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대한영상의학회지

Clinical Usefulness of C-Arm Cone-Beam CT in Percutaneous Drainage of Inaccessible Abscess
접근이 어려운 농양의 경피적배액술에서 C-Arm Cone-Beam CT의 임상적 유용성

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Purpose: The objective of this study was to evaluate the usefulness of C-arm cone-beam CT (CBCT) in drainage of inaccessible abscesses.
Materials and Methods: To identify the trajectory of the needle or guide wire, CBCT was performed on 21 patients having an inaccessible abscess. CBCT was repeated until proper targeting of the abscess was achieved, before the insertion of a large bore catheter. The etiology, location of the abscess, causes of inaccessibility, radiation dose, technical and clinical success rates of drainage, and any complications confronted, were evaluated.
Results: A total of 29 CBCTs were performed for 21 abscesses. Postoperative and non-postoperative abscesses were 9 (42.9%) and 12 (57.1%) in number, respectively. Direct puncture was performed in 18 cases. In 3 cases, the surgical drain or the fistula opening was used as an access route. The causes of inaccessibility were narrow safe window due to adjacent or overlying organs ($n = 9$), irregularly dispersed abscess ($n = 7$), deep location with poor sonographic visualization ($n = 4$), and remote location of the abscess from surgical drain ($n = 1$). Technical and clinical successes were 95.5% and 100%, respectively. Cumulative air kerma and dose-area product were 21.62 ± 5.41 mGy and 9179.87 ± 2337.70 mGycm^2, respectively. There were no procedure related complications.
Conclusion: CBCT is a useful technique for identifying the needle and guide wire during drainage of inaccessible abscess.

Index terms
C-Arm CT
Abscess
Drainage
Catheter
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INTRODUCTION

Percutaneous abscess drainage has become a widely accepted procedure for the treatment of various abdominal or pelvic abscesses (1-4). According to several studies, percutaneous abscess drainage is curative in 80–90% of cases (5-10). While the majority of cases are manageable, having a straightforward access, some cases may be inaccessible or undrainable due to limited topographic factors caused by anatomic distortions secondary to surgery, surrounding organs, and difficult location. To overcome an access limitation, invasive transgressions of surrounding organs may often be necessary. Occasionally, a surgical drain placed near the abscess during surgery, can be used as an alternative access route (11). However, even with alternative access route, some abscesses remain inaccessible and eventually require surgical drainage.

The recently developed C-arm cone-beam CT (CBCT) system, that enables imaging with wide z-axis coverage in 1 axial scan, offers a greater flexibility in orientating the detector around the patient, than the closed CT gantry systems (12). CBCT is space and time-saving because it is integrated with the C-arm gantry, which enables real-time CT during procedures without patient transfer to CT room. For these lesions, CBCT has been applied in various interventional procedures and surgeries for hepatic tumor embolization, guidance for biopsy, and surgeries for spine and skull base (13-18).

Table 1. Patients Data, Causes of Inaccessibility, and Results of Drainage Procedures

