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Original Article

Effects of early detection of peritoneal catheter migration on clinical outcomes: 15-years experiences from a single centre

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SUMMARY AT A GLANCE

In this retrospective study of 135 peritoneal dialysis patients, serial X-rays were used for early detection of catheter migration. In over 90% patients, conservative management with rigorous catharsis (defined as an increase in stool frequency more than four times a day) was successful in restoring normal catheter position and function when the problem is identified early.

ABSTRACT:

Aim: **Catheter migration is an important cause of catheter malfunction in peritoneal dialysis (PD). The purpose of this study was to investigate the effect of early detection of catheter migration on clinical outcomes.**

Methods: **A retrospective review of 135 consecutive patients initiating PD immediately following catheter insertion from 2002 to 2017 was undertaken. In order to detect catheter migration without malfunction early, serial abdominal-pelvic radiographic examinations were performed according to a predefined protocol. Conservative management with rigorous catharsis was undertaken to correct catheter migration. A Kaplan–Meier method was used to calculate survival rate.**

Results: **Mean follow-up period was 42.8 ± 34.9 months. Catheter migration occurred in 62.4%. Among them, 85.9% occurred within the first 2 weeks after catheter insertion. There were no significant associations between catheter migration and variables such as gender, obesity, DM and type of catheter. Success rate of conservative management with rigorous catharsis was 91.1%. Catheter survival at 1 and 5 years were 91.5% and 64.6% in the migration group and 81.2% and 69.9% in the non-migration group, respectively (Log–rank test, $P = 0.915$). Patient survival at 1 and 5 years were 96.8% and 85.8% in the migration group and 91.9% and 82.3% in the non-migration group, respectively ($P = 0.792$).**

Conclusion: **Early detection of PD catheter migration allowed the migrated tip to be easily corrected with conservative management. Once the migrated catheter tip was restored, catheter migration itself did not affect catheter survival. These findings suggest that early detection and correction of catheter migration is important for improving clinical outcomes.**

Catheter malfunction is not uncommon in peritoneal dialysis (PD) patients. The most common causes of catheter malfunction are catheter migration and omental wrapping. Catheter migration is common (up to 48%).[1–3] Although not all migrated catheters are problematic, catheter migration often results in PD failure.[2–4] In addition, according to previous reports, spontaneous cure of a migrated catheter is rare.[5]

Therefore, restoration of a migrated tip of catheter, especially accompanied with malfunction, requires corrective procedures such as conservative management or invasive methods. Usually, non-invasive conservative therapy such as laxatives and enemas can be initially undertaken as an attempt to correct persistent outflow failure due to catheter migration.[2] However, in the previous reports, the success rate of conservative management was only about 25%, which is quite disappointing.[1,6–8] If the displacement of catheter tip cannot be restored by conservative measures, fluoroscopy-guided wire manipulation or laparoscopic repositioning is undertaken. These methods have a higher success rate than conservative methods, but they are complex, costly, and at greater risk of complications.[9,10] The

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open surgery should eventually be performed to rescue catheter malfunction due to catheter migration when fluoroscopic or laparoscopic procedures fail. However, the surgical procedures are associated with the risk of complications, such as peritonitis, adhesion and dialysis leakage.[7]

In our centre, we insert PD catheter with a percutaneous method using guidewire and initiate PD immediately following catheter insertion without a break-in period. Our previously published results have shown that most of catheter migration did not associate with catheter malfunction in these PD population.[11] Our practice is to detect catheter migration without poor outflow early and then to attempt conservative management with rigorous catharsis using high doses of oral lactulose. Unlike the results of previous studies, fluoroscopic or laparoscopic procedures and surgical revision are rarely needed to restore catheter migration in our centre. We assumed that our practice of early detection and management of catheter migration contributed to avoiding invasive procedures.

Therefore, we conducted this retrospective review of our PD population to evaluate the efficacy of early detection of catheter migration and correction by conservative management, to determine which factors are associated with catheter migration, and to assess the effect of correction of catheter migration on clinical outcomes such as catheter survival and patient survival.

METHODS

Study population

We conducted this retrospective cohort study of consecutive adult end-stage renal disease (ESRD) patients who PD had been initiated from January 2002 to August 2017 in our tertiary teaching hospital. Demographic and clinical data was obtained from hospital electronic databases. Patients over 18 years of age and who PD catheter was inserted percutaneously using a guidewire were included. The exclusion criteria were as follows: the use of an insertion method other than a percutaneous catheter placement using guidewire, a break-in period with any duration, an observation for less than 14 days, and pregnant women. The study protocol was approved by the Hospital Institutional Review Boards (IRB number: KUH1010771).

