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Original Article

Anatomical consideration for safe pericardiocentesis assessed by three-dimensional computed tomography: Should an anterior or posterior approach be used?

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ABSTRACT

Background: The efficacy of epicardial catheter ablation for ventricular tachycardia has been reported. However, the safest anatomical method for pericardial puncture has not been determined.
Methods: Thirty patients who underwent 3-dimensional computed tomography (3D-CT) preceding catheter ablations for atrial fibrillation were enrolled in this study. We used the skin surface 1 cm below the xiphisternum as the puncture site. For the anterior approach, the attainment site was the pericardium of the mid portion of right ventricular anterior site, and for the posterior approach it was the pericardium of the inferior ventricular site. The distance and the angle between the 2 sites were measured using 3D-CT.
Results: For the anterior approach, the distance was 54 ± 11 mm and the needle angle was 37 ± 11° toward the left scapula and 34 ± 12° towards the back of the body. For the posterior approach, the distance was 56 ± 10 mm and the corresponding needle angles were 60 ± 9° and 86 ± 13°. The distance correlated with BMI for the anterior and posterior approaches (anterior approach: $r^2 = 0.43$, $P < 0.001$; posterior approach: $r^2 = 0.49$, $P < 0.001$). Liver existed along the pathway of the posterior approach in 11 (37%) of 30 patients, and through in 2 (18%) of 11 patients. The liver and lung were not located along the pathway of the anterior approach in any patients.
Conclusions: Performing subxiphoid pericardiocentesis is anatomically safer via the anterior approach than via the posterior approach.

1. Introduction

Ventricular tachycardia (VT) originating from the epicardium is an important reason for failure of the endocardial ablation procedure [1]. The percutaneous epicardial approach allows for VT ablation in many cases to be performed in the electrophysiology laboratory [2]. Catheter ablation (CA) from the epicardium is often required for VT ablation of non-ischemic cardiomyopathy due to the presence of epicardial substrates. In a recent survey of 3 tertiary centers performing VT ablation from the epicardium, CA had a risk of 5% for acute and 2% for delayed major complications related to epicardial access [3]. The risks associated with conventional pericardial access using conventional posterior puncture remain. Recently, a modified pericardial approach using anterior puncture has been reported, but the safety has not been systematically assessed [4].

The primary goal of this study was to examine the adequate needle angle required for the anterior and posterior pericardial approaches. The secondary goal was to identify the location of surrounding organs such as lung and liver through the pathway and assess whether the anterior approach is safer than the posterior approach.

2. Materials and methods

2.1. Patient population

The present study included consecutive 30 patients who underwent 3-dimensional computed tomography (3D-CT) preceding

Abbreviations: CA, catheter ablation; VT, ventricular tachycardia; 3D-CT, 3-dimensional computed tomography; BMI, body mass index; LVEDD, left ventricular end-diastolic diameter; LVESD, left ventricular end-systolic diameter

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atrial fibrillation (AF) ablation. Pulmonary vein isolation for paroxysmal or persistent symptomatic drug-refractory AF was performed at our center between April 2011 and June 2011. After written informed consent was obtained, all patients underwent 3D-CT.

2.2. Scan protocol

Area-detector computed tomography (ADCT) was performed with a 320-detector slice computed tomography system (Aquilion One, Toshiba Medical System, Toshiba, Otawara, Japan). Before enhanced ADCT, a non-enhanced ADCT scan was performed without prospective electrocardiographic (ECG)-triggering to establish the conditions and settings for enhanced ADCT. Computed tomography was started at the top of the lung cavity and stopped at the diaphragm caudally. The CT acquisition parameters were collimation thickness, 0.5 mm; rotation time, 350 ms; tube voltage, 120 kV; and tube current, auto mA. Scanning was started 5 s after the peak time of contrast density at the left atrium in 10 mL of test injection. Images were collected in the supine position. Scanning was initiated during a single breath-hold. Acquisition was ECG-gated in patients with sinus rhythm and ECG-non-gated in patients with atrial fibrillation, and took less than 1 s. A non-ionic contrast medium (300 mg/mL, iodine) of 0.7 mL/kg was administered through the antecubital vein with a power injector at a rate of 0.7 mL/kg/10 s followed by a 30 mL saline flash injected at the same rate.

2.3. Image reconstruction

Cardiac structure images were reconstructed using the cardiac-phase search software (Phase Navi, slice thickness, 0.5 mm; and increment, 0.25 mm); the phase of end-systole was selected. Images were reconstructed using volume rendering and multiplanar reconstruction methods and analyzed using an offline workstation for post-processing (ZIO STATION, AMIN Corporation, Tokyo, Japan) to check the main anatomic landmarks by multiplanar reformation.

