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CLINICAL INVESTIGATION NON-VASCULAR INTERVENTIONS

Retrospective Study in 40 Patients of Utility of C-arm FDCT as an Adjunctive Modality in Technically Challenging Image-Guided Percutaneous Drainage Procedures

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Abstract
Purpose To explore the utility of C-arm flat detector computed tomography (FDCT) as an adjunctive modality in technically challenging image-guided percutaneous drainage procedures.
Methods Clinical and image data were reviewed on 40 consecutive patients who underwent percutaneous drainage of fluid collections in technically challenging anatomic locations that required the use of C-arm FDCT between 2009 and 2013. Percutaneous drainage was performed under ultrasound and fluoroscopic guidance with the use of C-arm FDCT as a problem-solving tool to identify appropriate needle/wire placement prior to drainage catheter placement ($n = 33$) or to confirm catheter positioning within the fluid collection ($n = 8$). Technical success and procedural complications were recorded and retrospectively analyzed.
Results Forty one fluid collections were identified in 40 patients. Mean number of C-arm FDCT rotational acquisitions per patient was 1.25. Mean procedure time per patient was 59.3 min. Mean fluoroscopy time was 5.5 min, and mean air kerma was 394.3 mGy. Percutaneous drainage with the use of C-arm FDCT was successful in 35 of 40 patients (87.5 %). Technical failure was encountered in 5 of 40 patients due to too narrow window ($n = 1$), too small or no fluid collection noted on C-arm FDCT images ($n = 2$), and poor image quality requiring the use of a conventional CT scan ($n = 2$). Three procedure-related complications occurred (7.5 %), which included traversed rectum, traversed spleen, and sepsis.
Conclusion C-arm FDCT is useful as an adjunctive modality in the interventional suite for technically challenging percutaneous drainage procedures by providing sufficient anatomic detail. Complications of catheter misplacement can be avoided if C-arm FDCT is used prior to tract dilatation. If C-arm FDCT image quality of needle and/or wire placement is poor, conventional CT guidance is recommended.

Keywords Non-vascular interventions · Catheter drainage · Abscess

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Introduction

Many institutions rely on a separate computed tomography (CT) scanner for guiding percutaneous drainage procedures. The drawbacks of performing these procedures in a CT scanner include lack of real-time visualization, including needle advancement, availability, and need for a separate procedural room [1]. C-arm flat detector computed tomography (FDCT), also known as cone-beam CT, is an area of active research that has shown promising results in combining the speed and flexibility of fluoroscopy with the spatial information and soft tissue contrast provided by volume CT. Many reports have already demonstrated the utility of this technology in interventional radiology, including minimally invasive intracranial vascular procedures [2–5], vertebroplasty and spine interventions [6, 7], percutaneous biopsies [8–10], embolization of visceral abdominal organs [11–14], translumbar type 2 endoleak repair [15], percutaneous liver tumor ablation [16], and adrenal vein sampling [17]. Ikeda et al. [18] and Froelich et al. [19] also demonstrate the value of using cone-beam CT as a primary tool to guide percutaneous abscess drainages.

C-arm FDCT provides both 3-D image acquisition and real-time procedural evaluation with a wide field-of-view in one room. Although image quality of C-arm FDCT is inferior to conventional CT, C-arm FDCT provides sufficient soft tissue contrast for some clinical applications and can be a valuable tool in the interventional suite [20]. Therefore, we explored the utility of C-arm FDCT retrospectively as an adjunctive modality in technically challenging image-guided percutaneous drainage procedures at our institution.

Materials and Methods

At our institution, all percutaneous drainage procedures are performed primarily with the combination of ultrasound (US) guidance and fluoroscopic guidance. C-arm FDCT is reserved as a secondary tool for procedural guidance in cases where the access may be difficult using both US and fluoroscopy. Our study defines a technically challenging drainage procedure as one when the targeted fluid collection is not well visualized on US (i.e., image artifact from adjacent bones, large patient size, deep location, etc.) or as a fluid collection located adjacent to visceral structures (i.e., vasculature, bowel, diaphragm, etc.). In these technically challenging drainage procedures, rotational C-arm FDCT is used as an adjunct to US and fluoroscopy to provide 3-D datasets for aid with percutaneous drainage. This is a retrospective review of prior technically challenging percutaneous drainage procedures in a single institution that utilized rotational C-arm FDCT.

