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SPECIAL SECTION: CROSS SECTIONAL INTERVENTIONS

Is routine imaging necessary prior to percutaneous abscess catheter removal?

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Abstract

Background Routine management after abscess drainage includes CT or fluoroscopic imaging to assess for residual abscess cavity prior to catheter removal. It is unclear whether this practice is necessary in patients without residual infection signs and symptoms.

Purpose To evaluate safety of abscess catheter removal without follow-up imaging in patients without residual clinical or laboratory signs of infection and catheter output < 10 cc/day for 2 consecutive days.

Materials and methods In this IRB-approved, HIPAA compliant, retrospective study, consecutive patients that underwent percutaneous CT-guided drainage of a single abdominal or pelvic abscess between 01/2015 and 12/2017 in a single tertiary academic institution with or without follow-up imaging prior to catheter removal were included. In our institution, catheters are routinely removed without imaging if there are no clinical (fever, pain) or laboratory (elevated WBC count) signs of infection and catheter output is < 10 cc/day for 2 consecutive days. Patients' and abscess's characteristics, repeat imaging data, and need for re-interventions were obtained through medical records review. Statistical analysis was performed with Fisher's exact test for independent data and Student's *t*-test for comparison of group means.

Results 310 consecutive patients (age 56 ± 16 years, 48% female) were included in the study. In 265/310 (85%) patients, no routine follow-up imaging prior to catheter removal was obtained. In 2/265 (0.8%, 95% CI 0.02–0.27%) patients without routine pre-removal imaging, repeat abscess drainage was required 6 and 15 days after catheter removal in patient with perforated appendicitis and after laparoscopic renal cyst decortication, respectively. No patients, 0/45 (0%, 95% CI 0–0.07), that underwent routine imaging without clinical or laboratory signs infection needed to undergo a repeat abscess drainage.

Conclusion There is a low rate (0.8%) of abscess recurrence if percutaneous abscess catheter is removed at the time cessation of drainage without routine imaging in clinically well patient.

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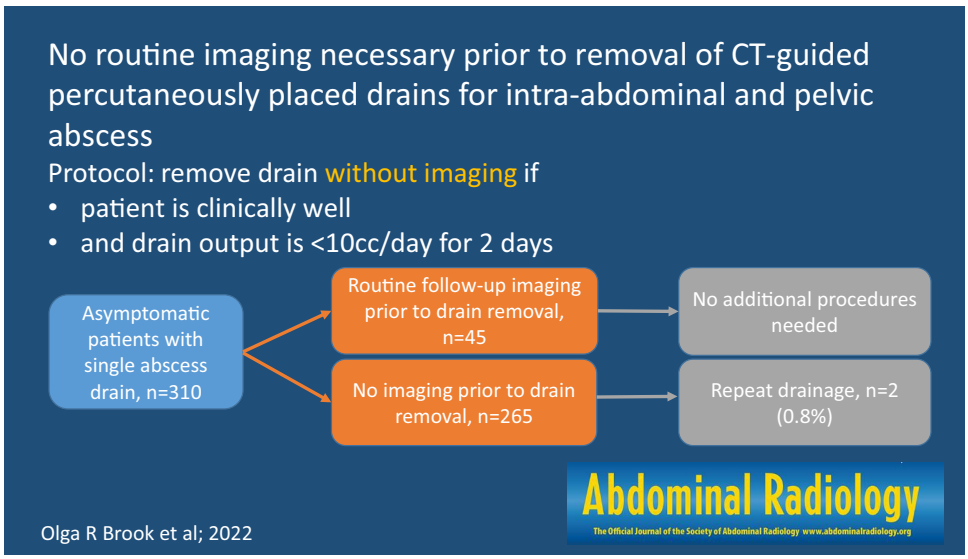
Graphical abstract



Keywords Percutaneous image-guided drainage · Abscess · Computed tomography

Abbreviations

HIPAA	Health insurance portability and accountability act
IRB	Institutional review board

Introduction

Percutaneous image-guided catheter drainage is a widely accepted treatment for abscesses, with reported rates of clinical success exceeding 90% combined with extremely low complication rates [1–7]. After catheter placement, close clinical follow-up for catheter output and residual signs of infection is essential for proper patient management. When the patient has recovered from infection, and the target abscess cavity has been adequately drained, the catheter should be removed to prevent complications secondary to the long-standing tube.

