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Percutaneous Drainage with Ultrasound Guidance in the Intensive Care Unit[1]

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Purpose: To determine the efficacy and safety of bedside percutaneous drainage procedures with ultrasound guidance in critically ill patients in the intensive care unit (ICU).

Materials and Methods: Sixty five percutaneous drainage procedures performed at the bedside, in 39 ICU patients, were evaluated. All of the procedures were performed with ultrasound guidance alone. The procedures consisted of percutaneous drainage of abdominal ($n=35$) and pleural ($n=27$) fluids, percutaneous cholecystostomy ($n=2$) and percutaneous nephrostomy ($n=1$). The clinical responses were classified as 'complete response', 'partial response', 'failure' or 'undetermined'. The medical records were reviewed retrospectively to evaluate the clinical response.

Results: Technical success was achieved in 64 of the 65 procedures (98.5%). The complication rate was 13.8% (9 cases). There was no immediate procedure-related death or worsening of the clinical condition of the patients. The clinical responses after drainage were 'complete response' in 39 cases (60.9%), 'partial response' in 14 (21.9%), 'failure' in 3 (4.7%), and 'undetermined' in 8 (12.5%).

Conclusion: Bedside drainage procedures with ultrasound guidance are effective and safe to perform when patients are too critically ill to be moved from the ICU to the angiography room.

Index words : Percutaneous drainage
Ultrasound guidance
Abscess
Thorax
Interventional procedures

Percutaneous catheter drainage (PCD) is one of the most commonly performed procedures worldwide. To guide the puncture needle and position the catheter, a variety of imaging tools can be used, such as fluoroscopy, computed tomography and ultrasonography (US). Among these different procedures, ultrasonography has gained in popularity for several reasons, including its easy availability, low cost, lack of radiation hazard, good manageability and mobility. The greatest advantage of ultrasound is its real-time capability. The target, the advancing needle and the intervening structures can be visualized at all times, allowing the operator to plan the route, confirm precise needle placement, and

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avoid vital structures (1, 2).

Due to the severity of their illness, and the large amount of life-support equipment involved, such as monitoring devices, ventilators, hemodialysis machines, and infusion pumps, patients in the intensive care unit (ICU) are rarely candidates for routine percutaneous catheter drainage in the interventional suite. When an ICU patient requires a percutaneous drainage procedure, it therefore has to be performed at the bedside with ultrasound guidance alone (3).

We retrospectively evaluated percutaneous drainage procedures performed on ICU patients at the bedside using ultrasound guidance alone; these included PCD, percutaneous cholecystostomy, and percutaneous nephrostomy. The technical success rate, procedure-related complications, and clinical efficiency of the procedure were analyzed.

Materials and Methods

Patient population

Between May 1998 and May 2003, 65 US-guided percutaneous drainage procedures were performed at the bedside of 39 ICU patients in our hospital. The patients were 25 men and 14 women, ranging from 3 to 85 years of age (mean 49.8 years). All of the patients were critically ill, with sepsis or unstable vital signs, and required a large amount of life-support equipment (Table 1). Therefore, the drainage procedures could not be performed in the interventional suite under fluoroscopic guidance. Since our patients were critically ill or in the terminal stage of their disease, the absolute contraindications were limited to bleeding diathesis (platelet count < 50,000/mm^3, partial thromboplastin time > 15 sec) and no safe access route under ultrasonography. The nature of the drainage procedures is summarized in Table 2.

The percutaneous drainage procedures performed were PCD of abdominal (n=35) or pleural (n=27) fluid, percutaneous cholecystostomy (n=2) and percutaneous nephrostomy (PCN, n=1). Multiple drainage procedures were performed in 17 patients: consisting of 2, 3 and 4 procedures in 9, 7 and 1 patients, respectively. Multiple procedures were commonly performed in patients with bilateral or multiple fluid collections, and in patients with simultaneous abdominal and pleural fluid collections. One patient with panperitonitis after surgery for rectal lymphoma required three drainage catheters for bilateral pleural effusions and an abdominal abscess. One patient with a traumatic liver laceration and hemothorax had a total of four drainage catheters for left-side hemothorax, right-side pleural effusion, right-side hemoperitoneum and left-side abscess cavity.

