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ORIGINAL ARTICLE

Peritoneal dialysis-associated peritonitis: incidence, microbiology and outcomes at a South African hospital

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ABSTRACT

Background: Kidney failure is a major health issue in South Africa. The public health sector has adopted a 'peritoneal dialysis (PD) first' policy for kidney replacement therapy. PD may be characterized by high failure rates, commonly due to PD-associated peritonitis (PDP), although no data exist for the Eastern Cape (EC) province. Here we describe PDP episodes and their outcomes at a tertiary hospital in Gqeberha, EC.

Methods: A retrospective study was conducted on all adult patients receiving chronic PD at Livingstone Tertiary Hospital from 2022–2024, evaluating microbiological profiles and outcomes of all PDP episodes.

Results: Of 91 patients (mean age 38.8 years; 52% male), 61 (67%) experienced PDP. Overall, 117 episodes of PDP occurred over 126.9 patient-years (0.85 episodes/patient-year). Twelve patients (20%) had ≥3 episodes. The culture-negative rate was low (11%); Gram-positive organisms predominated (71%). The medical cure rate was 65%. Relapse (OR 0.21; 95% CI 0.06–0.76) and fungal episodes (OR 0.09; CI 0.02–0.39) were associated with lower odds of cure, whereas Gram-positive cases had higher odds than Gram-negatives (OR 3.19; 1.18–8.64). HIV was not associated with episode profile or outcomes. Catheter removal occurred in 21 (18%) episodes; 16 (14%) episodes required modality switch to haemodialysis. Only four patients successfully resumed PD after interval haemodialysis.

Conclusions: PDP rates in EC exceed international targets and contribute to technique failure. Culture-negative and medical cure rates were acceptable. Gram-positive organisms predominated, suggesting a need for improved patient training. Resource restrictions and socio-economic factors may contribute to the high rate.

Keywords: peritoneal dialysis, South Africa, peritonitis, microbiology, rates.

INTRODUCTION

Kidney failure (KF) is a significant public health issue with increasing prevalence in South Africa [1], yet resource limitations necessitate ethical rationing of kidney replacement therapy (KRT) in the public health sector [2]. Peritoneal dialysis (PD) is a preferred initial dialysis modality for many patients, with advantages relevant to the South African context including reduced reliance on fragile water and electricity infrastructure, lower patient travel costs, and flexibility promoting continued employment. However, PD may be limited by high failure rates, of which the most frequent cause is PD-associated peritonitis (PDP) [1]. Assessment of peritonitis rates, the microbiological profile of infections and clinical outcomes are key quality measures in these patients' management [3].

The International Society for Peritoneal Dialysis (ISPD) provides standardised definitions and targets for PDP, with the 2022 update revising the target to 0.4 episodes per patient-year (eppy) [3]. Historically, PDP rates have been decreasing, largely driven by PD technology and improvements in technique [4].

Most PDP episodes result from bacterial infection from an identifiable organism and have a positive PD effluent culture [5]. Gram-positive bacteria predominate in most cohorts [6]. However, a higher Gram-negative prevalence

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has been reported in Thailand [5] and India [7]. Interpretation of these findings is limited by high culture-negative rates, which likely underestimate the contribution of Gram-positive organisms [5]. Culture-negative peritonitis rates are therefore also included as a guideline-derived quality metric, with a recommended rate of <15% [3]. Geographical and climatic effects may influence the microbiological profile of PDP [8]. A study from Cape Town demonstrated a rising proportion of Gram-negative episodes during a regional drought [9]. This may be relevant for our facility in Gqeberha (formerly Port Elizabeth), which experienced a record drought from 2015–2023 [10].

The impact of HIV infection on patient and technique survival in the era of modern antiretroviral therapy has been studied in South Africa, although uncertainty remains. Retrospective studies at Helen Joseph Hospital in Johannesburg found that HIV infection did not increase peritonitis risk or affect patient or technique survival [11,12]. A prospective study from KwaZulu-Natal demonstrated higher PDP rates in people with HIV (PWH), especially at lower CD4 counts, but not higher technique failure rates [13]. These centres identified contrasting microbiological profiles: one reporting higher Gram-positive and culture-negative rates in PWH [13], and another recording that Gram-negatives were correspondingly more frequent in such patients [11]. Further research into HIV's role in PDP is required.

The preferred outcome of PDP is medical cure, with symptom resolution and allowing PD to continue. Approximately 69% of episodes are cured with antimicrobial treatment [14]. The likelihood of medical cure is influenced by several patient, microbiological and episode factors. Lower cure rates have been reported with fungal peritonitis, certain Gram-negative organisms such as *Pseudomonas aeruginosa*, and Gram-positives such as *Staphylococcus aureus* [3]. Episodes associated with exit-site or tunnel infections more frequently require catheter removal [3]. Other factors associated with PDP incidence and outcomes include episode subtype and serum albumin levels [15,16].

No data have been published from the EC in South Africa, a historically underserved province. This study aimed to describe PDP episodes and outcomes in our nephrology unit and compare them with existing South African and international data.