There is currently no standard practice with regard to what type of patient evaluation is required prior to catheter removal. Within the radiology community, the current practice in many institutions includes imaging with CT or fluoroscopic sinogram to confirm resolution of the abscess cavity when the catheter output ceases [1, 2, 5, 8–10]. CT and fluoroscopic studies performed for follow-up after catheter placement are adding radiation exposure to the patient and can be burdensome for patients and their caretakers. In contrast, when catheters are placed after surgery and managed in surgical practices, they are removed when the daily output decreases below a certain threshold without imaging confirmation of abscess cavity resolution, unless patient is not doing well clinically [11].

Yet, no consensus exists as to when radiology-placed catheters should be removed, nor any guidance on what role imaging plays in determining when catheter removal is appropriate [12]. Anecdotally in our practice, we have noticed that routine pre-removal imaging studies rarely affect clinical management in patients with limited catheter output without residual clinical signs and symptoms of infection. This has led us to develop a protocol for accelerated catheter removal, when catheter output decreases to less than 10 cc/day for two consecutive days, a patient is assessed for presence of residual clinical and laboratory signs of infection. If the patient is clinically well, then the catheter is removed without any additional imaging. Yet, safety and efficacy rates of re-intervention for abscess re-accumulation are unknown in patients followed with this protocol. In this study, we assessed safety of this approach to catheter management by retrospectively evaluating patients managed with the above protocol in a single academic institution.

Materials and methods

The study was HIPAA-compliant and IRB-approved, with a waiver of informed consent due to the retrospective nature of the study. All patients provided informed consent for image-guided drainage.

Patient population

This was a retrospective study of consecutive patients that underwent CT-guided percutaneous drainage of an abscess in the abdomen and pelvis, at a single tertiary referral center between January 1, 2015 and December 31, 2017. In this period, 553 patients underwent percutaneous image-guided drainage of suspected abscess at our institution. The abscess was suspected based on patients' clinical presentation (fever, pain, leukocytosis) and organized fluid collection on CT.

The following patients were excluded from further analysis: patients with multiple separate abscesses and/or multiple catheters placed over the course of their care ($n = 124$), patients in which the catheter was removed at the time of elective surgery ($n = 43$), patients that expired prior to the catheter removal ($n = 29$), patients that were lost to follow-up at our institution ($n = 25$), and patients with follow-up available at our institution, but no data regarding date of catheter removal ($n = 12$). Addition exclusion criteria included patients that underwent imaging studies obtained due to lack of clinical improvement ($n = 2$), new clinical issues unrelated to the original abscess ($n = 3$), or worsening of the medical condition ($n = 5$) prior to catheter removal. The remaining 310 patients with a single percutaneous abscess catheter placed were included in this analysis evaluating feasibility of catheter removal based solely on clinical status and catheter output without performed imaging (Fig. 1). Postoperative abscess was the leading etiology for abscess source in all patients. Of the postoperative abscesses, intestinal type surgery was the most common type.

