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Pleural and intra-abdominal long-term drainage: comparison of a novel double-loop and a conventional single-loop catheter

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PURPOSE

To evaluate the efficacy and advantages of a novel double-loop drainage catheter (nDLC) compared with a conventional single-loop catheter (cSLC) in overcoming dysfunctional retraction for pleural and intra-abdominal drainage.

METHODS

A retrospective review of 356 patients who underwent drainage procedures between January and October 2023 was conducted. Of these, 221 received cSLC and 135 received nDLC, all using 8-F catheters. Complicated collections (e.g., empyema, pneumothorax, bile, pancreatic secretions, bloody collection, urine, or air) were excluded. The complication-free catheter indwelling time was analyzed using the Kaplan–Meier method. Patient characteristics and complications were compared using paired t-tests and Fisher's exact tests.

RESULTS

The nDLC group demonstrated a significantly longer mean complication-free catheter indwelling time [70.3 days, 95% confidence interval (CI): 52.8–87.9] than the cSLC group (19.6 days, 95% CI: 17.9–21.2; $P < 0.05$). Subgroup analysis showed superior indwelling times with nDLC for both intra-abdominal (77.5 vs. 18.7 days) and pleural drainage (35.9 vs. 19.7 days) ($P < 0.05$). Dysfunctional retraction occurred in 10 cases in the cSLC group but in no cases in the nDLC group ($P < 0.001$).

CONCLUSION

The nDLC significantly reduces dysfunctional retraction and provides a longer complication-free catheter indwelling time than the cSLC for both pleural and intra-abdominal drainage.

CLINICAL SIGNIFICANCE

The nDLC design effectively prevents catheter retraction and eliminates the need for suture anchoring, potentially reducing suture-related complications and improving long-term catheter performance in patients requiring prolonged pleural or intra-abdominal drainage.

KEYWORDS

Double-loop catheter, pleural effusion, ascites, abdominal drainage, catheter occlusion

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The use of pigtail catheters has become the preferred minimally invasive treatment modality for draining pleural or intra-abdominal fluids.[1] Compared with conventional large-bore chest tubes, pigtail catheters, which are made from smaller and more flexible materials, are equally effective but cause less pain and are better tolerated by patients.[2] However, a smaller bore increases the risk of catheter blockage.[2]

Maintaining the correct position of an indwelling pigtail catheter is crucial for the successful drainage of pleural or intra-abdominal fluids.[3] Despite being securely fixed to the skin with sutures, a long-term catheter can still be inadvertently pulled out, leading to catheter dysfunction. To overcome this, the development of a double-pigtail catheter, which features additional coiling in the middle section, has been reported.[2] This design not only facilitates

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drainage but also helps prevent complete dislodgement and maintains catheter function by resisting retraction. However, we observed that although the double-pigtail catheter helps prevent displacement, blockages can still occur if any side holes near the chest wall in the second loop become obstructed (Figures 1a and b).

Consequently, we designed a novel double-loop drainage catheter (nDLC) that lacks side holes along the proximal coiling segment. Drainage occurs exclusively through the side holes located in the distal loop, whereas the proximal loop, which has no drainage holes, functions primarily as a mechanical anchor against retraction. This design aims to address specific clinical issues, with particular emphasis on preventing catheter occlusion due to side-hole blockage in the second loop. Omitting side holes in the proximal loop was intended to reduce the risk of blockage by preventing debris accumulation at the wall interface, and retraction resistance is provided by the proximal loop's mechanical anchoring. Therefore, this study aims to compare the survival and effectiveness of conventional single-loop catheters (cSLCs) with those of nDLC.

Methods

Characteristics of a novel double-loop drainage catheter

The pigtail catheters used in this study were designed as follows: (1) the cSLC was an 8-F/21-cm multipurpose drainage catheter made of polyurethane, with a hydrophilic-coated distal segment (5 cm, five side holes with pigtail formation; Sungwon Medical, Cheongju, Republic of Korea, and UreSil LLC, Skokie, IL, USA); and (2) the nDLC was an 8-F/21-cm catheter made of polyurethane, with hydrophilic-coated proximal and distal segments (5 cm, five side holes only in the distal pigtail coiling, no side holes in the mid-shaft, and proximal coiling), a distal pigtail loop size of 2 cm, and a proximal loop of 1 cm (EQ drainage catheter, Hepato, Seoul, Republic of Korea) (Figure 2).