METHODS

Livingstone Tertiary Hospital (LTH) is located in the city of Gqeberha in South Africa's Eastern Cape province. It is the only public nephrology referral centre for adult patients serving the Nelson Mandela Bay and Sarah Baartman districts, providing for a mixture of urban, semi-urban and rural communities with an estimated population of 1.8 million people [17]. It pursues a 'PD-first' policy for KRT, similar to other centres in the country [18].

A retrospective review was performed of all adults receiving chronic PD at LTH between 1 January 2022 and 31 December 2024. All patients over 18 years of age were included, who were identified from renal unit records, with further accounts of PDP episodes from folder and peritonitis register review. Ethical approval for the study was obtained from the Walter Sisulu University Health Sciences Research Ethics Committee (WSU HREC 069/2025). In view of the nature of the study, participant consent was waived. Clinical, biochemical and microbiological data were obtained from medical records, which were anonymised, captured in an Excel database and analysed using Stata 18 (StataCorp LLC).

Participant information collected included demographic information, the presence of HIV infection or diabetes mellitus, and the ascribed KF aetiology. In PWH, the most recent CD4 and HIV viral loads (VL) were noted. For VL reported as <20 copies/mL, a value of 19 was used for calculation. Start and end dates for PD exposure were obtained to calculate time-at-risk. The modality of PD (either continuous ambulatory peritoneal dialysis (CAPD) or automated peritoneal dialysis (APD)) was recorded.

Data pertaining to each PDP episode were collected using standard ISPD definitions [3]. These included: the timing of the episode (pre-PD, PD-related, or PD-catheter insertion-related), the cause/context (catheter-related, enteric, or typical) and the episode subtype (index, relapse, recurrent or repeat). Episodes were defined as 'index' episodes if they did not meet the criteria for one of the other episode subtypes. Serum albumin level (if tested within 90 days prior to the episode) was recorded. For albumin levels reported as <10 g/L, a value of 9 g/L was used for statistical calculation.

Microbiological data collected included the culture status (positive or negative), the Gram-status of culture-positive bacterial episodes, and the specific organism(s) isolated (bacterial, fungal or mycobacterial). Reported sensitivity to usual antimicrobial therapy was documented.

Clinical outcomes were reported as per ISPD definitions [3]. Medical cure was defined as resolution of symptoms and the absence of one of the following adverse outcomes: catheter removal, relapse or recurrence, transfer to HD for >30 days, or PDP-related death. Hospitalisation due to PDP was also recorded.

At unit level, PDP incidence rate was calculated using the ISPD formula [3]:

$$\text{Episodes per patient year} = \frac{\text{Peritonitis episodes}}{\text{Cumulative days at risk}/365.25}$$

As per ISPD guidelines, relapse episodes were counted once (the index episode) for the rate calculation.

Technique failure rate was recorded as per ISPD definitions, with patients censored for transplant, non-PDP death or other outcomes, and the proportion of technique failures due to PDP was calculated.

Descriptive statistics used appropriate measures of central tendency based on data distribution, which was assessed using the Shapiro–Wilk W test of normality and histogram inspection. Baseline characteristics were compared between patients with and without PDP using the χ^2 or Fisher's exact tests for categorical variables and t-test for continuous variables. Comparison by total patient-days exposed was performed using the Kruskal–Wallis test.

As participants could experience multiple episodes of PDP, the data have a clustered structure that required a statistical method to account for intra-class correlation (ICC). The GEE (Generalised Estimating Equations) regression framework was employed to assess the population-average effect while adjusting standard error for within-patient correlation. Primary inferences were reported using cluster robust (GEE) estimates, with non-clustered χ^2 or Fisher exact tests reported for sensitivity. While using the GEE framework produces small increases in standard error (and therefore P values), it provides possibly more statistically plausible associations by accounting for the lack of independence between multiple episodes in a single individual. To limit the false discovery rate, the Benjamini–Hochberg procedure was performed on the clustered tests.

Several associations were evaluated, specifically: the effect of HIV status on Gram-status of infections and medical cure rate of the episode, and the effect of organism type, bacterial Gram-status and episode type on medical cure rate. Each subgroup was analysed; for some analyses index and repeat episodes were grouped and compared against relapse and recurrent episodes.

RESULTS

Participants

A total of 96 individual patients received PD during the study period, of whom five were under the age of 18 and therefore excluded from the study. The participants' baseline characteristics are detailed in Table 1.

Table 1. Characteristics of participants.