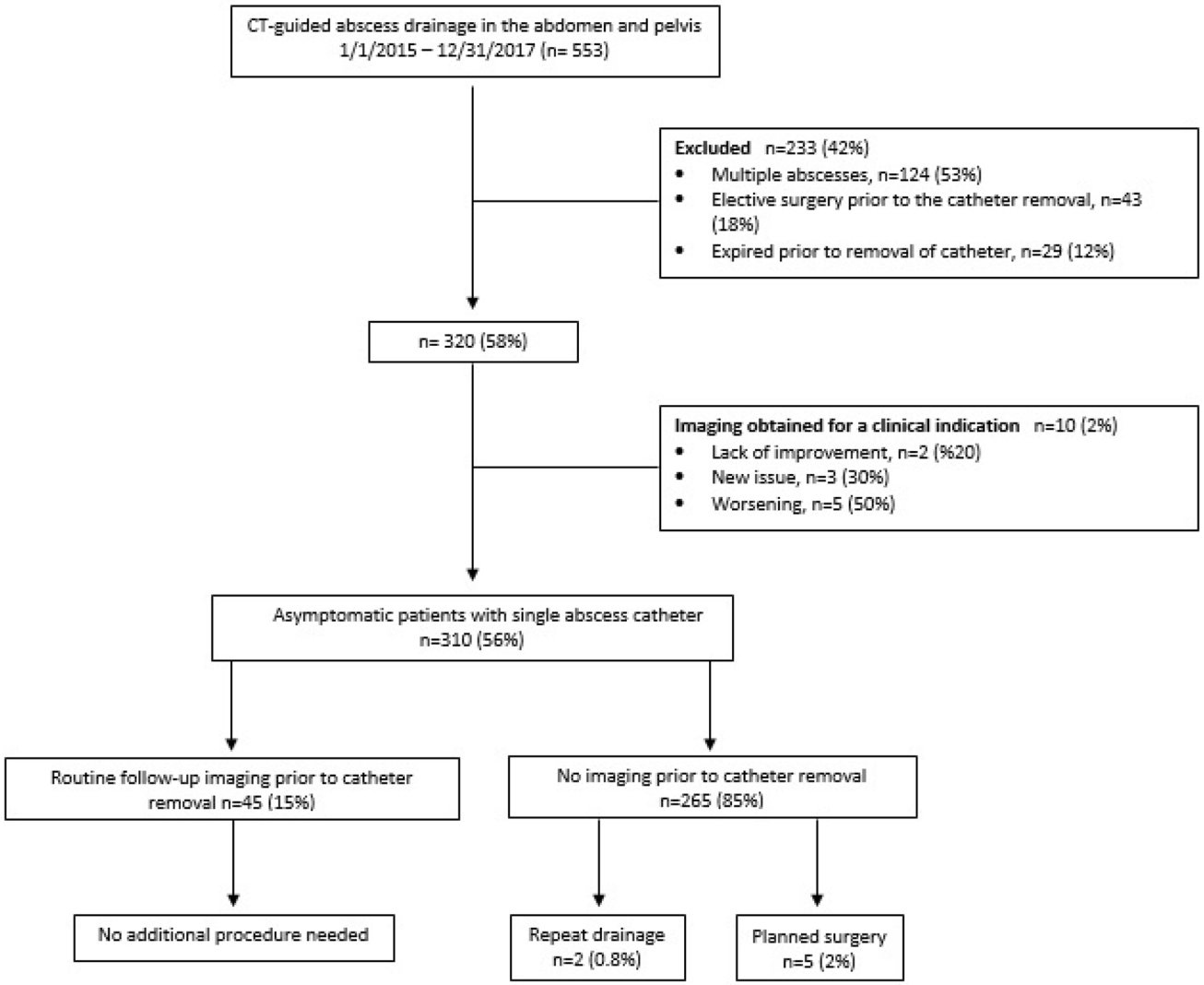


Fig. 1 STARD diagram with inclusion and exclusion criteria for the study and outcomes

Percutaneous image-guided drainage procedure

Percutaneous drainage was performed by an attending abdominal radiologist or interventional radiologist and trainee under CT fluoroscopy guidance. Deep collections were drained using moderate sedation, while superficial collections were drained under local anesthesia. The procedure was performed with Seldinger technique and placement of a 8 or 10 French pigtail catheter into the collection (Exodus Array Multipurpose Drainage Catheter, Angiodynamics, MA), with catheter size selection based on fluid thickness (with thicker fluid requiring larger catheter). A sample of abscess fluid was sent for microbiology evaluation to modify empiric antibiotic therapy prescribed prior to the procedure based on culture and sensitivity results [13]. The abscess cavity was usually aspirated to completion as feasible, and the catheter was connected to a suction bulb with low-grade suction.

Data collection

The data were collected by a clinical research fellow (MAS) with 2 years of clinical experience. The following procedure data were collected: date of catheter removal, assessment of the patient's clinical status at the time of catheter removal (presence or absence of abdominal pain, fever, abnormal white blood cell count), and recorded catheter output for 2 days prior to the removal. The dates of imaging studies and indication for study performance, if performed prior to the catheter removal and within 30 days after the catheter removal, were obtained. The dates and indications for additional procedures were recorded. The following patient data were collected: age, gender, hospitalization status (inpatient/outpatient), whether patient is treated with immunosuppressive therapy, Charlson comorbidity score, location, etiology and compartment of the abscess, presence or absence of gas in the collection, bacterial culture results, average size of collection, and time interval between first procedure to catheter removal.

