# *Staphylococcus aureus* Peritonitis Complicates Peritoneal Dialysis: Review of 245 Consecutive Cases

Cheuk-Chun Szeto, Kai-Ming Chow, Bonnie Ching-Ha Kwan, Man-Ching Law, Kwok-Yi Chung, Samuel Yu, Chi-Bon Leung, and Philip Kam-Tao Li

*Department of Medicine & Therapeutics, Prince of Wales Hospital, The Chinese University of Hong Kong, Shatin, Hong Kong, China*

**Peritonitis that is caused by *Staphylococcus aureus* is a serious complication in peritoneal dialysis (PD), but the clinical course of PD-related *S. aureus* peritonitis remains unclear. All of the *S. aureus* peritonitis in a dialysis unit from 1994 to 2005 were reviewed. During this period, 2065 episodes of peritonitis were recorded; 245 (11.9%) episodes in 152 patients were caused by *S. aureus* and 45 (18.4%) episodes were caused by methicillin-resistant *S. aureus* (MRSA). Patients with a history of recent hospitalization had a higher risk for isolation of MRSA than the others (30.6 *versus* 14.2%; $P = 0.004$). The overall primary response rate was 87.8%; the complete cure rate was 74.3%. However, 21 (8.6%) episodes developed relapse and 59 (24.1%) developed repeat *S. aureus* peritonitis. Episodes that were caused by MRSA had a lower primary response rate (64.4 *versus* 93.0%; $P < 0.001$) and complete cure rate (60.0 *versus* 77.5%; $P = 0.023$) than the others. Episodes that were treated initially with vancomycin had better primary response rate than those that were treated with cefazolin (98.0 *versus* 85.2%; $P = 0.001$), but the complete cure rate was similar. Adjuvant rifampicin treatment was associated with a significantly lower risk for relapse or repeat *S. aureus* peritonitis than was treatment without rifampicin (21.4 *versus* 42.8%; $P = 0.004$). In contrast, initial antibiotic regimen (cefazolin *versus* vancomycin) and concomitant exit-site infection did not have any effect on the risk for relapse or repeat peritonitis. *S. aureus* peritonitis is a serious complication of PD. Recent hospitalization is a major risk factor of methicillin resistance in the bacterial isolate. Rifampicin is a valuable adjunct in preventing relapse and repeat *S. aureus* peritonitis after the index episode.**

*Clin J Am Soc Nephrol* 2: 245–251, 2007. doi: 10.2215/CJN.03180906

Peritonitis is a serious complication of peritoneal dialysis (PD) (1–3); it probably is the most important cause of technique failure in PD (2–5). In Hong Kong, >16% of the deaths in patients who are being treated with PD are secondary to peritonitis (6). Similarly, 18% of the infection-related mortality in PD patients is the result of peritonitis in the United States (7).

Gram-positive organisms remain the most common bacteriologic cause of PD-related peritonitis (1,5,8). Although coagulase-negative *Staphylococcus* species accounted for nearly half of all Gram-positive episodes (9,10), *Staphylococcus aureus* peritonitis generally is a more severe form of Gram-positive peritonitis (11,12). *S. aureus* peritonitis occurs predominantly in patients who have a history of *S. aureus* catheter infections. Patients who have *S. aureus* colonization in the nares (13–15), on the skin (16), or at the peritoneal catheter exit site (16–18) are at particular risk for developing *S. aureus* peritonitis. Even one positive nose culture increases the risk for *S. aureus* peritonitis (13,19). Patients with *S. aureus* peritonitis often have severe abdominal pain, require hospitalization, and may require catheter removal for resolution, especially when a concomitant tunnel infection is present (20,21). The outcome of peritonitis that is caused by *S. aureus* is worse than that of other staphylococci (11,12,22), and the risk for recurrent peritonitis is 60% within 6 mo (9).

Current guideline for the management of *S. aureus* peritonitis by the Ad Hoc Advisory Committee on Peritonitis Management recommends single effective antibiotics therapy, for example, cefazolin or vancomycin, for 3 wk (23). However, this recommendation was based largely on small clinical studies (11–13,21,22). The clinical course of PD-related *S. aureus* peritonitis remains unclear. In Hong Kong, PD is the first-line renal replacement therapy for all patients with ESRD (3). Patients are switched to long-term hemodialysis only when they have ultrafiltration failure or peritoneal sclerosis. This policy provides an excellent opportunity for us to examine the clinical feature and therapeutic outcome of *S. aureus* peritonitis in a large unselected group of PD patients.

## Patients and Methods

All episodes of continuous ambulatory PD peritonitis in our unit from 1994 to 2005 were reviewed. The diagnosis of peritonitis was based on at least two of the following (24,25): (*1*) Abdominal pain or cloudy peritoneal dialysis effluent (PDE), (*2*) leukocytosis in PDE (white blood cell count >100/ml), and (*3*) positive Gram stain or culture from PDE. Episodes with peritoneal eosinophilia but negative

*Received September 20, 2006. Accepted November 30, 2006.*

*Published online ahead of print. Publication date available at www.cjasn.org.*

**Address correspondence to:** Dr. Cheuk-Chun Szeto, Department of Medicine & Therapeutics, Prince of Wales Hospital, The Chinese University of Hong Kong, Shatin, Hong Kong, China. Phone: +852-2632-3126; Fax: +852-2637-3852; E-mail: ccszeto@cuhk.edu.hk



ISSN: 1555-9041/202–0245

bacterial culture were excluded. Exit-site infection was diagnosed when there was purulent drainage, with or without erythema, from the exit site (26).