Protocol for detecting and correcting catheter migration

As described previously, all PD catheters were inserted by a nephrologist with a modified percutaneous placement method using guidewire.[11] All PD catheters were double-cuffed, straight-end, Tenckhoff catheters with a swan neck (SN) or non-swan neck (NSN) configuration. PD was initiated without a break-in period immediately after catheter insertion. It was conducted with 500 mL of 1.5% dialysis solution for the first 3 days, with 1000 mL for next 4 days, and with 2000 mL for the second weeks. A 15 mL of lactulose was administrated three times daily as a routine after catheter insertion.

In order to detect the catheter migration without poor outflow early, abdominal-pelvic radiographic examinations were conducted according to a predefined protocol as follows: abdominal-pelvic radiographic examinations were performed daily during the first week after catheter implantation and every other day in the second week. Beginning in the second month, it was performed monthly for 1 year and once or twice a year after the second year. In addition, abdominal-pelvic radiographic examinations were conducted immediately whenever outflow volume decreased.

If catheter migration was found, rigorous catharsis was immediately implemented through the administration of high dosages of oral lactulose. Oral lactulose (20 mL) was taken every 6 h for two or 3 days. If necessary, oral lactulose was administered every 3 to 4 h. An additional glycerine enema was conducted when adequate catharsis was not facilitated or the migrated tip was not restored. Adequate catharsis was defined as an increase in stool frequency more than four times a day. Abdominal-pelvic radiography was repeatedly performed to document whether PD catheter migration was restored.

Catheter migration was defined as a displacement of catheter tip from the pelvis to the abdomen above the posterior border (sacral promontory) of pelvic brim on abdominal-pelvic radiograph. In order to determine catheter migration, radiographs were read by two physicians who were irrelevant to this study. Migration-related catheter malfunction was defined as poor outflow associated with catheter migration. Success was defined as a restoration of the tip position and function of PD catheter within 48 h after achieving adequate catharsis. Spontaneous remission was defined as a restoration of the tip position despite adequate catharsis was not achieved.

Outcomes

The primary outcome was catheter survival at 1 and 5 years following initiation of PD. Catheter survival was defined as the continuation of PD without catheter failure, which was defined as the removal of malfunctioning catheter due to catheter-related complications. In order to analyse the effect of catheter migration on survival, the patients were divided into two groups based on catheter migration, comprising the migration group and the non-migration group. Secondary outcomes included patient survival at 1 and 5 years, incidence of catheter migration, incidence of migration-related catheter malfunction, success rate of conservative management and risk factors associated with catheter migration.

Statistical analysis

Statistical analyses were performed using the IBM SPSS software version 22.0 (IBM Inc., Armonk, NY, USA). All data is expressed as number (percentage) or mean ± standard deviation (SD) as appropriate depending on the situation. Comparison of categorical variables was performed by χ^2 test or Fisher's exact test. Continuous variables were analysed by Student *t*-test or Mann–Whitney test. Univariate and multivariate logistic regression were performed to evaluate the independent variables that were associated with catheter migration. The included variables were as follows: age, sex, obesity (body mass index ≥25 kg/m^2), DM and type of catheter. Catheter survival rates and patient survival rates were calculated using Kaplan–Meier analysis. All analyses were 2-tailed. The statistical significance was defined as $P < 0.05$.

RESULTS

General characteristics

A total of 135 consecutive PD patients were enrolled in the study. Of them, 125 patients were included in the final analysis (Fig. 1). Ten patients were excluded from this study because of surgical implantation with break-in period ($n = 7$) and short observation period less than 14 days ($n = 3$). The baseline demographics and characteristics are summarized in Table 1. No significant differences were found in age, gender, BMI, obesity, DM and type of catheter between the migration group and non-migration group (Table 1). The mean age of patients was 53.9 ± 12.8 years, 71 patients (56.8%) were male and 80 patients (64.0%) had diabetes. The swan neck (SN) and non-swan neck (NSN) catheters were 82 (65.6%) and 43 (34.4%), respectively. From 2002 to 2008, NSN catheters were more commonly used than SN catheters (NSN:SN = 35:13). Since 2009, SN catheters have been mainly used (NSN:SN = 8:69). A comparison of various characteristics including type of catheter between the two separate cohorts (2002–2008 *vs* 2009–2017) is shown in the Table S1 (Supporting Information). Of 125 patients who included in the final analysis, 30 patients (24.0%) had missed radiographic examinations consecutively for three or more times in the predefined protocol (Table S2).

Incidences

The periods of observation were 42.8 ± 34.9 months. The migration rate of the PD catheter was 62.4% (78 catheters). Among them, 67 patients (85.9%) experienced catheter migration within the first 2 weeks after catheter insertion (early onset) and 11 patients (14.1%) after 2 weeks (late onset). Figure 2 shows the distribution of onset of catheter migration over time. The catheters were migrated to the right side in 35 patients (46.2%) and to the left side in 43 patients (53.8%). Recurrent migration was observed in 20 patients (25.6%). Migration-related catheter malfunction was observed in 10 patients (12.8%).

