Case Report

J Korean Soc Radiol 2024;85(6):1209-1214
https://doi.org/10.3348/jksr.2024.0014
eISSN 2951-0805

JOURNAL of THE KOREAN SOCIETY of RADIOLOGY

Right Atrial Rupture on CT Angiography in a Patient Receiving Cardiopulmonary Resuscitation and Extracorporeal Membrane Oxygenation: A Case Report

심폐소생술과 체외막산소공급을 받은 환자의 CT 혈관조영술에서 발견된 우심방파열: 증례 보고

Received January 11, 2024
Revised May 11, 2024
Accepted July 25, 2024
Published Online November 21, 2024

***Corresponding author**
Eun-Ju Kang, MD
Department of Radiology,
Dong-A University College of Medicine,
26 Daesingongwon-ro, Seo-gu,
Busan 49201, Korea.

Tel 82-51-240-5367
Fax 82-51-253-4931
E-mail medcarot@dau.ac.kr

Bon Jae Koo, MD[1], Eun-Ju Kang, MD[1*], Hyun Jin Kim, MD[1], Dong Hyun Lee, MD[2]

Departments of [1]Radiology and [2]Intensive Care Medicine, Dong-A University College of Medicine, Busan, Korea

Cardiac rupture is a rare but fatal complication among patients undergoing cardiopulmonary resuscitation (CPR). Myocardial rupture can manifest as a discontinuity in the myocardial wall, communication between the ventricle or atrium and the pericardium, hemopericardium, or active extravasation of contrast into the pericardium. It can also occur alongside pericardial rupture or hemothorax. Diagnosing myocardial rupture via imaging is uncommon due to its clinical urgency and high mortality rate. We present a rare case of a 50-year-old man who developed a right atrial rupture, as seen on CT angiography, following CPR and venoarterial extracorporeal membrane oxygenation (VA-ECMO) for sudden cardiac arrest.

Index terms Right Atrial Rupture; Pericardial Injury; Post-Cardiopulmonary Resuscitation; CT Angiography; Venoarterial Extracorporeal Membrane Oxygenation

INTRODUCTION

Cardiac trauma is common following blunt chest injuries and can present a wide range of clinical symptoms, from asymptomatic to life-threatening (1). The causes of cardiac trauma are classified into penetrating and non-penetrating injuries (blunt injuries), such as motor vehicle collisions, crush injuries, and cardiopulmonary resus-

JOURNAL of THE KOREAN SOCIETY of RADIOLOGY

citation (CPR) (1, 2). Although cardiac damage from CPR-associated thoracic injuries is rare, it can be fatal when it occurs (3). CPR-associated cardiac injuries include myocardial contusions, hemorrhages, and cardiac rupture (3). Among these, cardiac rupture is rarely reported in the medical literature (3).

CT is the standard imaging modality for patients with suspected cardiac trauma and is crucial for diagnosing and managing life-threatening injuries (1, 4). However, obtaining CT imaging features of traumatic cardiac rupture can be challenging because most patients die before reaching the hospital (4). RA rupture as a complication of CPR has seldom been reported in the medical literature, and CT findings for this condition have not been previously documented. We describe an extremely rare case of RA rupture observed on CT angiography following CPR, with distinctive imaging features attributed to post-venoarterial extracorporeal membrane oxygenation (VA-ECMO) placement.