In the 12 yr of study period, 2065 episodes of peritonitis were recorded; 279 (13.5%) episodes were caused by *S aureus*. Thirty-four episodes were excluded from analysis because PDE culture showed mixed bacterial growth. The case records of the remaining 245 episodes in 152 patients were reviewed. The demographic characteristics, underlying medical conditions, previous peritonitis, recent antibiotic therapy, antibiotic regimen for the peritonitis episode, requirement of Tenckhoff catheter removal, and clinical outcome were examined.

### *Microbiological Investigations*

Bacterial culture of PDE was performed by BacTAlert bottles (Organon Teknika Corp., Durham, NC). Species identification was performed by the API 20E identification system (BioMerieux, Marcy l'Etolie, France). Antibiotic sensitivity was determined by the disc-diffusion method according to the National Committee for Clinical Laboratory Standard (27).

### *Clinical Management*

Peritonitis episodes were treated with standard antibiotic protocol of our center at that time, which was changed systemically over time. Initial antibiotics for peritonitis generally were intraperitoneal administration of a third- or fourth-generation cephalosporin, plus or minus intermittent vancomycin every 5 d, or cefazolin as continuous administration plus an aminoglycoside or ceftazidime (5). The dosages of vancomycin and cefazolin followed the contemporary guideline (23). Antibiotic regimens for individual patients were modified when culture results were available. Rifampicin sometimes was added as adjunct therapy, as judged by the individual nephrologist. In our center, nasal swab screening for *S. aureus* carrier was performed in all patients with *S. aureus* peritonitis or exit-site infection. Positive nasal culture of *S. aureus* was treated routinely with mupirocin ointment; adjuvant rifampicin was used for *S. aureus* peritonitis by individual nephrologist decision but independent of the result of nasal swab culture.

In general, patients received effective antibiotic for 21 d. When the initial antibiotic was cefazolin and the PDE did not clear up on day 5, the antibiotic was changed to vancomycin. Primary response was defined as resolution of abdominal pain, clearing of dialysate, and PDE neutrophil count <100/ml on day 10 with antibiotics alone. When the PDE did not clear up on day 10, the Tenckhoff catheter was removed immediately irrespective of the *in vitro* sensitivity of the bacterial strain and effective antibiotic was continued for another 2 wk.

Tenckhoff catheters were removed and patients were put on temporary hemodialysis when peritonitis failed to resolve with antibiotics. Tenckhoff catheter reinsertion was attempted in all cases. In our locality, as described in our previous study (4), patients were switched to long-term hemodialysis only when attempts of Tenckhoff catheter reinsertion failed because of peritoneal adhesion or when there was ultrafiltration failure as a result of peritoneal sclerosis. Relapse peritonitis was defined as an episode that occurred within 4 wk of completion of therapy of a previous episode with the same organism (or culture negative) (23). Recurrent peritonitis was defined as an episode that occurred within 4 wk of completion of therapy of a previous episode but with a different organism (23). Complete cure was defined as complete resolution of peritonitis by antibiotics alone without relapse or recurrence within 4 wk of completion of therapy. Repeat peritonitis was defined as an episode that occurred more than 4 wk after completion of therapy of a previous episode with the same organism (23). All of the patients were followed for at least 3 mo after their treatment was completed.

### *Statistical Analyses*

Statistical analysis was performed by SPSS for Windows software (version 10.0; SPSS, Chicago, IL). All data are expressed in mean ± SD unless otherwise specified. Data were compared by $\chi^2$ test, Fisher exact test, and *t* test as appropriate. Multivariate analysis by logistic regression and backward stepwise analysis was used to test for independent factors that predicted therapeutic response. All baseline demographic and clinical variables, including age, gender, duration of dialysis, underlying renal diagnosis, diabetes status, number of previous peritonitis episode, recent peritonitis episode, recent antibiotic usage, treatment regimen of the episode, and presence of exit-site infection, were included in the model construction. $P < 0.05$ was considered significant. All probabilities were two tailed.

## Results

From 1994 to 2005, 2065 episodes of PD-related peritonitis were recorded in our unit. The overall peritonitis rate was 19.8 patient-months per episode. We reviewed 245 episodes of *S. aureus* peritonitis in 152 patients. The absolute rate of *S. aureus* peritonitis was 0.072 episode per patient-year of treatment. Their demographic and baseline clinical data are summarized in Table 1. All patients had cloudy dialysis effluent. In 20 (8.2%) episodes, there was fever, hypotension, or other feature of systemic sepsis that required hospital admission.