Patients' follow-up

Inpatients were followed daily by the procedural radiology team. The catheter was removed when the catheter output was recorded as being < 10 cc/day for 2 consecutive days and the patient had no clinical evidence of infection (no fever, no abdominal pain, and normalization of leukocytosis). The decision to perform a follow-up imaging study prior to catheter removal was made by the surgeon or by the procedural radiology team (Abdominal and/or Interventional attending Radiologists) during clinical rounds. Procedural radiology only recommended imaging if it was deemed to be clinically necessary. Surgery teams, at times, requested imaging for routine assessment of abscess resolution despite lack of clinical symptoms suggesting residual abscess. This imaging performed without indication beyond routine follow-up of known abscess was then defined as "follow-up imaging" for the purpose of this study.

Patients discharged from the hospital with the catheter in place were instructed to call interventional radiology when the catheter output decreased to < 10 cc/day for two consecutive days. At that time the patient was clinically assessed and if there was no fever, abdominal pain, or any other presenting symptoms of infection, then the catheter was removed without routine imaging.

The primary outcome measure in this study was a need for repeat percutaneous drainage or unplanned surgery for the abscess within 30 days after catheter removal.

Statistical analysis

Quantitative data are expressed as the average ± standard deviation (SD) with range. Categorical data are expressed as number (%). Categorical data and quantitative data were compared using chi-square or Fisher's exact test when the number < 5 and Student's *t*-test, respectively. The significant difference was set at $p < 0.05$. The age, average Charlson score, average size of the collection, and time interval between the first procedure and catheter removal were evaluated by Student's *t*-test. The population's gender, hospitalization status, location, etiology and compartment of the abscess, gas in the collection, immune system status, and positive bacterial culture were evaluated by the chi-square test. Fisher's exact test was utilized for comparison of the patient's outcomes with and without imaging prior to catheter removal.

Results

There were 310 patients with a single abscess catheter included in the study. The majority of patients (265/310 patients, 85%) had no imaging studies prior to the catheter removal (Fig. 1). Based on clinical presentation, an abscess recurred in two patients (2/265, 0.8%) who had not undergone imaging prior to catheter removal (Fig. 2 and Fig. 3). These patients required a repeat abscess catheter placement (Table 1). No patients required unplanned surgery for abscess recurrence. There was no evidence of abscess recurrence in five patients that underwent planned surgery within 30 days after catheter removal, three with sigmoidectomy for diverticulitis and two with appendectomy for appendicitis. Patients who had follow-up imaging prior to catheter removal ($n = 45$), did not require any additional drainage procedures. The success rates for catheter removal with and without imaging were 100%

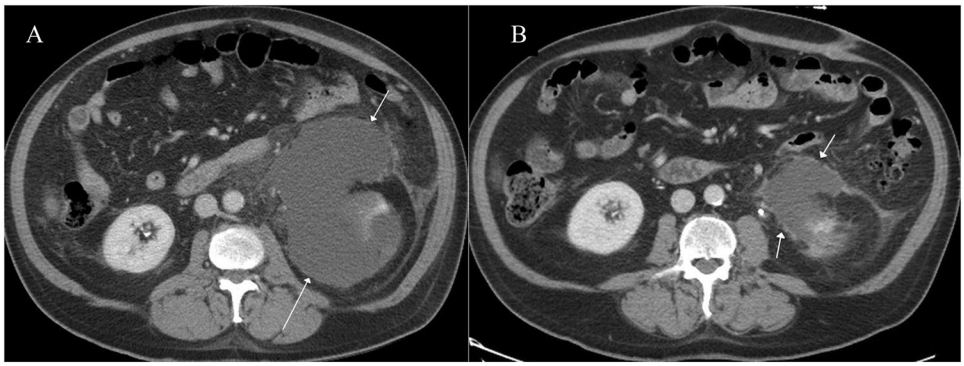


Fig. 2. 67-year-old man that underwent laparoscopic renal cyst decortication and presented with diffuse abdominal pain. Axial CT images show 14 × 10 cm perirenal collection (**A**). The patient presented with ureteral pain and fever 4 days after the catheter removal and CT showed 6.8 × 6 cm residual collection (**B**), which was treated by successful percutaneous drainage