Main points

- The novel double-loop drainage catheter (nDLC) completely prevented dysfunctional retraction (0 cases vs. 10 cases in conventional single-loop catheters; $P < 0.001$) and did not require suture anchoring, potentially avoiding suture-related complications such as infection or tissue damage.
- The mean indwelling time without dysfunction was significantly longer with the nDLC (70.3 vs. 19.6 days; $P < 0.05$), with consistent benefits in both pleural (35.9 vs. 19.7 days) and intra-abdominal (77.5 vs. 18.7 days) drainage.
- The clinical success rate was higher with the nDLC (91.9% vs. 80.5%; $P = 0.004$), suggesting it is particularly advantageous for patients needing prolonged drainage of uncomplicated pleural effusions or ascites.

Patient characteristics

The need for informed consent from participants was waived due to the study's retrospective design. The protocol for this study was approved by the Institutional Review Board of the Catholic Medical Center of The Catholic University of Korea (approval number: KC25RISI0353, date: June 4, 2025). All consecutive drainage procedures performed between January and October 2023 were reviewed. The inclusion criteria focused on patients who underwent pleural or intra-abdominal drainage using 8-F catheters. Patients were excluded from the study if they had complicated intra-abdominal collections, such as bile, pancreatic secretions, bloody collections, urine, or air (n = 16), or complicated pleural collections, such as empyema or pneumothorax (n = 11). To focus

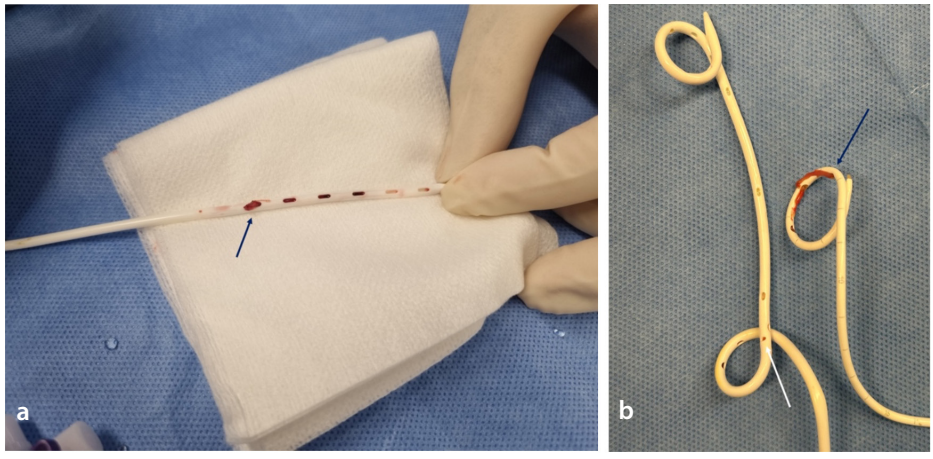


Figure 1. Occlusion pattern of the pigtail catheter. **(a)** Substantial amount of debris accumulation in the last side hole, potentially causing progressive catheter blockage (black arrow). **(b)** Similarly, in the case of double-loop catheters, debris starts to accumulate at the last side hole of the second loop adjacent to the chest or abdominal wall (white arrow).