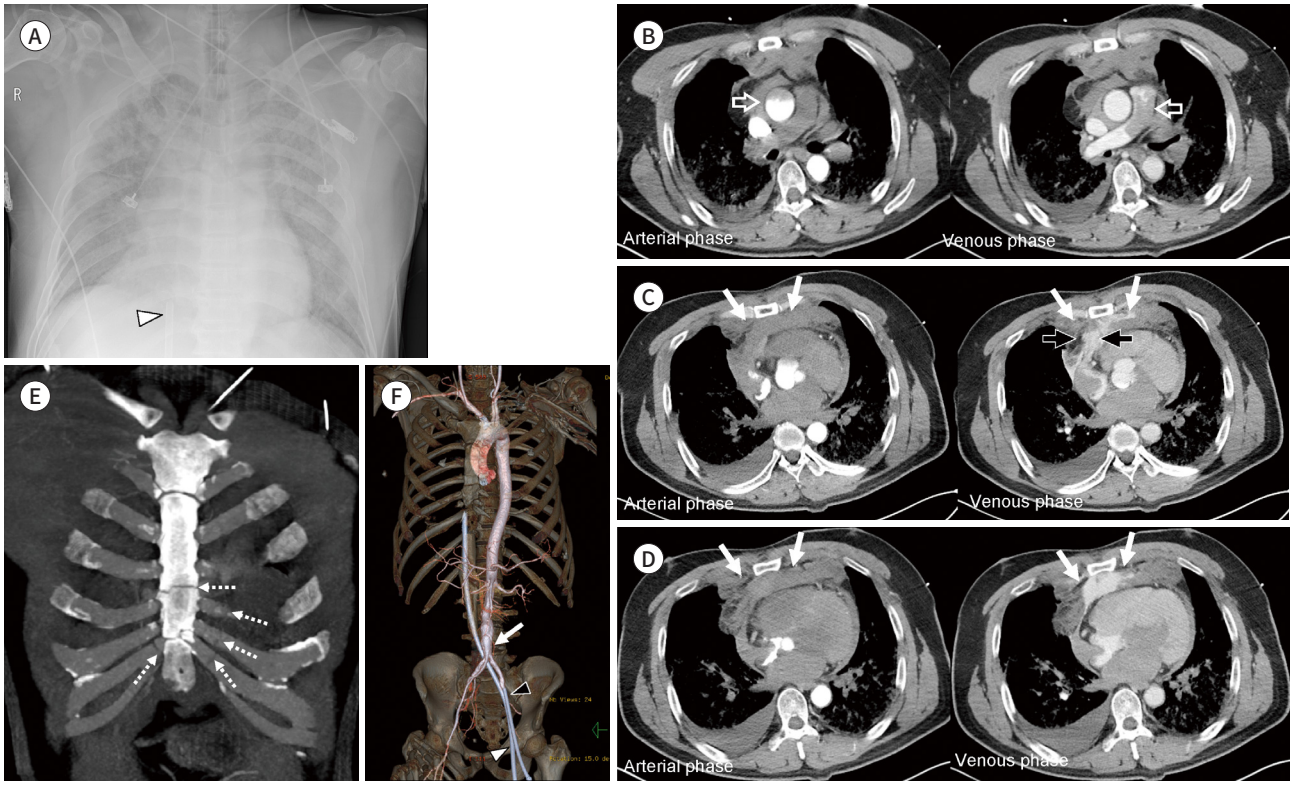
CASE REPORT

A 50-year-old man presented with sudden chest discomfort while walking. He sought emergency medical services and experienced out-of-hospital cardiac arrest with ventricular fibrillation (VF) in an ambulance. Spontaneous circulation was restored after immediate defibrillation and CPR; however, cardiac arrest with VF recurred shortly thereafter. The patient was admitted to the emergency department. Initial arterial blood gas analysis revealed decreased oxygen saturation (85.6%), low hemoglobin (10 g/dL), and elevated serum lactate levels (96 mg/dL). Laboratory results showed elevated levels of troponin I (0.466 ng/mL), creatine kinase (902 U/L), creatine kinase–myocardial band (164 U/L), and lactate dehydrogenase (1489 U/L). The patient's medical history was otherwise unremarkable. VA-ECMO was performed through peripheral cannulation of the left femoral vein and artery due to failed right femoral access.

An initial anteroposterior chest radiograph showed diffuse ill-defined haziness in both lung fields and mediastinal widening (Fig. 1A). To evaluate for cardiac or great vessel conditions as the cause of the chest pain, further assessment via CT angiography was conducted. CT imaging was performed without electrocardiogram gating, covering from the lung apex to the inguinal area. An iodinated contrast agent (150 mL) was administered intravenously at a rate of 5 mL/s, followed by 30 mL of normal saline at a rate of 5 mL/s using a power injector. Real-time bolus tracking was used to start arterial-phase imaging 6 seconds after reaching a trigger threshold of 200 Hounsfield units in the descending thoracic aorta, followed by a 2-minute venous phase imaging.