Variables	Total	Experienced PDP	No. episodes of PDP	P value
Participants, n (%)	91 (100)	61 (67.0)	30 (33.0)	
Female, n (%)	44 (48)	27 (44)	17 (57)	0.266 [a]
Age at study entry, mean (SD)(years)	38.8 (10.7)	38.6 (11.1)	39.3 (9.8)	0.766 [b]
Comorbidities, n (%)				
HIV	16 (18)	10 (16)	6 (20)	0.671 [a]
Diabetes mellitus	3 (3)	2 (3)	1 (3)	0.989 [a]
Ascribed aetiology, n (%)				
Glomerulonephritis	32 (35)	24 (39)	8 (27)	0.593 [a]
Hypertension	29 (32)	17 (28)	12 (40)	
Unknown	14 (15)	9 (15)	5 (17)	
Diabetes mellitus	3 (3)	2 (3)	1 (3)	
HIV-associated	2 (3)	2 (3)	–	
Other [c]	10 (11)	7 (12)	3 (10)	
Data missing	1 (1)	–	1 (3)	
Modality, n (%)				
CAPD	78 (86)	50 (87)	28 (93)	0.207 [a]
APD	13 (14)	11 (13)	2 (7)	
Patient-years exposed				
Total, PY (%)	126.9	94.3 (74.3)	32.6 (25.7)	0.026 [d]
Median (IQR)	1.21 (0.54–2.27)	1.29 (0.60–2.39)	0.87 (0.22–1.63)	

Comparisons calculated between PDP and non-PDP groups. PDP, peritoneal dialysis-associated peritonitis; SD, standard deviation; PY, patient-years; IQR, interquartile range.

[a] P value from Fisher's exact test used (expected cell frequencies <5).

[b] t-test used for comparison of age at entry.

[c] 'Other' aetiologies: polycystic kidney disease (1), FSGS (4), urological (3 – posterior urethral valve, vesico-ureteric reflux, pelviureteric junction obstruction), genetic calciuria (1), mixed (1).

[d] Kruskal–Wallis test: P = 0.026, $\chi^2(1) = 4.94$.

The mean age at entry was 38.8 years (SD = 10.7) and 48% of patients were female. HIV prevalence was 18%, with low diabetes mellitus prevalence (3%). Similar numbers of patients received PD across the study period (2022: 62; 2023: 63; 2024: 56). The only significant difference between the groups with or without PDP episodes was duration of PD; median total patient-days exposure was higher in the PDP group: 470 (IQR 220–874) versus 317 (IQR 80–594); P = 0.026. There was no significant difference in annual patient-years exposure during the study period (Kruskal–Wallis $\chi^2(2) = 2.00$, P = 0.368). Most patients used CAPD as their modality (86%), with 14% using APD.

All patients in the HIV-positive subgroup were on antiretroviral therapy. The median CD4 count was 449 cells/μL (IQR 343–567) with a median HIV VL that was <20 copies/mL (IQR 19–26), with 81% (13/16) achieving VL <50 copies/mL.

Episodes

During the study period, 117 peritonitis episodes occurred, with 61 patients (67%) experiencing at least one episode and 30 patients (33%) remaining peritonitis-free. Of those who experienced PDP, 30 (49%) had one episode and 19 (31%) experienced two episodes. These 49 patients (80% of subgroup) accounted for 68 (58%) of the total episodes.

In contrast, 12 'peritonitis-prone' patients (20%) each experienced three or more episodes (range 3–8 episodes), disproportionately contributing 49 episodes (42%) in total. The characteristics of all episodes are detailed in Table 2.

Most episodes were typical (neither enteric nor catheter-related) and were index PDP episodes. The peritonitis-prone group's episodes were similarly predominantly index episodes, with only 5/49 (10%) episodes being relapses or recurrences.

Serum albumin levels within 90 days preceding an episode were available for 111/117 (95%) episodes. The median value was 28 g/L (IQR 23–33), taken a median of 31 days (IQR 13–54.5) prior.

Peritonitis rate

A total of 108 episodes were included for the rate calculation as per the ISPD guidelines (nine relapse episodes excluded from 117 total episodes). The overall rate was 0.85 eppy. Rates per year are reported in Table 3.

There was a slight increase in rate over the study period, which was not statistically significant (Poisson regression analysis comparing 2022 to 2024 demonstrated IRR = 1.16, 95% CI 0.74–1.84, P = 0.512).

The PDP incidence rate in the 'PDP-prone' group was higher than the total incidence rate, at 1.99 eppy. When the rest of the cohort is considered without this group, the incidence rate was 0.60 eppy, a significant difference (IRR 3.38, 95% CI 2.30–4.94, P < 0.001).

Table 2. Characteristics of PD peritonitis episodes (n = 117).

Characteristic	Number (%)
Age at time of episode (years), mean (SD)	39 (11)
Male sex, n (%)	64 (55)
Clinical	
HIV status, n (%)	–
Positive	19 (16)
Negative	98 (84)
Diabetes, n (%)	2 (2)
Albumin (g/L), median (IQR)	28 (23–33)
Modality, n (%)	
CAPD	98 (84)
APD	19 (16)
Episode timing, n (%)	
Chronic PD-related	116 (99)
Insertion-related	1 (1)
Episode context, n (%)	
Typical	110 (94)
Catheter-related	6 (5)
Enteric	2 (2)
Episode subtype, n (%)	
Index	92 (79)
Relapse	9 (8)
Recurrent	4 (3)
Repeat	12 (10)

Table 3. Peritonitis episodes and incidence rate by year.

