Published in final edited form as:

Acad Radiol. 2020 February ; 27(2): e1–e9. doi:10.1016/j.acra.2019.03.010.

Paired Drainage Catheter Insertion: Feasibility of Placing Two Catheters Within the Same Complex Abscess Cavity as a Primary and Salvage Percutaneous Drainage Technique

David H. Ballard, MD¹, Sarah T. Flanagan, MD², Ryan W. Brown, MD³, Romulo Vea, MD², Chaitanya Ahuja, MD², Horacio B. D'Agostino, MD²

¹Mallinckrodt Institute of Radiology, Washington University School of Medicine. 510 S. Kingshighway Blvd, St. Louis, Missouri, 63110

²Department of Radiology; Louisiana State University Health Shreveport. 1501 Kings Highway, Shreveport, Louisiana, 71103

³Department of Radiology; The University of Mississippi Medical Center. 2500 North State Street, Jackson, Mississippi 39216

Abstract

Rationale and Objectives—To assess the feasibility of paired catheter drainage for management of complex abdominal abscesses.

Materials and Methods—This was a single-center retrospective study of 54 patients (35 males; mean age 48.9 years) that underwent paired catheter insertion for complex abdominal fluid collections in an 18-month period. Complex collections were defined as abscesses ≥ 6 cm in diameter with septations, high viscosity fluid or necrotic debris, or abscesses with an associated fistula. Abscess etiologies included: postoperative (n=28), pancreatitis (n=12), perforated bowel (n=7), liver abscess (n=4), and perihepatic from gallbladder perforation (n=3). Paired catheter insertion was defined two catheters co-located within one collection through the same skin incision or two closely spaced insertion sites. Paired catheter insertion was used primarily as initial drainage for complex intraabdominal abscesses and for salvage drainage in collections that could not be evacuated by a single catheter. Primary paired catheter insertion was used in 45 patients and as salvage in 9 patients.

Correspondence to: David H. Ballard, MD, Mallinckrodt Institute of Radiology, Washington University School of Medicine, 510 S. Kingshighway Blvd, Campus Box 8131, St. Louis, Missouri, 63110, davidballard@wustl.edu, Phone: (314) 226-5464; Fax: (314) 747-4671.

Disclosures: All other authors claim no conflicts of interest or disclosures.

Conference Presentation:

A preliminary form of this study was presented at the SIR Annual Scientific Meeting: Ballard DH, Brown RW, Hamidian Jahromi A, Romulo V, Ahuja C, D'Agostino HB. Initial or salvage paired drainage catheter insertion for effective evacuation of complex abdominal fluid collections: indications, results, and complications. Oral Presentation at: Society of Interventional Radiology Annual Scientific Meeting; Atlanta, GA.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Results—Abscess resolution occurred in 51 (94.4%) patients. Patients had a median of 3 drainage procedures. Median duration of paired catheterization was 22 days. Seven abscesses recurred and all resolved with repeated drainage. Complications included 1 hemorrhage that was taken for surgical exploration. Overall, 48 patients had good clinical outcome, 3 patients died (multiorgan failure, n=2; sepsis, n=1), and 3 patients were lost to follow-up.

Conclusion—Percutaneous paired catheter drainage is a feasible technique for the treatment of both complex intraabdominal abscesses and abscesses unresponsive to single catheter drainage.

Introduction

Image-guided percutaneous drainage of intraabdominal abscesses is among the most common procedures performed by radiologists, and it is the standard of care procedure for most abdominal fluid collections (1, 2). The causes of failure of percutaneous drainage for abdominal abscesses have included multiloculation and phlegmon, abscesses associated with fistulae, hematomas, and improper catheter position (3, 4). Percutaneous drainage has a high threshold for clinical success with a curative and partial success rate of 85% (5, 6).

