of PD care. Table 6 shows the maximum likelihood estimates of the regression coefficients. Level of literacy was the only parameter significantly associated ($p = 0.01$) with the onset of peritonitis among patients undergoing PD.

Discussion

Peritonitis associated with PD is a severe complication, and its prevention and treatment are crucial to decrease mortality and morbidity in ESRD patients. In this study, peritonitis for 3 years was reported in 32.42% (224 of 691) of the patients. As per ISPD guidelines, the proportion of PD patients with peritonitis should be less than 20%. Similarly. The ISPD 2022 revised the definitions of various forms of peritonitis and updated its recommendations on managing the condition, aiming to reduce peritonitis rates to < 0.40 episodes per year with > 80% peritonitis-free patients per year [13]. In this study, the rate of peritonitis was 0.96 episodes per patient-year, which exceeded that specified in the ISPD guidelines (< 0.40 per year). The high peritonitis rates observed in the present study exceeding the ISPD guidelines, can be attributed to variations across the nine centers. Four centers; An Giang, Can Tho, Cu Chi, and TN-Dong Nai, reported the highest peritonitis rates. These centers faced challenges such as poor handwashing practices, unclean

Table 6 Analysis exploring the associations between various clinical characteristics and the occurrence of peritonitis

Parameter	Odds ratio	CI 95%	Significance (*p*)
Age group			
Age (0–20 vs. > 65)	0.89	(0.32, 2.17)	0.70
Age (21–35 vs. > 65)	0.82	(0.54, 1.26)	0.36
Age (36–50 vs. > 65)	1.16	(0.80, 1.69)	0.45
Age (50–65 vs. > 65)	1.31	(0.91, 1.87)	0.15
Gender (F vs. M)	0.85	(0.71, 1.00)	0.06
Level of education			
Primary, secondary, or high school (Yes vs. No)	0.77	(0.57, 1.04)	0.09
Did not attend school/primary schooling not completed (Yes vs. No)	0.59	(0.39, 0.88)	**0.01**
Causes of ESRD			
DM (Yes vs. No)	0.95	(0.76, 1.18)	0.62
Comorbidities (Yes vs. No)	1.08	(0.91, 1.28)	0.39
Type of PD			
CAPD (Yes vs. No)	1.28	(0.55, 2.97)	0.57
APD (Yes vs. No)	1.73	(0.79, 3.79)	0.17
Type of PD care			
Selfcare (Yes vs. No)	0.85	(0.49, 1.47)	0.55
Assisted (Yes vs. No)	0.76	(0.44, 1.30)	0.32

Model: Binomial Logistic Regression ($n = 689$)

Age groups are categorized as 0–20 years, 21–35 years, 36–50 years, and 50–65 years

Education levels are classified as primary, secondary, or high school, and did not attend school/primary schooling not completed

Causes of ESRD include diabetes mellitus and other comorbidities

Type of PD care includes self-care and assisted care

APD: Automated peritoneal dialysis; CAPD: Continuous ambulatory peritoneal dialysis; CI: Confidence interval; ESRD: End-stage kidney disease; PD: Peritoneal dialysis

water supplies [17], lower educational levels among patients, and a low PD nurse-to-patient ratio, all contributing to the elevated peritonitis rates.

The present study identified gram-negative bacteria as the primary causative organisms for peritonitis. This may be due to the reliance on unsafe water sources for handwashing in certain centers, such as Can Tho, An Giang, and Kien Giang, where residents use underground water and water from the Mekong Delta River [17]. Additionally, poor compliance with hand hygiene practices, particularly among elderly patients, diabetics, and those with comorbid conditions, such as failure to wash hands after using the toilet and before changing dialysis fluids, may further exacerbate the risk [18, 19]. These combined factors likely contribute to the higher prevalence of peritonitis in these regions, with gram-negative bacteria being the predominant pathogens.

In this study, *Staphylococcus aureus*. (*S. aureus)* was the second most common pathogen in peritonitis cases following gram negative bacteria. A Taiwanese study reported 50% methicillin resistance in coagulase-negative *Staphylococcus* cases [20]. Studies have reported gram-positive bacteria (especially *Staphylococcus*) to be the primary causative organisms of peritonitis. *S. aureus*-related peritonitis increased over the years, associated with risk factors like diabetes mellitus (95% confidence interval [CI]: 0.64–1.43) and prolonged duration of PD, and both in young and immunocompromised elderly individuals in the Chinese population [21, 22].

As per ISPD guidelines, the proportion of culture-negative peritonitis should be < 15% of all peritonitis episodes [13]. However, in this study, a large percentage of the peritonitis cases were culture-negative as opposed to the recommended guidelines. A high rate of culture negative bacteria in the present study can be attributed to various reasons which are also reported in the literature [11]. Firstly, there was delayed sample collection, as antibiotics were often administered before the samples were obtained, compromising the culture results. Secondly, the sample collection process was non-standard due to a shortage of trained PD nurses and insufficient staffing, leading to improper methods. Thirdly, and most importantly, the microbiological laboratories in these centers were not adequately equipped to isolate and culture pathogens effectively. These culture-negative cases were predominantly observed in centers such as An Giang (27.46%), Can Tho (19.69%), Cu Chi (10.88%), and TN-Dong Nai (16.06%), which have some of the poorest medical resources in Vietnam. In contrast, better-equipped centers, including the Kien Giang (5.70%), Thong Nhat (2.59%), and Da Nang (4.15%), reported lower peritonitis rates.