Year	Episodes	Patient-years (PY)	Rate (EPPY)
2022	36	45.15	0.80
2023	35	41.86	0.84
2024	37	39.87	0.93
Total	108 [a]	126.89	0.85

PY, patient-years; EPPY, episodes per patient-year. [a] Relapse episodes excluded as per ISPD guidelines.

Microbiology of episodes

A total of 104 episodes (89%) were culture-positive; the culture-negative rate was 11% (n = 13). Of the culture-positive episodes, 89% (n = 92) cultured a single organism, of which 95% (n = 87) were bacterial and 5% were fungal. The remaining 12% (n = 12) were polymicrobial, consisting of 10 polybacterial episodes and two mixed-pathogen episodes (one bacterial-fungal and one bacterial-mycobacterial).

Of the 87 monomicrobial bacterial episodes, 71% (n = 62) were Gram-positive and 29% (n = 25) were Gram-negative. The 10 polybacterial episodes' organisms were all Gram-

positive in five cases, all Gram-negative in two cases and of mixed Gram-status in the remaining three.

Overall, bacteria were isolated in 95% (n = 99) of culture-positive episodes, whereas fungi were observed in 6% (n = 6).

The frequency of specific organisms cultured is reported in Table 4.

Gram-positive bacteria predominated, particularly coagulase-negative staphylococci (CNS) and viridans group streptococci. Gram-negatives were less frequently cultured, with *Enterobacter cloacae* complex and *Pseudomonas* species most commonly identified.

Catheter-related episodes (n = 6) were caused by various bacteria, namely *Staphylococcus aureus* (n = 1), *Staphylococcus epidermidis* (n = 1), *Pseudomonas aeruginosa* (n = 1), and *Burkholderia multivorans* (n = 1). Two episodes were culture negative.

Both enteric episodes were polymicrobial – one occurring in a case of appendicitis, and one following a colonoscopy. The remainder of the polymicrobial episodes (n = 10) did not have an enteric or surgical cause identified.

Relapse and recurrent episodes (n = 13) were mostly culture positive (12/13; 92%), with 11/12 (92%) caused by bacteria and with one fungal case. The bacterial cases were evenly divided between Gram-positive and Gram-negative organisms (6/12 each). Gram-positives here were CNS (n = 3) and *Corynebacterium* species (n = 2). Gram-negatives included *Neisseria mucosa* (n = 2), and one each of *E. coli, E. cloacae* complex and *P. aeruginosa*. The single fungal episode was *Candida parapsilosis*.

The antimicrobial sensitivity of all cultured organisms was assessed. Of the common Gram-positives, all CNS (29/29) were sensitive to vancomycin. Of the reported viridans group streptococci, 85% were ceftriaxone sensitive and 65% were penicillin sensitive. The 6/6 that were tested for vancomycin were all sensitive.

There were no methicillin-resistant *S. aureus* cases. All *Corynebacterium* species were vancomycin sensitive; all enterococci were sensitive to ampicillin. There was one vancomycin-resistant *Enterococcus* (VRE).

The Gram-negative organisms isolated were generally susceptible to the usual antibiotic choices, with only two extended spectrum beta-lactamase (ESBL) producing organisms (one *E. cloacae* complex and one *E. coli*, both of which were sensitive to ertapenem). All *E. cloacae* complex, *E. coli* and *Klebsiella* episodes were sensitive to gentamicin. All *Pseudomonas* cases were sensitive to ceftazidime and ciprofloxacin.

Neither ESBL case occurred in an index episode (one recurrent, one relapse). One was successfully cured, while one patient died during this episode.

Table 4. Distribution of isolates in culture-positive cases of PDP (n = 122).

Organism	Isolates (n)	Proportion of all isolates (%)	Proportion of subgroup (%)
Gram-positive bacteria	80	65.6	–
Coagulase-negative staphylococci	35	28.7	43.8
Viridans group streptococci	25	20.5	31.3
Staphylococcus aureus	7	5.7	8.8
Corynebacterium species	5	4.1	6.3
Enterococcus species	3	2.5	3.8
Bacillus species	2	1.6	2.5
Other Gram-positive [a]	3	2.5	3.8
Gram-negative bacteria	35	28.7	–
Enterobacter cloacae complex	7	5.7	20.0
Pseudomonas species	7	5.7	20.0
Klebsiella species	4	3.3	11.4
Neisseria species	4	3.3	11.4
Acinetobacter species	4	3.3	11.4
Escherichia coli	3	2.5	8.6
Other Gram-negative [b]	6	4.9	17.1
Fungi	6	4.9	–
Candida parapsilosis	4	3.3	66.7
Acremonium species	2	1.6	33.3
Mycobacteria	1	0.8	–
Mycobacterium tuberculosis	1	0.8	100.0

Note: 122 organisms isolated from 104 culture-positive episodes.

[a] Other Gram-positive: *Listeria monocytogenes* (1), *Rothia* species (1), *Micrococcus luteus* (1).