Typically, percutaneous drainage is achieved by placing a single catheter in the dependent portion of a fluid collection. Complex abscesses with necrotic debris, clots, or enteral content can be challenging to adequately drain and resolve. A single catheter may not be sufficient for drainage of such collections. Paired catheter insertion is percutaneous insertion of two or more catheters into the same abscess with the goal of enhancing drainage by optimizing evacuation and facilitating irrigation for debris removal. At initial insertion, the two catheters increase the drainage capacity compared to a single catheter to facilitate initial complete evacuation. The catheter tips are positioned in close proximity to one another within the abscess cavity to allow for vigorous irrigation and aspiration. Subsequent catheter management with daily irrigation and aspiration played an important role in rapid resolution of the abscess with clinical improvement. Daily irrigation/aspiration allows for mechanical debridement and removal of particulate debris that otherwise may remain as a source of infection within the collection and preventing the attachment and volume reduction of the collection wall cavity.

Several studies report using multiple catheters to drain a single collection (7–14), some dating back to the earliest reports of image-guided percutaneous drainage (3, 10). However, to the best of our knowledge, there have been no reports that describe robust criteria for multiple drainage catheters in a single abdominal fluid collection. The purpose of the present study is to determine whether paired catheter drainage is a feasible technique for both primary and salvage management of complex abdominal abscesses.

Materials and Methods

This was an Institutional Review Board-approved single-center retrospective study conducted in accordance with Health Insurance Portability and Accountability Act. The need to obtain informed consent was waived. This single-center retrospective study included all patients in a consecutive 18-month period who had paired catheter insertion into intraabdominal abscesses. Paired catheter insertion consists of placing two or more catheters

within a single collection cavity with a goal of initial complete abscess evacuation and subsequent postprocedural catheter management, which consisted of vigorous daily irrigation and aspiration aimed at removing residual debris. This was accomplished with 60 mL syringes with 60 mL of irrigant, which was forcibly injected with manual pressure into the abscess cavity. The irrigant was then aspirated. After this first cycle, the cavity was aspirated to check for residual. If there was greater than 50 mL of residual fluid (following aspiration of the 60 mL irrigant), another 60 mL irrigant/aspiration cycle was used. This was repeated until the volume of residual fluid aspirated was less than 60 mL.

All cases of intraabdominal drainage during the study period were reviewed for paired catheter insertion. Inclusion criteria included patients who had an abdominopelvic fluid collection in which multiple catheters were used to drain a single abscess at the initial drainage procedure or at a subsequent procedure. Exclusion criteria included patients who had one or multiple collections drained and resolved by only a single catheter, collections outside the abdominopelvic cavity, and patients with incomplete chart data. Indications for primary paired catheter insertion were complex collections of ≥ 6 cm containing septations and fluid with necrotic debris or high viscosity and/or abscesses with an associated fistula. Debris or high viscosity of the fluid collections was determined by the fluid characteristics upon standard Seldinger insertion of a single catheter. Salvage paired catheter insertion at a subsequent procedure was defined as using the technique on patients who had inadequate evacuation of a collection by a single catheter at initial drainage. If two or more drainage catheters were used in a single collection with an abscess-fistula complex, catheters not used for abscess drainage were selectively used to cannulate the fistula (15, 16). Fistulas were typically not appreciated at initial drainage but diagnosed at follow-up sinogram. Selection of whether to cannulate the fistula feeding the abscess depended on the output of the abscess as high (>200 mL/day) or low (<200 mL/day). High output abscess-fistula complexes used a drainage catheter not involved in draining the abscess to cannulate the fistula. The cannulation was achieved with standard catheter manipulations.