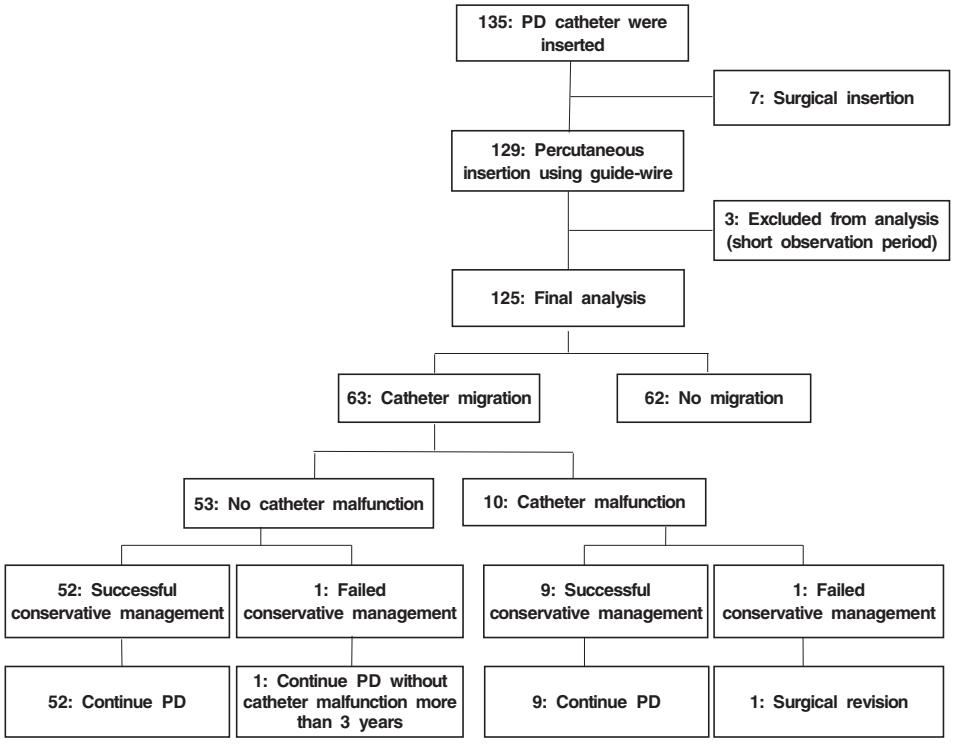

Fig. 1 Flowchart of outcomes for the migrated PD catheter after correction with conservative management.

Table 1 Comparisons between migration and non-migration group

	Migration group	Non-migration group	*P*
Number of patients, *n* (%)	78 (62.4%)	47 (37.6%)	–
Patient characteristics			
Age (year)	54.1 ± 12.6	51.4 ± 13.4	0.259
Male sex, *n* (%)	47 (60.3%)	24 (51.1%)	0.354
Body mass index (kg/m^2)	24.3 ± 3.8	23.8 ± 4.9	0.495
Obesity (BMI ≥ 25 kg/m^2)	28 (35.9%)	13 (27.7%)	0.432
Diabetes mellitus, *n* (%)	55 (70.5%)	25 (53.2%)	0.057
Duration of PD (months)	42.9 ± 31.9	42.1 ± 39.7	0.903
Catheter characteristics			
Type of catheter, *n* (%)			
Swan neck: Non-swan neck	52 (66.7%): 26 (33.3%)	30 (63.8%): 17 (36.2%)	0.846
Straight tip in intraperitoneal segment	78 (100%)	47 (100%)	1.000
Catheter implantation, *n* (%)			
Percutaneous placement using guidewire	78 (100%)	47 (100%)	1.000
No-break-in period	78 (100%)	47 (100%)	1.000
Migration-related outcomes			
Diminished outflow volume, *n* (%)	10 (12.8%)	–	–
Persistent outflow failure, *n* (%)	1 (1.3%)	–	–
Migration onset† (early: late), *n* (%)	67 (85.9%): 11 (14.1%)	–	–
Migration site (right: left), *n* (%)	35 (46.2%): 43 (53.8%)	–	–
Success of adequate catharsis, *n* (%)	71 (91.1%)	–	–
Spontaneous restoration‡, *n* (%)	5 (6.4%)		
Recurrent migration, *n* (%)	20 (25.6%)	–	–

†Early migration was defined as occurrence of catheter migration within 2 weeks after catheter implantation. ‡Spontaneous restoration was defined as a restoration of the tip position despite adequate catharsis was not achieved.