[b] Other Gram-negative: *Proteus mirabilis* (1), *Pantoea agglomerans* (1), *Sphingomonas paucibacillus* (1), *Burkholderia multivorans* (1), *Aeromonas caviae* (1).

Episode outcomes

Most episodes did not require hospitalisation, which occurred in 31% (n = 36) of cases. The indication for hospitalisation was not specified per episode. Potential reasons included severity of disease or socio-economic factors, such as concerns regarding distance to health facility, adherence or ability to perform exchanges.

In total 65% (n = 76) of episodes were successfully cured with medical treatment. However, in 35% (n = 41) there was at least one adverse outcome. The most common complications were the need for catheter removal (n = 21, 18% of all episodes), HD transfer (n = 16, 14%) and peritonitis relapse (n = 10, 9%). One patient required catheter removal twice (on two separate episodes). There were six PDP-related deaths during the study period (5% of episodes). Of the episodes requiring removal, 16 were index episodes, with two relapses, one recurrence and two repeat episodes. One removal occurred in the context of enteric PDP (appendicitis). The characteristics of the episodes requiring catheter removal are summarised in Table 5.

Catheter removal was seldom followed by successful re-establishment of chronic PD. Only four of the 20 patients whose PD catheters required removal during a PDP episode successfully returned to regular PD within the study period – one was replaced immediately and three had delayed replacement after interval HD. Of these 20 patients, 16 (80%) were transferred to HD at the time of the episode. The remainder either had later modality switch (n = 2), one personally decided against further KRT or, in one case, were declined for further KRT due to resource restrictions.

Using the definition of PD technique failure as transfer to HD for >30 days or PDP-related death, and censoring for transplants, non-PDP deaths or other outcomes, 35 technique failure events occurred (39%). A total of 56 (62%) patients were either censored or still on PD at conclusion of the study. PDP was the primary attributable cause of technique failure in 23/35 (66%) cases, with the remaining 12 (34%) due to catheter dysfunction, migration or inadequate dialysis. Outcomes varied by episode subtype, summarised in Table 6.

Patients experiencing relapse/recurrent episodes had lower odds of medical cure when compared with index/repeat episodes (OR = 0.26, 95% CI 0.08–0.80, P = 0.019).

In a four-category subtype comparison, relapse episodes specifically showed lower odds of medical care when compared with index episodes (OR = 0.21, 95% CI 0.06–0.76, P = 0.017). Recurrent and repeat episodes did not differ significantly from index episodes. The overall clustered Wald test was not significant (P = 0.104), mirroring the unclustered X^2 (P = 0.182).

Associations

Various associations were tested using the GEE framework and are presented in Table 7. Non-clustered P values are presented from standard tests performed for sensitivity.

Table 5. Characteristics of episodes requiring catheter removal (n = 21).

Characteristic	Episodes
Organism isolated	
Staphylococcus aureus	4
Fungi	4
Pseudomonas species	4
Coagulase-negative staphylococci	2
Other Gram-negative	5
Culture-negative	2
Indication for removal	
Fungal peritonitis	4
Concurrent tunnel/exit-site infection	4
Refractory peritonitis	2
Early catheter dysfunction from PDP	3
Surgical indication (appendicitis)	1
For permanent HD transfer	1
Unclear from record	6

Table 6. Treatment outcomes of PDP episodes by subtype.

Episode subtype	Medical cure	No medical cure	GEE odds ratio	P value
	n (%)	n (%)	(95% CI)	
All episodes	76 (65)	41 (35)	–	—
Subtype				
Index	63 (69)	29 (32)	Reference	–
Relapse	3 (33)	6 (67)	0.21 (0.06–0.76)	0.017
Recurrent	2 (50)	2 (50)	0.40 (0.05–3.06)	0.379
Repeat	8 (67)	4 (33)	1.02 (0.23–4.63)	0.978
Grouped subtype				
Index and repeat	71 (68)	33 (32)	Reference	–
Relapse and recurrence	5 (39)	8 (62)	0.26 (0.08–0.80)	0.019

GEE, Generalised estimating equations framework; OR, odds ratio; CI, confidence interval.

Table 7. Microbiological characteristics and associations.

Covariate	GEE odds ratio (95% CI)	GEE P value	Non-clustered P value
Culture positive	(n=117; clusters=61[a])	–	–
HIV-positive [b]	0.39 (0.14–1.07)	0.069	0.222
Medical cure	1.17 (0.37–3.65)	0.792	0.767
Episode year [c]	–	0.097 [d]	0.052
Subtype [e]	1.42 (0.16–12.47)	0.749	1.000
Bacterial infection	(n=104; clusters=56)	–	–
HIV-positive [b,f]	–	–	1.000
Medical cure	8.68 (0.87–86.73)	0.066	0.048
Episode year	–	0.895 [d]	0.179
Polymicrobial	(n=104; clusters=56)	–	–
HIV-positive [b]	1.40 (0.30–6.57)	0.670	0.658
Medical cure	0.91 (0.33–2.54)	0.862	1.000
Episode year	–	0.880 [d]	0.846
Fungal infection	(n=104; Clusters=56)	–	–
HIV-positive [b,g]	–	–	0.590
Medical cure	0.09 (0.02–0.39)	0.013	0.018
Subtype	2.31 (0.32–16.82)	0.410	0.498
Gram-positive	(n=95; Clusters=52)	–	–
HIV-positive [b]	0.31 (0.08–1.16)	0.082	0.051
Medical cure	3.19 (1.18–8.64)	0.022	0.005
Episode year	–	0.018 [d]	0.017
Subtype	0.52 (0.18–1.47)	0.215	0.474