During the study period, 134 patients had catheter drainage of intraabdominal abscesses, 54 (40.3%; 35 males, 19 females; mean age 48.9 years) of whom met inclusion criteria for this study. Abscess etiologies included: postoperative following gastrointestinal surgeries ($n=28$), peripancreatic fluid collections from pancreatitis ($n=12$), perforated bowel ($n=7$), liver abscess ($n=4$), and perihepatic from gallbladder perforation ($n=3$). In the patients with peripancreatic fluid collections from pancreatitis, imaging findings to help differentiate pseudocysts from infected collections on preceding diagnostic CT included the presence of debris or gas in the collection with or without hypoenhancement of the pancreas. A multidisciplinary team of radiologists, gastroenterologists, and surgeons also discussed management. In terms of There were 5 patients with abscess-fistula complexes: 4 were postoperative from gastrointestinal surgery (2 high-output, 2 low-output) and one patient developed a low-output abscess-fistula complex following an embolization of a gastrointestinal bleed. The 2 patients with high-output abscess-fistula complexes had their fistula cannulated with a drainage catheter to promote closure.

Catheters were inserted using standard Seldinger technique under image-guidance, including fluoroscopy, ultrasound, and CT. Paired catheters were preferentially inserted through two

Results

Primary paired catheter insertion was used in 45 patients, and salvage paired catheter insertion was used in 9 patients. Causes for salvage paired catheter drainage, after initial insertion of a single catheter, were failure of clinical improvement in 7 cases causing prompt drainage revisions and delayed discovery of an abscess-fistula complex on a routine drainage revision in 2 patients. Two of the 7 patients whose clinical status prompted an early drainage revision were found to have abscess-fistula complexes. The drainage revision with the additional catheter insertion occurred at a median of 7 days.

Resolution of the abscess occurred in 51 (94.4%) patients, including 42 of the 45 (93.3%) patients with primary paired catheter insertion and in all 9 (100%) patients with salvage paired catheter insertion. Patients had a median of 3 drainage procedures (range 1 to 23), which included the initial insertion, catheter exchanges, upsizing/downsizing, repositioning, and sinograms. Patients who underwent salvage paired catheter drainage had significantly more procedures (median = 4 procedures) than those who had primary paired catheter drainage (median = 2 procedures) (Mann-Whitney U $p = 0.012$). Median duration of catheterization for paired catheters for all patients was 22 days (range 1 to 284 days). Patients who underwent salvage paired catheter insertion had significantly a higher number of catheter days (median = 66 days) compared to those that underwent primary paired catheter insertion (median = 18 days) (Mann-Whitney U $p = 0.025$). Catheter sizes ranged from 10.2-F to 24-F. There were no propagation of sepsis events following initial drainage or at follow-up irrigation. There 7 abscess recurrences that were resolved with repeated drainage. Abscess recurrences were all in the original pocket and, in review, thought to be due to incomplete drainage of the cavity. Complications included 1 hemorrhage observed at follow-up irrigation that was taken for surgical exploration on the basis of the change in characteristics of the fluid drainage from sanguineous to bloody. At laparotomy, no active bleeding was found; postoperatively, bleeding did not recur. Overall, 48 patients had good clinical outcome, 3 patients died (multiorgan failure, $n=2$; sepsis, $n=1$), and 3 patients were discharged and lost to follow-up. These data are summarized in Table 1. The authors' data compared to other percutaneous drainage series both with and without the use of multiple catheters are highlighted in Table 2 (3, 7–14, 17–21).

Discussion

The present study describes paired catheter insertion, a technique in which two drainage catheters are inserted into a single complex intraabdominal fluid collection with the purpose of complete evacuating its content. The two catheters allow for fluid collection drainage facilitated by an inlet and an outlet for simultaneous isovolumetric irrigation and aspiration. This technique supports a controlled irrigation of the drained cavity through mechanical debridement of the collection cavity. While the use of the multiple catheters for multiple collections is a common clinical practice, the authors advocate the concept of placing two catheters selectively in complex collection. Although a single catheter may adequately manage some of these collections, the use of paired catheters was successful in our series.

The use of paired catheters is conceptually a salvage technique for incompletely or poorly drained collections. When a single catheter has failed to adequately evacuate a collection, the alternatives are to manipulate the first catheter, add an additional catheter, or undergo open surgical drainage. Based on the success of the 9 cases of this salvage technique in the present series, placement of one additional catheter the same size or larger may spare the patient an open surgical procedure.