Risk factors associated with catheter migration

Table 2 demonstrates the results of univariate and multivariate logistic regression analysis to evaluate the independent variables that were associated with catheter migration (Table 2). No significant association was observed between catheter migration and variables including age, gender, obesity, DM and type of catheter.

Success rate

As shown in Figure 1, of the 78 migrated catheters, 71 catheters (91.1%) were successfully restored with conservative management using rigorous catharsis (Fig. 1). Success rates for the right-sided and the left-sided catheter migration were 94.3% (33 of 35 patients) and 88.4% (38 of 43 patients), respectively ($P = 0.347$). There was no significant difference in success rate between SN and NSN groups (Table S3). Only two patients failed to restore catheter migration with conservative management using vigorous catharsis. One patient who had failed to correct catheter migration despite adequate catharsis was conducted. The malfunctioning catheter was removed and a new catheter was inserted by percutaneous implantation method using guidewire. The other patient continued to receive PD therapy for more than 3 years after catheter insertion because there is no outflow failure despite of a sustained migration of catheter tip. Spontaneous restoration of the migrated tip was observed in five patients despite of the absence of adequate catharsis.

Survival rate

Overall catheter survival and patient survival rates at 1, 3 and 5 years were 89.2%, 81.4% and 68.6%, and 96.3%, 92.1% and 87.3%, respectively. The catheter survival rates at 1, 3 and 5 years in the migration group and the non-migration group were 91.5%, 79.5% and 64.6%, and 81.2%, 81.2% and 69.9%, respectively (Log–rank test, $P = 0.915$) (Fig. 3). The patient survival rates in both groups were 96.8%, 93.8% and 85.8%, and 91.9%, 82.3% and 82.3%, respectively, at 1, 3 and 5 years (Log–rank test, $P = 0.792$) (Fig. 4). Neither catheter nor patient survival rates had significant correlations with catheter migration. The reasons for PD discontinuation of the migration group were not significantly different from those of the non-migration group (Table S4).

DISCUSSION

In this study, we showed that early-detected catheter migration without poor outflow was easily corrected by conservative management using rigorous catharsis, with 91.1% of success rates. In addition, once catheter migration was corrected, migration itself did not affect catheter survival; the 1 and 5 year survival rates were 91.5% and 64.6%, respectively. These findings suggest that early diagnosis of catheter migration by periodic abdominal-pelvic radiographic examinations can led to a higher success rate of conservative management and may improve clinical outcomes such as survival rate.

Our study has several features that distinguish it from previously reported studies. The first feature is a remarkably high incidence (62.4%) of catheter migration. The high rate of catheter migration in this study probably resulted from the fact that most patients received the abdominal-pelvic radiographic examinations as a predefined protocol for the first 2 weeks. In fact, most (85.9%) of catheter migration occurred within the first 2 weeks after catheter insertion. Meanwhile, it is well known that high-dose radiation exposure increases lifetime risk for death of cancer. However, exposure to a lifetime dose of 100 mSv has not been associated with health risks.[12] That is equal to 10 000 chest X-rays

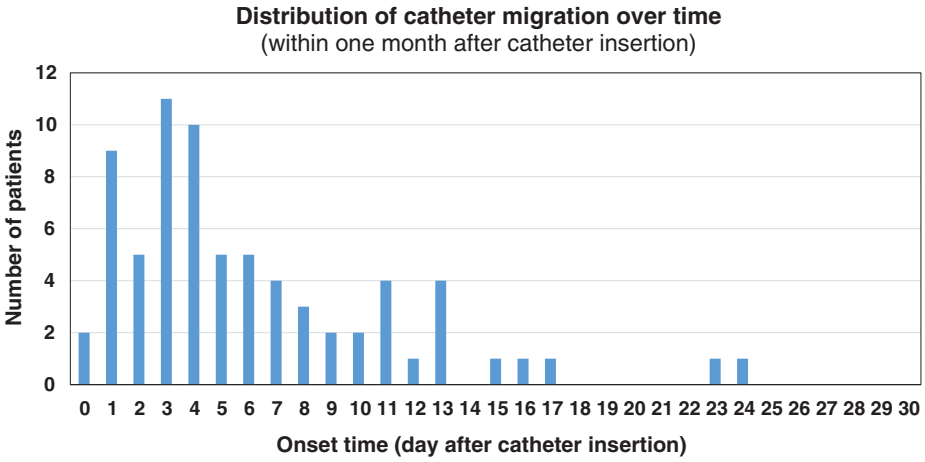

Fig. 2 Distribution of onset time of catheter migration over time within 1 month after catheter insertion. Among the total 78 cases of catheter migration, 85.9% occurred within 2 weeks after catheter insertion.