Drainage procedure

Ultrasound (VST MASTER; Diasonics Ultrasound Corp., U.S.A.) was performed just before the drainage procedure with a 3.5- or 7-MHz convex probe and the skin entry site was determined in this way. The skin entry site was prepared and draped in a sterile manner and the US probe was covered with a sterile covering. Then, 5 to 10 ml of 0.1 or 0.2% lidocaine were administered for local anesthesia, and a small incision (2–3 mm) was made at the skin entry site with a surgical blade. US-guided puncture was done using a needle-guidance system with a 22-gauge micro-puncture introducer needle (Cook, Bloomington, U.S.A.) or an 18-gauge Chiba needle (Cook) (Fig. 1). The drainage catheter was inserted

Table 1. Primary Diagnosis in Patients Undergoing US-guided PCD

Primary diagnosis	No. of patients
Trauma	10
Malignancy	7
Infection	7
Post-op complication	5
Bowel perforation	4
Liver transplantation	2
Abdominal aortic aneurysm	1
Postpartum bleeding	1
Neuroganglioma	1
Drug toxicity	1
Total	39

Table 2. The Nature of the Percutaneous Drainage Procedures Performed (Numbers in parentheses are the numbers of patients)

Cause of procedure		No. of cases
Intraabdominal fluid collection (35)	Abdominal abscess	18
	hemoperitoneum	6
	Ascites	3
	Liver abscess	3
	Abdominal fluid collection	3
	Biloma	2
Pleural fluid collection (27)	Pleural effusion	20
	Hemothorax	4
	empyema	3
Gallbladder (2)	Acute cholecystitis	2
Kidney (1)	Pyonephrosis	1
Total		65

using the Seldinger technique. When using a 22-gauge needle, first the wire (Cook) was advanced and then the yellow sheath (Cook) was inserted. Then, the 0.035-inch guide-wire (Terumo, Tokyo, Japan) was advanced sufficiently and echogenic looping of the guide-wire within the lumen was confirmed. Then, the 18-gauge puncture needle or yellow sheath was removed and a 7 to 10 French pigtail catheter (Boston Scientific, Spencer, U.S.A.) with an inner stylet was introduced along the guide-wire. As soon as the tip of the catheter entered the target lumen, the inner stiffening stylet of the catheter was withdrawn slightly, in order to allow the pigtail loop to reform. With this blunt loop leading the way, the catheter was advanced further into the target lumen (Fig. 2A, B). After performing the PCD of pleural fluid, we routinely checked for the development of pneumothorax, by taking a portable chest radiograph in the antero-posterior projection.

In performing PCN, the patient was prepared and draped in the prone position. After administering local anesthesia at the needle entry site, an 18-gauge Chiba needle with an inner stylet was introduced into the posterior calyx of the lower pole of the kidney under continuous ultrasound guidance, and the puncture of the collecting system was confirmed by noting the efflux of urine. A 0.035 guide-wire (Terumo) was passed into the renal pelvis and the pigtail catheter was inserted under real-time US guidance. The presence of the complete looping curve of the pigtail catheter in the renal pelvis on the sonogram confirmed the proper position of the catheter in the urinary system.

Evaluation of technical and clinical results

We retrospectively evaluated the technical success rate, procedure-related complication rate and clinical response. Technical success was defined as proper positioning of the catheter in the target space with proper drainage. The clinical response was evaluated retrospectively by reviewing the medical records, using a modified version of the criteria of Civardi et al. (4). The result