In 60 (24.56%) episodes, there was concomitant exit-site infection; *S. aureus* was isolated in 35 (14.3%) episodes. The bacteriologic cause of exit-site infection is summarized in Table 2. Twelve (4.9%) episodes developed when the patient was hospitalized for other medical reasons. In another 39 (15.9%) episodes, the patient had had hospitalization within 30 d before the onset of *S. aureus* peritonitis. There was a history of antibiotic therapy within 30 d before the onset of *S. aureus* peritonitis in 133 (54.3%) episodes. Antibiotics were given in 36 (14.7%) cases for a recent peritonitis episode by other organisms, in 54 (22.0%) cases for recent exit-site infection, and in 43 (17.6%) cases for unrelated medical reasons. In 19 (7.8%) cases, the patient received two or more antibiotics within 30 d before the onset of *S. aureus* peritonitis.

### *Methicillin-Resistant* S. aureus

Forty-five (18.4%) episodes were caused by methicillin-resistant *S. aureus* (MRSA). In general, MRSA peritonitis was clinically severe and more likely to require hospital admission than were the episodes that were caused by methicillin-sensitive *S. aureus* (MSSA; 17.8 *versus* 6.0%; $P = 0.009$).

We further analyzed the risk factors of isolating methicillin-resistant strains from the patient. Patients with a history of recent hospitalization had a higher risk for isolation of MRSA than did the others (30.6 *versus* 14.2%; $P = 0.004$), but a history of recent antibiotic therapy did not impose a higher risk (17.3 *versus* 19.6%; $P = 0.6$). Patients who developed *S. aureus* peritonitis during hospitalization also had a higher risk for isolation of MRSA than did outpatients (50.0 *versus* 16.7%; $P = 0.004$), but the absolute number of inpatient MRSA peritonitis was small (six of the 45 episodes). Diabetes status, Charlson comor-

*Table 1.* Baseline characteristics of the patients

| Characteristic | Value |
|---|---|
| No. of patients | 152 |
| Gender (M:F) | 81:71 |
| Age (yr) | 52.3 ± 13.5 |
| Duration of dialysis (mo) | 39.3 ± 29.7 |
| Body height (m) | 1.60 ± 0.08 |
| Body weight (kg) | 60.1 ± 11.2 |
| Diagnosis (*n* [%]) | |
| glomerulonephritis | 42 (27.6) |
| diabetes | 38 (25.0) |
| hypertension | 16 (10.5) |
| polycystic | 6 (3.9) |
| obstruction | 9 (5.9) |
| other/unknown | 41 (27.3) |
| Major comorbidity (*n* [%]) | |
| coronary heart disease | 32 (21.1) |
| congestive heart failure | 43 (28.3) |
| peripheral vascular disease | 9 (5.9) |
| cerebrovascular disease | 20 (13.2) |
| dementia | 10 (6.6) |
| chronic pulmonary disease | 1 (0.7) |
| connective tissue disorder | 9 (5.9) |
| peptic ulcer disease | 12 (7.9) |
| mild liver disease | 22 (14.5) |
| diabetes | 9 (5.9) |
| hemiplegia | 20 (13.2) |
| diabetes with end-organ damage | 38 (25.0) |
| any tumor, leukemia, lymphoma | 11 (7.2) |
| moderate or severe liver disease | 2 (1.3) |
| metastatic solid tumour | 0 |
| AIDS | 0 |
| Charlson comorbidity score | 4.7 ± 2.1 |

*Table 2.* Summary of bacterial species that caused exit-site infection

| | |
|---|---|
| No. of cases | 60 |
| Organisms identified (*n*) | |
| *S aureus* | 35[a] |
| Coagulase-negative *Staphylococcus* species | 3 |
| *E. coli* or other *Enterobacteriaceae* | 3 |
| *Pseudomonas* species | 5 |
| Polymicrobial | 6 |
| No growth | 8 |

[a]Four of them were methicillin-resistant *Staphylococcus aureus*.

bidity score, and concomitant exit-site infection did not affect the risk for isolation of MRSA strains (data not shown).

### *Clinical Outcome*

The overall primary response rate was 87.8%; the complete cure rate was 74.3%. Episodes that were caused by MRSA had significantly lower primary response rate (64.4 *versus* 93.0%; $P < 0.001$) and complete cure rate (60.0 *versus* 77.5%; $P = 0.023$) than did the others. The clinical outcome, according to the bacterial isolate's sensitivity to methicillin, is summarized in Figure 1. Twelve (4.9%) patients died during the treatment of peritonitis (see Figure 1). The causes of death were peritonitis *per se* (five patients), nonperitonitis infection (three patients), myocardial infarction (three patients), and stroke (one patient). Another six patients died within 2 mo after completion of treatment; the causes of death were recurrent peritonitis by another organism (three patients), nonperitonitis infection (two patients), and intestinal obstruction (one patient). The overall 2-mo mortality was 7.3%. Tenckhoff catheter removal was needed in 14 (5.7%) episodes; resumption of PD was possible in eight patients after 3 to 4 wk of temporary hemodialysis.