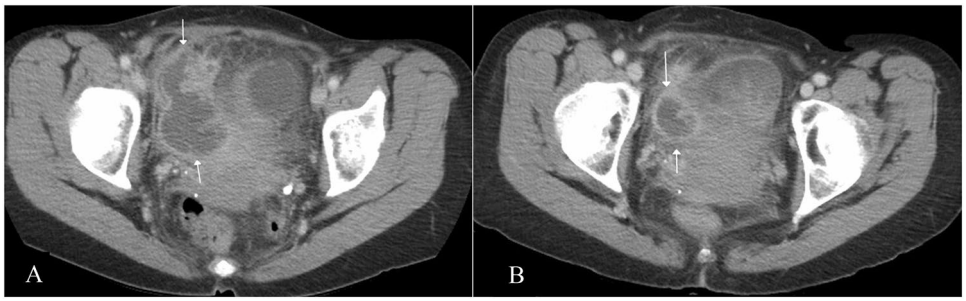


Fig. 3. 63-year-old female with perforated appendicitis presented with right lower abdominal pain and fever. Axial CT images show 7 × 6 cm right pelvic collection prior to image-guided drainage procedure (**A**). The patient presented with pelvic pain 6 days after the catheter removal and CT showed 3 × 2 cm residual abscess cavity (**B**) that was treated by successful percutaneous drainage

Table 1 Characteristics of two patients that underwent additional procedures after catheter removal

	Patient 1	Patient 2
Gender	M	F
Age (years)	67	63
Inpatient/Outpatient	Inpatient	Inpatient
Etiology of abscess	Laparoscopic renal cyst decortication	Perforated appendicitis
Compartment of abscess	Perirenal space	Pelvic
Size of collection (cm)	18	7
Gas in the collection	No	No
Antibiotic therapy	Yes	Yes
Positive bacterial sample	Yes	Yes
Time between first drainage to catheter removal (days)	15	6
Time between catheter removal to additional procedure (days)	4	6
Charlson comorbidity score	0	0
Immunosuppression	No	No

(45/45) and 99.2% (263/265), respectively (Fig. 1). There was no significant difference in abscess recurrence rates and associated need for additional drainage procedures between patients with and without follow-up imaging prior to catheter removal (95% confidence interval (Cl) − 0.071–0.027, $p = 0.731$).

Patients who underwent routine imaging prior to drain removal were older (57.4 ± 16 years vs. 50.4 ± 16.3 years, $p = 0.005$) as compared to patients who did not undergo routine imaging prior to catheter removal. The number of female patients was significantly higher in the group without imaging as compared to the group with imaging prior to catheter removal (52% and 29% respectively, $p = 0.004$). Other patients' and abscess characteristics were similar between the groups with and without imaging prior to catheter removal (Table 2).

Discussion

Our results show that abscess catheter removal in clinically well patients with a single abscess with minimal or no catheter output can be performed with a very small risk of abscess recurrence. Implementing a "no imaging prior to catheter removal in clinically well patient with minimal catheter output" approach decreases patients' radiation exposure and overall healthcare expenditure, and caretakers' and patients' burden from yet another appointment.

Our results indicate an extremely low rate (0.8%) for repeat drainage after utilization of our protocol that focuses

Table 2 Patient demographics, abscess characteristics, and drainage time in patients with and without follow-up imaging prior to catheter removal

	Routine follow-up ($n=45$)		No imaging ($n=265$)		p value
Age (years ± SD)	50.4 ± 16.3		57.4 ± 16		**0.005**
Charlson comorbidity score	1.3 ± 2.1		1.3 ± 2.3		0.436
Mean size of collection (cm)	8 ± 4.2		7.1 ± 3.4		0.195
Interval between catheter placement to removal (days)	23.2 ± 26		22 ± 26		0.373
	%	*n*	%	*n*	
Male gender (M/F)	71	32/13	48	128/137	**0.004**
Inpatient/outpatient	96	43/2	95	251/14	0.814
Extra visceral/Visceral	56	25/20	66	174/91	0.191
Etiology of abscess					
Postoperative	47	21	55	146	
Other causes*	35	16	9	24	
Appendicitis	11	5	13	34	
Diverticulitis	7	3	23	61	
Compartment of abscess					
Pelvic	44	20	52	138	
Abdominal	13	6	16	42	
Liver	13	6	9	23	
Peri-pancreatic	11	5	5	12	
Muscle	6	3	6	16	
Gallbladder fossa	2	1	4	11	
Peri-renal	2	1	3	7	
Splenic	2	1	2	6	
Tubo-ovarian	2	1	2	5	
Abdominal wall	2	1	2	4	
Prostatic	2	0	0.3	1	
Gas in the collection	24	34/11	28	75/190	0.472
Immunosuppression	2	44/1	1	3/262	0.549
Positive culture from abscess	71	32/13	79	210/55	0.222