No.	Sex	Age (yr)	Etiology of Abscess	Location of Abscess	Depth of Abscess (cm)	Causes of Inaccessibility to Abscess	No. of CBCTs	Technical Success	Clinical Success
1	F	67	Postoperative	Left subphrenic	2.6	Irregularly dispersed abscess with remote main portion	1	Success	Success
2	F	75	Postoperative	Left subphrenic	9.4	Deep seated abscess with poor sonographic visualization	3	Success	Success
3	M	62	Postoperative	Left subphrenic	5.3	Narrow access window d/t spleen and colon	1	Success	Success
4	F	49	Postoperative	Left subphrenic	3.6	Irregularly dispersed abscess with remote main portion	1	Success	Success
5	F	44	Postoperative	Pelvic cavity	6.0	Narrow access window d/t rectum and internal iliac artery	1	Success	Success
6	F	66	Postoperative	Right subphrenic	4.5	Irregularly dispersed abscess with remote main portion	2	Success	Success
7	M	72	Postoperative	Right subphrenic	Not available*	Irregularly dispersed abscess with remote main portion	1	Success	Success
8	M	59	Postoperative	Right subphrenic	Not available*	Remote abscess from surgical drain	2	Success	Success
9	F	64	Postoperative	Subhepatic	3.6	Irregularly dispersed abscess with remote main portion	1	Success	Success
10	F	75	Liver abscess	Liver dome	7.7	Deep seated abscess with poor sonographic visualization	3	Success	Success
11	M	71	Liver abscess	Liver dome	8.6	Deep seated abscess with poor sonographic visualization	1	Success	Success
12	M	61	Perianal abscess	Pelvic cavity	Not available*	Irregularly dispersed abscess with remote main portion	1	Success	Success
13	F	53	Infected lymphocele	Pelvic cavity	6.3	Narrow access window d/t small bowel, bladder, and external iliac artery	1	Success	Success
14	M	67	Cancer related bowel perforation	Pelvic cavity	7.6	Deep seated abscess with poor sonographic visualization	2	Success	Success
15	M	83	Cancer related bowel perforation	Pelvic cavity	4.0	Narrow access window d/t overlying small bowel	1	Success	Success‡
16	F	37	Acute pancreatitis	Pararenal	6.0	Irregularly dispersed abscess with remote main portion	1	Fail†	Success
17	F	42	Acute pancreatitis	Peripancreatic	4.9	Narrow access window d/t spleen and colon	1	Success	Success
18	M	50	Pancreatic pseudocyst	Peripancreatic	3.2	Narrow access window d/t overlying small bowel	2	Success	Success
19	F	52	Acute appendicitis	Periappenceal	3.8	Narrow access window d/t overlying small bowel and colon	1	Success	Success‡
20	F	46	Acute appendicitis	Periappenceal	6.0	Narrow access window d/t overlying small bowel and colon	1	Success	Success‡
21	F	44	Acute appendicitis	Periappenceal	3.6	Narrow access window d/t overlying small bowel	1	Success	Success

*Surgical drain (patient No. 7 and 8) or fistula opening (patient No. 12) was used as an access route.
†Catheter insertion into the main portion of the abscess was failed.
‡After clinical improvement, patients underwent surgical treatment for underlying disease and the drainage catheter was removed during the surgery.
CBCT = cone-beam CT

Until now, there have been few studies on the use of CBCT in drainage procedure, and no reports with respect to drainage of inaccessible or undrainable abscess. CBCT is expected to allow the identification of the trajectory of needle and guide wire during procedures, which can improve the accuracy and efficiency of the process. In addition, real-time fluoroscopic capability of CBCT can reduce the procedure time, as compared with conventional CT fluoroscopic system because on-site imaging during interventional procedure is possible with CBCT. Thus, the purpose of this study was to evaluate the clinical usefulness of CBCT in drainage of inaccessible abscess.

MATERIALS AND METHODS

This retrospective study was approved by our Institutional Review Board and requirement for informed consent was waived.

Patient Characteristics

From September 2009 to February 2015, a total of 29 CBCTs were performed for 21 inaccessible abscesses (21 patients: 8 male and 13 female; mean age: 59 years) (Table 1).

CBCT Equipment and Parameters

CBCT was performed using a flat-panel detector C-arm system (XperCT, Allura FD20; Philips Heathcare, Best, the Netherlands). Two CBCT protocols (Abdomen Fast LD or Abdomen Roll) were followed. Three hundred and twelve images were acquired during 180–240° rotation of C-arm in a session of CBCT. Rotation time of C-arm was 5.2–10.4 seconds, depending on the scanning protocol used. Raw data was transferred to an external workstation and the images were reconstructed with 1.98 mm slice thickness.

