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Non-invasive Removal of Tethered Surgical Drains Using Kirschner Wire with Ultrasound Guidance: An In-Vitro Experimental Study

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ABSTRACT

Background. Surgical drain retention is rare but can cause significant consequences if not addressed promptly. Few studies have investigated non-invasive methods to remove tethered drains. This study aimed to determine whether tethered drains could be removed using a Kirschner wire under ultrasound guidance.

Methodology. The study was an experimental in-vitro study on pork loin specimens. Drain tubes (No. 10, No. 15) were placed subfascially with one suture stitch passing through the lumen of the drain tube (Vicryl 2-0, Vicryl 1-0). An ultrasound machine (Sonosite M Turbo) was used to locate the area of tethering. Kirschner wires (1.6 mm and 2.0 mm, threaded and smooth) were inserted and thrust multiple times intraluminally to cut the suture. There were eight possible combinations of wire type, drain diameter, and suture size with seven replicates per combination. Ultrasound accuracy was set at 0.5 cm from the tethering site, and durations were recorded with a cut-off value of five minutes.

Results. Ultrasound was able to locate the tethered site in 47 out of 56 attempts (83.93%). Most attempts (48 out of 56, 85.71%) were successful in cutting the tethered suture and removing the drain. The overall duration for drain removal was 1'35". Shorter durations were recorded for threaded compared to smooth Kirschner wires (1'34" vs 1'37"), for size No. 10 compared to No. 15 drains (1'20" vs 1'50"), and for Vicryl 2-0 compared to Vicryl 1-0 sutures (1'25" vs 1'45").

Conclusion. Using ultrasound to locate the area of tethering and using Kirshner wire intraluminally was an effective non-invasive way to remove tethered drains in pork loin specimens. This combined method can simplify drain removal and can be used as a first-line option before open removal.

Keywords. tethered drain, Kirschner wire, intralumenal, non-invasive, ultrasound

INTRODUCTION

Surgical drains allow blood and other fluids to be removed from the surgical wound postoperatively.[1] While their use has been documented as early as Hippocrates, it remains controversial and highly dependent on the surgeon's preference. Advantages include reducing ecchymosis, hematoma, seroma (which are culture media for bacteria), and dressing changes,[2] while complications include retrograde infection, increased postoperative bleeding (paradoxically), and breakage or retention.[3-5] A retained drain (either broken or tethered) is rare, easily overlooked, and avoidable but can lead to serious complications.[6]

The incidence rate is unknown and likely underreported because of legal implications. The primary cause for a tethered drain is accidental suture fixation during wound closure. Post-operative drains are usually pulled out at bedside. Unfortunately, tethering is often discovered only

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upon attempting removal.[7] Most surgeons support surgical exploration for complete removal. However, the additional procedure places the patient at risk of anesthesia and surgery, causes anxiety for both patient and surgeon, and increases costs, infection rates, and postoperative pain.

To prevent reoperation, non-invasive methods to remove tethered drains have been attempted. Namyslowski was able to remove a retained Jackson-Pratt drain percutaneously by inserting, maneuvering, and inflating an angioplasty balloon over a hydrophilic-coated steerable guidewire.[8] Rue and Johnson removed silicone drains by applying gentle in-line traction while twisting the drain five to seven times.[9] Lazarides used the pointed tip of Kirschner wires intraluminally to cut the suture and remove the drain.[10] To date, this is the only paper describing the use of Kirschner wires to remove tethered drains. They reported a 100% success rate but did not mention the specimens used.

Percutaneously locating the tethering site is also a challenge. Traditionally, plain radiographs, computed tomography (CT) scans, and contrast-enhanced magnetic resonance imaging (MRI) have been used. Given that silicone and polyvinyl chloride (PVC) tubes are radiolucent, ultrasound can visualize their path within the body. Li et al. used ultrasound to indirectly visualize the site of tethering.[11] After locating the walls of the drain tube on the longitudinal view, the authors described the "sliding sign," which was visualized as the drain tube sliding in the surrounding soft tissue with repeated gentle tugging of its free end. Moving the transducer proximally (or away from the free end of the drain tube), the authors identified the point where the sliding sign disappears, and the drain tube and soft tissue move as one during repeated tugging. This area was marked as the "vanishing point" and corresponded to the tethering site. Under ultrasound guidance, the authors were able to successfully remove the tethered drains in all three patients and were able to reproduce the same results in pork models.