ISPD 2022 guidelines define culture-negative peritonitis with a white cell count of > 100/mL and cloudy dialysis effluent and/or abdominal pain without causative organism from the effluent, classifying it as enteric peritonitis [13]. Studies demonstrate that peritonitis resulting from enteric causes (e.g., strangulated bowel, appendicitis, ischemic colitis) poses diagnostic challenges, which can lead to delayed treatment. This delay has been associated with an increase in morbidity and mortality rates in some cases [13]. The prevalence of culture-negative cases may be reduced by improving laboratory standards. This may be achieved by using different culture methods, i.e., hemoculture bottle without centrifugation (sensitivity:

76.50%), centrifugation 10 mL + hemoculture bottle (79%), and centrifugation 50 mL + hemoculture bottle (84%) to improve the culture positivity rate, especially in community hospitals that are not equipped to centrifuge large volumes of fluid [23].

In the present study, the rate of peritonitis increased from 2019 to 2021. Despite the COVID-19 pandemic, which improved overall personal hygiene measures worldwide, no improvement in peritonitis rates in this study was observed. A similar finding was reported by Hu et al. (2022), who observed no change in the overall rate of peritonitis during the COVID-19 pandemic [24]. It should be noted that, unlike other countries (the Philippines, Thailand, and Hong Kong), Vietnam lacks a national program to promote home-based PD. However, a program launched in 2018 to encourage patients to embrace home PD, reported significant success by 2020, with the proportion of new patients on PD rising from < 5–10.34–13.39%. The rise in peritonitis rates from 2019 to 2021 may be linked to this increased number of patients undergoing PD [6]. Moreover, this rise may also be attributed to several factors, including inadequate initial training for new PD patients, lack of ongoing training for existing patients, poor living conditions, and suboptimal environmental hygiene [11, 25]. In the present study, nine centers revealed notable variability in peritonitis rates. Among these, four centers; An Giang, Can Tho, Cu Chi, and TN-Dong Nai, reported the highest rates. These centers face specific challenges such as poor hand hygiene practices, lack of access to clean water, lower educational levels, and high PD-to-patient ratios contributing to rise in peritonitis rate.

To report the standard peritonitis rate in PD-related peritonitis cases as per ISPD 2022 guidelines, the "time at risk" should start when the patient begins PD and should continue if the patient remains on PD [13]. Based on these guidelines, the rate of peritonitis occurrence in this study was 0.96 episodes per patient-year. This rate was notably higher than 0.28 per patient-year reported in peritoneal dialysis outcomes and practice patterns study including data from seven countries. The variations reported in the rate of peritonitis can be attributed to variations in PD practices across the countries [16].

The association between age and peritonitis has been inconsistent across studies. In the present study, individuals between the ages of 35 and 50 years were highly susceptible to peritonitis (30.31%). The higher rate of PD-peritonitis in this age group may be due to patients in this age range believing that CAPD is generally safe. Therefore, during the solution exchanges, they did not follow the guidance in steps and hygiene standards due to time constraints at work. Additionally, this age group rarely had peritonitis during the first year of treatment but became more frequent in the following years.

An increased risk of peritonitis is linked to lower socioeconomic status. In the present study, literacy was significantly negatively associated with peritonitis rate. Similar to the results obtained in the present study, another study found that lower education levels were significantly associated with higher rates of peritonitis [26]. This further aligns with another study carried out across several countries, associating a higher prevalence of peritonitis with a lower level of education; this could be attributed to the significant disparities in healthcare, education, and social welfare systems among educated and uneducated classes in the countries involved [27]. Peritonitis has also been associated with race and ethnicity, with Asians having higher rates of peritonitis than Canadians [15]. Likewise, a retrospective analysis also reported a lower level of education to be a significant risk factor for higher peritonitis rates. However, it was not associated with an increase in the mortality rate [28].

The present study demonstrated an increase in patients undergoing Tenckhoff catheter removal and transition to HD between 2019 and 2021, which likely contributed to decline in peritonitis rates from 2020 to 2021. This finding is consistent with a 21-year retrospective study that reported Tenckhoff catheter removal was associated with a higher peritonitis cure rate (especially in relapsing peritonitis cases), a lower hospitalization rate, and a higher survival rate. Removing the Tenckhoff catheter reduces the risk of recurrent peritonitis by the same microorganism [29]. Further supporting this, a 10-year retrospective cohort study of 1,025 PD patients in Thailand reported that early treatment strategies such as catheter removal can improve the prognosis [30]. Additionally, a 5-year retrospective study reported that a higher rate of catheter removal improved the survival rate [31].