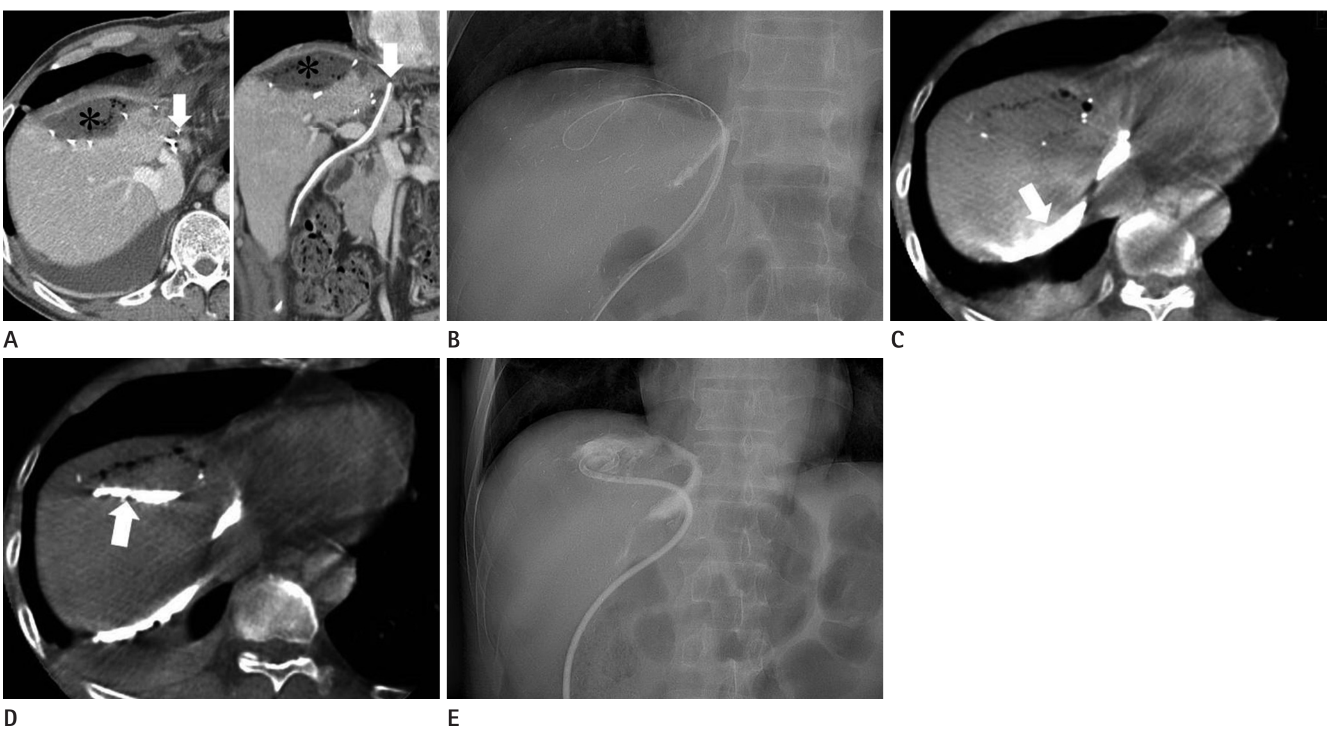
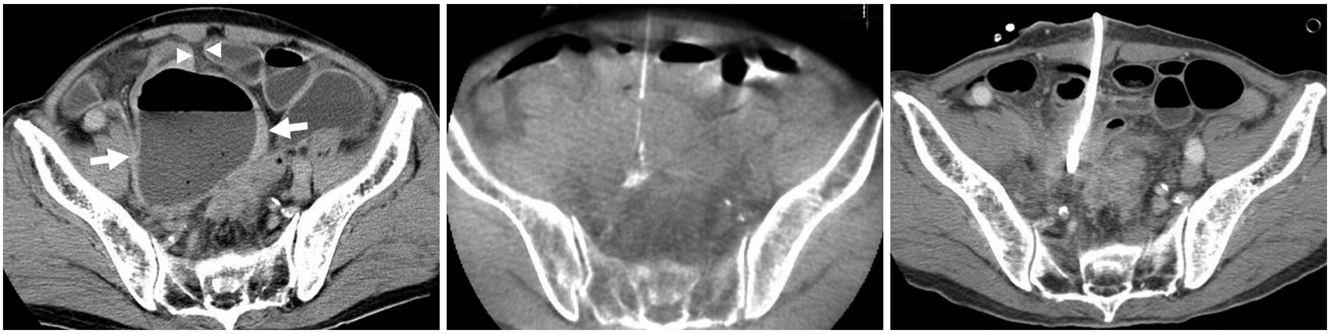