We then analyzed the predicting factor of treatment response. Patients with primary response were significantly younger than those without response (51.6 ± 13.5 *versus* 57.3 ± 13.2 yr; $P = 0.03$), but age had no effect on the complete cure rate. Episodes that were treated initially with vancomycin had a higher primary response rate than did those that were treated with cefazolin (94.0 *versus* 78.8%; $P = 0.001$), but the complete cure rate was similar (76.9 *versus* 73.1%; $P = 0.5$). Even after episodes that were caused by MRSA were excluded, initial treatment with vancomycin had a higher primary response rate than those with cefazolin (98.0 *versus* 85.2%; $P = 0.001$). As compared with episodes that could be treated as outpatient, those that required hospital admission had a lower primary response rate (55.0 *versus* 90.7%; $P < 0.001$) and complete cure rate (50.0 *versus* 76.4%; $P = 0.01$). Patients who developed *S. aureus* peritonitis during hospitalization also had a lower primary response rate than did the others (66.7 *versus* 88.8%; $P = 0.022$), but the complete cure rate was similar. Diabetes status, Charlson comorbidity score, concomitant exit-site infection, recent hospitalization, and recent antibiotic therapy did not affect significantly the primary response rate or complete cure rate (data not shown).

### *Relapse and Repeat* S. aureus *Peritonitis*

Of the 245 episodes, 21 (8.6%) developed relapse and 59 (24.1%) developed repeat *S. aureus* peritonitis. The time frame for development of repeat peritonitis is summarized in Figure 2. In four episodes, the initial bacterial isolate was methicillin sensitive, but the isolate became MRSA during the repeat episode. Contrary to general belief, peritonitis that was caused by MRSA had a slightly lower risk for relapse or repeat *S. aureus* peritonitis than did the episodes that were caused by methicillin-sensitive strains (20.7 *versus* 39.8%; $P = 0.048$). The initial antibiotic regimen (cefazolin *versus* vancomycin) had no significant effect on the risk for relapse or repeat peritonitis (31.7 *versus* 40.9%; $P = 0.15$). Age, diabetes status, Charlson comorbidity score, concomitant exit-site infection, recent hospitalization, and recent antibiotic therapy did not have any effect on the risk for relapse or repeat *S. aureus* peritonitis (data not shown).

The primary response rate was similar between patients with and without adjuvant rifampicin therapy (82.4 *versus* 89.8%;

