ORIGINAL ARTICLE

Excessive risk and poor outcome of hospital-acquired peritoneal dialysis-related peritonitis

Cheuk-Chun Szeto1,2, Jack Kit-Chung Ng1, Winston Wing-Shing Fung1, Gordon Chun-Kau Chan1, Phyllis Mei-Shan Cheng1,2, Man-Ching Law1, Wing-Fai Pang1, Philip Kam-Tao Li1, Chi-Bon Leung1 and Kai-Ming Chow1

1Carol and Richard Yu Peritoneal Dialysis Research Centre, Departments of Medicine and Therapeutics, Prince of Wales Hospital, Hong Kong, China and 2Li Ka Shing Institute of Health Sciences, Faculty of Medicine, Chinese University of Hong Kong, Shatin, Hong Kong, China

Correspondence to: Cheuk-Chun Szeto; E-mail: ccszeto@cuhk.edu.hk

ABSTRACT

Background. Peritoneal dialysis (PD) is a home-based renal replacement therapy. Since hospital staff are not often familiar with PD and its complications, PD patients may have an excess risk of developing PD-related peritonitis during hospital admission for unrelated reasons, and the outcome may be affected.

Methods. We reviewed 371 episodes of hospital-acquired PD peritonitis in our center from 2000 to 2019. Their clinical characteristics and outcomes were compared with 825 episodes that required hospital admission and 1964 episodes that were treated as outpatient.

Results. Hospitalized PD patients had a significantly higher risk of developing peritonitis than outpatients [incident rate ratio 4.41 (95% confidence interval 3.95–4.91)]. Hospital-acquired peritonitis episodes were more commonly culture negative. Bacterial isolates from the hospital-acquired episodes were more likely resistant to ceftazidime (P < .0001) than the other groups. The primary response rate, complete cure rate and overall mortality of the hospital-acquired episodes were 66.6%, 62.0%, and 23.2%, respectively, all worse than episodes that developed outside the hospital (P < .0001 for all).

Conclusion. PD patients admitted to the hospital had a 4-fold increase in the risk of developing peritonitis. Hospital-acquired peritonitis episodes were more likely culture negative and resistant to antibiotics. They also had a lower primary response rate, a lower complete cure rate and higher mortality than episodes that developed outside the hospital.

LAY SUMMARY

Peritoneal dialysis (PD) is a home-based therapy. We hypothesize that PD patients have an excess risk of developing PD-related peritonitis during hospital admission for unrelated reasons and the outcome may be affected. We reviewed 371 episodes of hospital-acquired PD peritonitis. Their clinical characteristics and outcomes were compared with 825 episodes that required hospital admission and 1964 episodes treated as outpatient. We found that hospitalized PD patients had a 4-fold higher risk of developing peritonitis than outpatients. Hospital-acquired peritonitis episodes were more likely culture negative and the bacterial isolates were more likely resistant to ceftazidime. The primary response rate, complete cure rate and overall mortality of the hospital-acquired episodes were all significantly worse than the others. Our result highlights the importance of staff education on early identification and treatment of
PD-related peritonitis. Clinicians should be mindful of antibiotic resistance in hospital-acquired PD-related peritonitis and consider early adjustment of treatment according to the clinical response.

GRAPHICAL ABSTRACT

Peritoneal dialysis (PD) is a home-based therapy. Since hospital staff are not often familiar with PD, patients may have an excess risk of developing PD-related peritonitis during hospital admission.

INTRODUCTION

Peritoneal dialysis (PD) is a widely used method of providing home-based renal replacement therapy [1, 2]. In the era of the coronavirus disease 2019 pandemic, with social distancing and the pressing need of avoiding frequent healthcare attendance, PD has the distinct advantages of allowing home-based self-care, having simple equipment and minimizing staff costs [3, 4].

Traditionally, PD-related peritonitis is the Achilles heel of PD [5, 6] and is a major cause of technique failure that necessitates conversion to long-term hemodialysis (HD) [2, 7]. Following the publication of treatment guidelines for PD-related peritonitis in the past decade [8, 9], the management of PD-related peritonitis has gradually become standardized. A key element of these guidelines is that PD-related peritonitis should be treated, preferably with intraperitoneal antibiotics, and unless the patient has evidence of severe sepsis or other concomitant problems, hospital admission is usually not necessary [8, 9].