Fig. 1. A 59-year-old male presented with postoperative abscess after extended left hemihepatectomy.
A. Axial and coronal CT show air containing abscess (asterisk) at the resection margin of the liver in high subphrenic area. Previously inserted surgical drain is observed remote from the abscess cavity (arrow).
B. We decided to use surgical drain as an alternative access route because a straight access was impossible due to its unfavorable topographic location. Guide wire and 5-Fr catheter was advanced into the subphrenic space, but abscess could not be aspirated through the catheter.
C. After injection of a small amount of contrast material, CBCT was performed to check the position of the catheter. CBCT shows that the contrast material is not in the abscess cavity (arrow).
D. Based on the CBCT finding, we tried to correct the guide wire and catheter position, after which CBCT was repeated. It now reveals contrast material in the abscess cavity (arrow).
E. Drainage catheter is correctly inserted into the abscess cavity.
CBCT = cone-beam CT



A B C

Fig. 2. An 83-year-old male with a pelvic abscess caused by bowel perforation due to colon cancer.
A. Abdomen CT shows large abscess cavity (arrows) with poor sonic window due to overlying bowel (arrowheads). We punctured the abscess with US guidance, but we could not confirm that the bowel was not penetrated, since the sonic window was very narrow and US finding was obscure.
B. CBCT was performed to check the position of the needle. CBCT shows the pathway of the needle that runs between the bowel loops.
C. Follow-up CT shows complete drainage of the abscess.
CBCT = cone-beam CT, US = ultrasonography

Drainage Procedure with CBCT

The planning of each drainage procedure was performed by the attending interventional radiologist. Before each drainage procedure, the diagnostic CT scans were reviewed and the access route was determined, including skin puncture site and the needle path. The placement of surgical drains at the time of surgery, either near the abscess or fistula opening on skin, was chosen as an alternative access route.

Initially, local anesthesia (2% lidocaine hydrochloride) was administered at the skin puncture site and the planned needle path, using a 21-gauge needle. Local anesthesia was not administered when the surgical drain or fistula opening was used as an access route. During local anesthesia, skin puncture, and needle insertion, ultrasonography (US) was used for determination of the puncture site although the abscess was not clearly depicted on the US.

CBCT was indicated when 1) the safe access window to the abscess was narrow and there was a risk of transgression of adjacent or overlying organs, 2) the abscess was deeply seated and had a poor sonographic visualization, 3) the abscess had an irregular dispersed shape with a remote main segment, which made it difficult to localize the needle or guide wire to the main portion of the abscess, 4) the guide wire could not be inserted in the abscess, despite repeated trials.

In case of direct puncture, CBCT was performed after a 22-gauge Chiba needle was advanced to the target depth along the planned path, previously estimated by a diagnostic CT scan. When the surgical drain or fistula opening was used as an access route, CBCT was performed if the guide wire positioning to the main portion of the abscess failed, despite repeated trials. Drainage was continued if proper placement of the needle or guide wire into the abscess was identified on CBCT. However, if not properly inserted into the abscess, CBCT was repeated after correction of needle or guide wire position, based on the acquired CBCT information, until proper targeting of the abscess was achieved. All drainage procedures were performed by using standard coaxial technique. The attending radiologist decided the catheter size and length, based on viscosity of the contents of the abscess and its distance from the skin entry site.

Outcome Assessment

We retrospectively reviewed the diagnostic CT scans, and evaluated the etiology, the location of the abscesses, and the causes of inaccessibility. During the drainage procedure, radiation dose of CBCT was recorded. We also evaluated the technical and clinical success rates of drainage, and any subsequent complications. Technical success was defined as a successful needle or guide wire localization with subsequent placement of drainage catheter into the main part of the abscess. Technical failure was defined as an incomplete drainage catheter placement into the epicenter of the abscess, regardless of successful needle or guide wire localization. Clinical success was defined as normalization of laboratory findings related to the infection, along with complete resolution of the abscess. Clinical failure was de-