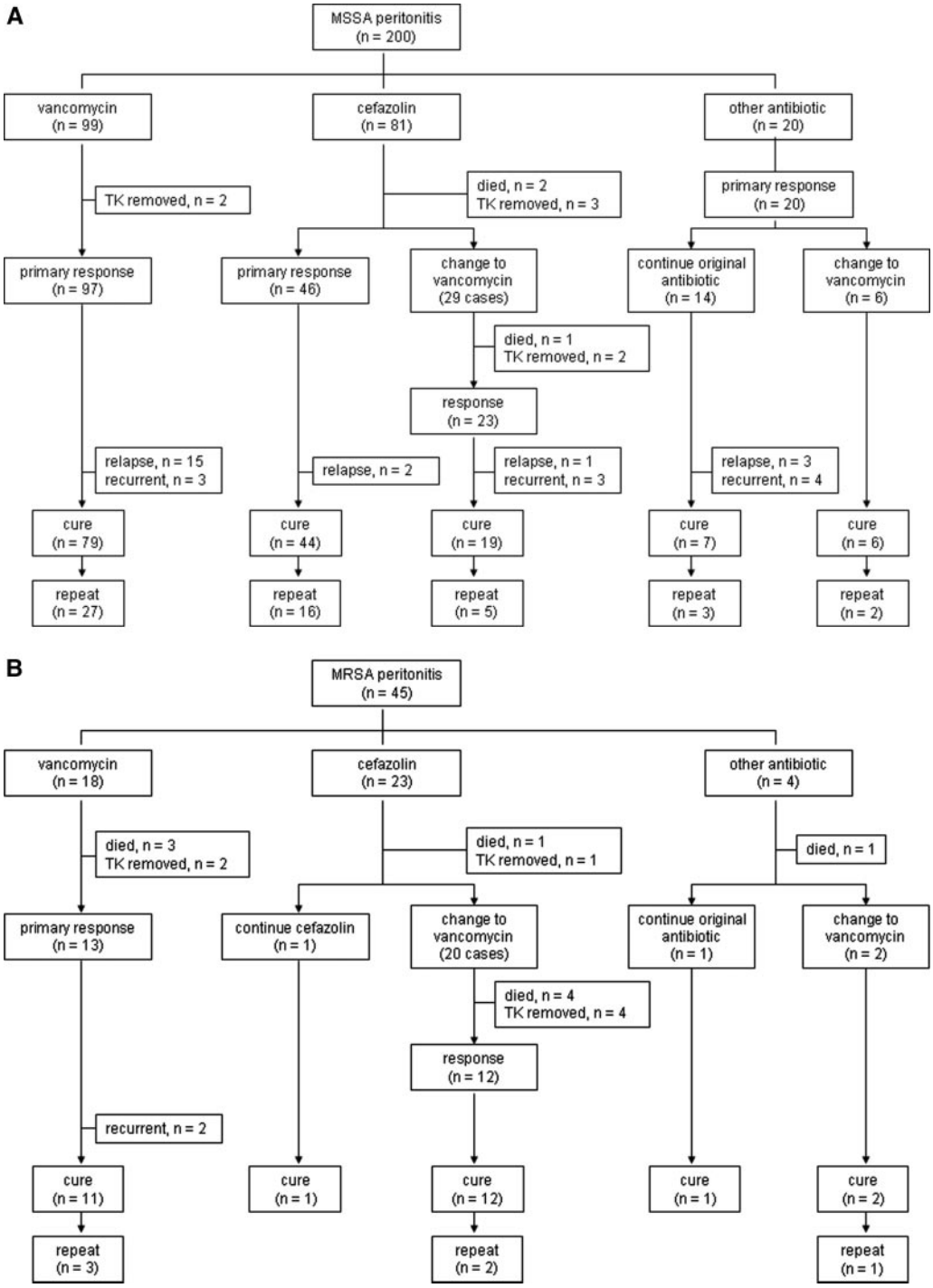


*Figure 1.* Summary of clinical outcome. (A) Methicillin-sensitive *Staphylococcus aureus* (MSSA) peritonitis. (B) Methicillin-resistant *Staphylococcus aureus* (MRSA) peritonitis. See text for the definitions of relapse, recurrent, and repeat peritonitis. TK, Tenckhoff catheter.

$P = 0.11$) and so was the complete cure rate (77.9 *versus* 72.9%; $P = 0.4$). However, adjuvant rifampicin treatment was associated with a significantly lower risk for relapse or repeat *S. aureus* peritonitis than was treatment without rifampicin (21.4 *versus* 42.8%; $P = 0.004$). Adjuvant rifampicin treatment resulted in 49.9% relative risk reduction in relapse or repeat *S. aureus* peritonitis (95% confidence interval 14.6 to 70.6%). In other words, one case of relapse or repeat peritonitis could be prevented by treating approximately five patients with rifampicin. The effect of rifampicin remained substantial even after exclusion of cases with early relapse (within 4 wk after completion of antibiotics): Adjuvant rifampicin significantly reduced the risk for repeat peritonitis (23.3 *versus* 38.0%; $P = 0.012$). In seven cases, we performed simultaneous Tenckhoff

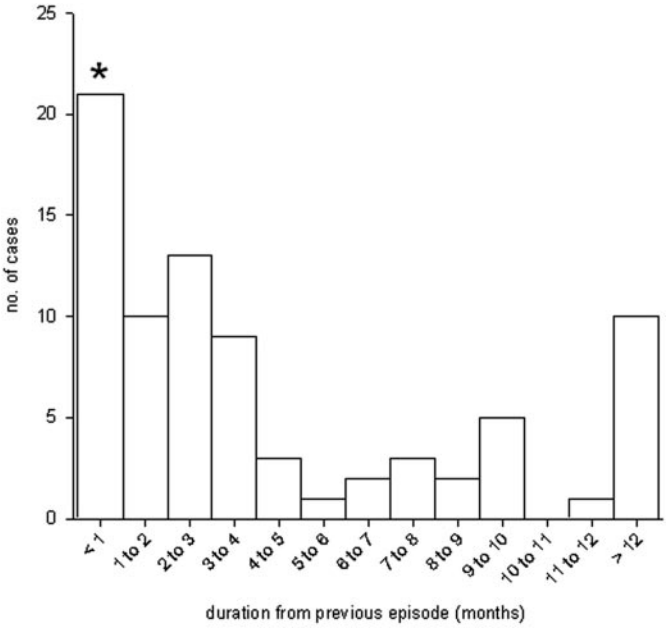


*Figure 2.* Distribution histogram of the time of developing repeat peritonitis after antibiotic treatment was completed. *Relapse *S. aureus* peritonitis by definition.

catheter exchange after PDE cleared up because of persistent exit-site infection (not necessarily caused by *S. aureus*). Three of them, nonetheless, developed repeat *S. aureus* peritonitis 4 to 12 wk later.

## *Discussion*

We found that the overall clinical outcome of *S. aureus* peritonitis is not encouraging. Only 51% of patients with MSSA peritonitis and 46% with MRSA peritonitis had complete cure without need for catheter removal, relapse, or recurrent or repeat peritonitis. Notably, repeat *S. aureus* peritonitis developed in almost one third of the patients with complete cure. More important, we found that more than half of the repeat peritonitis occurred within 3 mo after completion of antibiotics. The result is distinctly different from that of our previous study on *Enterobacteriaceae* peritonitis (28), which found that repeat peritonitis occurred evenly in 1 yr after the index episode. Traditionally, most cases of *S. aureus* peritonitis are associated with a catheter infection (29); catheter removal often is required to resolve the peritonitis or to prevent repetitive episodes (21,30,31) because concomitant colonization or infection of the exit site with *S. aureus* is associated with a substantially increased risk for relapse (32). In the present series, one fourth of the patients had exit-site infection. Contrary to our previous reports on *Pseudomonas* (33) and *Enterobacteriaceae* peritonitis (28), exit-site infection was not associated with the treatment response in the present study, and elective change of PD catheter seemed ineffective in preventing repeat *S. aureus* peritonitis. Our result suggests that there are important contributing factors of relapse, and repeat episodes were caused by factors in addition to an infected catheter. Persistent carrier state (*e.g.*, in the nasal cavity) is one of the most likely explanations. However, intraperitoneal sequestration of bacteria also is possible, at least theoretically. A previous study showed that mesothelial cells can ingest *S. aureus*, and the ingested staphylococci proliferated abundantly within mesothelial cells, which may be released subsequently (34). Recently, Haslinger-Loffler *et al.* (35) showed that after host cell invasion, *S. aureus* resided within phagocytic vacuoles, and mesothelial cells seemed to be able to degrade staphylococci. However, even after prolonged infection, a high percentage of *S. aureus* remained alive within mesothelial cells and might be released after host cell death (35).