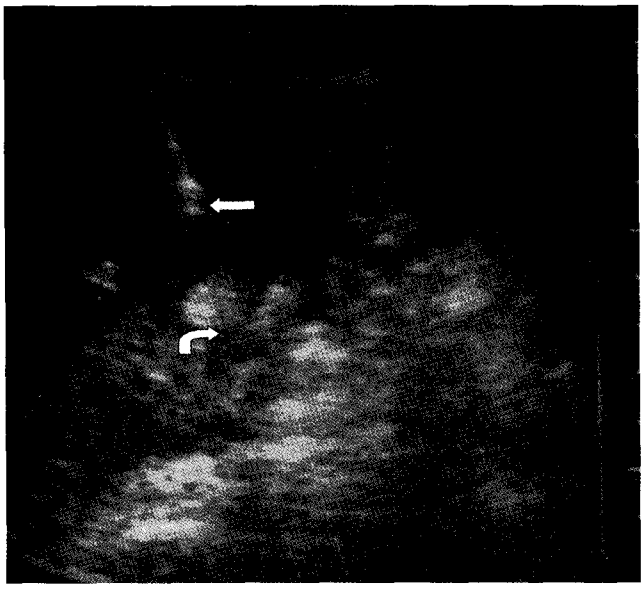
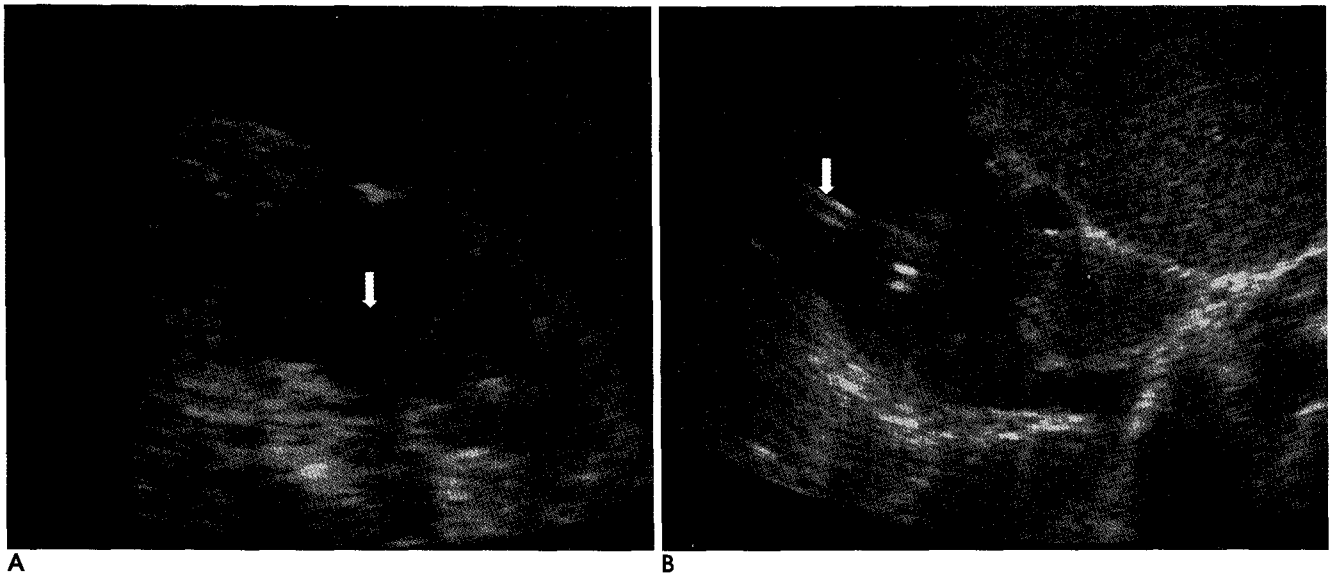


Fig. 1. This US picture shows an 18-gauge Chiba needle inserted along a US biopsy guide (curved arrow) into an abdominal abscess cavity. The tip of the needle (straight arrow) is within the abscess cavity.



A **B**

Fig. 2. Percutaneous cholecystostomy in a patient with acute cholecystitis.
A. This US picture shows the curled guide-wire (arrow) within the gall bladder lumen.
B. This US picture shows a typical echogenic double linear image (arrow) indicating the catheter tip within the gall bladder lumen.

was defined as a 'complete response' when the lesion was drained completely and the catheter removed (Fig. 3A-C). When PCD improved the clinical status, but another procedure (e.g., surgery) was required to cure the condition, or the patient died with a well-functioning catheter, the result was defined as a 'partial response'. When the patient obtained no benefit from the procedure, the result was defined as a 'failure'. Finally, when the patient died or was discharged before the clinical response could be evaluated, the response was defined as 'undetermined'.

Results

Technical success rate

US-guided PCD was technically successful in 64 of the 65 procedures (98.5%). In one patient, because the pleural effusion was located at a considerable depth, exact targeting of the anechoic fluid failed due to poor ultrasound guidance, resulting from a thick subcutaneous fat layer. In this case, no pleural effusion was drained through the puncture needle, although a blood clot was aspirated.

The procedure time was less than 1 hour in all cases.