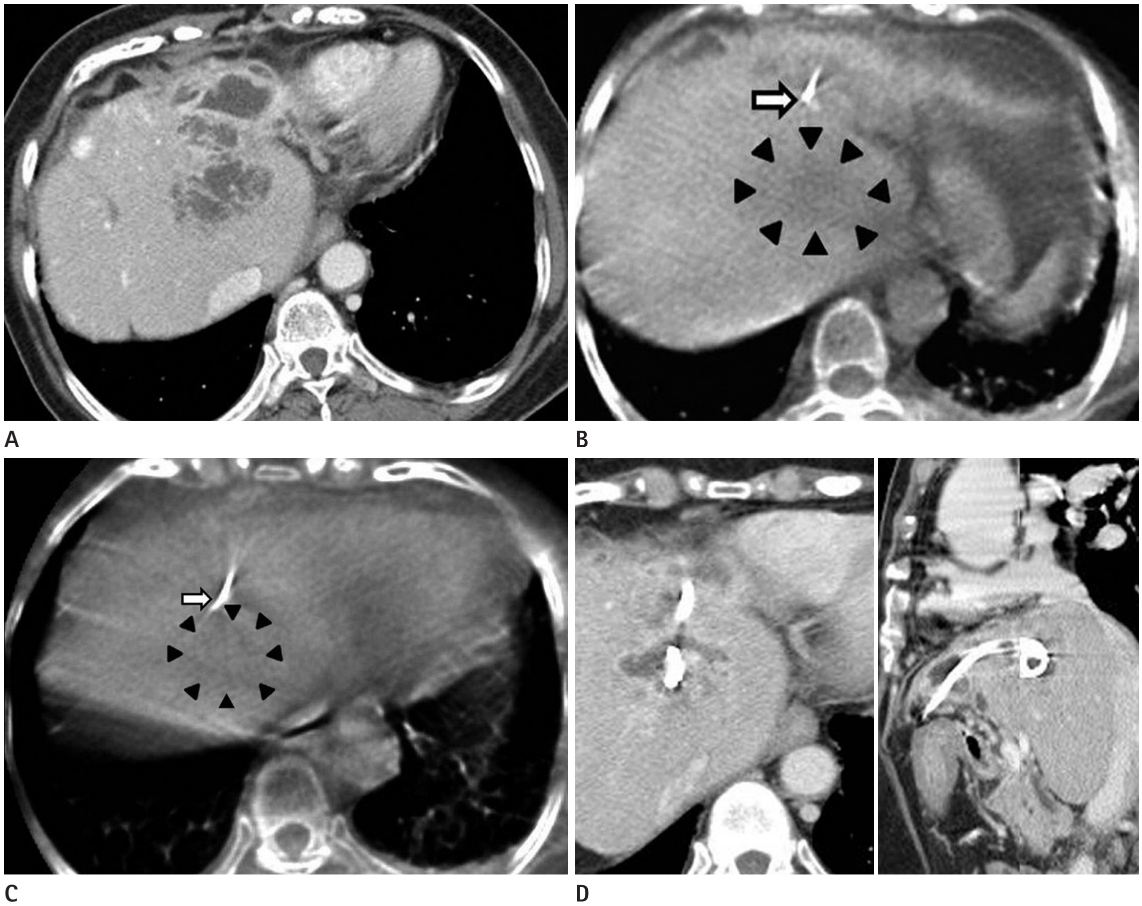


Fig. 3. A 75-year-old female with liver abscess related with IHD stone.
A. Liver CT shows dilated left IHD and the abscess in the S1 of the liver. This abscess had poor accessibility due to deep location and adjacent heart. We decided the needle entry site with US guidance, but assumed the direction and depth of the needle based on the diagnostic liver CT.
B. We performed CBCT to check the needle position. CBCT shows the position of the needle tip (arrow) does not reach to the abscess cavity (arrowheads).
C. CBCT was done after re-insertion of the needle with correction of the direction and the depth of the needle. The needle tip (arrow) is advanced to the border of the abscess cavity (arrowheads). After slight advancement of the needle, the abscess cavity was punctured and the drainage catheter was inserted safely.
D. Follow-up CT shows the drainage catheter located in the abscess cavity, in spite of the long course just below the heart, and a markedly decreased the abscess cavity.
CBCT = cone-beam CT, IHD = intrahepatic duct, US = ultrasonography

fined as presence of a persistent abscess without normalization of laboratory findings related to the infection.