The Institutional Review Board approved this retrospective study, and informed consent was waived. The equipment used included ultrasound and two flat-panel angiographic units equipped with syngo DynaCT (Artis Zee ceiling-mounted system and Artis Zeego; Siemens Medical Solutions, Forchheim, Germany). The DynaCT software used modified filtered back projection with additional algorithms to correct for beam hardening, scattered radiation, truncated projections, and ring artifacts. A volumetric dataset in a 512 × 512 matrix was created and was further processed to generate multi-planar reconstructions (MPRs) and CT-like soft tissue images. The images were reviewed at the time of the procedure by the operating interventional radiologist.

From April 2009 to September 2013, 2507 percutaneous drainage procedures were performed at our institution using a combination of US and fluoroscopic guidance. Among these procedures, rotational C-arm FDCT was used as an adjunct to US and fluoroscopy for 41 (1.6 %) percutaneous drainage procedures in 40 patients.

C-arm FDCT was used to identify appropriate needle and wire placement prior to drainage catheter placement ($n = 33$) or to confirm appropriate positioning of the drainage catheter within the fluid collection ($n = 8$). For all cases, we recorded the patient's age and gender, indication for the procedure, location of fluid collection, and type of catheter placement. We also reviewed follow-up clinical and imaging data. Technical success and procedural complications were also recorded and retrospectively analyzed. Technical failure was defined as being unable to access the fluid collection or to confirm catheter position with the aid of C-arm FDCT. Complications were classified according to the Society of Interventional Radiology (SIR) criteria [21, 22].

The procedures were performed or closely supervised by 11 different interventional radiologists between 2 and 27 years of experience. Thirty nine procedures were performed under moderate sedation and two under general anesthesia.

Results

Forty one fluid collections (Table 1) were identified for drainage in 40 patients; only one patient had two collections drained at the same setting. The mean patient age was 52.3 years. There were 23 females and 17 males. Mean procedure time per patient was 59.3 min ($n = 36$ and SD = 26.8 min); procedural time was not available for four of the 40 patients. The mean number of C-arm FDCT rotational acquisitions obtained per patient was 1.25 (range = 1–3 and SD = 0.53). Mean fluoroscopy time was 5.5 min ($n = 27$ and SD = 3.5 min), and mean air kerma was 394.3 mGy ($n = 15$ and SD = 364.4 mGy).

Percutaneous drainage with the use of C-arm FDCT was successful in 35 of the 40 patients (Table 2). An example case is illustrated in Fig. 1. In two patients, percutaneous aspirations were only performed without placement of a drainage catheter. Drainage catheters ranging in size from 8.5 French to 24 French were placed in the other 33 patients. Two patients had their drains exchanged multiple

Table 1 Etiologies of the 41 collections in 40 patients

Post-operative abscess	23 (56.1 %)
Neoplasm resection	10
Bowel surgery for bowel inflammation	4
Bowel surgery for obstruction	2
Bowel surgery for familial adenomatous polyposis	1
Surgery at outside hospital for unknown cause	2
LVAD placement	1
Liver transplant	2
Cholecystectomy	1
Other post-operative fluid collection	4 (9.8 %)
Hematoma	1
Urinoma	2
Lymphocele	1
Adjacent visceral inflammation	12 (29.3 %)
Diverticulitis	6
Appendicitis	1
Inflammatory bowel disease	2
Hepatitis	1
Discitis	1
Pelvic inflammatory disease	1
Parenchymal abscess	1 (2.4 %)
Hepatic abscess	1
Malignant effusion	1 (2.4 %)
Total	41

Table 2 Successful and unsuccessful use of C-arm FDCT in identifying needle/guidewire placement or catheter position according to the locations of the 41 collections

	Total	Successful	Unsuccessful
Retroperitoneal	17 (41.5 %)	14 (41.2 %)	3 (50.0 %)
Presacral	9	8	1
Peripancreatic	6	4	2
Adnexal	1	1	
Periprostatic	1	1	
Peritoneal	21 (51.2 %)	20 (58.8 %)	1 (16.7 %)
Right lower quadrant	6	6	
Left lower quadrant	3	3	
Right mid abdomen	1	1	
Epigastric	3	2	1
Perihepatic	2	2	
Subphrenic	2	2	
Intrahepatic	1	1	
Perirectal	3	3	
Abdominal wall	1 (2.4 %)	1 (3.0 %)	
Paraspinal	1 (2.4 %)		1 (16.7 %)
Pleural space	1 (2.4 %)		1 (16.7 %)
Total	41	35	6