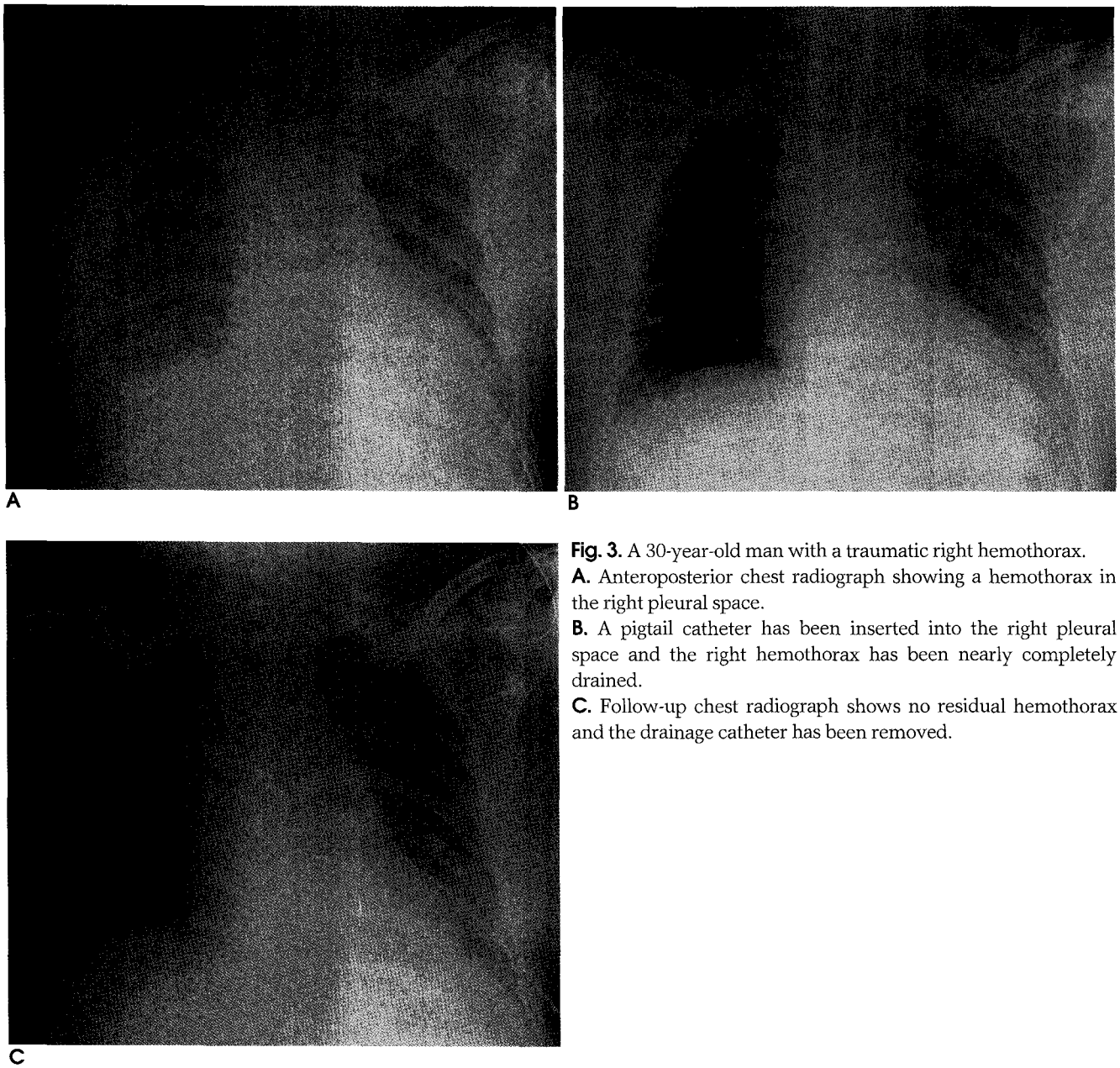


Fig. 3. A 30-year-old man with a traumatic right hemothorax.
A. Anteroposterior chest radiograph showing a hemothorax in the right pleural space.
B. A pigtail catheter has been inserted into the right pleural space and the right hemothorax has been nearly completely drained.
C. Follow-up chest radiograph shows no residual hemothorax and the drainage catheter has been removed.