Herein, we present a technique of tethered drain tube removal under ultrasound guidance using an intraluminal Kirschner wire. To the best of our knowledge, there has been no study combining the use of both Kirschner wire and ultrasound to remove tethered drains.

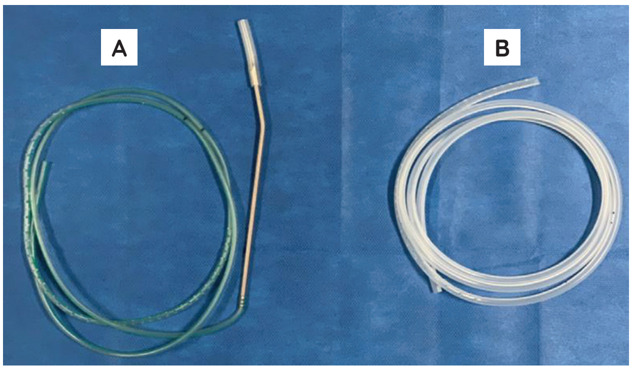

Figure 1. (A) Drain tube Fr. 10 (polyvinyl chloride; Biometrix); **(B)** Drain tube Fr. 15 (silicone; Cardinal Health).

OBJECTIVES

General objective

To demonstrate the efficacy of using Kirschner wire with ultrasound guidance as a non-invasive method to remove tethered drains.

Specific objectives

1. To determine the success rate of ultrasound in locating the site of tethering
2. To measure the duration required to cut the suture and remove the drain
3. To determine the success rate in cutting the suture and removing the drain
4. To demonstrate the effect of the thickness of the suture, Kirschner wire type, and drain diameter on the success rate and duration required to cut the tethered drain

METHODOLOGY

The protocol was approved by our institution's ethics review board (ERB).

Design and patients

We conducted an in-vitro experimental study using boneless pork loin specimens (each measuring 20 x 5 x 5 cm [L x W x H]), instead of cadaveric or actual patients. Pork models were used because they are simple and cost-effective models and have similar anatomic structures and echogenicity to human tissue.[11]

Sample size determination

With eight possible combinations of wire type, drain diameter, and suture size, we required a minimum of seven replicates per combination. The sample size was calculated using the formula in the study by Arifin and Zahiruddin for animal models.[12]

$$\text{Minimum: } 10/(r-1)+1^{a,b}$$

$$\text{Maximum: } 20/(r-1)+1^{a,b}$$

Materials and specifications

- 1.6 mm (threaded and smooth) Kirschner wire with trocar tip – stainless steel, Olten Instruments
- 2.0 mm (threaded and smooth) Kirschner wire with trocar tip – stainless steel, Olten Instruments
- Drain tube Fr. 15 silicone – Cardinal Health (Figure 1)
- Drain tube Fr. 10 medium polyvinyl chloride (PVC) – Biometrix (Figure 2)
- Smooth, synthetic, absorbable suture (Polyglactic 910) – Vicryl 2-0, Vicryl 1-0 – Johnson & Johnson
- Ultrasound machine – Sonosite M-Turbo