Bold values indicate comparisons that show statistically significant difference

*Other causes include bacteremia, cholangitis, acute cholecystitis, Crohn disease, duodenal perforation, endocarditis, osteomyelitis, pancreatic necrosis, pancreatitis, perforated stomach ulcer, pyelonephritis, septic arthritis, small bowel perforation, tubo-ovarian abscess, unknown origin

on clinical presentation instead of imaging follow-up. This rate is much lower than previously reported in literature [14–17], where need for repeat abscess recurrence was reported to be up to 10%. The difference is likely due to the fact that our study group was focused on relatively uncomplicated patients with a single abscess drain. Furthermore, older studies that utilized routine follow-up imaging in all patients after drainage, were based on set up time interval for follow-up imaging and not necessarily clinical presentation and drain output. For example, in the study by Stabile et al., in 19 patients with percutaneous drainage of diverticular abscess [18], a sinogram was performed within 48 h of catheter placement to assess abscess cavity or any fistula formation and then repeated every 3–7 days. The percutaneous catheter was removed when the sinogram showed significant decrease in the size of the abscess cavity and catheter output was minimal without a specific definition of the output. Similarly, Springer et al. [19], in a recent retrospective study of 188 patients, showed that imaging prior to catheter removal decreases the odds of abscess recurrence by 66%. However, that study did not report the grounds for drain removal and therefore it is unclear whether drain output, clinical presentation and/or imaging findings, or something else was taken into account in the decision making process for drain removal. Furthermore, this study showed abscess recurrence rate of 21%, much higher than up to 5% [20] previously reported in the literature or 0.8% in our study.

In the study by Gervais et al. of 785 patients with 956 drainages, all patients underwent routine imaging prior to catheter removal with resultant abscess recurrence rate after catheter removal of 4.9% [1]. In our study, basing the decision to remove the abscess drain on clinical information only

without routine imaging study, resulted in repeat drainage in 0.8% of patients. Therefore, it appears that routine imaging all patients prior to abscess drain removal does not adversely impacts patients' clinical outcomes.

Our results are applicable to our chosen study population which includes patients with a single abscess. Therefore, indications for drain removal, and appropriate follow-up protocol in patients with multiple abscesses needs to be further evaluated in the future studies.

Clinical criteria used in our protocol included low (< 10 cc/day) drain output for two consecutive days followed by symptom assessment at that time. This approach resulted in an average time to abscess drain removal of 22 days in our study. The threshold to prompt clinical assessment for drain removal varies in literature. Brac et al. [21] in the retrospective study of 53 patients, used a threshold of 20 cc per day output for catheter removal together with imaging follow-up was able to remove abscess drain after 10.1 days on average; however, it did result in 10% of patients requiring additional interventions, such as surgery or repeat drainage. Lagana et al. [10] in the retrospective study of 95 patients, used threshold of the catheter output of less than 10 cc per day, imaging follow-up and clinical assessment prior to drain removal with resulting average time between drainage and catheter removal of 14.2 days with 8.5% of patients requiring additional interventions. Therefore, using our criteria resulted in longer catheter dwell time, as compared to other studies, however, abscess recurrence rate was much lower. Prolonged catheter dwell time carried increased patient's discomfort and may potentially cause skin irritation and even secondary access site infections. There were no access site infections in our study, though given the retrospective nature of this study we could have missed some. Therefore, optimal thresholds for abscess drain removal should ideally be evaluated in the prospective future studies that would evaluate access site infections as well.