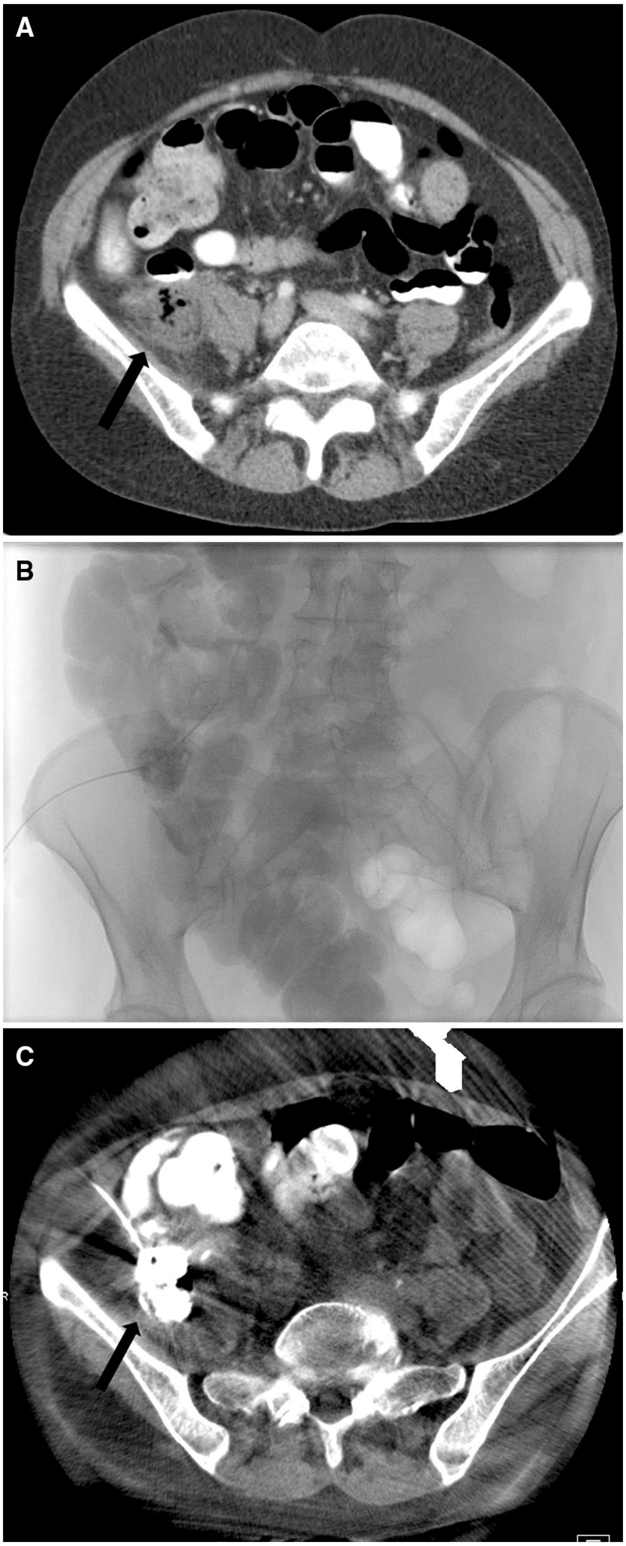
times due to adjacent fistulous communication to bowel with a time to drain removal of 540 and 240 days. Excluding these two patients, the mean time to drain removal was 28.4 days ($n = 24$ and SD = 17.1 days). No follow-up data regarding the drainage catheters were found in seven of the 33 patients.

Technical failure was encountered in 5 of 40 patients (12.5 %), which included too narrow of a safe access window ($n = 1$) without additional procedure or operation prior to discharge, too small or no fluid collection noted on C-arm FDCT images ($n = 2$) without additional procedure or operation prior to discharge, and poor image quality requiring the use of a conventional CT scan on the same day ($n = 2$). Of these last two patients, one patient underwent a CT-guided drainage procedure the following day and the other patient underwent video-assisted thoracoscopy for a malignant pleural effusion 4 days later.