We found that adjuvant rifampicin is highly effective in preventing relapse or repeat *S. aureus* peritonitis, presumably by eradicating occult colonization in other body parts. It is interesting that rifampicin also is particularly useful in targeting intracellular bacteria, as discussed. Our result is consistent with previous reports (36–39). For example, Zimmerman *et al.* (37) reported that periodic oral rifampin reduced the rate of staphylococcal exit-site infection. Bernardini *et al.* (38) showed that the use of either rifampin or mupirocin was associated with low rates of staphylococcal catheter infections and catheter loss. In another study with historical controls, the rate of staphylococcal exit-site infection and peritonitis was lower after oral rifampin prophylaxis (39). However, extensive use of rifampicin for the eradication of *S. aureus* carriage is hindered by rapid recolonization (39), and the risk for development of resistance is considerable. Our data, however, provide support for the use of rifampicin for the secondary prevention of *S. aureus* peritonitis after an index episode, which probably can reduce the unnecessary use of rifampicin.

The overall rate of *S. aureus* peritonitis in our present series is 0.072 episode per patient-year of dialysis, which is much lower than that reported in the literature of the late 1990 (38,40) but similar to more recent series (10). It is possible that during these years, the practice of nasal swab and treatment of carrier have improved (10). Unfortunately, because of the retrospective nature of our study, we do not have the complete data on the nasal *S. aureus* carrier status or mupirocin treatment in our patients. Because of the limitations in our data, we cannot ascertain whether the beneficial effect of rifampicin is restricted to nasal *S. aureus* carrier, and we cannot make any conclusion on the use of mupirocin ointment in secondary prevention of *S. aureus* peritonitis.

Although we found that episodes that were treated initially with cefazolin had a lower primary response rate than did those that were treated with vancomycin, our data do not argue strongly for either cefazolin or vancomycin as the first-line coverage of Gram-positive organisms. However, a small but considerable proportion of patients with MSSA peritonitis did not respond clinically to initial cefazolin treatment but were cured when changed to vancomycin, generally 3 to 5 d after onset of peritonitis. The mechanism of this "*in vivo*" resistance to cefazolin is unknown. First, the sensitivity of the conventional single selective medium method for the detection of methicillin resistance is only 65 to 100% (41). Alternatively, stable cell wall–deficient L-phase variants may be induced by cefazolin but remain susceptible to vancomycin (42). Although

the actual reason remains obscure, our result indicates that vancomycin is a valuable salvage agent of MSSA peritonitis when response to cefazolin is unsatisfactory.

In the present study, nearly 20% of the episodes were caused by MRSA. Published literature on MRSA peritonitis in PD patients is scarce; our series probably is the largest one to date. Conforming to the general belief, the major risk factor for MRSA was recent hospitalization but not recent antibiotic treatment. It could be argued that patients with recent hospitalization should receive vancomycin rather than cefazolin as first-line coverage of Gram-positive organisms. However, only 19 of the 51 patients with recent hospitalization before *S. aureus* peritonitis actually had MRSA isolated; a substantial proportion of patients would be treated with vancomycin unnecessarily if the antibiotic is used as the first-line agent.

## Conclusion

*S. aureus* peritonitis is a serious complication of peritoneal dialysis. Recent hospitalization is a major risk factor for methicillin resistance in the bacterial isolate. However, in patients with inadequate response to cefazolin, vancomycin often is effective even when the bacterial isolate is sensitive to methicillin *in vitro*. Relapse and repeat peritonitis is common. Rifampicin is a valuable adjunct in preventing relapse and repeat *S. aureus* peritonitis after the index episode.

## Acknowledgments

This study was supported in part by the Chinese University of Hong Kong research account 6901031.

We thank Lau Miu Fong for clerical support.

## Disclosures

None.