Although the use of multiple catheters has been described in several studies, the present study defines criteria for complex collections. As highlighted in Table 2, direct comparison of results with other series of percutaneous drainage is difficult due to the heterogeneity of patients and often poorly defined rationale for using multiple catheters. Our literature search failed to identify any study with a primary or secondary purpose of paired catheter insertion into a single collection or an emphasis on the concept of optimizing drainage through simultaneous irrigation-aspiration through two catheters. In one of the earliest and landmark reports of percutaneous drainage, Gerzof et al. (10) mentioned the use of “dual catheters” in selected collections. In their study, 7 of 71 abscesses were drained using multiple catheters: 4 of which were due to the size or complexity of the abscess and in 3 pancreatic abscesses that had no definable cavity. In another of the earliest reported series of percutaneous drainage, vanSonnenberg et al. (3) reported insertion of multiple catheters “often” in cases where single catheter placement failed and, overall, in 48 of 250 collections in that series.

The use of multiple catheters in percutaneous drainage is described in a number of series reporting percutaneous drainage of pancreatic fluid collections (11,12,14). One retrospective series used multiple drainage catheters in 8 of 23 patients with infected pancreatic fluid collections. Their criterion was that if a collection persisted for more than 2–3 days, additional catheters were placed (14). In another retrospective series, 34 patients with infected acute necrotizing pancreatitis were treated by percutaneous drainage, and Freeny et al. (12) reported that on average, three catheters were used in the initial drainage procedure. Similarly, in a study of 30 patients with complicated pancreatitis, the majority of collections were complex and infected, requiring insertion of multiple catheters (11). However, the authors reported only a 47% successful drainage rate (14 out of 30 patients), with a mortality rate of 33% (10 out of 30 patients) and concluded that percutaneous drainage should be performed only after initial surgical drainage of central areas. Though, since that report, techniques have optimized and a step-up approach starting with percutaneous drainage and advancing to more invasive measurements has proved to be more effective in terms of reducing major complications compared to open surgical debridement (22). Additionally, these series and others with lower success rates are now dated (older than 20 years) and the heterogeneity in results are related to morbid patients, different patient population, and paradigms in intensive care management and diagnostic imaging.

The limitations of this study are its retrospective nature, small sample size, and data from a single institution. Data on the paired catheter technique is described without comparison to insertion of a single catheter. The small sample size and lack of comparison to collections drained with a single catheter precluded meaningful comparisons with inferential statistics. As paired catheter drainage is now the preferred approach to complex intraabdominal abscesses at our institution, a comparison of patients with abscesses drained with a single

catheter would not serve as an adequate control as those collections did not meet the criteria as complex collections. It is unknown how many complex collections would have resolved with a single catheter. Primary insertion of paired catheters slightly increases procedural time and cost with the insertion of a second catheter. From the present study, it is unknown what advantage, if any, the addition of a second catheter confers compared to a single catheter. Prospective data comparing paired drainage catheter insertion to single drainage catheter insertion would substantiate the findings in the present series and help to define the value of paired catheter insertion.

Even though the use of multiple catheters has been reported in prior studies, it has not previously been the primary focus and the data often fails to discern between two or more catheters draining a single collection or multiple collections. Paired catheter drainage was successful in resolving the majority of complex intraabdominal abscesses as both a primary and salvage technique in the present series. This technique allows for initial large volume evacuation and vigorous catheter management for the removal of residual debris. This study demonstrates that paired catheter drainage is feasible for management of complex intraabdominal abscesses. Future studies comparing the use of this technique to single catheter drainage are needed to assess the relative effectiveness of paired catheter drainage.

Acknowledgments

Funding: Dr. Ballard receives salary support from National Institutes of Health TOP-TIER grant T32-EB021955.