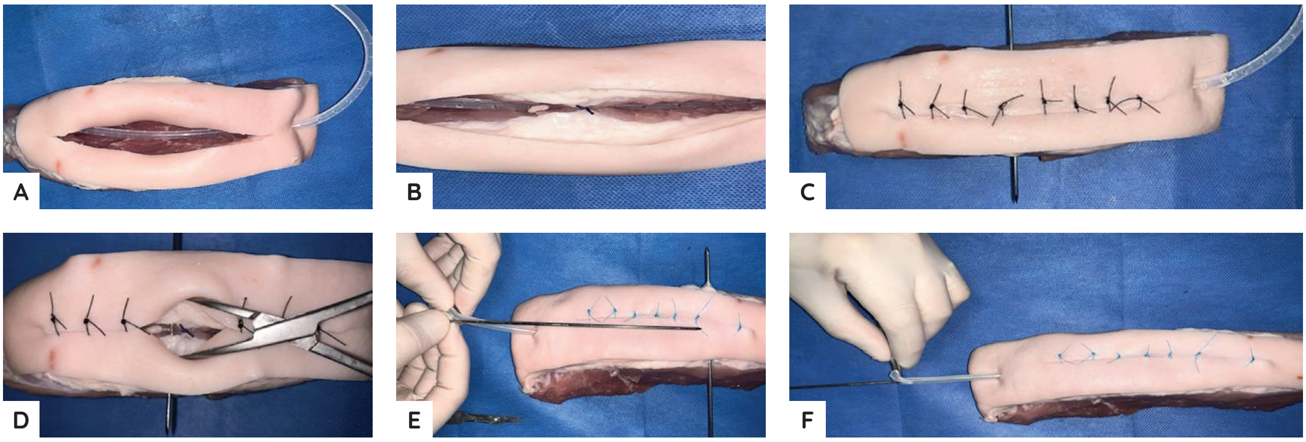

Figure 2. **(A)** Porkloin specimen sample with the Fr. 15 silicone drain tube placed subfascially, approximately 3 cm in depth from the skin. **(B)** Vicryl 2.0 sutured through the drain tube within the fascial layer. **(C)** With the skin closed using interrupted sutures, the approximated location of tethering was determined via ultrasound, and the level was marked by a K-wire. **(D)** With the skin closed using interrupted sutures, the approximated location of tethering was determined via ultrasound, and the level was marked with a K-wire. **(E)** Accuracy of the ultrasound was determined via visual inspection with a cut-off distance value of 0.5 cm. **(F)** A straight clamp was used to maintain in-line tension while the K-wire was being inserted.

Unlike Lazarides' study, we used trocar tips (because diamond-pointed tips were not available locally), and included threaded Kirschner wires.

Pork loin preparation

Specimens were prepared by an orthopedic resident. The specimens were secured manually by one end to a table. Each specimen was incised in the midline. Subcutaneous tissue, fascia, and muscle were incised in line with the skin incision, with an approximate depth of 3 cm. The suction drain tube was placed subfascially. The fascia was closed with an absorbable suture in a simple interrupted inverted T technique with one suture stitch passing through the lumen of the drain tube. The skin was closed with non-absorbable sutures in a simple interrupted manner, obscuring the site of tethering. A minimum of 10 cm of drain tube length was placed inside the pork loin specimen (Figure 2). The combinations of the Kirschner wire type, tube diameter, and suture size used are listed in Table 1.

Locating the site of tethering using ultrasound

A second examiner (an orthopedic surgeon fellowship-trained in sports and musculoskeletal ultrasound) used a portable ultrasound machine's (Sonosite M-Turbo) linear probe (6–13 mHz) in standard 2D mode to locate the site of tethering. On longitudinal view, the drain tube, its perforations, and its path within the surrounding soft tissue were identified based on the difference in echogenic properties. The free end was repeatedly tugged to elicit the "sliding sign." The "vanishing point", where the sliding sign disappeared was also determined (Figure 3). This corresponded to the transition point where the drain tube slides freely within the surrounding soft tissue and the drain tube and soft tissue move as one during repeated tugging. The "vanishing point" matched the site where the drain was tethered and was pinned in place with a separate

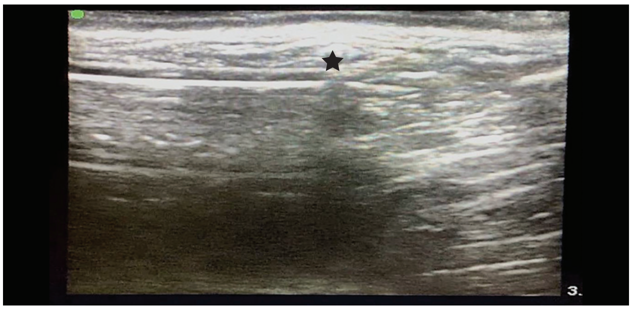

Figure 3. The black star represents the "vanishing point" where the suture was located within the drain tube.

(marking) Kirschner wire inserted within the soft tissue, perpendicular to the incision. The specimen was then visually inspected. The attempt was marked successful if the marking wire was found within a set distance of 0.5 cm from the actual suture location.