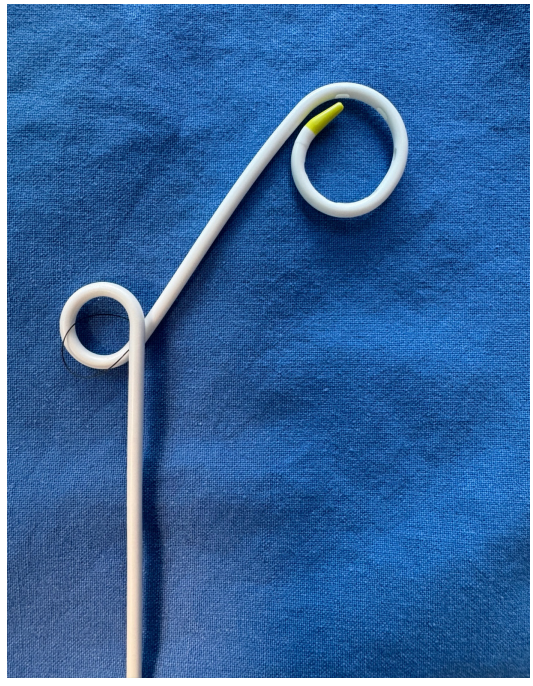


Figure 2. Detailed structure of the novel double-loop catheter. The multipurpose drainage catheter features two pigtail coiling segments spaced at 5-cm intervals. Side holes facing the centripetal direction inside the loop were only present in the distal pigtail coiling—the mid-shaft and proximal coiling segments have no side holes. Suture fixation was only applied to the proximal coil.

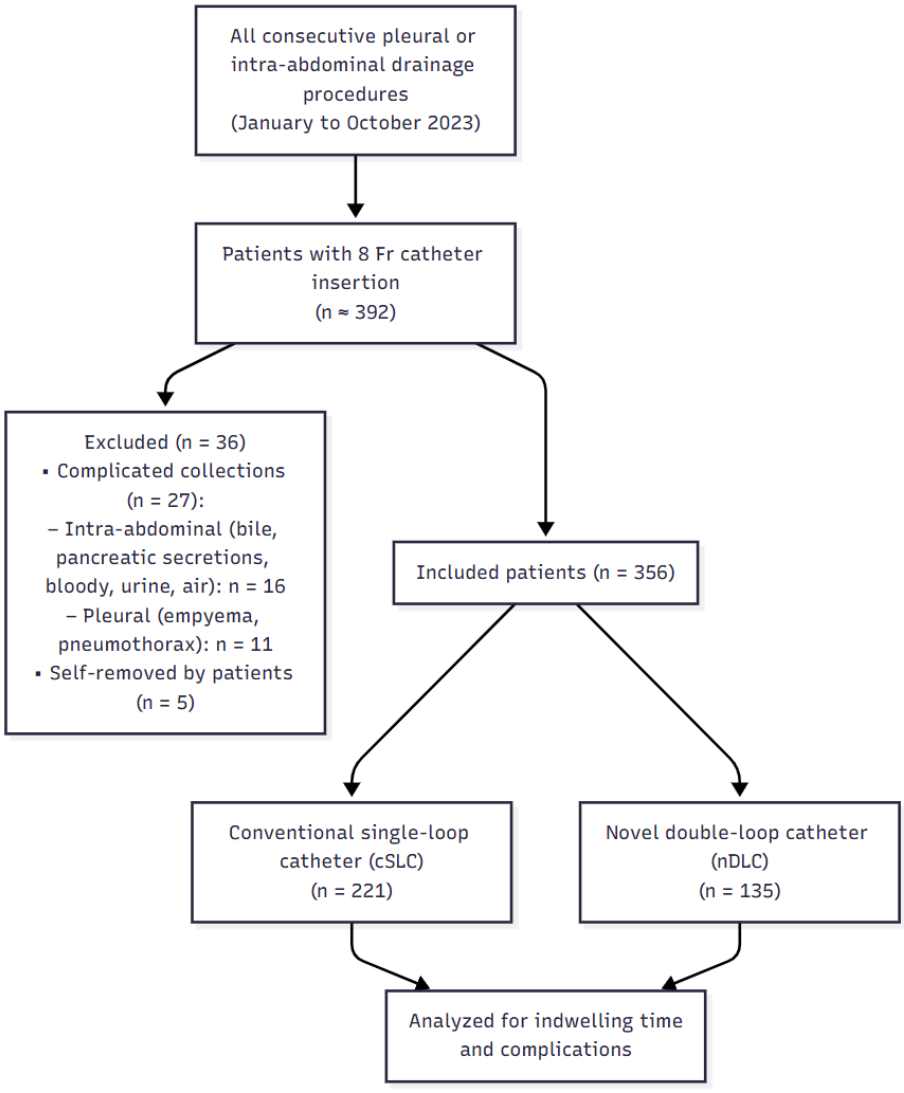


Figure 3. Flowchart of patient selection for the study.