2.4. Measurement data

We used the skin surface 1 cm below the xiphisternum as the puncture site. For the anterior attainment site, we used the pericardium of the mid portion of the right ventricular anterior site, and for the posterior attainment site, we used the pericardium of the ventricular inferior site. The pathway between the puncture site and the anterior attainment site was defined as the anterior approach; the pathway between the puncture site and the inferior attainment site was defined as the posterior approach (Fig. 1). We measured the distance and angle between the puncture and attainment sites using a 3D-CT analyzer (ZIO STATION, AMIN Corporation, Tokyo, Japan) and we investigated any correlation with body weight, height, body mass index (BMI), LVEDD, and LVESD. Furthermore, we assessed the anatomical relationship between the surrounding organs, such as the liver and lungs, and the access pathway using both the anterior and posterior approaches. Fig. 2A and B shows a representative case for measuring these parameters.

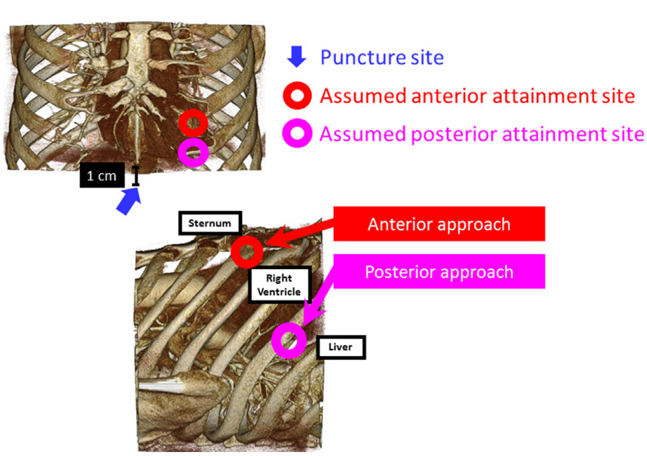

Fig. 1. Definition of the puncture site, anterior attainment site, and posterior attainment site: *Blue arrow* indicates the puncture site, *red circle* indicates the anterior attainment site, and *pink circle* indicates the posterior attainment site (*upper panel*). Pericardiocentesis with anterior puncture and posterior puncture: *Red arrow* indicates the anterior approach and *pink arrow* indicates the posterior approach (*bottom panel*).