References

1. Jaffe TA, Nelson RC, Delong DM, Paulson EK. Practice patterns in percutaneous image-guided intraabdominal abscess drainage: survey of academic and private practice centers. *Radiology* 2004;233:750–756. [PubMed: 15516608]
2. Levin DC, Eschelmann D, Parker L, Rao VM. Trends in Use of Percutaneous Versus Open Surgical Drainage of Abdominal Abscesses. *J Am Coll Radiol* 2015;12:1247–1250. [PubMed: 26653832]
3. vanSonnenberg E, Mueller PR, Ferrucci JT. Percutaneous drainage of 250 abdominal abscesses and fluid collections. Part I: Results, failures, and complications. *Radiology* 1984;151:337–341. [PubMed: 6709901]
4. Mueller PR, vanSonnenberg E, Ferrucci JT. Percutaneous drainage of 250 abdominal abscesses and fluid collections. Part II: Current procedural concepts. *Radiology* 1984;151:343–347. [PubMed: 6709903]
5. Wallace MJ, Chin KW, Fletcher TB, et al. Quality improvement guidelines for percutaneous drainage/aspiration of abscess and fluid collections. *J Vasc Interv Radiol* 2010;21:431–435. [PubMed: 20346880]
6. Ballard DH, Flanagan ST, Griffen FD. Percutaneous Versus Open Surgical Drainage: Surgeon's Perspective. *J Am Coll Radiol* 2016;13:364. [PubMed: 26922598]
7. Lambiase RE, Deyoe L, Cronan JJ, Dorfman GS. Percutaneous drainage of 335 consecutive abscesses: results of primary drainage with 1-year follow-up. *Radiology* 1992;184:167–179. [PubMed: 1376932]
8. 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;43:1095–1102. [PubMed: 23408085]
9. 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;207:915–921. [PubMed: 24280147]

10. 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;305:653–657. [PubMed: 7266601]
11. Lee MJ, Rattner DW, Legemate DA, et al. Acute complicated pancreatitis: redefining the role of interventional radiology. *Radiology* 1992;183:171–174. [PubMed: 1549667]
12. Freeny PC, Hauptmann E, Althaus SJ, Traverso LW, Sinanan M. Percutaneous CT-guided catheter drainage of infected acute necrotizing pancreatitis: techniques and results. *AJR Am J Roentgenol* 1998;170:969–975. [PubMed: 9530046]
13. McNeeley MF, Vo NJ, Prabhu SJ, Vergnani J, Shaw DW. Percutaneous drainage of intraabdominal abscess in children with perforated appendicitis. *Pediatr Radiol* 2012;42:805–812. [PubMed: 22246413]
14. Freeny PC, Lewis GP, Traverso LW, Ryan JA. Infected pancreatic fluid collections: percutaneous catheter drainage. *Radiology* 1988;167:435–441. [PubMed: 3357952]
15. Ballard DH, Hamidian Jahromi A, Li AY, Veal R, Ahuja C, D'Agostino HB. Abscess-Fistula Complexes: A Systematic Approach for Percutaneous Catheter Management. *J Vasc Interv Radiol* 2015;26:1363–1367. [PubMed: 26314645]
16. Ballard DH, Erickson AM, Ahuja C, Veal R, Sangster GS, D'Agostino HB. Percutaneous Management of Enterocutaneous Fistulae and Abscess–Fistula Complexes. *Digestive Disease Interventions* 2018;2:131–140. [PubMed: 31073548]
17. Chen MT, Huang CN, Chou YH, Huang CH, Chiang CP, Liu GC. Percutaneous drainage in the treatment of emphysematous pyelonephritis: 10-year experience. *J Urol* 1997;157:1569–1573. [PubMed: 9112478]
18. Politano AD, Hranjec T, Rosenberger LH, Sawyer RG, Tache Leon CA. Differences in morbidity and mortality with percutaneous versus open surgical drainage of postoperative intra-abdominal infections: a review of 686 cases. *Am Surg* 2011;77:862–867. [PubMed: 21944348]
19. Akinci D, Akhan O, Ozmen MN, et al. Percutaneous drainage of 300 intraperitoneal abscesses with long-term follow-up. *Cardiovasc Intervent Radiol* 2005;28:744–750. [PubMed: 16091990]
20. Laganà D, Carrafiello G, Mangini M, et al. Image-guided percutaneous treatment of abdominal-pelvic abscesses: a 5-year experience. *Radiol Med* 2008;113:999–1007. [PubMed: 18795233]
21. Gobien RP, Stanley JH, Schabel SI, et al. The effect of drainage tube size on adequacy of percutaneous abscess drainage. *Cardiovasc Intervent Radiol* 1985;8:100–102. [PubMed: 4084924]
22. van Santvoort HC, Besselink MG, Bakker OJ, et al. A step-up approach or open necrosectomy for necrotizing pancreatitis. *N Engl J Med* 2010;362:1491–1502. [PubMed: 20410514]