Table 2 Logistic regression analysis to examine variables that were associated with catheter migration

Variables	Beta estimate	SE	Wald	*P* value	Odds ratio (OR)	95% CI for OR
Univariate analysis						
Gender	0.389	0.385	1.017	0.313	1.475	0.693–3.140
Age	0.012	0.015	0.573	0.449	1.012	0.982–1.042
Obesity	0.219	0.422	0.270	0.604	1.245	0.544–2.848
Diabetes mellitus	0.640	0.400	2.557	0.110	1.897	0.866–4.157
Type of catheter	0.744	0.384	3.763	0.768	1.126	0.512–2.474
Multivariate analysis[†]						
Diabetes mellitus	0.864	0.382	5.109	0.052	2.104	0.992–4.463

[†]Multivariate logistic regression analysis was performed using variables of *P* values were < 0.20 in the univariate analysis.

or 1500 abdominal-pelvic X-rays. According to the protocol of this study, patients will be exposed to approximately 20 abdominal-pelvic X-rays during the first year after starting PD. However, it is desirable to avoid unnecessary radiation exposure if possible. Considering this fact, it is advisable to perform abdominal-pelvic radiography two or three times per week during the first week after catheter insertion and once or twice during the second week. After 1 month following catheter insertion, abdominal-pelvic radiography does not need to be taken regularly unless there is 'poor outflow'.

The second feature is that the result of this study first revealed the importance of early detection of catheter migration. Previously reported success rates for conservative management have shown only approximately 25%.[1,6–8] Surprisingly, in our series of 78 patients with catheter migration, conservative management with rigorous catharsis was successful in 91.1% of patients. The results of this study are valuable in that early diagnosis of catheter migration without poor outflow can help to avoid more complicated and costly procedures such as fluoroscopic or laparoscopic manipulation or surgical revision. The remarkably high success rate in this study may be explained by several factors. First, an early detection of catheter migration without poor outflow would have contributed to the high success rate of conservative measure. In other words, the predefined protocol of this study made it possible to detect catheter migration early before being tightly wrapped or entrapped by the greater omentum. Despite a retrospective observational cohort study, because of regular abdominal-pelvic radiographic examinations performed according to a predefined protocol, catheter migration was detected in as much as 62.4% of patients. Most (87.3%) of these migrated catheters was not malfunctioning. Unlike the result of this study, Miller *et al*. reported that the success rate of fluoroscopic manipulation for catheter migration with mechanical obstruction was only 62.9% and the causes of primary failure were omental wrapping of the catheter or compartmentalization by adhesions in the lesser sac.[9] Once omental wrapping occurs, correcting catheter migration may not be easy, even with fluoroscopic manipulation. These results suggest that if the migrated catheter tip is not tightly wrapped by the greater omentum, catheter migration can be easily restored with conservative measures. Second, it cannot be ruled out that the type and configuration of the catheter may have affected the success rate. In a study comparing the straight-tip catheter with the coiled-tip catheter, catheter tip migration and omental wrapping were significantly higher in patients with a coiled-tip catheter.[13] A straight-tip catheter was used in our study, and as a result it is possible that the incidence of omental wrapping and subsequent catheter malfunction has decreased.