on the analysis of the catheter's inherent anchoring efficacy and patient outcomes, catheters that were self-removed by patients (n = 5) were excluded from the study.

A total of 356 patients met these criteria and were divided into two groups based on the catheter design employed. The nDLC group comprised 135 patients, and the cSLC group included 221 patients. Demographic information, including age and sex, as well as clinical characteristics such as fluid location (ascites or pleural effusion), underlying etiology (e.g., cardiac or renal failure, infection, portal hypertension, pneumoconiosis, or malignancy), and fluid type (transudate or exudate), were gathered (Figure 3).

Procedures

Four interventional radiologists performed all the pleural or intra-abdominal drainage procedures in the interventional radiology suite. All four interventional radiologists had over 5 years of procedural experience. Drainage catheter placement was performed under fluoroscopy and ultrasound guidance using the Seldinger technique as follows: (1) after confirmation of fluid collection in the lower thorax or dependent position in the supine (intra-abdominal fluid drainage) or lateral decubitus position (pleural drainage), 1% lidocaine hydrochloride was locally administered at the skin surface of the prepared puncture site. Under ultrasound guidance, the fluid collection was punctured with an 18-gauge Angiocath needle, and a few milliliters of fluid were aspirated. After dilation, an 8-F pigtail catheter was inserted over the introduced 0.035-inch guidewire (Radifocus; Terumo, Tokyo, Japan) under fluoroscopic control. No suture anchoring was performed in the nDLC group because the second loop of the catheter was expected to prevent retraction effectively. However, all catheters in the cSLC group were secured with suture anchoring to ensure proper placement and prevent displacement.

Catheter survival and complications

Clinical success was defined as an improvement in intra-abdominal or pleural fluid collection on follow-up radiographs without catheter dysfunction. The complication-free catheter indwelling time was defined as the catheterization period without catheter dysfunction. If a catheter was exchanged or removed due to catheter dysfunction or catheter-related complications, it was treated as an uncensored event. If the patient was either discharged with the catheter or lost to follow-up without catheter dysfunction, the catheter indwelling time was determined as the period up to the last follow-up radiograph or the most recent assessment of drainage volume, and it was treated as a censored event.

Major complications included dysfunctional retraction, simple blockage, and complete dislodgement. Dysfunctional retraction is characterized by the outward pulling of the pigtail loop, causing it to retract toward the chest or abdominal wall. This results in blockage of the last side hole of the drainage catheter, ultimately leading to catheter dysfunction. Simple blockage refers to an obstruction within the drainage catheter without any displacement despite substantial residual fluid collection evident on simple radiographs or ultrasound. Complete dislodgement is defined as full displacement of the catheter tip outside the pleural or peritoneal cavity.

Statistical analysis

No formal a priori sample size calculation was conducted in this retrospective observational study. Post-hoc power analysis showed that the achieved sample sizes (n = 221 for cSLC, n = 135 for nDLC) provided > 95% power to detect the observed difference in the complication-free indwelling time (log-rank test) and > 90% power to detect the difference in dysfunctional retraction rates (Fisher's exact test) at α: 0.05. Continuous variables are reported as mean ± standard deviation, and categorical variables are presented as numbers (percentages). Comparisons between the novel and conventional catheter groups were conducted using the chi-square test or Fisher's exact test for categorical variables and Student's t-test for continuous variables. Kaplan–Meier survival

analysis was used to calculate the indwelling time of each group. Statistical significance was set at $P < 0.05$.