RESULTS

Of 21 abscesses, postoperative and non-postoperative abscesses were 9 (42.9%) and 12 (57.1%), respectively. Postoperative abscesses developed after the following operations: subtotal gastrectomy (n = 2), subtotal pancreatectomy (n = 1), hepatectomy (n = 3; 1 right hepatectomy and 2 left hepatectomy), laparoscopic cholecystectomy with left hepatectomy (n = 1), left hemicolectomy (n = 1), and distal pancreatectomy (n = 1). The location of the 21 abscesses were subphrenic (n = 7; 3 right, 4 left) (Fig. 1), pelvic (n = 5) (Fig. 2), periappendiceal (n = 3), peripancreatic (n = 2), liver (n = 2) (Fig. 3), pararenal (n = 1), and subhepatic (n = 1). Direct skin puncture for access was done in 18 cases. In 3 cases, the surgical drain or fistula opening was used as an access route. In case of direct puncture, the mean depth from skin puncture site to the abscess was 5.37 ± 1.97 cm.

The causes of inaccessibility were: narrow safe window due to adjacent or overlying organs (n = 9), irregularly dispersed abscess having a remote main area (n = 7), deep seated abscess with poor sonographic visualization ($n = 4$), and remote abscess from previously inserted surgical drain ($n = 1$). The details of inaccessibility are described in Table 1.

During the drainage procedure, a total of 29 CBCTs were performed. Multiple sessions of CBCT was performed in 6 abscesses. CBCT was performed thrice in 2 of the abscesses. For the other 4 abscesses, 2 sessions of CBCTs were performed in each. Cumulative air kerma and dose-area product of CBCT were 21.62 ± 5.41 mGy and 9179.87 ± 2337.70 mGycm^2, respectively.

Technical and clinical success of the drainage was 20 (95.5%) and 21 (100%), respectively. In the 1 case with technical failure, catheter insertion into the main portion of the abscess failed due to the irregular dispersion of the abscess, despite a successful needle localization. However, complete drainage through communication of abscess locules culminated in a clinical success. Clinical success was achieved in all the 21 (100%) cases. Three patients underwent surgical treatment for an underlying disease, and the drainage catheter was removed during the surgery.

There were no complications during the drainage procedures.

DISCUSSION

US, fluoroscopy, computed tomography, or magnetic resonance imaging can be used for insertion of the drainage catheters during percutaneous procedures. Recent advancements of imaging modalities have facilitated more sophisticated needle or wire guidance. However, despite these improvements, some abscesses may appear to be inaccessible or undrainable due to an intrinsic limitation of imaging modality, unfavorable nature of the abscess, or topographic factors. In terms of imaging modality, US has been most widely used in percutaneous intervention for real-time guidance, but the acquired signal becomes weak as it travels deeper into the body. This results in the inevitable decrease of spatial resolution in imaging of deep seated lesions (19). In addition, for interventions in structures surrounded by air or air containing abscesses, US often cannot provide sufficient images because of artifacts (20). Unfavorable topographic factors are usually caused by anatomic distortions secondary to surgery, the surrounding organs, and difficult locations.

To overcome limitation due to access, procedures such as invasive transgressions of surrounding organs, or use of the surgical drain as an alternative access route rather than a straight access to the abscess, have previously been used (11). However, alternative approaches were not always possible because some major organs cannot be transgressed. In addition, surgical drains placed at the time of surgery are not always available.

The recently developed CBCT system enables imaging with wide z-axis coverage in 1 axial scan with ultra-high spatial resolution. Several studies for its potential application were previously reported in areas of clinical, preclinical, animal, and *in vivo* human imaging (12). Among the various CBCT systems, the C-arm based CBCT systems have a lower spatial resolution, as compared with CT gantry-based CBCT systems, since they are less mechanically stable and have limitations of C-arm rotation for data acquisition. However, C-arm based CBCT systems are particularity suitable for interventional and surgical application because they offer a better flexibility in orienting the detector around the patient, as compared to the closed CT gantry-based CBCT systems. In most cases, interventional procedures usually can be performed under C-arm fluoroscopy in the intervention room. However, cross sectional imaging, including CT scan, is sometimes needed to check the needle or guide wire position during the procedure. Therefore, application of CBCT system in C-arm fluoroscopy has been of great assistance in interventional procedures.