Complications (six immediate complications and three delayed complications) arose in nine cases (13.8%). No bleeding from any inserted catheter persisted for more than 6 hours after the procedure in any of the patients. Immediate bleeding occurred in three cases and was stabilized within 1 hour by capping the drainage tube. Other immediate complications were three cases of pneumothorax and these resolved spontaneously. There were no cases of immediate procedure-related death or worsening of the clinical or pathological condition in our series. Delayed complications consisted of two cases of tract infection and one catheter fracture.

Clinical responses

The clinical response was 'complete' in 39 cases (60.9%), 'partial' in 14 (21.9%), 'failure' in 3 (4.7%) and 'undetermined' in 8 (12.5%) (Table 3).

Of the 'partial responses ($n=14$)', six patients ($n=11$) died and one underwent a hemi-nephrectomy after PCN, and two with percutaneous cholecystostomy underwent cholecystectomy. Ineffective fluid drainage was the most common cause of failure ($n=3$). In the three cases of 'failure' (three patients), one patient had a chest tube inserted as an additional drainage procedure, and two patients with intraabdominal abscess required surgical therapy. The eight 'undetermined' cases (five patients) consisted of patients who either died or were discharged within 5 days of the procedure.

Discussion

Percutaneous drainage is a well-established therapeutic technique and is one of the most commonly performed procedures worldwide. PCD can be guided using fluoroscopy, US or computed tomography.

Ultrasound has the advantage of being both widely available and portable (1). However, radiologists find US-guided PCD at the bedside inconvenient, because of the additional difficulty caused by the lack of fluoroscopic guidance. Nevertheless, in some situations the patient's clinical condition prevents transport to the interventional suite in the radiology department. In such situations, US-guided PCD at the bedside constitutes a safe alternative.

Ultrasound guidance is optimal for targets located superficially or at moderate depth in thin to average-sized patients. The use of US as a guidance system may be precluded by the inability to visualize the target because of its depth, because it is obscured by overlying bowel gas or bone, or because of poor penetration by the sound waves in the case of an obese patient. Our one instance of failure resulted from targeting an anechoic fluid with poor ultrasound guidance, due to a thick subcutaneous fat layer.

Problems can be encountered when performing PCD using US guidance alone, because of the difficulties involved in visualizing the needle itself, manipulating the catheter in the target area or obtaining the final catheter position. The improvements made in the resolution of US transducers combined with the development of echogenic polymer-coated needles have improved both needle shaft and tip visibility in clinical practice, compared with previous methods involving standard uncoated needles (5). The polymer film has a porous microstructure that entraps microbubbles of air. As the coated needle is advanced into the tissue, the air bubbles trapped in the polymeric coating create multiple specular reflectors on the surface of the needle (6).

To document the proper position of the catheter in the target and to avoid inaccurate positioning of the sideholes, it is important to visualize the complete loop of the pigtail catheter in the target lumen. Some investigators have proposed several signs that are useful for confirming proper target puncture. In US-guided percutaneous transhepatic biliary drainage, hyperechoic lines at the tip of the needle can often be recognized when the duct has successfully been penetrated. These lines widen as the needle is advanced more deeply relative to the probe. During percutaneous transhepatic biliary drainage, this widening occurs at the moment of duct

Table 3. Clinical Response in the US-guided Drainage Procedures

Drainage	Clinical responses				Total
	Cure	Partial response	Failure	Undetermined	
PCD of abdominal fluid	21	7	2	5	35
PCD of pleural fluid	18	4	1	3	26
Percutaneous cholecystostomy		2			2
Percutaneous nephrostomy		1			1
Total	39 (60.9%)	14 (21.9%)	3 (4.7%)	8 (12.5%)	64 (100%)

penetration, thus providing a reliable indication of successful puncture. The absence of hyperechoic lines in US images suggests that the needle has shifted away from the center of the probe. Therefore, hyperechoic lines at the tip of the needle are a useful sign, providing confirmation of successful bile duct puncture (7). Using these methods, we can perform US-guided PCD at the bedside more safely and effectively.