Results

Demographic data, including patient characteristics and fluid composition, showed no significant differences between the two groups (Table 1). In the nDLC group, 23.1% of patients had transudative fluids and 76.9% had exudative fluids, whereas in the cSLC group, 25.9% had transudative fluids and 74.1% had exudative fluids; these differences were not statistically significant ($P = 0.372$). Catheter dysfunction was observed in 28 cases (12.7%) in the cSLC group and in 9 cases (6.7%) in the nDLC group. A significant difference was noted in the incidence of dysfunctional retraction, with 10 occurrences in the cSLC group and none in the nDLC group ($P < 0.05$). Simple blockages were observed in 18 cases (8.1%) with the cSLC and 9 cases (6.7%) with the nDLC; however, this difference was not statistically significant ($P = 0.609$).

In total, 124 of the 135 patients in the nDLC group and 178 of the 221 patients in the cSLC group demonstrated improvement in intra-abdominal or pleural fluid collection on follow-up radiographic evaluations without catheter dysfunction. The clinical success rates for the nDLC and cSLC groups were 91.9% and 80.5%, respectively, with a statistically significant difference between the two groups ($P < 0.05$). The mean catheter indwelling time before the occurrence of an event (catheter dysfunction, catheter-related complications, discharge with a functioning catheter, or loss to follow-up) was 13 days in the nDLC group and 8.7 days in the cSLC group when the censored data were not considered. Kaplan–Meier survival analysis, which accounted for both censored and uncensored data, demonstrated a significant difference in the complication-free catheter indwelling time between the two groups ($P < 0.05$; Figure 4a). The nDLC group showed a markedly longer mean indwelling time [72.1 days, 95% confidence interval (CI): 54.0–90.1] than the cSLC group (20.4 days, 95% CI: 18.8–22.0). This result indicates a substantial improvement in catheter function duration with the nDLC. (Table 2).

Subgroup analyses further confirmed the superiority of the nDLC in both drainage settings ($P < 0.05$ for both comparisons). In the pleural drainage subgroup, the mean indwelling time was 36.9 days with the nDLC versus 20.7 days with the cSLC (Figure 4b). In the intra-abdominal drainage subgroup, the corresponding values were 77.5 vs. 19.1 days, respectively (Figure 4c).

Table 1. Baseline characteristics of the study patients

	Single loop	Double loop	*P* value
No. of patients	221	135	
Sex			
Men	107	67	0.733
Women	114	68	
Age (years), mean ± SD	66.5 ± 15.6	69.9 ± 14.8	0.233
Fluid location			
Ascites	31 (14.0%)	24 (17.7%)	0.095
Pleural effusion	190 (86.0%)	111 (82.3%)	
Etiology			
Cardiac or renal failure	49	32	
Infection	32	25	
Portal hypertension	3	4	0.057
Pneumoconiosis	0	1	
Malignancy	137	73	
Nature of fluid			
Transudate	51 (23.1%)	35 (25.9%)	0.372
Exudate	170 (76.9%)	101 (74.1%)	

SD, standard deviation.

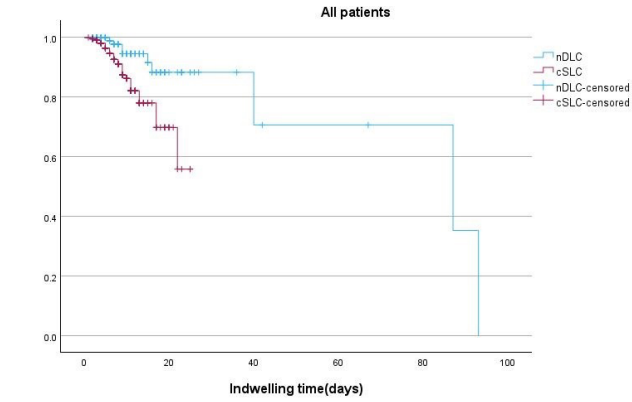
Table 2. Summary of study outcomes

	Single loop (n = 221)	Double loop (n = 135)	*P* value
Catheter dysfunction	28	9	
Dysfunctional retraction	10	0	< 0.001
Simple blockage	18	9	0.295
Complete dislodgement	1	0	0.411
Clinical success	178 (80.5%)	124 (91.9%)	0.004
Complication-free catheter (days) **Indwelling time** (days)	20.4	72.1	0.012
Pleural	20.7	36.9	0.048
Intra-abdominal	19.1	77.5	0.007