## References

1. Piraino B: Peritonitis as a complication of peritoneal dialysis. *J Am Soc Nephrol* 9: 1956–1964, 1998
2. Oreopoulos DG, Tzamaloukas AH: Peritoneal dialysis in the next millennium. *Adv Ren Replace Ther* 7: 338–346, 2000
3. Szeto CC, Wong TY, Leung CB, Wang AY, Law MC, Lui SF, Li PK: Importance of dialysis adequacy in mortality and morbidity of Chinese CAPD patients. *Kidney Int* 58: 400–407, 2000
4. Szeto CC, Chow KM, Wong TY, Leung CB, Wang AY, Lui SF, Li PK: Feasibility of resuming peritoneal dialysis after severe peritonitis and Tenckhoff catheter removal. *J Am Soc Nephrol* 13: 1040–1045, 2002
5. Szeto CC, Leung CB, Chow KM, Kwan BC, Law MC, Wang AY, Lui SF, Li PK: Change in bacterial aetiology of peritoneal-dialysis-related peritonitis over ten years: Experience from a center in South-East Asia. *Clin Microbiol Infect* 10: 837–839, 2005
6. Szeto CC, Wong TY, Chow KM, Leung CB, Li PK: Are peritoneal dialysis patients with and without residual renal function equivalent for survival study? Insight from a retrospective review of the cause of death. *Nephrol Dial Transplant* 18: 977–982, 2003
7. Bloembergen WE, Port FK: Epidemiological perspective on infections in chronic dialysis patients. *Adv Ren Replace Ther* 3: 201–207, 1996
8. Prowant B, Nolph K, Ryan L, Twardowski Z, Khanna R: Peritonitis in continuous ambulatory peritoneal dialysis: Analysis of an 8-year experience. *Nephron* 43: 105–109, 1986
9. Troidle L, Gorban-Brennan N, Kliger A, Finkelstein F: Differing outcomes of gram-positive and gram-negative peritonitis. *Am J Kidney Dis* 32: 623–628, 1998
10. Zelenitsky S, Barns L, Findlay I, Alfa M, Ariano R, Fine A, Harding G: Analysis of microbiological trends in peritoneal dialysis-related peritonitis from 1991 to 1998. *Am J Kidney Dis* 36: 1009–1013, 2000
11. de Lourdes Ribeiro de Souza da Cunha M, Montelli AC, Fioravante AM, Neves Batalha JE, Teixeira Caramori JC, Barretti P: Predictive factors of outcome following staphylococcal peritonitis in continuous ambulatory peritoneal dialysis. *Clin Nephrol* 64: 378–382, 2005
12. Peacock SJ, Howe PA, Day NP, Crook DW, Winearls CG, Berendt AR: Outcome following staphylococcal peritonitis. *Perit Dial Int* 20: 215–219, 2000
13. Piraino B, Perlmutter JA, Holley JL, Bernardini J: *Staphylococcus aureus* peritonitis is associated with *Staphylococcus aureus* nasal carriage in peritoneal dialysis patients. *Perit Dial Int* 13[Suppl 2]: S332–S334, 1993
14. Sesso R, Draibe S, Castelo A, Sato I, Leme I, Barbosa D, Ramos O: *Staphylococcus aureus* skin carriage and development of peritonitis in patients on continuous ambulatory peritoneal dialysis. *Clin Nephrol* 31: 264–268, 1989
15. Oxton LL, Zimmerman SW, Roecker EB, Wakeen M: Risk factors for peritoneal dialysis-related infections. *Perit Dial Int* 14: 137–144, 1994
16. Pignatari A, Pfaller M, Hollis R, Sesso R, Leme I, Herwaldt L: *Staphylococcus aureus* colonization and infection in patients on continuous ambulatory peritoneal dialysis. *J Clin Microbiol* 28: 1898–1902, 1990
17. Davies SJ, Ogg CS, Cameron JS, Poston S, Noble WC: *Staphylococcus aureus* nasal carriage, exit-site infection and catheter loss in patients treated with continuous ambulatory peritoneal dialysis (CAPD). *Perit Dial Int* 9: 61–64, 1989
18. Swartz R, Messana J, Starmann B, Weber M, Reynolds J: Preventing *Staphylococcus aureus* infection during chronic peritoneal dialysis. *J Am Soc Nephrol* 2: 1085–1091, 1991
19. Wanten GJ, van Oost P, Schneeberger PM, Koolen MI: Nasal carriage and peritonitis by *Staphylococcus aureus* in patients on continuous ambulatory peritoneal dialysis: A prospective study. *Perit Dial Int* 16: 352–356, 1996
20. Gupta B, Bernardini J, Piraino B: Peritonitis associated with exit site and tunnel infections. *Am J Kidney Dis* 28: 415–419, 1996
21. Kim D, Tapson J, Wu G, Khanna R, Vas SI, Oreopoulos DG: *Staph aureus* peritonitis in patients on continuous ambulatory peritoneal dialysis. *Trans Am Soc Artif Intern Organs* 30: 494–497, 1984
22. Bunke CM, Brier ME, Golper TA: Outcomes of single organism peritonitis in peritoneal dialysis: Gram negatives versus gram positives in the Network 9 Peritonitis Study. *Kidney Int* 52: 524–529, 1997
23. Piraino B, Bailie GR, Bernardini J, Boeschoten E, Gupta A, Holmes C, Kuijper EJ, Li PK, Lye WC, Mujais S, Paterson DL, Fontan MP, Ramos A, Schaefer F, Uttley L; ISPD Ad Hoc Advisory Committee: Peritoneal dialysis-related in-