Introduction of Kirschner wire within the drain tube lumen

A third examiner (an orthopedic surgeon fellowship-trained in trauma) performed this step. The free end of the tube was measured and cut to the same length as the depth of the Kirschner wire to be introduced into the lumen, determined by the surface marking from the previous step. This was done to allow ease in the handling of the Kirschner wire. The free end of the drain tube was cut longitudinally (about 1 cm) and a straight clamp was applied. With firm in-line traction on the clamp and tube, the drain was pulled taut, straightening the drain, making it easier to introduce the wire, and reducing the risk of tube perforation. The Kirschner wire was advanced intraluminally and once there was resistance from the suture was felt, the wire was thrust forcefully one to two times per second, with forward, backward, and rotational movements. The durations were recorded for each material combination.

Table 1. Combinations for wire type, drain diameter, and suture size

1	Smooth 1.6 mm Kirschner wire x No. 10 drain x Vicryl 2.0
2	Smooth 1.6 mm Kirschner wire x No. 10 drain x Vicryl 1.0
3	Smooth 2.0 mm Kirschner wire x No. 15 drain x Vicryl 2.0
4	Smooth 2.0 mm Kirschner wire x No. 15 drain x Vicryl 1.0
5	Threaded 1.6 mm Kirschner wire x No. 10 drain x Vicryl 2.0
6	Threaded 1.6 mm Kirschner wire x No. 10 drain x Vicryl 1.0
7	Threaded 2.0 mm Kirschner wire x No. 15 drain x Vicryl 2.0
8	Threaded 2.0 mm Kirschner wire x No. 15 drain x Vicryl 1.0

Table 2. Ultrasound location success rate

	Number located successfully via ultrasound		*p*-value
	n	%	
Overall	47	83.93	-
Drain diameter			
No. 10	24	85.71	0.7185
No. 15	23	82.14	
Suture size			
Vicryl 1.0	23	82.14	0.7185
Vicryl 2.0	24	85.71	

If the procedure could not be completed in five minutes, the attempt was marked as failed. This endpoint was set arbitrarily, since previous studies did not mention any time endpoints for their attempts (Lazarides), or were successful within five minutes. All attempts exceeding the 5-minute cut-off were designated a value of 5 minutes and 1 second (5'01"). Attempts were also marked as failed if the Kirschner wire perforated the tube.

Disposal

Pork loin specimens and the materials used were disposed of properly according to local health standards.

Outcome measures

The efficacy of ultrasound in identifying the site of tethering was based on the success rate (number of successful attempts within 0.5 cm cut-off distance of the actual suture location divided by the total number of attempts).

The efficacy of the Kirschner wire in cutting the suture intra-luminally was evaluated based on the duration (starting from probe placement onto the pork loin specimen after successful ultrasound identification and ending with the K-wire reaching the site of tethering) and the success rate (number of successful attempts divided by the total number of attempts).

Statistical analysis

Descriptive statistics (mean and standard deviation) were used to summarize the data. There were three factors for this analysis: A – Wire type (smooth, threaded), B – drain diameter (No. 10, No. 15), and C – suture size (Vicryl 1-0, Vicryl 2-0). Three-way ANOVA was used to determine any difference in the attempt durations. Three-way analysis (A x B x C) was performed, followed by two-way analysis (A x B, A x C, B x C), and then the main effects analysis (A, B, C).

All valid data were included in the analysis. Missing variables were neither replaced nor estimated. STATA 15.0 was used for data analysis.

RESULTS

Success rate of locating the site of tethering using ultrasound

Using the ultrasound, the examiner was able to successfully locate the site of tethering in 47 out of 56 attempts (83.93%). The success rate was 85.71% for No. 10 size tubes and 82.14% for No. 15 size tubes ($p = 0.7185$). The success rate was 85.71% for Vicryl 2-0 and 82.14% for Vicryl 1-0 ($p = 0.7185$) (Table 2).

Duration

The overall mean duration required to cut the suture and removing the tethered drain was 1'35" (1.58 ± 1.62). Using threaded Kirschner wires took a mean of 1'34" (1.56 ± 1.61) compared to a mean of 1'37" (1.61 ± 1.65) using smooth wires. The mean duration was 1'20" (1.34 ± 1.50) for tube size Fr. 10 and 1'50" (1.83 ± 1.72) for Fr. The mean duration was 1'25" (1.42 ± 1.31) for Vicryl 2-0 and 1'45" (1.75 ± 1.88) for Vicryl (Tables 3 and 4).