Ironically, as a home-based therapy, many hospital clinicians and nurses are not familiar with the PD procedure or the recognition and management of PD-related peritonitis [10–12]. PD patients may therefore have a particularly high risk of developing peritonitis after hospital admission for unrelated reasons, and the outcome of PD-related peritonitis episodes that develop during a hospital stay may be adversely affected because of the potential delay in recognition or treatment. However, there are few published data on the incidence or clinical outcome of PD-related peritonitis that developed during a hospital stay. In this study we described the incidence, microbiological cause and outcomes of PD-related peritonitis episodes that developed during hospitalization for unrelated reasons.

MATERIALS AND METHODS

The study was approved by the Joint Chinese University of Hong Kong–New Territories East Cluster Clinical Research Ethics Committee (reference CREC-2020.224). All study procedures were in compliance with the Declaration of Helsinki.

Case selection

This was a retrospective study. We reviewed the clinical records of all episodes of PD-related peritonitis in our center between January 2000 and December 2019. The PD-related peritonitis episodes were diagnosed by the standard criteria, based on at least two of the following [9]: abdominal pain or cloudy PD effluent, leukocytosis in the PD effluent (white cell count >100/ml) and positive Gram stain or culture from the PD effluent. The peritonitis episodes were then linked to our territory-wide electronic
wards or nonmedical wards, they were managed by the on-site staff. For patients admitted to general medical wards and nonmedical wards also received basic training in the principles and procedures of PD.

Calculation of peritonitis rate

The peritonitis rate of the hospital-acquired group was calculated by the number of peritonitis episodes divided by the total duration of hospitalization for the entire PD population during the study period. The peritonitis rate of episodes that developed outside the hospital (i.e. including both the need hospital admission group and the outpatient group) was calculated by the number of corresponding peritonitis episodes divided by the total duration of follow-up, excluding the period of hospital stay. Both rates were expressed as the number of peritonitis episodes per patient-year as recommended by the international guidelines [9].

Microbiological investigations

After the initial clinical assessment, three rapid hourly dialysis cycles were performed. PD effluent was sent for cell count, differential count, culture and sensitivity testing as described previously [9, 14]. The bacterial culture of PD effluent was performed using BacTAlert bottles (Organon Teknika, Durham, NC, USA). Species identification was performed with the API 20E identification system (BioMerieux, Marcy l’Etoile, France). Isolation and identification were performed by standard techniques. Antibiotic sensitivity was determined by the comparative disc diffusion method according to the National Committee for Clinical Laboratory Standards [15].

Clinical management

In general, peritonitis episodes were treated with the standard antibiotic protocol with intraperitoneal administration of cefazolin and ceftazidime, with their dosages according to the contemporary guidelines of the International Society for Peritoneal Dialysis (ISPD) [9, 16]. Episodes were generally treated on an outpatient basis and patients were admitted to the hospital only if they had features of severe sepsis, hemodynamic instability or difficulty in continuing PD at home during peritonitis. For patients admitted to general medical wards or nonmedical wards, they were managed by the on-site ward staff and renal nurses were available for troubleshooting. Intravenous antibiotics were used when there was evidence of clinical sepsis. Antibiotic regimens for individual patients were modified according to the clinical response and bacterial culture results. All patients received oral nystatin for the secondary prevention of fungal peritonitis. The duration of antibiotic treatment followed the recommendation of the contemporary guideline [9]. PD catheters were removed and patients were put on temporary HD when peritonitis failed to resolve with antibiotics. PD catheter reinsertion was attempted as much as possible. As described in our previous study [17], patients were only switched to long-term HD when attempts at PD catheter reinsertion failed because of peritoneal adhesion or when there was ultrafiltration failure due to peritoneal sclerosis.