In our study, several factors contributed to inaccessibility to the abscess (Table 1). In such cases, US usually could not provide a sufficient view for access. However, we could achieve exact localization of the needle or guide wire by identifying and correcting their position on the basis of CBCT-derived three dimensional information. Especially in cases of postoperative abscess, CBCT was quite useful because the anatomic alterations had usually resulted in a poor sonic window, or there was presence of irregularly dispersed fluid collection.

In terms of the radiation dose of CBCT in our study, cumulative air kerma and dose-area product of CBCT were 21.62 ± 5.41 mGy and 9179.87 ± 2337.70 mGycm^2, respectively. The radiation dose in our study cannot be directly compared to that of multidetector CT, because the CT dose index (CTDI) and the dose-length product (DLP) of multidetector CT cannot be used in CBCT (12). Although the total amount of radiation dose was more in CBCT, the post-procedural conventional CT to check the position of the drainage catheter, or re-intervention for reposition of drainage catheter, was avoided. Therefore, we believe that CBCT consequently reduces the possibility of additional radiation exposure by increasing the accuracy of the procedure.

In our study, the technical and clinical success of drainage was 20 (95.5%) and 21 (100%), respectively, with no complications related to the procedure. Without CBCT, some cases might be excluded or become surgical candidates. Therefore, although our cases were inaccessible abscesses, we had a high technical and clinical success rate. Even in patients with technical failure, CBCT provided the exact topographic information, and we could avoid catheter malposition outside the abscess cavity and finally achieve complete drainage of the abscess.

Our study had some limitations that warrant consideration. First, cases for CBCT were selected based on the decision of the attending radiologist. Therefore, our definition of poor accessibility was subjective and operator dependent. However, we believe that CBCT, though possibly unnecessary, can enhance the operator's confidence and accuracy of the procedure during drainage. Second, this study was limited by the small number of cases and retrospective nature. Therefore, further prospective studies with more cases are needed to confirm the clinical efficacy of CBCT in drainage of abscesses with poor accessibility.

In conclusion, CBCT is useful not only in targeting the inaccessible abscess, but the accuracy and success rates of drainage is also increased.

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접근이 어려운 농양의 경피적배액술에서 C-Arm Cone-Beam CT의 임상적 유용성

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목적: 접근이 어려운 농양의 경피적배액술에서 C-arm cone-beam CT (이하 CBCT)의 임상적 유용성을 평가하고자 하였다.

대상과 방법: 접근이 어려운 농양을 가진 21명의 환자를 대상으로 천자침과 유도철사의 경로를 확인하기 위하여 CBCT를 시행하였다. 큰 직경의 카테터를 삽입하기 전에 농양의 적절한 천자 또는 유도철사의 농양내 진입이 확인될 때까지 CBCT를 반복하여 시행하였다. 농양의 원인, 위치, 접근이 어려웠던 원인, 방사선 선량, 기술적 및 임상적 성공률, 합병증을 분석하였다.

결과: 총 21예의 농양에 대해 29회의 CBCT를 시행하였다. 수술 후 농양은 9예(42.9%), 수술과 관련되지 않은 농양은 12예(57.1%)였다. 농양의 직접 천자는 18예에서 시행되었고, 3예에서는 수술 중 삽입된 배액관 또는 누공을 이용하였다. 접근이 어려웠던 원인으로는 인접 장기로 인한 좁은 접근 창(n = 9), 불규칙하게 퍼져있는 농양(n = 7), 깊은 위치에 있어 초음파로 확인이 어려운 농양(n = 4), 수술 중 삽입된 배액관과 떨어진 위치의 농양(n = 1)이었다. 배액의 기술적, 임상적 성공률은 95.5%, 100%였다. Cumulative air kerma와 dose-area product는 각각 21.62 ± 5.41 mGy와 9179.87 ± 2337.70 mGycm^{2}였다. 시술관련 합병증은 없었다.

결론: CBCT는 접근이 어려운 농양의 배액술에서 천자침 또는 유도철사의 위치를 확인하는 데 유용하였다.

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