Mortality is rare in PD-related peritonitis, with < 10% of all episodes resulting in death. In the present study, the mortality rate was low (2.68%), with most deaths attributed to non-peritonitis causes or comorbidities. The variation in mortality rates observed in the present study compared to those reported in literature may be due to the fact that the reviews reported in the literature included patient registry data of multiple countries, each with different healthcare systems and infrastructure [32]. These variations in healthcare setups could explain the differences in mortality rates.

The low mortality rate observed in the present study can be attributed to the proactive PD practices implemented at the centers. These included the early initiation of empiric antibiotic therapy, timely removal of PD catheters within five days in cases of non-response, and transitioning patients with severe peritonitis to HD when PD treatment was unsuccessful. Such evidence-based interventions likely contributed to the favorable mortality outcomes by minimizing delays in addressing

treatment-resistant infections and associated complications. About 23.30% patients reported death due to non-peritonitis cause. Deaths caused by severe peritonitis could only be determined for patients who were admitted to the hospital. Other deaths in the present study, classified as non-peritonitis-related, occurred at home. These deaths were likely due to causes such as cancer, COVID-19, or cardiovascular diseases, as families reported that these patients experienced sudden death. Majority of these patients were above 51 years (66.46) and had comorbidities (64.60%). These causes align with those reported in the literature [12].

There was no significant difference in the mortality rate due to peritonitis among genders, age groups, type of care, or type of PD administered. These findings contrast with a study that reported a positive association between peritonitis-related mortality and age, as well as poorer outcomes when transferring APD patients to CAPD [33]. Another study identified peritonitis incidence as an independent predictor of death due to cardiovascular conditions and infections [34]. Further, the present study revealed a higher prevalence of peritonitis, i.e., 37.20% in patients with cardiovascular comorbidities. This is similar to the results of a retrospective cohort study on CAPD patients in China, where cerebrovascular disease was the primary comorbidity (29%) among peritonitis patients, followed by an increased infection incidence in 19.40% of the population [9].

Strengths and limitations

The strength of the study lies in the large sample size, which enhances the statistical power and robustness of the findings, and its multicenter design, incorporating data from multiple hospitals across Vietnam. This approach ensures a diverse patient population, improving the generalizability and external validity of the results within the Vietnamese healthcare context. The study has certain limitations; being retrospective in nature, it relies on the accuracy and completeness of medical records, which may result in missing or biased data. Variability in management protocols, and record-keeping practices across the nine hospitals may have an impact on the consistency of findings. Additionally, the results may not be generalizable to populations outside Vietnam due to regional differences in patient characteristics and healthcare systems. Further, the temporal relationship could not be assessed due to the lack of data from the pre- and post-COVID-19 periods, as this aspect was not within the intended scope of the study. Literature does provide some evidence on the peritonitis rate being affected by climatic and is higher in hot, humid and rural areas [14]. Nevertheless, the present study did not assess the seasonal variation of peritonitis.

Conclusion

The overall prevalence of peritonitis across nine sites in Vietnam from 2019 to 2021 was 32.42%. In PD patients, lower educational status was a significant factor associated with peritonitis. However, it was independent of the presence of comorbidities such as diabetes mellitus, and the type of care administered (self-care/assisted). The study observed an increase in the peritonitis rate from 2019 to 2021. Furthermore, this study reported a notable increase in the rates of Tenckhoff catheter removal, transfer to HD, and mortality among patients with peritonitis in 2021. However, the mortality rate due to peritonitis was low and was mainly due to other comorbidities. Assessing the rate of occurrence of peritonitis and the risk of peritonitis can help identify disease burden and the unmet treatment needs of PD patients in Vietnam. Several potential risk factors for PD-peritonitis were not explored in this study and could be addressed in future research. Additionally, analyzing seasonal variation in peritonitis may provide valuable insights into the management of PD-peritonitis.

Abbreviations

APD	Automated peritoneal dialysis
CAPD	Continuous ambulatory peritoneal dialysis
CKD	Chronic kidney disease
COVID-19	Coronavirus disease-2019
eGFR	Estimated glomerular filtration rate
ESRD	End-stage renal disease
HD	Hemodialysis
IDS	Investigational drug service
ISPD	International Society for Peritoneal Dialysis
MI	Myocardial infarction
PD	Peritoneal dialysis
S. aureus	Staphylococcus aureus
WBCs	White blood cells

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Author contributions

NB conceived and designed the study. TTKC, LCT, NHBN, TPTH, HNPT, THK, DAD, PXT, and VQD collected data from their hospital. All authors examined and revised the manuscript. All authors read and approved of the final manuscript.

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Data availability

Data will be available upon reasonable request from the corresponding author.

Declarations

Ethics approval and Consent to participate

The study was approved by the Ethics Committee of Thong Nhat Hospital (reference No. 352/QĐHĐYĐ-BVTN). Since this was a retrospective study, a waiver of consent was given by the ethics committee. All methods were carried out in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests
The authors declare no competing interests.

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