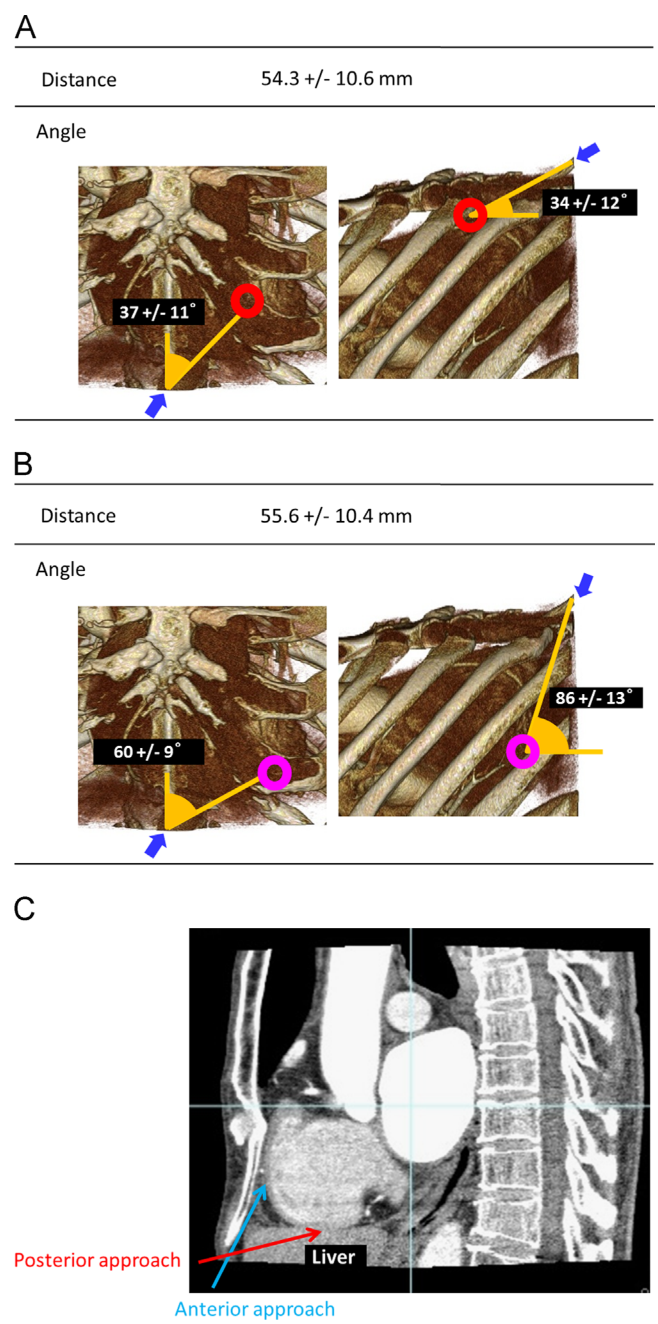

Fig. 2. (A) The distance and needle angle in the representative case for the anterior approach. The distance is defined as the minimum distance between *blue arrow* and *red circle* (B) The distance and needle angle in the representative case for the posterior approach. The distance is defined as the minimum distance between *blue arrow* and *purple circle* and (C) The assumed pathway (green line) of this case was considered to penetrate the liver.

2.5. Statistics

The data were tested with the Kolmogorov–Smirnov test and are presented as mean ± SD for normally distributed variables. Categorical variables are expressed as number and percentage of patients. A paired Student's *t*-test was used to compare the distance and needle angle between the anterior and posterior approaches. Using a linear regression model, we evaluated the relationship between the pathway to the pericardial space and clinical parameters, including BMI, body weight, height, LVEDD, and LVESD. A *P*-value <0.05 was considered statistically significant. All statistical analyses were performed with JMP (SAS Institute Japan, Tokyo, Japan), release 10.

3. Results

3.1. Patient characteristics

Table 1 shows the patient characteristics. Their mean age was 61 ± 10 years, 22 (73%) were men, the mean LVEDD was 48.7 ± 4.9 mm, the mean LVESD was 33.0 ± 4.9 mm, and the mean LVEF was 57.8 ± 7.9%. The mean body height, weight, and BMI were 1.66 ± 0.1 m, 69.9 ± 12.3 kg, and 25.2 ± 3.7 (weight (kg)/height $(m)^2$), respectively. No sustained ventricular tachyarrhythmia was documented in any patient.

Table 1
Baseline characteristics of the study patients.

Age (year)	61 ± 10
Sex male	22/30 Patients
Height (m)	1.66 ± 0.1
Weight (kg)	69.9 ± 12.3
BMI	25.2 ± 3.7
LVEDD (mm)	48.7 ± 4.9
LVESD (mm)	33.0 ± 4.9
LVEF (%)	57.8 ± 7.9

BMI, body mass index; LVEDD, left ventricular end diastolic diameter; LVESD, left ventricular end systolic diameter; and LVEF, left ventricular ejection fraction.

3.2. Anterior approach

For the anterior approach, Fig. 2A shows the representative case. In this case, the distance was measured as 52 mm. The needle angle was 35° towards the left scapula and 35° towards the back of the body. In all patients, the mean distance was 54.3 ± 10.6 mm between the 2 points. The mean needle angle was 37 ± 11° towards the left scapula and 34 ± 12° towards the back of the body (Table 2). The distance correlated with BMI ($r^2=0.43$, $P<0.001$) and body weight ($r^2=0.29$, $P=0.002$) (Fig. 3A), but not body height ($r^2=0.003$, $P=0.78$), LVEDD ($r^2=0.09$, $P=0.11$), and LVESD ($r^2=0.07$, $P=0.16$). Additionally, the needle angle towards the left scapula did not correlate with these parameters (BMI: $r^2=0.11$, $P=0.07$; body weight: $r^2=0.14$, $P=0.04$; body height: $r^2=0.047$, $P=0.25$; LVEDD: $r^2=0.02$, $P=0.41$; LVESD: $r^2=0.012$, $P=0.57$). Moreover, the needle angle toward the back of the body did not correlate with these parameters (BMI: $r^2=0.04$, $P=0.30$; body weight: $r^2=0.002$, $P=0.80$; body height: $r^2=0.04$, $P=0.30$; LVEDD: $r^2=0.02$, $P=0.44$; LVESD: $r^2=0.02$, $P=0.41$).