Outcome measures

All patients were followed for 6 months after completion of antibiotic therapy. The primary response was defined as resolution of abdominal pain, clearing of dialysate and PD effluent neutrophil count <100/μl on day 5 with antibiotics alone. Relapsing peritonitis was defined as an episode that occurs within 4 weeks of completion of therapy of a prior episode with the same organism (or culture negative in the second episode) [9]. Recurrent peritonitis was defined as an episode that occurs within 4 weeks of completion of therapy of a prior episode but with a different organism [9]. Complete cure was defined as complete resolution of peritonitis by antibiotics alone without relapsing or recurrent episodes within 4 weeks of completion of therapy. Repeat peritonitis was defined as an episode that occurs >4 weeks after completion of therapy of a prior episode with the same organism [9]. Secondary outcomes included the duration of hospital stay, catheter removal, conversion to long-term HD, death due to peritonitis, death due to other causes and all-cause mortality within 30 days of completing antibiotic therapy.

Statistical analysis

Statistical analysis was performed using SPSS Statistics version 24.0 (IBM, Armonk, NY, USA). Descriptive data are represented as mean ± standard deviation (SD). Data between groups were compared by the chi-squared test, Student’s t-test or one-way analysis of variance as appropriate. The relative risk of peritonitis during hospitalization was described as an incidence rate ratio (IRR) and a 95% confidence interval (CI). Since the data on the duration of hospital stay are highly skewed, they are described as median (interquartile range (IQR)) and compared by the Mann–Whitney U-test between groups. For the hospital-acquired group, patients were further subdivided into two groups according to the onset time of the peritonitis episode after hospital admission. P-values <0.05 are considered significant. All probabilities are two-tailed.

RESULTS

From 2000 to 2019, we reviewed 3160 episodes of peritonitis from 1193 patients; 371 episodes (11.7%) were classified as the hospital-acquired group, 825 episodes (26.1%) as the need hospital admission group and 1964 episodes (62.2%) as the outpatient group. The overall peritonitis rate was 0.41 episodes/patient-year. For the periods 2000–14, 2015–9, 2010–4 and 2015–9, the peritonitis rates were 0.47, 0.42, 0.33 and 0.46 episodes/patient-year, respectively. During the study period, our PD cohort had a
total hospital stay of 81 578 days; and the incidence of PD-related peritonitis during the hospital stay was 1.21 episodes/patient-year. During the same period there were 2816 episodes of PD-related peritonitis that developed outside the hospital in 91 330 patient-months of follow-up; the incidence of PD-related peritonitis that developed outside the hospital was therefore 0.37 episodes/patient-year. In other words, hospitalized PD patients had a substantially higher risk of developing peritonitis episodes than outpatients [IRR 4.41 (95% CI 3.95–4.91)].

The baseline clinical characteristics of the three groups are summarized in Table 1. In essence, there was no significant difference in the baseline clinical characteristics between the groups except the hospital-acquired group was more likely to receive automated PD and had a shorter vintage of dialysis than the other two groups. For the hospital-acquired group, the distribution of peritonitis onset after hospital admission is summarized in Fig. 1; the median time between hospital admission and the onset of peritonitis was 2 days (IQR 1–5). Their admission diagnoses are summarized in Fig. 2. Notably, 177 episodes (47.7%) were admitted for cardiovascular disease. In the hospital-acquired group, 335 (90.3%) developed in the general medical ward, 30 (8.1%) in nonmedical wards and only 6 (1.6%) in the renal ward. For the needed hospital admission group, 705 (85.5%) were admitted to general medical wards, 112 (13.6%) to the renal ward and 8 (1.0%) to nonmedical wards.

Causative organisms and antibiotic treatment

There was a significant difference in the distribution of the causative organisms between patient groups, as summarized in Table 2 (overall chi-squared test; P = .0001). Notably, episodes of the hospital-acquired group were more commonly culture negative and less commonly caused by Streptococcus species, while episodes of the need hospital admission group were more commonly caused by Pseudomonas species or polymicrobial. In the hospital-acquired group, there was a modest but insignificant difference in the distribution of causative organisms between episodes that developed within 2 days of hospital admission and those that developed after 2 days (chi-squared test; P = .1). Notably, episodes that developed after 2 days (chi-squared test; P = .003, respectively) within the hospital-acquired group, bacterial isolates were more likely extended-spectrum beta-lactamase (ESBL) positive and resistant to cotrimoxazole when the onset of peritonitis that developed outside the hospital was therefore 0.37 episodes/patient-year. In other words, hospitalized PD patients had a substantially higher risk of developing peritonitis episodes than outpatients [IRR 4.41 (95% CI 3.95–4.91)].