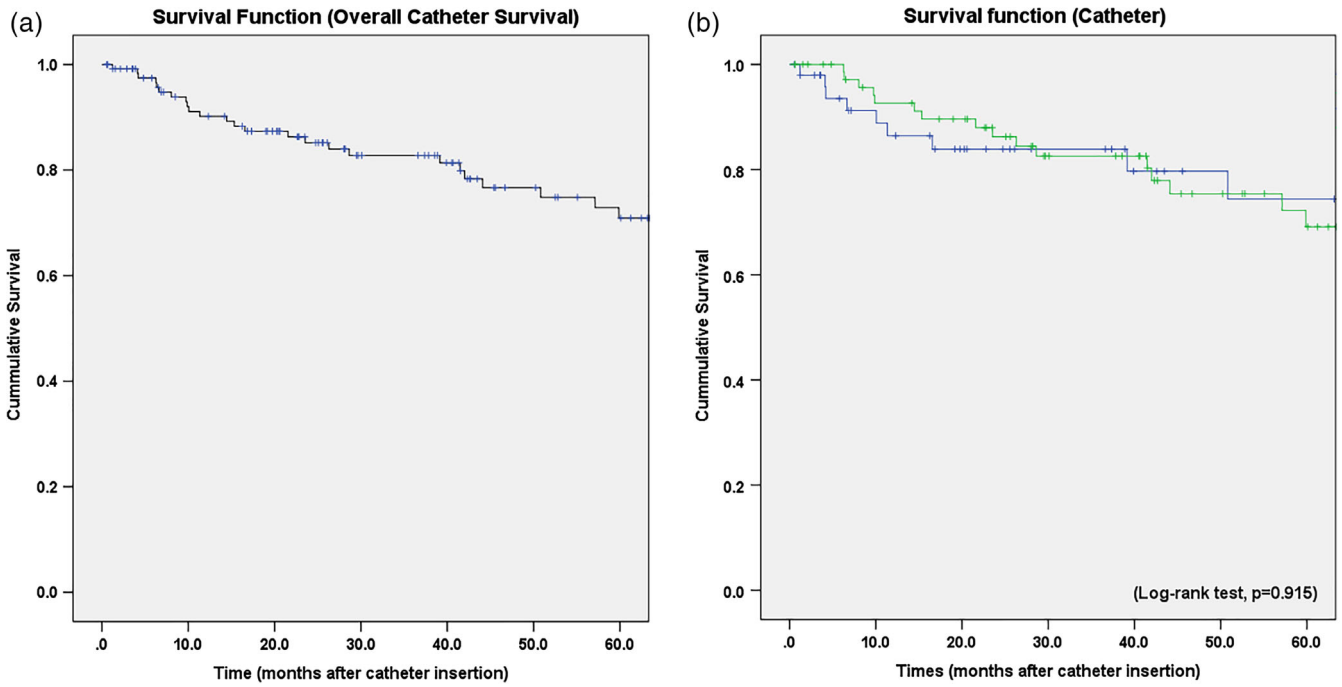

Fig. 3 Kaplan–Meier survival curve for catheter survival. (a) Overall catheter survival. ——, Catheter survival; —|—, Censored. (b) Catheter survival rates in the migration group and non-migration group. The difference between the groups was not statistically significant (log–rank test, P = 0.915). ——, 0: Non –migration group; ——, 1: Migration group; —|—, 0-censored; —|—, 1-censored.

Another feature that distinguishes this study from previous reports is that the success rate of conservative management is very high even for the right-sided upward migration. It has been perceived that the left-sided upward migration is easily restored to its original position by conservative management, but the right-sided upward migration is

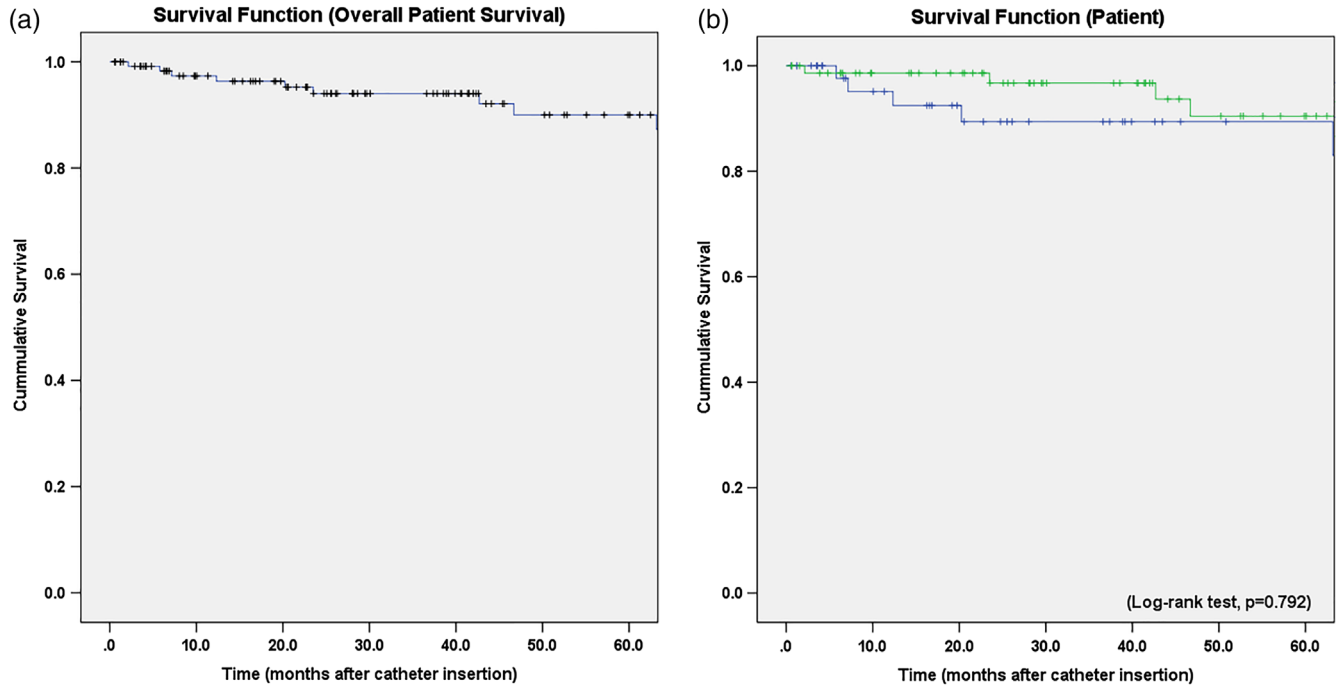

Fig. 4 Kaplan–Meier survival curve for patient survival. (a) Overall patient survival. ——, Patient survival; —|—, Censored. (b) Patient survival rates in the migration group and non-migration group. The difference between the groups was not statistically significant (log–rank test, P = 0.792). ——, 0: Non –migration group; ——, 1: Migration group; —|—, 0-censored; —|—, 1-censored.