Table 3. Mean durations

	Mean ± SD	Label
Overall	1.58 ± 1.62	1'35"
Wire type		
Smooth	1.61 ± 1.65	1'37"
Threaded	1.56 ± 1.61	1'34"
Drain diameter		
No. 10	1.34 ± 1.50	1'20"
No. 15	1.83 ± 1.72	1'50"
Suture size		
Vicryl 1.0	1.75 ± 1.88	1'45"
Vicryl 2.0	1.42 ± 1.31	1'25"

Table 4. Mean durations per combination of wire type, drain diameter, and suture size

Wire type	Drain diameter	Suture	Mean	SD	N	Label
Threaded	No. 10	Vicryl 1.0	1.17	1.84	7	1'10'
		Vicryl 2.0	1.92	1.51	7	1'55"
	No. 15	Vicryl 1.0	1.31	1.65	7	1'19"
		Vicryl 2.0	1.85	1.68	7	1'51"
Smooth	No. 10	Vicryl 1.0	1.75	1.62	7	1'45"
		Vicryl 2.0	0.50	0.59	7	30"
	No. 15	Vicryl 1.0	2.76	2.34	7	1'46"
		Vicryl 2.0	1.41	0.88	7	1'25"

Success rate of tethered drain removal

Out of a total of 56 attempts, 48 (85.71%) attempts were successful in cutting the tethered suture and removing the drain. The success rate was 85.71% for both smooth and threaded Kirschner wires. The success rate for removing No. 10 tubes was higher than for No. 15 tubes (89.29% vs 82.14%, $p = 0.449$) (Table 5).

Three-way ANOVA showed no significant effect on duration among the three factors of wire type, drain diameter, and suture size ($p = 0.944$). Main effects analysis showed that wire type ($p = 0.919$), tube diameter ($p = 0.253$), and suture size ($p = 0.443$) did not significantly affect duration (Table 6).

DISCUSSION

This study aimed to determine the efficacy of Kirschner wire under ultrasound guidance in non-invasively removing tethered drains in terms of duration and success rates.

The examiner performing the ultrasound was able to locate the area of the tethering in 47 out of 56 attempts (83.9%), with an accuracy within 0.5 cm. Most of the nine failed attempts were located between 0.5 and 1 cm of the suture and only one attempt was more than 2 cm off. This radius may have little implication as it is often exposed during open removal. It was encouraging that the "sliding sign" and "vanishing point" (Li et al.) were easily reproduced. This method is easy to learn, quick, and simple.[11] The PVC tubes were more hyperechoic than the silicone, making them easier to visualize within the soft tissue. There were no differences in ultrasound characteristics between Vicryl 1-0 and 2-0.

The high overall success rate for cutting the suture and removing tethered drains (85.71%) showed that using a Kirschner wire was effective in cutting the suture within the lumen of the drain tube. Out of the 56 attempts, there were eight failed attempts: three attempts took longer than the 5-minute cut-off, two attempts resulted in tube perforation by the Kirschner wire, and in the remaining three attempts, the wire failed to cut the suture. Both instances of perforation involved No. 15 silicone tube drains, which were softer and more pliable compared to the No. 10 medium PVC. Upon visual inspection of the three attempts wherein the sutures were not cut, the suture thread was seen tightly adjacent to the inner lumen wall (Figure 4). Thereby, in these instances, the tip and the threaded part of the Kirschner wires introduced into the lumen had limited contact with the suture, making this technique unsuccessful.

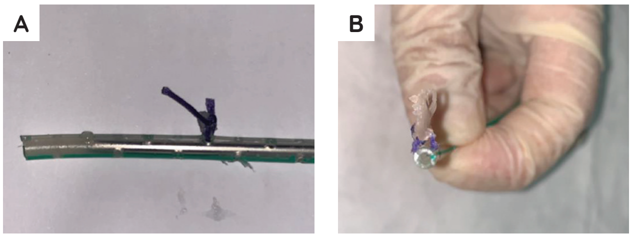

Figure 4. Suture thread adjacent to the inner wall on the drain tube lumen: **(A)** longitudinal view; **(B)** cross-sectional view.

The three-way ANOVA analysis of the different variables (wire type, drain diameter, and suture size) yielded no significant differences, implying that these factors (singly or in combination) did not affect the procedure duration.