Three procedure-related complications occurred (7.5 %), which included traversed rectum, traversed spleen, and sepsis. The first patient presented with diverticulitis and a perirectal abscess (Fig. 2). The right lateral rectal wall was traversed during the placement of a right transgluteal perirectal abscess drain, which was noted on C-arm FDCT images. An 8.5-French Dawson–Muller drainage catheter was left in place because the catheter tract was already dilated. The patient returned the following day for catheter removal and new placement using CT guidance (Major Complication, C). He did well post CT-guided drainage and was discharged 4 days later. In the second patient, the spleen was traversed during the placement of a left pleural drainage catheter for a malignant pleural effusion. This was confirmed on conventional CT images. This catheter was immediately removed by the patient in the holding area against medical advice with no immediate or delayed complications noted after removal (Minor Complication, B). Four days later, cardiothoracic surgery was performed using video-assisted thoracoscopy and drainage of the pleural effusion. The third patient presented for hepatic abscess drainage in the setting of sepsis and bacteremia. He developed tachycardia and hypertension after the drainage catheter was placed. This may have been related to the patient's ongoing sepsis, aggravation of the infection, or pain/anxiety. He received ciprofloxacin, demerol, and intravenous fluids in the IR suite with clinical improvement of vital signs (Minor Complication, B). He was transferred back to the patient floor in stable condition and was discharged 2 days after the drain was placed.

Discussion

Cross-sectional imaging is a frequently used tool in most interventional radiology departments with CT-guided percutaneous drain placements commonly performed [23]. CT



◀**Fig. 1** A 55-year-old woman presents with a periappendiceal abscess. **A** Contrast-enhanced axial CT image shows acute appendicitis with periappendiceal abscess (*arrow*). **B** Anteroposterior fluoroscopic image obtained during percutaneous drainage shows a 5-French catheter and guidewire within the right lower quadrant. Contrast is injected into the periappendiceal abscess cavity; however, contrast-opacified bowel has a similar appearance. **C** Axial C-arm flat detector computed tomography image of the pelvis demonstrates appropriate placement of the 5-French catheter (*arrow*) into the contrast-opacified periappendiceal abscess cavity. The catheter tract is subsequently dilated with successful placement of a 10-French Dawson–Mueller catheter

offers superior anatomic detail for difficult-access fluid collections; however, CT-guided drainage procedures can be time consuming and rely on the need for a separate CT scanner. C-arm FDCT provides an open geometry, 3-D volumetric imaging, and combined fluoroscopic/CT modes of image acquisition [24].

Major impediments to C-arm FDCT are reconstruction artifacts resulting from organ motion, field-of-view, and metal tools that cause beam hardening [24]. During image acquisition, it is highly desirable that the patient maintains an appropriate breath-hold and that the field-of-view encompasses the lateral extent of the object in all views [24]. Although image quality of C-arm FDCT is inferior to conventional CT, it provides sufficient anatomic detail in the interventional suite for guiding needle/wire placement and for confirming appropriate catheter position in most percutaneous drainage procedures. In 35 out of 40 patients, C-arm FDCT provided sufficient anatomic detail for guiding needle/wire placement ($n = 29$) or for confirming appropriate position of catheter placement ($n = 6$).

In previous studies [18, 19], C-arm CBCT or C-arm-supported CT fluoroscopy was used as the primary guiding tool for percutaneous abscess drainage procedures. In our study, C-arm FDCT was used as an adjunct to US and fluoroscopy. Therefore, the mean number of C-arm FDCT rotational acquisitions obtained per patient was only 1.25.

Overall complication rate was 7.5 %. Although there were no medical implications from the two drainage catheters traversing the rectum and spleen, this may have been prevented altogether if we used C-arm FDCT prior to tract dilatation or drainage catheter placement. Therefore, we recommend the use of C-arm FDCT or conventional CT to check the position of the needle or guidewire before tract dilatation.

Several limitations were inherent in our study. This was a retrospective review at a single institution, and the patient population size was small. Also, the decision to proceed with percutaneous drainage of some of the smaller collections was determined at the discretion of the working interventional radiologist, which may have caused bias in our results. Finally, there was no control group for which to compare procedural times, radiation doses, technical success and complication rates.