not easily corrected. Twardowski explained that when the catheter tip is displaced to the right upper quadrant, one-way obstruction occurs more frequently because of colon peristalsis.[14] In other words, a left-sided upward migration is easily restored to the proper position due to downward peristalsis of the descending colon while a right-sided upward migration is not easily corrected because the peristalsis of the ascending colon tends to push the tip upwards. Surprisingly, contrary to these argument, we found that the success rate of conservative management by rigorous catharsis was remarkably high (94.3%) even for the right-sided upward migration. It is not clear why this study shows an unprecedented high success rate even for the right-sided upward migration. We speculated that previous researchers might have accepted this hypothetical explanation as the proven fact, despite there is not enough evidence to suggest that the right-sided upward migration cannot usually be corrected by conservative management. Indeed, we found through a detailed literature review that the success rate (25%) reported by Rubin[6] as well as a Twardowski's hypothetical explanation[14] have been cited in subsequent studies without proper validation.[8,15–17]

Overall catheter survival at 1 and 5 years of our patients was 89.2% and 68.6%, respectively. Catheter survival showed no difference between the non-migration group and the migration group. The survival rates for catheter at 5 years reported in other series are variable, ranging from 27% to 70.0%.[18–21] The variability of catheter survival between centres was associated many factors, including the number of PD patients in a centre. Lower technical survival rates are found mainly in centres with less than 20 patients on PD, and the relative risk of technical failure was 1.68 compared to large centers.[19] Our centre has more than 45 PD patients, which may be related to favourable catheter survival rates. We analysed whether catheter migration affects catheter survival and patient survival. Neither catheter survival nor patient survival rates had significant correlations with catheter migration. These results indicate that if catheter migration is early diagnosed and corrected, the migration itself does not affect catheter survival or patient survival.

The present study has some potential limitations. First, the design is a small-sized retrospective observational study. However, in this study, serial abdominal-pelvic radiographic examinations were performed immediately after catheter insertion according to the predefined protocol. Especially during the first 2 weeks after catheter insertion, 76.0% of patients underwent abdominal-pelvic radiographies according to a predefined protocol. As a result, the limitations of a retrospective study have been largely overcome. Second, this study is not a randomized controlled trial. It is not possible to exclude the possibility that the catheter implantation method affected catheter migration and catheter survival. However, among 135 catheters in this study, 125 catheters were inserted by a percutaneous implantation method and PD was initiated immediately after catheter insertion without a break-in period. Because of the small number of patients with surgical implantation or break-in procedure, the statistical power was too small to compare the two groups (surgical implantation group *vs* percutaneous implantation group, or break-in group *vs* no-break-in group). As a result, it is unclear whether the success rate of our study is due to difference in catheter insertion methods or break-in period. Finally, other factors influencing catheter survival such as peritonitis, exit site infection, or tunnel infection were not taken into account in the present study. To overcome these limitations, a large randomized controlled prospective study is required.

Our study demonstrated that catheter migration without poor outflow was easily restored by conservative management with rigorous catharsis. In addition, once the migrated tip of catheter was restored, the migration itself did not affect catheter survival. Our results suggest that regular abdominal-pelvic radiographic examinations should be performed to detect early catheter migration, especially during the first 2 weeks after catheter insertion.

DISCLOSURE

We have no conflict of interest to report. This work has not been published before and it is not under consideration for publication anywhere else. Its publication has been approved by all co-authors.