GEE, Generalised estimating equations framework; CI, confidence interval.
[a] One cluster = one participant.
[b] Reference = HIV-negative.
[c] Episode year was compared (2022, 2023, 2024).
[d] Wald test used to calculate P value.
[e] Subtype was grouped as 'Index and repeat' versus 'Recurrent and relapse'.
[f] There were no non-bacterial episodes in HIV-positive patients for calculation.
[g] No fungal cases in HIV-positive patients for calculation.
Non-clustered comparisons were performed using χ^2 test or Fisher's exact test (in categories with small samples).
Intra-class correlation coefficients (ICCs) were low to modest (included in Supplemental material).

HIV status was not associated with episodes being culture-positive or -negative, nor was it associated with Gram-status. There was no association between episode subtype (index, relapse, etc.) and Gram-status or presence of fungal infection. Fungal episodes demonstrated lower odds of medical cure (OR 0.09, 95% CI 0.02–0.39, P = 0.013) when compared with bacterial episodes. Gram-positive bacterial episodes had higher odds of medical cure than Gram-negative episodes (GEE OR 3.19, 95% CI 1.18–8.64, P = 0.022). There was no relationship between polymicrobial episodes and medical cure rate.

There was a significant correlation between year of episode and Gram-status, and a pairwise analysis per year versus 2022 revealed increased odds of Gram-positive infections in 2024 (OR 4.36, 95% CI 1.41–13.49, P = 0.011). Gram-positives comprised a higher proportion in 2024 (85% compared with 63% in 2022).

DISCUSSION

This study provides important data from the Eastern Cape, a unique region of South Africa where a PD-first policy is followed, with restricted haemodialysis access. The study population, while similar to those in other South African studies, is notably different from international cohorts, with younger median age and low rates of diabetic nephropathy. This reflects the rationing criteria adopted by several centres, in which patients with diabetes mellitus over the age of 50 are excluded from KRT programmes, and younger patients with poor diabetes control or extensive target organ damage are less likely to be accepted [19].

The peritonitis rate (0.85 eppy) exceeds the ISPD's guideline of 0.4 eppy. The Peritoneal Dialysis Outcomes and Practice Pattern Study (PDOPPS), a large multinational cohort investigation, reported a median PDP rate of 0.26 eppy [5], with inter-country variation (between 0.23 and 0.47 eppy). By comparison, a systematic review of African PDP literature reported a median PDP rate of 0.57 eppy in the subset of adult series between 2000–2019 [20]. Other South African studies have reported PDP rates higher than international averages, with recent rates ranging from 0.51 to 1.45 eppy [12,21].

While comparable to other South African cohorts, this centre's PDP rate remains significantly higher than inter-

national targets. Furthermore, the presence of a 'peritonitis-prone' group of patients represents an important investigational target. These patients might ordinarily have been transferred to HD but due to severe resource limitations were not considered candidates – forcing continuation with a suboptimal modality. However, even accounting for this subgroup's disproportionate contribution, the rate for the remaining cohort was still above target, at 0.60 eppy.

Culture-negative rates were low (11%) – likely reflecting standardised sampling performed by renal staff. The microbiological profile aligned with international trends, with Gram-positive bacterial predominance (particularly CNS and viridans group streptococci) – organisms classically associated with touch contamination or PD technique errors. In the context of the region's severe drought during the study period, reduced access to clean water may have influenced this. This pattern highlights the need to identify individuals in need of retraining and to review training policy.

HIV status did not affect culture positivity nor Gram-status of bacterial infections, as reported in other South African data. Our study's HIV-positive participants had a relatively high median CD4 count with high rates of viral suppression, which may have contributed to the lack of a clear effect [13]. There was also no difference in rates of medical cure or development of relapse/recurrence, although the number of PWH in this study was small.

Prior studies have identified differences in microbiological profiles, episode types and outcomes, noting that recurrent episodes are more likely than index episodes to be fungal, and that relapse/recurrent episodes carry a higher risk of catheter removal and HD transfer [16]. The medical cure rate in our study (65% of all episodes) was similar to figures from abroad [3]. Medical cure rates in relapse and recurrence episodes were significantly lower than in index and repeat episodes, specifically driven by adverse outcomes in patients with relapses. Common organisms isolated in treatment failure episodes included *S. aureus*, *Pseudomonas* species and fungi.