Discussion

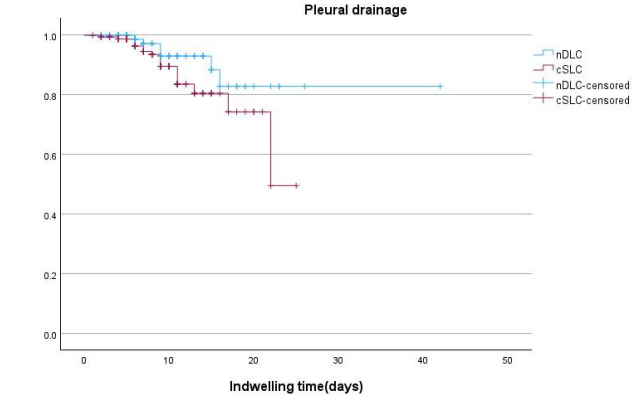
The average indwelling time for drainage catheters used in the management of ascites or pleural effusion varies according to patient factors, the type of effusion, and catheter characteristics. For ascitic fluid drainage catheters, the mean indwelling time typically ranges from 5 to 14 days. Some studies have reported longer durations, with safe usage documented for up to 30 days in certain cases.[4] Pleural drainage catheters exhibit a mean indwelling time of 3–14 days. However, in cases of chronic pleural effusion requiring long-term management, indwelling times may extend to several weeks or months.[5] Therefore, the selection and development of drainage catheters with improved performance for long-term use is necessary.

The main causes of catheter dysfunction can be categorized as catheter retraction, simple blockage, or complete dislodgement. Catheter retraction is one of the most common types of catheter malfunction.[4,6] Catheter migration can occur due to respiratory motion and routine movement even when the catheter is securely anchored to the skin.[7,8] This phenomenon is more prevalent in newly inserted catheters without an established tract formation, potentially leading to a relatively high incidence of relatively short-term intra-abdominal or pleural drainage catheters. In addition, suture-mediated anchoring can lead to various complications, including tissue damage caused by exces-



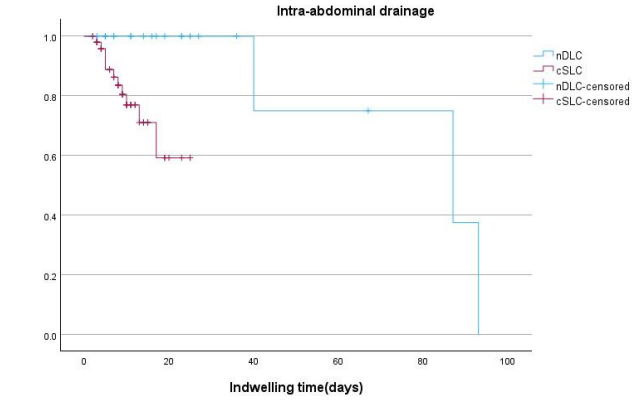
a

	0 days	20 days	40 days	60 days	80 days	93 days
Novel (nDLC)	130	14	5	3	2	1
Conventional (cSLC)	197	9	0	0	0	0



b

	0 days	10 days	20 days	30 days	40 days	42 days
Novel (nDLC)	111	40	6	1	1	1
Conventional (cSLC)	170	53	6	0	0	0



c

	0 days	20 days	40 days	60 days	80 days	93 days
Novel (nDLC)	24	9	4	3	2	1
Conventional (cSLC)	51	3	0	0	0	0

Figure 4. Kaplan–Meier curves showing the indwelling catheter survival time.