Figure 1. Insertion of paired catheters through a single incision (a) or multiple incisions (b). The authors prefer the latter when there is an adequate window.

Figure 2.
Illustrative diagram (a) of paired catheters in an intraabdominal abscess facilitating simultaneous irrigation and aspiration. Photograph (b) of the paired catheter technique being used for irrigation and aspiration.

Figure 3.

Illustrative case of salvage paired catheter drainage. A 39-year old female with necrotizing pancreatitis was diagnosed and drained with a single catheter at another center. She was transferred to our institution after sepsis persisted 7-days post single catheter insertion. CT upon arrival showed a large peripancreatic abscess (box) with a single 14-F catheter within the collection (arrows) (a). At drainage, the existing 14-F catheter was exchanged for two 20-F catheters (arrows and arrowheads) – over 1 L of pus was evacuated (b, c). The patient

improved clinically, underwent two drainage revisions, and was subsequently discharged 18-days following the initial salvage paired catheter insertion.

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Table 1.

Demographics, procedural information, and outcomes of patients with primary or salvage paired catheter insertion for complex intraabdominal fluid collections.

	Primary paired catheter insertion	Salvage paired catheter insertion	p value
Patients (Gender)	45 (M = 30, F =15)	9 (M = 5, F = 4)	-
Mean age	50.1	45.0	0.34
Drainage procedures / patient (median)	2.0	4.0	0.012 *
Catheter days / patient (median)	18.0	66.0	0.025 *
Etiology of abscess	-	-	
Postoperative (gastrointestinal surgery)	21	7	
Pancreatitis	11	1	-
Bowel perforation	7	0	
Liver abscess	3	1	
Gallbladder perforation	3	0	
Abscess-fistula complexes	4	1	
Resolution of fluid collection (percentage)	42 of 45 (93.3%)	9 of 9 (100.0%)	-
Complications	5 recurrences 1 delayed hemorrhage requiring surgery	2 recurrences	-

* = Mann-Whitney U p value

Summary of selected series reporting image-guided percutaneous drainage stratified by those that did or did not report results of patients or collections drained using multiple catheters.

Table 2.