The clinical outcome is summarized and compared between groups in Table 4. The overall mortality of the hospital-acquired group was 23.2%. In this group, the mortality was attributed directly to peritonitis in 38 patients (10.3%); other causes of death included nonperitonitis infections (13 cases), cardiovascular diseases (11 cases), cerebrovascular disease (4 cases), termination of dialysis (10 cases), malignancy (3 cases) and...
other specific causes (7 cases). As compared with the other two groups, the hospital-acquired group had a lower primary response rate and complete cure rate ($P < .0001$ for both), mostly because they had higher mortality ($P < .0001$), both directly because of peritonitis and for other causes. In contrast, the hospital-acquired group did not have a higher risk of catheter removal or developing relapsing, recurrent or repeat peritonitis episodes.

For the hospital-acquired group, episodes that developed after 2 days of hospitalization had a significantly lower complete cure rate and higher mortality than episodes that developed within the first 2 days of hospitalization ($P < .0001$ for both), but their rates of primary response and catheter removal were not significantly different. Specifically, patients who developed peritonitis after 2 days of hospitalization had a higher risk of dying from nonperitonitis causes than those who developed peritonitis within the first 2 days of hospitalization ($P < .0001$), but their risk of dying from peritonitis was similar.

The hospital-acquired group had a significantly longer hospital stay than the need hospital admission group [10 days (IQR 5–22) versus 4 days (IQR 2–9); Mann–Whitney U-test; $P < .0001$]. During the same period, the median duration of hospital stay for other causes in our PD population was 4 days (IQR 2–7).

**DISCUSSION**

In this study we found that when PD patients were admitted to the hospital they had a 4-fold increase in the risk of developing peritonitis. Hospital-acquired peritonitis episodes were more likely culture negative, with bacterial isolates more likely resistant to ceftazidime and, when the hospital stay was prolonged, ESBL positive. Hospital-acquired peritonitis episodes also had a lower primary response rate, a lower complete cure rate, and higher mortality, both due to peritonitis directly and to other causes.

The overall peritonitis rate of our present report is similar to that of the Peritoneal Dialysis Outcomes and Practice Patterns Study [18], but our result highlights the commonly observed but underrecognized risk of PD-related peritonitis during hospital...
admission. Traditional risk factors of PD-related peritonitis include heart failure, cardiovascular disease, diabetes, poor residual renal function, malnutrition, overweight, smoking, immunosuppression and low socioeconomic status [19–23]. Among the 35 publications on the risk factors of PD-related peritonitis reviewed by Kerschbaum et al. [19], hospital admission was never explored as a risk factor, and the reason for the excessive risk of peritonitis during hospitalization is not entirely clear. On the one hand, patients admitted for cardiovascular disease, heart failure or other concurrent infections have a higher risk of peritonitis because these are traditional risk factors [19–23]. Similarly, PD patients who are malnourished or have a low socioeconomic status, which are also risk factors for peritonitis, are more likely to require hospital admission [19]. On the other hand, hospital staff may not be familiar with the requirement and procedures of PD, which may also increase the risk of peritonitis. To support this notion we found that hospital-acquired peritonitis was particularly common in patients who received machine-assisted PD, probably because the cycler PD machine was not available in our wards. Most of the patients were temporarily switched to continuous ambulatory PD during a hospital stay, and a sudden switch in modality may add to the risk of developing peritonitis. Although we did not find an excessive risk of peritonitis episodes caused by Staphylococcus aureus or coagulase-negative Staphylococcus species, which suggested that touch contamination may not be the major cause of hospital-acquired peritonitis, the proportion of culture-negative cases was substantially higher in the hospital-acquired group. We believe that a higher risk of touch contamination in the hospital-acquired group could not be excluded, just that the culture yield was decreased in the hospital-acquired group. We believe that a higher risk of touch contamination in the hospital-acquired group could not be excluded, just that the culture yield was decreased because of practical problems of handling PD effluent samples in the ward and recent antibiotic therapy, which are major predicting factors of culture-negative peritonitis, as revealed in our previous study [24]. Unfortunately, we do not have complete data on the prevalence of antibiotic prescriptions prior to the onset of peritonitis episodes. As described in our previous study [24], recent antibiotic usage is common in our PD patients who developed peritonitis episodes outside the hospital.