Transaxial CT images revealed a hemothorax in the right pleural cavity and a high-density hematoma in the anterior mediastinum and pericardial space (Fig. 1B-D). At the aortic root level, the images showed active contrast extravasation anteriorly within the mediastinum and discontinuity of the anterior wall of the right atrium, indicating RA wall injury (Fig. 1C, D). A blood-contrast level was seen in the ascending aorta during the arterial phase, while the pulmonary trunk exhibited incomplete contrast filling, even in the venous phase (Fig. 1B). During the venous phase, early myocardial enhancement was noted in the absence of intracavitary contrast material in the left heart, due to retrograde aortic flow filling the coronary arteries (Fig. 1D). These findings were attributed to peripheral femoro-femoral VA-ECMO flow-related

Fig. 1. A 50-year-old man with right atrial rupture receiving peripheral femoro-femoral VA-ECMO support following cardiopulmonary resuscitation.
A. Anteroposterior chest radiograph shows diffuse ill-defined haziness in both lung fields, mediastinal widening, and the tip of the venous cannula (arrowhead) in the supradiaphragmatic inferior vena cava.
B-D. Transaxial CT angiography images obtained during the arterial phase (left images) and venous phase (right images). Hemopericardium and right hemothorax are noted. The CT images reveal active contrast extravasation (white arrows in C, D) anteriorly within the mediastinum, and discontinuity of the anterior wall of the right atrium (black arrows in C), suggesting RA wall injury. In the arterial phase, a blood-contrast level is observed within the ascending aorta (arrow in left image, B), while the pulmonary trunk shows incomplete contrast filling (arrow in right image, B) even in the venous phase. During the venous phase, early myocardial enhancement (right image, D) is noted in the absence of intracavitary contrast material in the left heart, attributed to retrograde aortic flow filling the coronary arteries. These findings are consistent with peripheral femoro-femoral VA-ECMO flow-related phenomena, which may be mistaken for pseudo lesions such as thrombus, dissection, or vascular occlusion.
E. Coronal reconstruction CT image using maximal intensity projection shows multiple fractures (dotted arrows) in the sternal body and right 7th and left 5th, 6th, and 7th costal cartilages.
F. Three-dimensional CT volume rendering image shows aortic dissection (white arrow) extending from the infrarenal abdominal aorta to the right common iliac artery, which is considered to be an iatrogenic injury caused by the ECMO cannulation failure on the right. The absence of hematoma surrounding the abdominal aorta and the lack of any abnormalities along the thoracic aorta (not shown in this figure) indicate that the abdominal aortic rupture resulting from the dissection do not occur. The image reveals correct arterial cannulation (black arrowhead) at left common femoral artery and venous cannulation (white arrowhead) at left common femoral vein.
VA-ECMO = venoarterial extracorporeal membrane oxygenation



phenomena, which limited evaluations of the myocardium and pulmonary arteries. Coronal reconstruction CT image with maximal intensity projection showed multiple fractures in the sternal body and the right 7th and left 5th, 6th, and 7th costal cartilages (Fig. 1E). Additionally, a three-dimensional CT volume-rendering image demonstrated aortic dissection extending from the infrarenal abdominal aorta to the right common iliac artery, likely an iatrogenic injury resulting from ECMO cannulation failure on the right side (Fig. 1F). The absence of a hematoma around the abdominal aorta and the lack of abnormalities along the thoracic aorta

JOURNAL of THE KOREAN SOCIETY of RADIOLOGY

indicated that abdominal aortic rupture did not occur. Immediately after the CT scan, the patient's vital signs were: 99/78 mmHg, 30 breaths/min, and 74% oxygen saturation on mechanical ventilation. However, his blood pressure dropped to 49/38 mmHg within half an hour.