3.3. Posterior approach

For the posterior approach, Fig. 2B shows the representative case. In this case, the distance was measured as 60 mm. The needle angle was 62° towards the left scapula and 85° towards the back of the body. In all patients, the mean distance was 55.6 ± 10.4 mm. The distance between anterior and posterior approaches was not

Table 2
The distance, needle angle and surrounding organs for anterior and posterior approaches.

	Anterior approach	Posterior approach	*P* value
Distance (mm)	54.3 ± 10.6	55.6 ± 10.4	*0.24*
Angle (deg)			
Toward the left scapula	37 ± 11	60 ± 9	
Toward the back of the body	34 ± 12	86 ± 13	
Surrounding organs			
Lung	None	None	
Liver	None	Along the pathway in 11/30 patients Through the pathway in 2/11 patients	

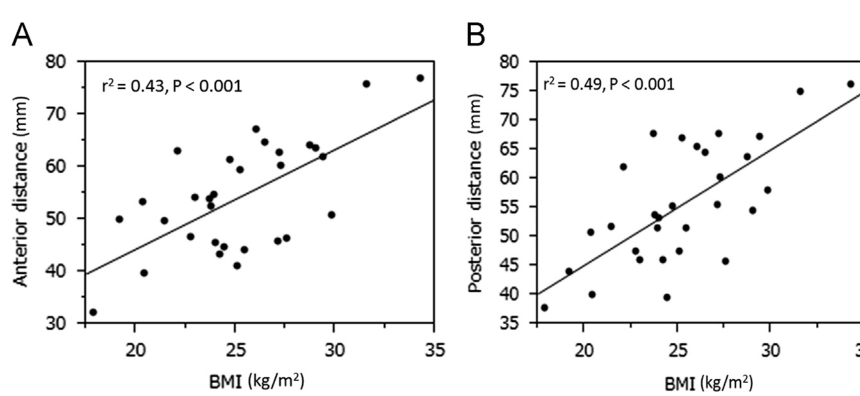

Fig. 3. Relationship between the distance and angle by each approach and body mass index (BMI). (A) Anterior approach and (B) posterior approach. Of note, in the anterior and posterior approaches, the distance is correlated with BMI, but not the angle.

significant ($P=0.24$). The mean needle angle for the posterior approach was $60\pm9^\circ$ towards the left scapula and $86\pm13^\circ$ towards the back of the body. The distance correlated with BMI ($r^2=0.49$, $P<0.001$) and body weight ($r^2=0.26$, $P=0.004$) (Fig. 3B), but not body height ($r^2=0.005$, $P=0.70$), LVEDD ($r^2=0.06$, $P=0.18$), and LVESD ($r^2=0.06$, $P=0.19$). Additionally, the needle angle towards the left scapula did not correlate with these parameters (BMI: $r^2=0.03$, $P=0.35$; body weight: $r^2=0.05$, $P=0.22$; body height: $r^2=0.03$, $P=0.40$; LVEDD: $r^2=0.03$, $P=0.36$; LVESD: $r^2=0.02$, $P=0.46$). Moreover, the needle angle towards the back of the body did not correlate with these parameters (BMI: $r^2=0.002$, $P=0.80$; body weight: $r^2=0.01$, $P=0.55$; body height: $r^2=0.03$, $P=0.38$; LVEDD: $r^2=0.02$, $P=0.42$; LVESD: $r^2=0.03$, $P=0.40$).

3.4. Location of surrounding organs

For the anterior approach, the liver and lung were not located along the pathway. On the other hand, the liver was located along the pathway in 11 (37%) of 30 patients and through the pathway in 2 (18%) of 11 patients for the posterior approach.

Fig. 2C presents a case of liver injury. The posterior approach (red line) in this case penetrated the liver, whereas the liver and lung were not located along the anterior approach (blue line).

4. Discussion

4.1. Main findings

The techniques of pericardiocentesis including the subxiphoid, parasternal, and apical approaches are commonly used. Of them, the subxiphoid approach is the safest without the use of ultrasound guidance [5]. Although the subxiphoid approach including the anterior and posterior approaches has been reported [6], the anatomical assessment by using 3D-CT has not been well discussed.

Therefore, with the primary goal of determining the adequate needle angle, we concluded that anterior puncture with almost 35° toward the left shoulder and caudal direction was recommendable as an initial puncture approach. It is helpful to understand the standard angle of 35° for anterior puncture under fluoroscopic guidance.

The secondary goal was to identify the existence of surrounding organs, such as the liver and lungs, through the pathway and assess whether the anterior approach was safer than the posterior approach. The liver and lung were not located along or through the pathway to the pericardial space with the anterior puncture approach. According to those anatomical considerations, we conclude that the anterior approach is recommended as an initial approach.