Our protocol, utilizing no routine follow-up imaging, results in significant reduction of population radiation exposure. While in the older population radiation exposure is of lesser concern, in younger patients, for example post-appendectomy or perforated appendicitis patients, every attempt should be made to reduce radiation exposure per ALARA principle [22].

Routine follow-up imaging also amounts to significant healthcare expenditure, in addition to non-trivial burden to patients and their caretakers with costs and work days lost attending medical appointments. Therefore, our protocol with no routine imaging may have a positive impact on patients' quality of life while reducing economic impact on patients' families. Therefore, using clinical criteria for catheter removal without routine imaging studies will help to reduce both healthcare expenditure and burden to patients' and their caretakers.

We report a low rate of need for repeat procedure, however, it noticeably lower than in all prior studies that have used imaging prior to catheter removal. Therefore, it is possible that even with routine follow-up imaging prior to catheter removal there will be a small number of patients that will require a repeat drainage.

This study has a number of limitations. Main limitations are in the retrospective study design, non-randomized nature of patients and single-center study. Future prospective multicenter studies will be useful to confirm our results and to evaluate an optimal threshold of catheter output prior to clinical evaluation for catheter removal. Additionally, only a small subgroup of our patients had routine follow-up imaging prior to catheter removal. In order to perform a cost-effectiveness analysis of our approach a larger patient cohort of patients is required to establish true rate of abscess recurrence in this subgroup of patients. Future studies should also assess whether viscosity of the fluid should be taken into account on whether imaging prior drain removal is necessary. Also, some patients did not have a positive culture from the collection fluid and therefore may not have had an abscess, but rather sterile fluid collection. Most of these patients still had abscesses, but cultures were negative due to prior antibiotic exposure, poor transport conditions, insufficient volume of the fluid sent for culture, slow-growing, or fastidious organism. Future studies will also need to develop an appropriate follow-up protocol for patients with multiple abscesses.

In conclusion, it appears that in clinically well patients with minimal catheter output for at least 2 days catheter removal without follow-up imaging results in very low rate of abscess recurrence. This approach results in decrease in the number of imaging studies performed, patients' radiation exposure, and time and costs encountered by patients and their caretakers.

References

1. Gervais DA, Ho CH, O'Neill MJ, et al. Recurrent abdominal and pelvic abscesses: incidence, results of repeated percutaneous drainage, and underlying causes in 956 drainages. AJR Am J Roentgenol. 2004;182(2):463–466. doi: https://doi.org/10.2214/ajr.182.2.1820463.
2. Gee MS, Kim JY, Gervais DA, Hahn PF, Mueller PR. Management of abdominal and pelvic abscesses that persist despite satisfactory percutaneous drainage catheter placement. AJR Am J Roentgenol. 2010;194(3):815–820. doi: https://doi.org/10.2214/AJR.09.3282.
3. Okita Y, Mohri Y, Kobayashi M, et al. Factors influencing the outcome of image-guided percutaneous drainage of intra-abdominal abscess after gastrointestinal surgery. Surg Today. 2013;43(10):1095–1102. doi: https://doi.org/10.1007/s00595-013-0504-x.