(a) Comparison between the novel double-loop catheter and conventional single-loop catheter in the overall cohort. **(b)** Subgroup analysis of the indwelling time for pleural drainage cases. **(c)** Subgroup analysis of the indwelling time for intra-abdominal drainage cases. nDLC, novel double-loop drainage catheter; cSLC, conventional single-loop catheter.

sive tension, leakage from improper track angles, catheter dislodgement (particularly in patients with obesity), and an increased risk of infection at suture sites.[8] Considering these issues, Huang et al.[8] proposed the use of internal pigtail loops for fixation instead of suture-mediated anchoring for long-term catheter use. In the present study, the nDLC group demonstrated significantly lower catheter retraction rates than the cSLC group despite the absence of suture-mediated anchoring. Moreover, no complete dislodgement was observed in the nDLC group. These findings suggest that the proximal coil of the nDLC effectively inhibited catheter retraction. Additionally, by eliminating the need for suture-based fixation, as typically required in conventional catheters, the nDLC design potentially reduces the risk of suture-related complications.

In this study, the cSLC group exhibited a higher blockage rate than the nDLC group (8.1% vs. 5.1%). Catheter obstruction can occur due to the accumulation of biological materials, including proteins, fibrin, and cellular debris, within the catheter lumen or drainage ports, progressively narrowing or completely occluding the inner diameter of the catheter. In our experience, a substantial amount of debris lodged only in the last hole of the pigtail coiling was frequently observed during the exchange of dysfunctional drainage catheters. Fibrin and cellular debris accumulation appears to accelerate when the catheter is retracted, causing the last hole in the pigtail coil to be occluded by the chest wall. To address this, we designed a dual-loop catheter without side holes in the proximal coil. This design effectively reduced the catheter retraction rate while preventing the last side hole from contacting the chest wall, thereby eliminating the risk of fibrin and cellular debris accumulation and potentially reducing the simple blockage rate. Although the difference in the simple blockage rate did not achieve statistical significance in this study, we hypothesize that catheter blockage may still occur due to the accumulation of biological materials when the drainage fluid volume decreases and the catheter contacts the pleura or peritoneum. Further systematic and detailed observational studies are needed to investigate this phenomenon.

This study has some limitations. First, it was retrospective in nature. However, to minimize bias, we compared consecutive cases of ascites and pleural drainage that were performed during the same period. To overcome the limitations of this retrospective study, a prospective randomized controlled

trial comparing the nDLC and the cSLC is being planned. Second, this study focused solely on uncomplicated fluid drainage. The nDLC has a fixed 5 cm interval between the proximal and distal pigtail coils. This interval might potentially reduce drainage efficacy in multiseptate complicated fluid collections. As catheter use continues to expand to various conditions and indications, further evidence-based studies are warranted to improve our understanding of this nDLC. Third, owing to the consecutive patient comparison during the same period, a high proportion of censored data was present (discharges with functioning catheters or loss to follow-up). This censoring can bias the simple mean indwelling time downward; therefore, we relied primarily on Kaplan–Meier estimates, which appropriately handle censoring, to compare catheter survival between groups. Another limitation is the lack of a subgroup comparison between the non-sutured nDLC and the non-sutured cSLC, which could have better delineated the role of suturing. This should be explored in future prospective studies. Furthermore, although simple blockage showed a numerical reduction with the nDLC, the difference was not statistically significant; thus, the proposed mechanism remains suggestive and requires confirmation in larger studies. Moreover, multivariable adjustment was not performed due to the retrospective design and standardized approach. However, the numerical difference in malignancy prevalence warrants multivariable regression in future prospective studies to exclude confounding.

In conclusion, this nDLC effectively improved the chronic issue of dysfunctional retraction associated with single-loop catheters. Notably, despite the absence of sutures, there were no instances of dysfunctional retraction or complete dislodgement, which suggests a lack of anchoring-related complications. These characteristics indicate that this nDLC may be suitable for long-term use.

Footnotes

Conflict of interest disclosure

The authors declared no conflicts of interest.

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