REFERENCES

1. Peppelenbosch A, van Kuijk WH, Bouvy ND, van der Sande FM, Tordoir JH. Peritoneal dialysis catheter placement technique and complications. *NDT Plus* 2008; **1**: iv23–8.
2. McCormick BB, Bargman JM. Noninfectious complications of peritoneal dialysis: Implications for patient and technique survival. *J. Am. Soc. Nephrol.* 2007; **18**: 3023–5.
3. Ersoy FF, Twardowski ZJ, Satalowich RJ, Ketchersid T. A retrospective analysis of catheter position and function in 91 CAPD patients. *Perit. Dial. Int.* 1994; **14**: 409–10.
4. Shahbazi N, McCormick BB. Peritoneal dialysis catheter insertion strategies and maintenance of catheter function. *Semin. Nephrol.* 2011; **31**: 138–51.
5. Reddy YS, Manjusha Y, Kishore CK, Sridhar N, Sriramnaveen P, Sivakumar V. Spontaneous cure of migrated peritoneal catheter. *Perit. Dial. Int.* 2012; **32**: 107–8.
6. Rubin J, Adair CM, Raju S, Bower JD. The Tenckhoff catheter for peritoneal dialysis - an appraisal. *Nephron* 1982; **32**: 370–4.
7. Ogunc G. *Malfunctioning Peritoneal Dialysis Catheter and Current Treatment [Homepage of the Internet]*. Dover, DE: SM Online Scientific Resources. [Cited 22 Dec 2016.] Available from URL: http://www.smgebooks.com/Progress-in-Peritoneal-Dialysis/chapters/PPD-16-02.pdf.
8. Lee CM, Ko SF, Chen HC, Leung TK. Double guidewire method: A novel technique for correction of migrated Tenckhoff peritoneal dialysis catheter. *Perit. Dial. Int.* 2003; **23**: 587–90.
9. Miller M, McCormick B, Lavoie S, Biyani M, Zimmerman D. Fluoroscopic manipulation of peritoneal dialysis catheters: Outcomes and factors associated with successful manipulation. *Clin. J. Am. Soc. Nephrol.* 2012; **7**: 795–800.

10. Santarelli S, Zeiler M, Marinelli R, Monteburini T, Federico A, Ceraudo E. Videolaparoscopy as rescue therapy and placement of peritoneal dialysis catheters: A thirty-two case single centre experience. *Nephrol. Dial. Transplant.* 2006; **21**: 1348–54.
11. Jo YI, Shin SK, Lee JH, Song JO, Park JH. Immediate initiation of CAPD following percutaneous catheter placement without break-in procedure. *Perit. Dial. Int.* 2007; **27**: 179–83.
12. AAPM. *Position Statement on Radiation Risks from Medical Imaging Procedures*. Virginia: American Association of Physicists in Medicine, 2011. [Cited 13 Dec 2011.] Available from URL: http://www.aapm.org/org/policies/details.asp?id=318&type=PP.
13. Ouyang CJ, Huang FX, Yang QQ *et al*. Comparing the incidence of catheter-related complications with straight and coiled Tenckhoff catheters in peritoneal dialysis patients - A single-center prospective randomized trial. *Perit. Dial. Int.* 2015; **35**: 443–9.
14. Twardowski ZJ, Nolph KD, Khanna R, Prowant BF, Ryan LP, Nichols WK. The need for a "swan neck" permanently bent, arcuate peritoneal dialysis catheter. *Perit. Dial. Int.* 1985; **5**: 219–23.
15. Bhatla B, Khanna R, Twardowski ZJ. Peritoneal access. *J. Postgrad. Med.* 1994; **40**: 170–8.
16. Kathuria P, Twardowski ZJ, Nichols WK. Peritoneal dialysis access and exit-site care including surgical aspects. In: Khanna R, Krediet RT (eds). *Nolph and Gokal's Textbook of Peritoneal Dialysis*, 3rd edn. New York, NY: Springer, 2009; 371–446.
17. Schmitt H, Hermanns B, Boeckmann W, Drube S, Sieberth H. Intra-abdominal complications in peritoneal dialysis with special reference to peritoneal fibrosis. In: Treutner HK, Schumpelick V (eds). *Peritoneal Adhesions*. Berlin: Springer, 1997; 255–67.
18. Hagen SM, Lafranca JA, JN IJ, Dor FJ. A systematic review and meta-analysis of the influence of peritoneal dialysis catheter type on complication rate and catheter survival. *Kidney Int.* 2014; **85**: 920–32.
19. Huisman RM, Niewenhuizen MG, de Charro FT. Patient-related and centre-related factors influencing technique survival of peritoneal dialysis in the Netherlands. *Nephrol. Dial. Transplant.* 2002; **17**: 1655–60.
20. Singh N, Davidson I, Minhajuddin A, Gieser S, Nurenberg M, Saxena R. Risk factors associated with peritoneal dialysis catheter survival: A nine year single center study in 315 patients. *J. Vasc. Access* 2010; **11**: 316–22.
21. Ma TKW, Chow KM, Kwan BCH *et al*. Peritoneal dialysis catheter revision and replacement by nephrologist for peritoneal dialysis catheter malfunction. *Nephron* 2018; **138**: 214–9.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher's website:

Table S1. Comparisons between the two separate cohorts, the '2002–2008' period and the '2009–2017' period
Table S2. Comparisons between the 'abdominal-pelvic radiography (AXR) protocol' group and the 'no AXR protocol' group
Table S3. Comparisons between the 'non-swan neck' group and the 'swan neck' group
Table S4. Reasons for drop out from peritoneal dialysis