4. Rotman JA, Getrajdman GI, Maybody M, et al. Effect of abdominopelvic abscess drain size on drainage time and probability of occlusion. Am J Surg. 2017;213(4):718–722. doi: https://doi.org/10.1016/j.amjsurg.2016.07.027.
5. Golfieri R, Cappelli A. Computed tomography-guided percutaneous abscess drainage in coloproctology: review of the literature. Tech Coloproctology. 2007;11(3):197–208. doi: https://doi.org/10.1007/s10151-007-0354-x.
6. Kassi F, Dohan A, Soyer *P*, et al. Predictive factors for failure of percutaneous drainage of postoperative abscess after abdominal surgery. Am J Surg. 2014;207(6):915–921. doi: https://doi.org/10.1016/j.amjsurg.2013.07.041.
7. Robert B, Yzet T, Regimbeau JM. Radiologic drainage of postoperative collections and abscesses. J Visc Surg. 2013;150(3 Suppl):S11-18. doi: https://doi.org/10.1016/j.jviscsurg.2013.05.005.
8. Benoist S, Panis Y, Pannegeon V, et al. Can failure of percutaneous drainage of postoperative abdominal abscesses be predicted? Am J Surg. 2002;184(2):148–153. doi: https://doi.org/10.1016/s0002-9610(02)00912-1.
9. Theisen J, Bartels H, Weiss W, Berger H, Stein HJ, Siewert JR. Current concepts of percutaneous abscess drainage in postoperative retention. J Gastrointest Surg. 2005;9(2):280–283. doi: https://doi.org/10.1016/j.gassur.2004.04.008.
10. Laganà D, Carrafiello G, Mangini M, et al. Image-guided percutaneous treatment of abdominal-pelvic abscesses: a 5-year experience. Radiol Med (Torino). 2008;113(7):999. doi: https://doi.org/10.1007/s11547-008-0320-3.
11. Durai R, Mownah A, Ng PCH. Use of drains in surgery: a review. J Perioper Pract. 2009;19(6):180–186. doi: https://doi.org/10.1177/175045890901900603.
12. Charles HW. Abscess Drainage. Semin Interv Radiol. 2012;29(4):325–336. doi: https://doi.org/10.1055/s-0032-1330068.
13. McGillen KL, Boos J, Nathavitharana R, et al. Diagnostic yield and clinical impact of microbiologic diagnosis from CT-guided drainage in patients previously treated with empiric antibiotics. Abdom Radiol N Y. 2017;42(1):298–305. doi: https://doi.org/10.1007/s00261-016-0833-5.
14. vanSonnenberg E, Mueller PR, Ferrucci JT. Percutaneous drainage of 250 abdominal abscesses and fluid collections. Part I: Results, failures, and complications. Radiology. Radiological Society of North America; 1984;151(2):337–341. doi: https://doi.org/10.1148/radiology.151.2.6709901.
15. Gerzof SG, Robbins AH, Johnson WC, Birkett DH, Nabseth DC. Percutaneous catheter drainage of abdominal abscesses: a five-year experience. N Engl J Med. 1981;305(12):653–657. doi: https://doi.org/10.1056/NEJM198109173051201.
16. Lambiase RE, Deyoe L, Cronan JJ, Dorfman GS. Percutaneous drainage of 335 consecutive abscesses: results of primary drainage with 1-year follow-up. Radiology. Radiological Society of North America; 1992;184(1):167–179. doi: https://doi.org/10.1148/radiology.184.1.1376932.
17. Civardi G, Fornari F, Cavanna L, Sbolli G, Di Stasi M, Buscarini L. Ultrasonically guided percutaneous drainage of abdominal fluid collections: a long-term study of its therapeutic efficacy. Gastrointest Radiol. 1990;15(3):245–250. doi: https://doi.org/10.1007/bf01888786.
18. Stabile BE, Puccio E, vanSonnenberg E, Neff CC. Preoperative percutaneous drainage of diverticular abscesses. Am J Surg. 1990;159(1):99–104; discussion. doi: https://doi.org/10.1016/s0002-9610(05)80613−0.
19. Springer JE, Doumouras AG, Nair S, Eskicioglu C, Forbes S. Does Imaging Before Percutaneous Drain Removal Affect Rates of Intra-abdominal Abscess Recurrence? J Surg Res. 2018;232:408–414. doi: https://doi.org/10.1016/j.jss.2018.06.062.
20. Gervais DA, Ho C-H, O'Neill MJ, Arellano RS, Hahn PF, Mueller PR. Recurrent Abdominal and Pelvic Abscesses: Incidence, Results of Repeated Percutaneous Drainage, and Underlying Causes in 956 Drainages. Am J Roentgenol. American Roentgen Ray Society; 2004;182(2):463–466. doi: https://doi.org/10.2214/ajr.182.2.1820463.
21. Brac B, Sabbagh C, Robert B, Chivot C, Yzet T, Regimbeau JM. Natural history of percutaneous drainage of postoperative collection following colorectal surgery: in which patients can follow-up imaging be dispensed with before drain removal? Abdom Radiol N Y. 2019;44(3):1135–1140. doi: https://doi.org/10.1007/s00261-018-1811-x.
22. Krishnamoorthi R, Ramarajan N, Wang NE, et al. Effectiveness of a staged US and CT protocol for the diagnosis of pediatric appendicitis: reducing radiation exposure in the age of ALARA. Radiology. 2011;259(1):231–239. doi: https://doi.org/10.1148/radiol.10100984.