The success rate was 89.29% when using drain size No. 10 and 82.14% for No. 15 ($p = 0.449$). Lazarides used 1.6 mm wires for No. 10 tubes and 2.5 mm wires for No. 14 tubes, corresponding to the thickest introducible wire diameter per drain size. For this study, since 2.5 mm Kirschner wires were not available, we used 2.0 mm wires instead. Since the wire was much smaller than the tube, the suture moved around within the lumen, making it more difficult to cut. The success rate was higher for Vicryl 2-0 than 1-0 sutures (92.86% vs 78.57% respectively, $p = 0.130$), likely because the thinner 2-0 suture was easier to completely cut.

For both smooth and threaded wires, the trocar tip's contact with the suture could be felt as the wire was being advanced in and out of the lumen. However, the threaded Kirschner wires provided more tactile feedback than the smooth Kirschner wires, thanks to the additional contact of the threaded portion, and an audible "grittiness." In terms of palpability of

Table 5. Removal success rate

	Success of cutting		*p*-value
	n	%	
Overall	48	85.71	-
Wire type			
Smooth	24	85.71	1.000
Threaded	24	85.71	
Drain diameter			
No. 10	25	89.29	0.449
No. 15	23	82.14	
Suture size			
Vicryl 1.0	22	78.57	0.130
Vicryl 2.0	26	92.86	

Table 6. Three-way interaction ANOVA table

	Type III Sum of Squares	df	Mean Square	F	*p*-value
Main effects					
Wire type	0.026	1	0.026	0.010	0.919
Drain diameter	3.425	1	3.425	1.340	0.253
Suture size	1.528	1	1.528	0.598	0.443
Two-way interaction					
Wire type x Drain diameter	2.979	1	2.979	1.166	0.286
Wire type x Suture size	13.195	1	13.195	5.164	0.028
Drain diameter x Suture size	0.083	1	0.083	0.032	0.858
Three-way interaction					
Wire Type x Drain Diameter x Suture Size	0.013	1	0.013	0.005	0.944
Residual Error	122.662	48			
Total	284.354	56			

R squared = 0.148 (Adjusted R squared = -0.023) suture size, Vicryl 1-0, being thicker, was more easily felt by the wire within the lumen tube, regardless of the drain size and wire type used.

Ultimately, preventing drain retention is still more effective than any treatment. When cutting the inner end of the drain, the cut should be made between the holes. This aids in early detection, as pulling out the tube and finding the inner end through holes indicates an unintentional break and drain retention. Jaafar recommended purposefully cutting the drain with a consistent number of holes and documenting this in the surgical technique.[3] During drain removal, the number of holes should be confirmed to be the same. Another technique is to leave slack in the drain such that the black dot (or any mark on the drain denoting the appropriate skin level) is buried below the skin. After closing the wound, the slack is to be pulled out until the marker is at the skin. If the tube glides easily, it is unlikely to be sutured in.[3,13]

LIMITATIONS AND RECOMMENDATIONS

While the present study's findings provide valuable outcomes, these results must be interpreted with care. This technique may be unsuccessful in cases where the suture stitch is tightly adjacent to the inner lumen wall or is around the tube, rather than through it. Some orthopedic surgeons who are not trained in musculoskeletal ultrasound might encounter difficulty in identifying the drain tube and locating the exact site of tethering. In this study, we did not infiltrate the site with local anesthetic, as in the setting of actual human subjects. Local infiltration can change the echogenicity of the soft tissue surrounding the tethered drain and might affect visualization. We recommend that careful thrusting should be done when removing silicone drain tubes since the material is softer and easier to perforate as compared to medium PVC drain tubes. If available, the authors also recommend the use of threaded Kirschner wires since they provide better tactile and auditory feedback.

Future researchers can investigate applying this technique in cadaveric specimens to simulate human tissue. When considering human subjects, informed consent should be secured. While ultrasound should not pose any undue risk to the patient, proper aseptic technique should be applied for the rest of the procedure.

CONCLUSION

Here, we report the efficacy of using Kirshner wire with ultrasound guidance to non-invasively remove tethered drains in-vitro. This method may be a first-line option done aseptically at the bedside under local anesthesia.

STATEMENT OF AUTHORSHIP

All authors certified fulfillment of ICMJE authorship criteria.

AUTHOR DISCLOSURE

The authors declared no conflict of interest.

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None.

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