4.2. Challenging pericardiocentesis and procedure-related complications

The pericardial space is usually accessed using an available needle, originally developed to perform a spinal tap via the anterior or posterior pericardial approach. Accompanying organ injuries associated with subxiphoid pericardiocentesis include cardiac perforation, puncture of coronary arteries, pneumothorax, arterial bleeding from the diaphragm, and liver injury. Blind performance is reported as a possible cause of cardiac perforation and can lead to death [7]. Therefore, elective pericardiocentesis is currently performed with ultrasound guidance, thus minimizing cardiac injury by visualizing the relation of the tip of the needle with the surrounding organs [8].

However, ultrasound guidance can have limited visualization due to chronic obstructive pulmonary disease, obesity, or an overall restricted field of view. The complication rate has been reduced using ultrasound guidance; however, difficulties with localizing the needle tip and distinguishing between the myocardium and pericardial space can remain [9].

To the best of our knowledge, assessment about the adequate needle angle and distance for subxiphoid pericardiocentesis based on anatomical findings has not been previously reported, and this study is the first report about the anatomical investigation for subxiphoid pericardiocentesis.

4.3. Relationship between the adequate pericardiocentesis and physical size

The posterior approach has conventionally been used for subcutaneous pericardiocentesis, but the risk of liver injury is known, even with the usage of ultrasound. Sosa et al. reported that the needle must always point to the left shoulder, and it must be introduced more horizontally if the target is the anterior portion of the ventricles [10]. d'Avila et al. also reported that the needle should be introduced at a 45° angle towards the left scapula [11]. We demonstrated that the adequate needle angle was almost 35° toward the left shoulder and that the caudal direction was safer than conventional pericardiocentesis with posterior puncture. Furthermore, it is not surprising that the distance correlates with BMI. Of interest, the angle in the anterior puncture does not correlate with physical size. This indicates that pericardiocentesis should be more carefully performed in patients with a low BMI in order not to penetrate the patient's heart. This angle of 35° still remains an adequate initial approach, regardless of BMI.

4.4. The correlation with surrounding organs

Schmidt et al. reported that 59 patients underwent epicardial VT ablation following an unsuccessful endocardial VT ablation procedure [12]. They gained pericardial access as described by Sosa et al. [2] with liver bleeding due to liver puncture occurring in 2 (3%) patients during the perioperative period. Thus, the conventional pericardiocentesis with posterior puncture described by Sosa et al. is likely to have a risk of hepatic injury. Recently, Jais et al. described the use of modified pericardiocentesis through an anterior approach [4], and they found that the anterior approach is safer than the conventional posterior approach. Of note, visceral complication and pneumothorax related to pericardiocentesis were not documented in their study. We believe that our anatomical evidence supports their conclusions.

4.5. Clinical implications

Recently, the use of the anterior approach has increased steadily [4,13,14] because of the low rate of complications, and operability of CA [14]. We demonstrate a safe method for pericardiocentesis. We performed subxiphoid pericardiocentesis through an anterior approach in 3 cases with VT requiring epicardial ablation. First, we set the needle almost 1 cm below the subxiphoid and kept it at 35° toward the left shoulder and caudal direction. Second, we tried to push and adjust it toward the anterior pericardial space under biplane fluoroscopy in the anteroposterior and left lateral view. In a few cases, we successfully reached the anterior pericardial space without complication. Neither the liver nor the lung was located along or through the anterior approach pathway. We believe that the anterior approach is safer than the posterior approach. Recently, percutaneous epicardial ablation has been used successful for the management of accessory pathways [15], atrial arrhythmias [16], and atrial fibrillation [17]. If a safer pericardiocentesis method is established, the indication for pericardial ablation would increase. We hope that this safer subxiphoid pericardiocentesis can be established and routinely performed in hospital electrophysiology laboratories.

4.6. Study limitations

Our study has 3 major limitations. First, the sample size was small. Second, this study did not aim to investigate VT in patients with enlarged left ventricles. Third, the location of the coronary artery or phrenic artery was not evaluated and coronary angiography should be performed before the pericardiocentesis procedure.

5. Conclusion

Based on anatomical findings, pericardiocentesis is safer and more reliable via the anterior approach than via the conventional posterior approach. Therefore, 3D-CT performed before an epicardial CA may reduce procedure-related complications and result in successful and safe CA.

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Conflict of interest

None of the authors has any conflict of interest with regard to this study.

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