Episode outcomes varied by organism. Gram-positive bacterial infections had higher odds of medical cure than Gram-negative ones, while fungal peritonitis episodes had significantly lower odds of cure. Our study did not identify a relationship between episode subtype and likelihood of a particular organism being cultured, a finding previously identified in the ANZDATA registry [16]. Fungal episodes were uncommon overall, which may be due to the routine use of anti-fungal prophylaxis with fluconazole during antibiotic use, as per ISPD guidelines [3]. Only one of the six fungal episodes was a recurrent PDP episode, the subtype with which fungal peritonitis is classically associated (following treatment of a prior bacterial episode) [16].

Interpreting these outcome associations is limited as ISPD guidelines recommend early catheter removal in cases of fungal peritonitis and current exit-site infections, with consideration for removal in cases involving certain organisms (*Pseudomonas* species and *S. aureus*) or clinical scenarios (relapsing peritonitis) [3]. Catheter removal (by ISPD definition) precludes 'medical cure' and this, therefore, generates an element of structural bias in the outcome data. Adherence to guidelines may therefore lower episode medical cure rates in such scenarios but potentially preserves long-term membrane viability and technique survival, outcomes that were not captured in this study.

Catheter removal was seldom followed by successful re-establishment of chronic PD during the study period. PDP was the most common primary contributing factor to technique failure (66%). This corresponds with regional and international literature and underscores the importance of prevention and prompt treatment of PDP. It also has important implications in under-resourced centres where HD transfer is not always available. While our study did not examine the precise causes of failure to resume PD in our centre, common reasons in the authors' experience include membrane dysfunction, challenges with surgical catheter insertion access, patient technique burnout/psychological factors or a clinician assessment of poor likelihood of successful future PD, which are similar to those reported in other research [22]. Several of the cases' reasons for catheter removal were factors associated with more severe membrane dysfunction, such as refractory or fungal peritonitis, which may have contributed.

Serum albumin levels were low in subjects who experienced PDP (median 28 g/L). A Chinese study reported a mean serum albumin of 37.4 ± 5.1 g/L at one year post-PD initiation, notably higher than in our population [15]. Lower pre-PD initiation albumin levels have been associated with increased PDP incidence, and lower levels during PD have been associated with higher mortality [15]. The low level in our cohort warrants concern for malnutrition or volume overload.

Antimicrobial sensitivity review revealed low rates of resistance to commonly used empiric antibiotics in cases of PDP. This confirmed the appropriateness of our unit's current empiric antibiotic choice (listed in Supplementary material).

This study's limitations include its retrospective nature, single-centre focus and relatively small size. As the cohort was not restricted to incident PD, the duration of long-term technique survival could not be accurately assessed. Although exploring the relationship between albumin and PDP was not a primary aim of this study, the absence of pre-KRT albumin levels or albumin levels in a non-PDP control group limits the interpretation of a causal rela-

tionship. During the study period, South Africa experienced recurrent problems with electricity supply; these resultant interruptions required many APD-assigned patients to perform manual exchanges. Consequently, comparisons between CAPD and APD modalities could not be reliably investigated.

Our study's strengths include comprehensive episode assessment and use of a robust statistical framework (GEE regression), with findings relevant to similar national PD programmes. A key priority for intervention is in reducing rates of Gram-positive infections. In addition to clinical factors, the psychological impact of chronic PD (especially in patients for whom PD may not have been their preferred modality) should be considered and proactively managed. In particular, the 'peritonitis-prone' group should be evaluated for characteristics that could predict membership in this high-risk group.

Future research will be required to describe long-term technique survival in incident PD cases. Repeated assessment of microbiological profiles will be required to determine if drought resolution affects relative peritonitis rates or organism proportions.

CONCLUSION

PDP is common in our 'PD-first' Eastern Cape centre and occurs at rates higher than guidelines targets. The microbiological profile of episodes is consistent with South African and international data, characterised by Gram-positive predominance, few fungal episodes and low rates of antimicrobial resistance. Relapse episodes and fungal episodes have low chances of medical cure. PDP frequently results in long-term PD technique failure, necessitating modality switch where resources allow. This study has highlighted the importance of PDP prevention and management in ensuring PD technique survival, especially in a resource-limited setting.

Conflict of interest

The authors have no conflicts of interest to declare.

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SUPPLEMENTARY MATERIAL

ISPD PD peritonitis-related definitions [3]:

Peritoneal dialysis-associated peritonitis diagnosis requires two of:

1) clinical features consistent with peritonitis, that is, abdominal pain and/or cloudy dialysis effluent;
2) dialysis effluent white cell count >100 cells/μL or >0.1x10^9/L (after a dwell time of at least 2 h), with >50% polymorphonuclear leukocytes (PMN);
3) positive dialysis effluent culture.

Culture-negative peritonitis: criteria 1 and 2 present with a negative dialysis effluent culture.

Catheter-related peritonitis: peritonitis that occurs in temporal conjunction (within 3 months) with a catheter infection (either exit-site or tunnel) with the same organism at the exit-site or from a tunnel collection and in the effluent or one site sterile in the context of antibiotic exposure.

Enteric peritonitis: peritonitis arising from an intestinal source involving processes such as inflammation, perforation or ischaemia of intra-abdominal organs.