In this study we found that bacterial isolates from hospital-acquired peritonitis episodes were more likely resistant to antibiotics than those from outpatient episodes. As revealed in Table 3, the pattern of antibiotic resistance is different between hospital-acquired and outpatient peritonitis. The bacterial isolates from hospital-acquired peritonitis episodes were more likely resistant to antibiotics than those from outpatient episodes. As revealed in Table 3, the pattern of antibiotic resistance is different between hospital-acquired and outpatient peritonitis. The bacterial isolates from hospital-acquired peritonitis episodes were more likely resistant to antibiotics than those from outpatient episodes.
ceftazidine and the absolute incidences of resistance were 56% and 40%, respectively. In contrast, the incidence of resistance to vancomycin and gentamicin remained reasonable. The result indicates that empirical treatment with ceftazolin plus cef-
tazidine, which is one of the regimens recommended by the ISPD [16] and the protocol adopted by our center during the study period, may not be suitable for hospital-acquired peritonitis episodes. Similarly, ESBL-positive organisms became common in peritonitis episodes that developed after the patient was hospitalized for >2 days. Although it may not be appropriate to cover ESBL-positive organisms for all patients in this group, clinicians should consider the possibility in case the response to em-
pirical ceftazidine or gentamicin is not satisfactory.

Two findings of our present study suggest that enhanced training of hospital staff would be valuable: hospitalized PD pa-
tients had a 4-fold increase in the risk of developing peritonitis and the episodes were more likely to be culture negative. How-
ever, there is no direct evidence that either of the problems was due to a lack of staff training; the benefit and optimal method of staff training would require further study. Since medical and nursing staff working outside the renal ward are unlikely to en-
counter PD patients frequently, it seems that intensive training would have little value. We believe a set of well-conceived and readily available protocols for the care of hospitalized PD pa-
tients and proper handling of PD effluent in case there is a peri-
tonitis episode would be a pragmatic approach. We also found that the hospital-acquired group had a worse outcome than the other groups. It is possible that the peritonitis episodes of the hospital-acquired group were recognized and treated later than the others. Although our general clinical impression does not support this hypothesis, we do not have solid data on their aver-
age time-to-antibiotic therapy to confirm this point. In addition, it would also be interesting to compare the baseline character-
istics of patients who did and did not develop peritonitis during hospitalization so as to identify potentially reversible risk fac-
tors for this complication.

In this study, most of the hospital-acquired episodes were diagnosed within 2 days of hospital admission. Although clear PD effluent was documented at the time of hospital admission, it remained possible that the peritonitis inception was prior to admission but simply recognized later. On the other hand, the difference in the distribution of the causative organ-
ism between the early hospital-acquired episodes and outpa-
tient ones, and the similarity between early and late hospital-
acquired episodes, would suggest they are distinct entities.

An important limitation of our study was being a retro-
spective analysis of patients from 2000 to 2019. The trend of peritonitis rates, as well as the prevention and management of peritonitis, might have changed during this period [25–27]. In our center, the patient education program, laboratory method of bacterial culture and initial empirical antibiotic regimen remained unchanged, but the duration of antibiotic therapy, use of adjuvant therapy and time of catheter removal for refractory peritonitis were gradually modified according to the contemporary ISPD guidelines [8, 9, 16]. In 2015 we had a one-off reinforcement program on PD for all nurses in our general medical and nonmedical wards, but that did not seem to reduce the subsequent peritonitis rate (see the Results section).

Being a single-center study, one should be cautious when ex-
trapolating our results to other centers. It is well known that cen-
ter characteristics affect peritonitis rates [28–31]. Because of the PD-first policy [32], ~80% of our dialysis population received PD, and 15% of them received helper-assisted PD (by a family mem-
er, domestic maid or home staff) [33]. Our center has a long-
established PD program, including standardized education and training programs for our PD patients and their caregivers. All of our renal nurses received standardized training in PD organized by the Hong Kong Hospital Authority, and most of the nurses in the general medical and nonmedical wards received basic training in performing PD exchanges. We believe all these factors con-
tribute to the excellent clinical outcome of our PD patients, but they are not readily available to many PD units worldwide.