A few reports have described bedside drainage procedures using US alone. Crass and Karl drained abdominal abscesses at the bedside in three patients who had unstable septic shock and were undergoing resuscitation, prohibiting their transfer to the radiology department (8). McGahan performed ten aspirations and six drainage procedures with US guidance in an ICU (9). US guidance was successful in all of the aspiration procedures, while catheter malpositioning occurred in one patient and required repositioning under fluoroscopic guidance. In another case, a chest tube was inserted by a surgeon. McGahan et al. performed 32 percutaneous drainage procedures with portable US guidance, mostly for thoracentesis or abdominal paracentesis (10). The failure rate was less than 7%. We also had a high technical success rate with US guidance (98.5%), and only one case resulted in failure.

Civardi et al. (11) performed US-guided PCD procedures for abdominal abscesses and fluid collection in 50 patients. These procedures resulted in complete recovery in 70% of cases, partial success in 20%, and failure in 10%. Lambiase et al. (12) retrospectively reviewed the percutaneous drainage of 335 abscesses in 323 consecutive patients. The overall cure rate was 62.4%, with a failure rate of 8.95%. The overall complication rate was 9.8%. The recent report by Civardi et al. (4) was the largest study of US-guided PCD of abdominal abscesses. They reported 886 cases of US-guided PCD from eight clinical institutions and observed an overall cure rate of 90.4%, temporization in 6.1% of cases, and failure in 3.6%. The frequency of complications was 6.6% and there were no drainage-related deaths. Our drainage procedure resulted in complete response in 60.9% of cases, partial response in 21.9%, and failure in 4.7% (Table 3). The overall complication rate in our study was 13.8%, while the final cure rate was relatively low, because many of our patients were critically ill (Table 1). Eleven patients (28.2%) in the study population died, or were discharged because they were deemed irremediable, over the course of the study period.

Image-guided percutaneous catheter drainage of pleural fluid collection is considered the mainstay treatment for patients with a diagnostic thoracentesis demonstrating a frank empyema or a complicated parapneumonic effusion (13). Success is measured by complete evacuation of the pleural fluid, so that pulmonary symptoms resolve and sepsis is avoided. Complications are uncommon and can be avoided by meticulous imaging and planning, approaching the fluid over the top of a rib, and avoiding the intra-mammary vessels and deep mediastinal structures. Possible complications include bleeding secondary to injury of the intercostal vessels and pneumothorax (13).

The management of acute cholecystitis remains controversial, especially in terms of the ability of critically ill hospitalized patients to undergo surgery and the timing of the surgical intervention. Some believe surgical cholecystectomy should be delayed until medical therapy is instituted. Percutaneous cholecystostomy is a low-risk interventional procedure (14) and is useful in long-term conservative management, either as a cure for very poor surgical candidates or as a temporizing treatment until surgical cholecystectomy can be performed (15). In our series, two percutaneous cholecystostomies were performed without complication, such as bile peritonitis or bile leakage. The catheters were removed 5 and 8 days following the initial drainage, respectively, at which point an additional surgical procedure was used to cure the condition.

Catheter placement can be performed using two different techniques: the trocar or Seldinger techniques (2). The trocar technique uses a catheter mounted over a stiffening cannula that has a sharp inner stylet, which are inserted into the collected fluid as a unit. The stylet is removed to allow fluid aspiration and confirm the location of the catheter tip, and then the cannula is removed, allowing the distal loop of the catheter to form, securing the catheter in the collected fluid. This technique is best suited for large or superficial fluid collection.

In the Seldinger or guide-wire exchange technique, a puncture needle is inserted into the fluid and a guide-wire is advanced into the fluid through the needle. The needle is then removed, and the guide-wire is used as an anchor and guide, as progressively larger dilators are passed over the guide-wire to prepare for the passage of a catheter and cannula assembly (or simply a catheter). A catheter is then passed over the guide-wire, and the guide-wire is removed, allowing the distal loop of the catheter to form, securing it in the fluid collection.

Some investigators have suggested that the Seldinger technique is more suitable for large abscess cavities and that the trocar technique is more suitable for small cavities (9, 16). In this study, all of the catheters were placed using the Seldinger technique, regardless of the size of the cavity.

In conclusion, percutaneous drainage procedures performed at the bedside with only US guidance are safe and effective in unstable ICU patients. Our relatively low clinical success rate was probably due to the morbid clinical state of the patients, rather than to any limitation in the efficiency of the procedure.