	Total number of patients and/or collections	Patient/collection characteristics	Reason for using multiple catheters	Patients with multiple catheters	Resolution of abscess	Duration of catheterization	Complications/Recurrences
Articles that report results with multiple catheters							
Authors' data	54 patients	Variable – all intraabdominal, majority (28/54) postoperative	Large 6cm Viscous fluid with debris Associated fistula Placed initially or as salvage	100% (54/54)	94% (51/54)	Median: 22 days	7 recurrences 1 delayed hemorrhage
Lambaise et al., 1992 (7)	335 collections in 323 patients	Variable – included intrathoracic collections and other extraabdominal sites	Intraperitoneal or pelvic abscesses; loculations or for complete evacuation; performed after initial procedure Pancreatic : complex structure; unclear if multiple drains were inserted primarily or subsequently	4% (12/291) patients with intraabdominal collections	'Cure' - 62% (209/335) 'Temporization' - 15% (51/335) 'Palliation' - 13% (45/335)	Mean duration: Reported categorically and variable by abscess type	14 transient septicemia 7 recurrences 4 bowel perforations 3 hemorrhages 2 pleural transgressions
vanSonnenberg et al., 1984 (3)	250 collections in 212 patients	Variable, majority (139/250) pyogenic	"...poor definition of the walls of the collection s with thick, nonfluid contents, and associated fistulae" Unclear if placed initially or subsequently	19% collections (48/250)	'Success' - 84% (209/250) 'Partial success' - 91% (227/250)	Not reported	20 recurrences 3 hemorrhages 2 septicemia 2 pleural transgressions 1 superinfection 1 bowel perforation
Okita et al., 2013 (8)	104 patients	Postoperative abdominal abscesses	"...size and number of catheters (were) based on the nature of the fluid obtained at needle aspiration and the extent of the abscess" Unclear if placed initially or subsequently	29% (30/104)	86% (89/104)	Group A (single or late-onset abscess): 14 days Group B (multiple or early onset abscess): 21 days	1 hemorrhage Drained recurrences were deemed successes
Kassi et al., 2014 (9)	81 patients	Postoperative abdominal abscess	Rationale not specified Placed at initial procedure	25% (20/81)	78% (63/81)	Mean: 13.2 days	17 Recurrences No major catheter-related complications.
Gerzof et al., 1981 (10)	71 collections in 67 patients	Postoperative and spontaneous	"size and shape" conducive to dual catheters; decompressive therapy for pancreatic abscesses Placed at initial procedure	10% collections (7/71)	86% (61/71)	Mean: 20.2 days	4 septicemia 1 hemorrhage 1 empyema 1 fistula 1 peritoneal spill
Lee MJ et al., 1992 (11)	59 collections in 30 patients; 44 complex collections	Acute complicated pancreatitis	"...persistent large cavity not adequately drained by existing catheters" "Unclear how many placed initially versus subsequently	70% patients overall (21/30)	47% (14/30)	Mean: 5 weeks	3 fistulas 1 hemorrhage 1 pneumothorax
Freeny et al., 1998 (12)	34 patients	Necrotizing pancreatitis	"the number and size of the initial catheters were determined by the size and location of the necrotic space (and viscosity/debris of fluid)" Unclear how many placed initially versus subsequently	Most (not specified) Mean 3 catheters/patient	47% (16/34)	Median: 85 days Mean: 89 days	No complications directly related to catheter insertion
McNeeley et al., 2012 (13)	33 patients	Complicated appendicitis in pediatric patients	Rationale not specified Placed at initial procedure	9% (3/33)	88% (29/33)	Median: 3 days	3 Recurrences 1 fistula
Chen et al., 1997 (16)	25 patients	Emphysematous pyelonephritis	Additional abscesses Placed at subsequent procedure	36% (9/25)	92% (23/25), including 3 bridges to surgery	Mean for single catheters: 3.9 weeks Mean for multiple catheters:	No major catheter-related complications

	Total number of patient s and/or collections	Patient/collection characteristics	Reason for using multiple catheters	Patients with multiple catheters	Resolution of abscess	Duration of catheterization	Complications/Recurrences
						6 weeks	
Articles that do NOT report results with multiple catheters							
Politano et al., 2011 (18)	359 collections in 260 patients	Postoperative abdominal abscesses	None given	None reported	69% (unclear if success percentage for collection s or patients)	Not reported Mean hospital stay: 13.5 days	Not reported
Akinci et al., 2005 (19)	300 collections in 255 patient s	Variable intraperitoneal, majority (158/300) postoperative	None given	None reported	68% (203/300)	Mean: 13 days	12 recurrences 4 septicemia 1 hemorrhage
Lagan et al., 2008 (20)	107 collect ions in 95 patient s	Variable abdominal, majority (68/95) postoperative	None given	None reported	92% (98/107)	Mean 14.2 days	1 delayed hemorrhage 1 transient septicemia
Gobien et al., 1985 (21)	51 patient s	Variable abdominal	None given	None reported	88% (45/51)	Mean: 18.3 days	1 septicemia