There are a number of inadequacies in our present study. First, this is a single-center study from a tertiary referral cen-
ter in Hong Kong, and our results may not be readily extrapo-
lated to centers that have less experience in PD. With a well-
established PD-first policy [34, 35], the medical and nursing staff of our center—even those working outside the renal specialty ward—generally have some experience in taking care of PD pa-
tients, which is unlikely to be the case in other parts of the
world. Second, there was likely bias in our estimation of the
IRR of hospital-acquired peritonitis, because patients who devel-
oped peritonitis episodes during their hospital stay would have
to stay longer in the hospital, and that period of extra hospital
stay was counted as part of the person-time at risk. Similarly, for
patients who were admitted for peritonitis episodes that devel-
oped outside the hospital, their hospital stay was also counted.
In essence, we believe the IRR of hospital-acquired peritonitis
that we described was likely an underestimate.

Taken together, our result highlights the importance of
hospital staff education so that PD-related peritonitis in hospi-
talized PD patients could be identified and treated in a timely
manner. Clinicians should also be mindful of the possibility of
antibiotic resistance in hospital-acquired PD-related peritonitis
and consider adjusting the treatment regimen according to the
clinical response in a timely manner.

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DATA AVAILABILITY STATEMENT

The data underlying this article will be shared on reasonable re-
quest to the corresponding author.

CONFLICT OF INTEREST STATEMENT

Cheuk-Chun Szeto is Member of the CKJ Editorial Board. The
other authors declare no conflicts of interest. The results
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REFERENCES