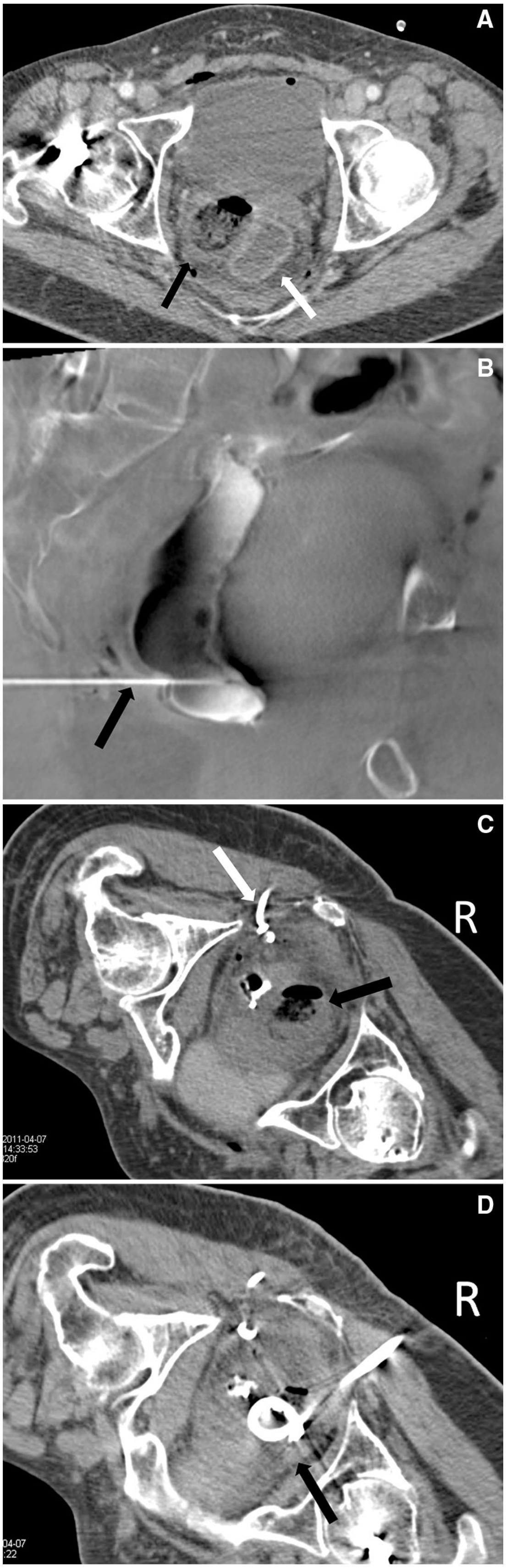


Fig. 2 A 63-year-old male with a history of perforated diverticulitis status post left colectomy and diverting colostomy presents with a right perirectal fluid collection. **A** Contrast-enhanced axial CT image demonstrates an air-filled right perirectal fluid collection (*black arrow*) and fluid-filled rectum (*white arrow*). **B** Sagittal C-arm flat detector computed tomography image obtained during percutaneous drainage demonstrates an 18-gauge trocar needle (*arrow*) in the contrast-filled rectum. It was decided to leave an 8.5-F Dawson–Muller drainage catheter because the catheter tract was already dilated. **C** Non contrast-enhanced axial CT image during the CT-guided drainage procedure the following day demonstrates that the previously placed 8.5-F Dawson–Muller catheter is outside the rectum (*white arrow*) and right perirectal fluid collection (*black arrow*). **D** A 16-French Cope loop catheter (*black arrow*) is successfully placed into the right perirectal fluid collection

In conclusion, C-arm FDCT is useful as an adjunctive modality in the interventional suite for technically challenging percutaneous drainage procedures. The technology provides sufficient anatomic detail for detecting needle/wire placement prior to tract dilatation or for confirming catheter position. Complications of catheter misplacement can be avoided if C-arm FDCT is used prior to tract dilatation. If C-arm FDCT image quality of needle and/or wire placement is poor, conventional CT guidance is recommended.

Conflict of interest Poyan Rafiei, Seung Kwon Kim, Mudassar Kamran, and Nael E. Saad declare that they have no conflicts of interest.

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