fections recommendations: 2005 update. *Perit Dial Int* 25: 107–131, 2005
24. Vas SI: Peritonitis during CAPD. A mixed bag. *Perit Dial Bull* 1: 47–49, 1981
25. Keane WF, Alexander SR, Bailie GR, Boeschoten E, Gokal R, Golper TA, Holmes CJ, Huang CC, Kawaguchi Y, Piraino B, Riella M, Schaefer F, Vas S: Peritoneal dialysis-related peritonitis treatment recommendations: 1996 update. *Perit Dial Int* 16: 557–573, 1996
26. Flanigan MJ, Hochstetler LA, Langholdt D, Lim VS: Continuous ambulatory peritoneal dialysis catheter infections: Diagnosis and management. *Perit Dial Int* 14: 248–254, 1994
27. National Committee for Clinical Laboratory Standards (NCCLS): *Performance Standards for Antimicrobial Susceptibility Testing, 9th Informational Supplement* [NCCLS document M100–S9], Villanova, NCCLS, 1999
28. Szeto CC, Chow VC, Chow KM, Lai RW, Chung KY, Leung CB, Kwan BC, Li PK: Enterobacteriaceae peritonitis complicating peritoneal dialysis: A review of 210 consecutive cases. *Kidney Int* 69: 1245–1252, 2006
29. Piraino B, Bernardini J, Sorkin M: The influence of peritoneal catheter exit-site infections on peritonitis, tunnel infections, and catheter loss in patients on continuous ambulatory peritoneal dialysis. *Am J Kidney Dis* 8: 436–440, 1986
30. Finkelstein ES, Jekel J, Troidle L, Gorban-Brennan N, Finkelstein FO, Bia FJ: Patterns of infection in patients maintained on long-term peritoneal dialysis therapy with multiple episodes of peritonitis. *Am J Kidney Dis* 39: 1278–1286, 2002
31. Troidle L, Watnick S, Wuerth DB, Gorban-Brennan N, Kliger AS, Finkelstein FO: Depression and its association with peritonitis in long-term peritoneal dialysis patients. *Am J Kidney Dis* 42: 350–354, 2003
32. Schaefer F, Klaus G, Muller-Wiefel DE, Mehls O: Intermittent versus continuous intraperitoneal glycopeptide/ceftazidime treatment in children with peritoneal dialysis-associated peritonitis. The Mid-European Pediatric Peritoneal Dialysis Study Group (MEPPS). *J Am Soc Nephrol* 10: 136–145, 1999
33. Szeto CC, Chow KM, Leung CB, Wong TY, Wu AK, Wang AY, Lui SF, Li PK: Clinical course of peritonitis due to *Pseudomonas* species complicating peritoneal dialysis: A review of 104 cases. *Kidney Int* 59: 2309–2315, 2001
34. Visser CE, Brouwer-Steenbergen JJ, Schadee-Eestermans IL, Meijer S, Krediet RT, Beelen RH: Ingestion of *Staphylococcus aureus*, *Staphylococcus epidermidis*, and *Escherichia coli* by human peritoneal mesothelial cells. *Infect Immun* 64: 3425–3428, 1996
35. Haslinger-Loffler B, Wagner B, Bruck M, Strangfeld K, Grundmeier M, Fischer U, Volker W, Peters G, Schulze-Osthoff K, Sinha B: *Staphylococcus aureus* induces caspase-independent cell death in human peritoneal mesothelial cells. *Kidney Int* 70: 1089–1098, 2006
36. Ritzau J, Hoffman RM, Tzamaloukas AH: Effect of preventing *Staphylococcus aureus* carriage on rates of peritoneal catheter-related staphylococcal infections. Literature synthesis. *Perit Dial Int* 21: 471–479, 2001
37. Zimmerman SW, Ahrens E, Johnson CA, Craig W, Leggett J, O'Brien M, Oxton L, Roecker EB, Engeseth S: Randomized controlled trial of prophylactic rifampin for peritoneal dialysis-related infections. *Am J Kidney Dis* 18: 225–231, 1991
38. Bernardini J, Piraino B, Holley J, Johnston JR, Lutes R: A randomized trial of *Staphylococcus aureus* prophylaxis in peritoneal dialysis patients: Mupirocin calcium ointment 2% applied to the exit site versus cyclic oral rifampin. *Am J Kidney Dis* 27: 695–700, 1996
39. Hanevold CD, Fisher MC, Waltz R, Bartosh S, Baluarte HJ: Effect of rifampin on *Staphylococcus aureus* colonization in children on chronic peritoneal dialysis. *Pediatr Nephrol* 9: 609–611, 1995
40. Thodis E, Bhaskaran S, Pasadakis P, Bargman JM, Vas SI, Oreopoulos DG: Decrease in *Staphylococcus aureus* exit-site infections and peritonitis in CAPD patients by local application of mupirocin ointment at the catheter exit site. *Perit Dial Int* 18: 261–270, 1998
41. Safdar N, Narans L, Gordon B, Maki DG: Comparison of culture screening methods for detection of nasal carriage of methicillin-resistant *Staphylococcus aureus*: A prospective study comparing 32 methods. *J Clin Microbiol* 41: 3163–3166, 2003
42. Watanakunakorn C: Mode of action and in-vitro activity of vancomycin. *J Antimicrob Chemother* 14[Suppl D]:7–18, 1984

Khirsagar *et al.* (pages 239–244) and Szeto *et al*. focus on specific infections seen in patients undergoing renal replacement therapy. The devastating consequences of such infections on hospitalization rates and outcomes is summarized in data from the US ESRD population by Chavers *et al*. in this month's issue of *JASN* (pages 952–959).