Despite continuous supportive care, the patient, unfortunately, died 4 hours and 5 minutes after the out-of-hospital cardiac arrest and 2 hours and 1 minute after the CT examination.

This case report was exempt from the ethical approval in our institution. This study was performed according to the latest ethical principles in the Declaration of Helsinki (2013).

DISCUSSION

Cardiac rupture occurs in approximately 0.6% of CPR-associated cardiac injuries (3, 5). Among these injuries, the right ventricle is the most frequently damaged chamber due to its anatomically vulnerable anterior position during closed-chest cardiac compression (2). However, RA rupture is an uncommon complication of closed-chest cardiac massage, with only a few cases reported in the literature (6).

Imaging signs of myocardial rupture include disruption of the myocardial wall, visible communication of the ventricle or atrium with the pericardium, acute pericardial effusion, and active contrast extravasation into the pericardium (1, 2, 4). Pericardial rupture is characterized by a focal discontinuity in the pericardium, often associated with hemopericardium (1). Right hemothorax is a common manifestation of RA rupture, typically resulting from a concurrent pleuropericardial tear that allows fluid to enter the thoracic cavity (1, 7). In our case, imaging revealed discontinuity of the RA myocardial wall, communication between the right atrium and pericardium, and active contrast extravasation into the anterior pericardial space and mediastinum, suggesting both RA rupture and concomitant pericardial rupture. Hemopericardium and right hemothorax were also observed. Additionally, multiple rib and sternal fractures indicated severe chest wall injury, supporting the diagnosis of myocardial rupture.

Peripheral femoro-femoral VA-ECMO was implemented in our patient due to refractory VF to provide cardiopulmonary support. There are several imaging specificities associated with VA-ECMO (8). Phenomena related to peripheral femoro-femoral ECMO, caused by antegrade cardiac output and retrograde ECMO return, can be mistaken for pseudo lesions, including thrombus, dissection, or vascular occlusion (8). Early myocardial enhancement before the arrival of intracavitary contrast material can occasionally be observed due to retrograde aortic flow to the coronary arteries (8). This unusual phenomenon is a result of poor antegrade flow caused by significantly impaired cardiac contractility (8). In our case, various CT imaging features related to ECMO were noted, including blood-contrast level within the ascending aorta, incomplete contrast filling within the pulmonary trunk, and early myocardial enhancement. Given the specificity of these imaging features, careful and intensive interpretation was required. Despite these challenges, there was no definitive evidence of additional injuries to other cardiac chambers or major vessels.

From a clinical standpoint, the causes of cardiac rupture are often linked to underlying heart disease, direct penetration of the myocardium by thoracic bone fractures, and other blunt chest trauma (1, 4, 5, 6). Autopsy and histological examinations have confirmed preexisting conditions such as myocardial infarction, coronary sclerosis, and myocarditis (5, 6). In

our patient, emergent invasive coronary angiography revealed no significant coronary artery lesions, and both his medical and family histories were unremarkable. Machii et al. reported a case of RA rupture due to direct penetration by sternal and rib fractures following CPR, which was discovered at autopsy (9). In our case, while the sternal body and rib fractures were identified, direct penetration by bony fragments was not visible on CT angiography. Consequently, blunt trauma induced by CPR is considered the most likely cause, with potential mechanisms as follows (7). When intraluminal pressure exceeds the elasticity of the cardiac wall due to hydraulic effects and rapid increases in venous return, blunt cardiac rupture typically occurs in the right atrium, the weakest area of the heart (7). Additionally, when shearing forces exceed cardiac elasticity, the right atrium may tear from the fixed superior and inferior venae cavae (7).

This case report has some limitations, including the absence of autopsy or surgical intervention, resulting in insufficient data to definitively determine the cause of death. Furthermore, evaluation of myocardial and pulmonary arterial abnormalities is constrained by the VA-ECMO system.