1. Mehrotra R, Devuyst O, Davies SJ. et al. The current state of
peritoneal dialysis. J Am Soc Nephrol 2016;27:3238–52.
2. Ho YW, Chau KF, Choy BY et al. Hong Kong Renal Registry
Report 2012. Hong Kong J Nephrol 2013;15:28–43.
3. Cozzolino M, Conte F, Zuppulo F et al. COVID-19 pandemic
era: is it time to promote home dialysis and peritoneal dialy-
sis? Clin Kidney J 2021;14:16–13.
4. Alfano G, Fontana F, Ferrari A et al. Peritoneal dialysis in the
time of coronavirus disease 2019. Clin Kidney J 2020;13:265–8.
5. MacTier R. Peritonitis is still the Achilles’ heel of peritoneal
dialysis. Perit Dial Int 2009;29:262–6.
6. Szeto CC, Li PK. Peritoneal dialysis-associated peritonitis.
Clin J Am Soc Nephrol 2019;14:1100–5.
7. Mujais S, Story K. Peritoneal dialysis in the US: evalua-
tion of outcomes in contemporary cohorts. Kidney Int, 2006;70(Suppl 103):S21–6.
8. Li PK, Szeto CC, Piraino B et al. Peritoneal dialysis-related
infections recommendations: 2010 update. Perit Dial Int
2010;30:393–423.
9. Li PK, Szeto CC, Piraino B et al. ISPD peritonitis recom-
mendations: 2016 update on prevention and treatment. Perit Dial Int 2016;36:481–508.
10. Muthucumaran K, Howson P, Crawford D et al. The relation-
ship between presentation and the time of initial adminis-
tration of antibiotics with outcomes of peritonitis in peri-
toneal dialysis patients: the PROMPT study. Kidney Int Rep
2016;1:65–72.
11. Al Sahlawi M, Bargman JM, Perl J. Peritoneal dialysis-
associated peritonitis: suggestions for management and
mistakes to avoid. Kidney Med 2020;2:467–75.
12. Szeto CC, Lo WK, Li PK. Clinical practice guidelines for the
provision of renal service in Hong Kong: peritoneal dialysis.
Nephrology 2019;24:27–40.
13. Szeto CC, Li PK, Johnson DW et al. ISPD catheter-related
infections recommendations: 2017 update. Perit Dial Int
2017;37:141–54.
14. Szeto CC, Ng JK, Fung WW et al. Extended antibiotic ther-
apy for the prevention of relapsing and recurrent periton-
itis in PD patients: a randomized control trial. Clin Kidney J
2021;14:991–7.
15. National Committee for Clinical Laboratory Standards. Per-
formance Standards for Antimicrobial Susceptibility Testing, 9th
Informational Supplement. NCCLS Document M100-S9. Vil-
lanova, PA: National Committee for Clinical Laboratory
Standards, 1999.
16. Li PK, Chow KM, Cho Y et al. ISPD peritonitis guideline rec-
ommendations: 2022 update on prevention and treatment.
Perit Dial Int 2022;42:110–53.
17. Szeto CC, Chow KM, Wong TY et al. Feasibility of resuming
peritoneal dialysis after severe peritonitis and Tenckhoff
catheter removal. J Am Soc Nephrol 2002;13:1040–5.
18. Perl J, Fuller DS, Bieber BA 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;76:42–53.
19. Kerschbaum J, König P, Rudnicki M. Risk factors associ-
ated with peritoneal-dialysis-related peritonitis. Int J Nephrol
2012;483250.
20. Chow KM, Szeto CC, Leung CB et al. Impact of social fac-
tors on patients on peritoneal dialysis. Nephrol Dial Trans-
plant 2005;20:2504–10.
21. Chow KM, Szeto CC, Leung CB et al. A risk analysis of contin-
uous ambulatory peritoneal dialysis-related peritonitis. Perit
Dial Int 2005;25:374–9.
22. Kotsanas D, Polkinghorne KR, Korman TM et al. Risk factors
for peritoneal dialysis-related peritonitis: can we reduce the incidence and improve patient selection? Nephrology 2007;12:239–45.
23. Oo TN, Roberts TL, Collins AJ. A comparison of peritonitis
rates from the United States Renal Data System database:
CAPD versus continuous cycling peritoneal dialysis pa-
patients. Am J Kidney Dis 2005;45:372–80.
24. Szeto CC, Wong TY, Chow KM et al. The clinical course of
culture-negative peritonitis complicating peritoneal dialy-
sis. Am J Kidney Dis 2005;42:567–74.
25. Htay H, Cho Y, Pascoe EM et al. Multicenter registry analy-
sis of center characteristics associated with technique fail-
ure in patients on incident peritoneal dialysis. Clin J Am Soc
Nephrol 2017;12:1090–9.
26. Ozisik L, Ozdemir FN, Tanrivor MD. The changing trends of
peritoneal dialysis related peritonitis and novel risk factors.
Ren Fail 2015;37:1027–32.
27. Boyer A, Lanot A, Lambie M et al. Trends in peritoneal dial-
ysis technique survival, death, and transfer to hemodialy-
sis: a decade of data from the RDPLF. Am J Nephrol 2021;52:
318–27.
28. Brown MC, Simpson K, Kerssens JJ et al. Peritoneal dialysis-associated peritonitis rates and outcomes in a national cohort are not improving in the post-millennium (2000–2007). *Perit Dial Int* 2011;31:639–50.

29. Nadeau-Fredette AC, Johnson DW, Hawley CM et al. Center-specific factors associated with peritonitis risk—a multicenter registry analysis. *Perit Dial Int* 2016;36:509–18.

30. Evans D, Lobbedez T, Verger C et al. Would increasing centre volumes improve patient outcomes in peritoneal dialysis? A registry-based cohort and Monte Carlo simulation study. *BMJ Open* 2013;3:e003092.

31. Lobbedez T, Verger C, Ryckelynck JP et al. Is assisted peritoneal dialysis associated with technique survival when competing events are considered? *Clin J Am Soc Nephrol* 2012;7:612–8.

32. Li PK, Lu W, Mak SK et al. Peritoneal dialysis first policy in Hong Kong for 35 years: global impact. *Nephrology (Carlton)* 2022; doi: 10.1111/nep.14042.

33. Ng JK, Chan GC, Chow KM et al. Helper-assisted continuous ambulatory peritoneal dialysis: does the choice of helper matter? *Perit Dial Int* 2020;40:34–40.

34. Li PK, Chow KM. Peritoneal dialysis-first policy made successful: perspectives and actions. *Am J Kidney Dis* 2013;62:993–1005.

35. Choy AS, Li PK. Sustainability of the peritoneal dialysis-first policy in Hong Kong. *Blood Purif* 2015;40:320–5.