PD catheter insertion-related peritonitis: episode of peritonitis that occurs within 30 days of PD catheter insertion.

PD-related peritonitis: time at risk starts from the day of PD commencement (i.e. first day of PD training or PD treatment in hospital or at home with the intention of continuing PD long-term, whichever occurs first) and continues while a patient remains on PD regardless of the setting (home, hospital, residential aged care facility, etc.) or who is performing the PD exchanges.

PDP episode outcomes definitions:

Medical cure: Complete resolution of peritonitis together with none of the following complications: relapse/ recurrent peritonitis, catheter removal, transfer to haemodialysis for 30 days, or death.

Refractory: Peritonitis episode with persistently cloudy bags or persistent dialysis effluent leukocyte count >0.1 x10^9/L after 5 days of appropriate antibiotic therapy.

Recurrent: Peritonitis episode that occurs within 4 weeks of completion of therapy of a prior episode but with a different organism.

Relapsing: Peritonitis episode that occurs within 4 weeks of completion of therapy of a prior episode with the same organism or one sterile (culture negative) episode (i.e. specific organism followed by the same organism, culture negative followed by a specific organism, or specific organism followed by culture negative).

Repeat: Peritonitis episode that occurs more than 4 weeks after completion of therapy of a prior episode with the same organism.

Peritonitis-associated catheter removal: Removal of PD catheter as part of the treatment of an active peritonitis episode.

Peritonitis-associated haemodialysis transfer: Transfer from PD to haemodialysis for any period of time as part of the treatment for a peritonitis episode.

Peritonitis-associated death: Death occurring within 30 days of peritonitis onset or death during hospitalisation due to peritonitis.

Additional definitions used in this article

Typical peritonitis episode: a PDP episode that was neither enteric nor catheter associated.

Index peritonitis episode: a PDP episode that did not meet criteria for relapse, recurrence or repeat (as per ISPD definitions listed above).

Peritonitis-prone patients: those experiencing three or more episodes of PDP during the study period.

PD technique failure: transfer to HD for >30 days or PDP-related death.

Livingstone Hospital Renal Unit initial antibiotic protocol for PDP

Initial antibiotic therapy:

Intraperitoneal vancomycin 2 g and ceftazidime 1–1.5 g.

Antimicrobial therapy thereafter tailored to culture results.

All patients receive alternate day fluconazole 200 mg orally for one month for fungal peritonitis prophylaxis.

SUPPLEMENTAL TABLE

Supplemental Table 1. Microbiological associations with intra-class correlation coefficients.

Correlate	GEE odds ratio	GEE	Non-clustered	ICC
	(95% CI)	P value	P value [h]	P value [i]
Culture positive	(n=117; clusters=61[a])	–	–	–
HIV-positive [b]	0.39 (0.14–1.07)	0.069	0.222	0.028
Medical cure	1.17 (0.37–3.65)	0.792	0.767	0.014
Episode year [c]	–	0.097 [d]	0.052	-0.010
Subtype [e]	1.42 (0.16–12.47)	0.749	1.000	0.019
Bacterial infection	(n=104; clusters=56)	–	–	–
HIV-positive [b,f]	–	–	1.000	-0.021
Medical cure	8.68 (0.87–86.73)	0.066	0.048	-0.048
Episode year	–	0.895 [d]	0.179	-0.038
Polymicrobial	(n=104; clusters=56)	–	–	–
HIV-positive [b]	1.40 (0.30–6.57)	0.670	0.658	0.026
Medical cure	0.91 (0.33–2.54)	0.862	1.000	0.016
Episode year	–	0.880 [d]	0.846	0.019
Fungal infection	(n=104; clusters=56)	–	–	–
HIV-positive [b,g]	–	–	0.590	0.162
Medical cure	0.09 (0.02–0.39)	0.013	0.018	0.214
Subtype	2.31 (0.32–16.82)	0.410	0.498	0.162
Gram-positive	(n=95; clusters=52)	–	–	–
HIV-positive [b]	0.31 (0.08–1.16)	0.082	0.051	0.250
Medical cure	3.19 (1.18–8.64)	0.022	0.005	0.228
Episode year	–	0.018 [d]	0.017	0.289
Subtype	0.52 (0.18–1.47)	0.215	0.474	0.286

GEE, Generalised estimating equations framework; CI, confidence interval; ICC, intra-class correlation coefficient; P: rho value.
[a] One cluster = one participant.
[b] Reference = HIV negative.
[c] Episode year was compared (2022, 2023, 2024).
[d] Wald test used to calculate P value.
[e] Subtype was grouped as 'Index and repeat' versus 'Recurrent and relapse'.
[f] There were no non-bacterial episodes in HIV-positive patients for calculation.
[g] No fungal cases in HIV-positive patients for calculation.
[h] Non-clustered comparisons were performed using χ^2 test or Fisher's exact test (in categories with small samples).
[i] ICC values close to zero indicate minimal intra-class correlation; negative values suggest negligible correlation.