References

1. McGahan JP. Invasive ultrasound principles (biopsy, aspiration, and drainage). In McGahan JP, Goldberg BB, eds. Diagnostic Ultrasound: A Logical Approach. Philadelphia, U.S.A.: Lippincott-Raven, 1998;39-75
2. Caspers JM, Reading CC, McGahan JP, et al: Ultrasound-guided biopsy and drainage of the abdomen and pelvis. In Rumack CM, Wilson SR, Charboneau JW, eds. Diagnostic ultrasound, 2nd. St Louis, U.S.A.: Mosby, 1997;599-628
3. Beagle GL. Bedside diagnostic ultrasound and therapeutic ultrasound-guided procedures in the intensive care setting. *Crit Care Clin* 2000;16:59-81
4. Civardi G, Di Candio G, Giorgio A, et al. Ultrasound guided percutaneous drainage of abdominal abscesses in the hands of the clinician: a multicenter Italian study. *Eur J Ultrasound* 1998;8:91-99
5. Bergin D, Pappas JN, Hwang JJ, Sheafor DH, Paulson EK. Echogenic polymer coating: does it improve needle visualization in sonographically guided biopsy? *AJR Am J Roentgenol* 2002;178: 1188-1190
6. Gottlieb RH, Robinette WB, Rubens DJ, Hartley DF, Fultz PJ, Violante MR. Coating agent permits improved visualization of biopsy needles during sonography. *AJR Am J Roentgenol* 1998;171: 1301-1302
7. Tamada K, Tomiyama T, Wada S, et al. Hyperechoic lines as a sonographic confirmatory sign during percutaneous transhepatic biliary drainage. *Abdom Imaging* 2001;26:39-42
8. Crass JR, Karl R. Bedside drainage of abscesses with sonographic guidance in the desperately ill. *AJR Am J Roentgenol* 1982;139:183-185
9. McGahan JP. Aspiration and drainage procedures in the intensive care unit: percutaneous sonographic guidance. *Radiology* 1985; 154:531-532
10. McGahan JP, Anderson MW, Walter JP. Portable real-time sonographic and needle guidance systems for aspiration and drainage. *AJR Am J Roentgenol* 1986;147:1241-1246
11. 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;15:245-250
12. 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
13. Klein JS, Schultz S, Heffner JE: Interventional radiology of the chest: image-guided percutaneous drainage of pleural effusions, lung abscess, and pneumothorax. *AJR Am J Roentgenol* 1995;164: 581-588
14. Lee MJ, Saini S, Brink JA, et al. Treatment of critically ill patients with sepsis of unknown causes: value of percutaneous cholecystostomy. *AJR Am J Roentgenol* 1991;156:1163-1166
15. Werbel GB, Nahrwold DL, Joehl RJ, Vogelzang RL, Rege RV. Percutaneous cholecystostomy in the diagnosis and treatment of acute cholecystitis in the high-risk patient. *Arch Surg* 1989;124:782-785
16. Browning PD, McGahan JP, Gerscovich EO. Percutaneous cholecystostomy for suspected acute cholecystitis in the hospitalized patient. *J Vasc Interv Radiol* 1993;4:531-538

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집중치료실에서 시행한 초음파 유도하 경피적 배액술의 유용성[1]

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목적: 집중치료실에서 치료를 요하는 위중한 환자에서 초음파 유도하에 시행한 경피적배액술의 효과와 안전성에 대하여 알아보고자 한다.

대상과 방법: 집중치료실에 입원한 39명의 환자에서 총 65예의 초음파 유도하 경피적배액술을 시행하였으며 복강내 액체 저류의 경피적배액술이 35예, 흉수의 경피적배액술이 27예, 경피적 담낭조루술이 2예, 경피적 신루설치술이 1예 였다. 임상적 반응은 '완전(complete response)', '부분적(partial response)', '실패(failure)', '미결(undetermined)'로 분류하였다.

결과: 기술적인 성공율은 98.5 %로 65예중 단지 1예에서 실패하였다. 합병증은 9예(13.8%)에서 있었으나 시술과 연관된 임상적 상태의 악화나 사망은 없었다. 임상적 반응은 '완전'이 39예(60.9%), '부분적'이 14예(21.9%), '실패'가 3예(4.7 %), '미결'이 8예(12.5%) 이었다.

결론: 집중치료실에서 초음파 유도하에서 시행한 경피적배액술은 중재시술실로 이동하기 힘든 위중한 환자에게 안전하면서도 효과적인 시술 방법이다.