In summary, we have presented an extremely rare case of RA rupture observed on CT following CPR and VA-ECMO. Despite its rarity, RA rupture can occur in patients undergoing CPR. Radiologists should be aware of the pathophysiology and imaging findings to facilitate rapid diagnosis and treatment planning. Additionally, understanding the hemodynamic changes associated with VA-ECMO, as illustrated in this case, is crucial for preventing incorrect diagnoses.

Author Contributions

Conceptualization, K.E.; investigation, all authors; supervision, K.E.; visualization, K.B.J., K.E.; writing—original draft, K.B.J.; and writing—review & editing, K.E.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

ORCID iDs

Bon Jae Koo https://orcid.org/0009-0005-6781-3895
Eun-Ju Kang https://orcid.org/0000-0003-0937-3607
Hyun Jin Kim https://orcid.org/0000-0002-8403-9871
Dong Hyun Lee https://orcid.org/0000-0001-6253-3396

Funding

This study was supported by research funds from Dong-A University.

REFERENCES

1. Baxi AJ, Restrepo C, Mumbower A, McCarthy M, Rashmi K. Cardiac injuries: a review of multidetector computed tomography findings. *Trauma Mon* 2015;20:e19086
2. Co SJ, Yong-Hing CJ, Galea-Soler S, Ruzsics B, Schoepf UJ, Ajlan A, et al. Role of imaging in penetrating and blunt traumatic injury to the heart. *Radiographics* 2011;31:E101-E115
3. Miller AC, Rosati SF, Suffredini AF, Schrump DS. A systematic review and pooled analysis of CPR-associated cardiovascular and thoracic injuries. *Resuscitation* 2014;85:724-731
4. Golshani B, Dong P, Evans S. Traumatic cardiac injury: ventricular perforation caught on CT. *Case Rep Radiol* 2016;2016:9696107
5. Hashimoto Y, Moriya F, Furumiya J. Forensic aspects of complications resulting from cardiopulmonary re-

JOURNAL of THE KOREAN SOCIETY of RADIOLOGY

suscitation. *Leg Med (Tokyo)* 2007;9:94-99
6. Focardi M, Maiolatesi F, Grifoni R, Gualco B, Bianchi I, Defraia B. Right atrial ruptures associated with cardiopulmonary resuscitation. Case report and review of the literature. *Rom J Leg Med* 2021;29:282-286
7. Maraqa T, Mohamed MAT, Wilson KL, Perinjelil V, Sachwani-Daswani GR, Mercer L. Isolated right atrial rupture from blunt trauma: a case report with systematic review of a lethal injury. *J Cardiothorac Surg* 2019;14:28
8. Shen J, Tse JR, Chan F, Fleischmann D. CT angiography of venoarterial extracorporeal membrane oxygenation. *Radiographics* 2022;42:23-37
9. Machii M, Inaba H, Nakae H, Suzuki I, Tanaka H. Cardiac rupture by penetration of fractured sternum: a rare complication of cardiopulmonary resuscitation. *Resuscitation* 2000;43:151-153

심폐소생술과 체외막산소공급을 받은 환자의 CT 혈관조영술에서 발견된 우심방파열: 증례 보고

구본재[1] · 강은주[1]* · 김현진[1] · 이동현[2]

심폐소생술을 받은 환자들 사이에서 심장파열은 드물지만 치명적인 합병증이다. 심근 파열은 심근 벽 불연속성, 심실 또는 심방과 심막사이의 교통, 심막혈종 및 심막으로의 조영제 혈관 외 유출로 보일 수 있다. 이외에도 심낭파열 및 혈흉과 동반될 수 있다. 심근 파열은 임상적으로 긴급하고 사망률이 높기 때문에 영상을 통한 진단은 매우 드물다. 저자들은 50세 남성이 갑작스러운 심정지로 인해 심폐소생술과 정맥-동맥간 체외막산소공급을 받은 후 촬영한 전산화단층촬영 혈관조영술상 발견된 우심방파열 증례를 소개하고자 한다.

동아대학교 의과대학 [1]영상의학교실, [2]중환자의학교실