



## Liver Injury Associated with Chest Compression in Cardiopulmonary Arrest Patients

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### Abstract

**Introduction:** Although chest compression is an effective emergency maneuver for cardiopulmonary arrest (CPA), it carries the risk of complications such as rib fracture, sternal fracture, and organ injury.

**Methods:** We summarized thirteen case reports of CPA patients presenting with liver injury associated with CPR including chest compression reported between 1993 and 2015 in Japan. Five were male and eight were female; their ages ranged from 31 to 83 years old. Unfractionated heparin was administered to ten patients as a treatment for embolism or indication of veno-arterial extra corporeal membrane oxygenation (VA-ECMO). Twelve cases survived surgery or non-surgical management, but one could not survive with non-surgical management.

**Case:** Two cases of CPA due to pulmonary thromboembolism were admitted to our department. Spontaneous circulation was restored due to cardiopulmonary resuscitation (CPR), including chest compression. After use of an anticoagulant drug and indication of VA-ECMO, contrast-enhanced computed tomography (CE-CT) revealed infra-diaphragmatic liver injury in both cases. One patient could survive with damage control surgery (DCS), while the other patient could not survive with non-surgical management.

**Conclusion:** Patients with hemorrhagic diathesis are at critical risk for complications from chest compression. Aggressive treatments, including DCS, might be effective, even for patients treated with anticoagulant drugs.

### Keywords

Chest compression, Liver injury, Pulmonary arterial embolization

injury following chest compression for CPA reported in Japan. In some cases, cardiopulmonary resuscitation (CPR) was administered by medical assistants such as doctors or medical technicians, but in other cases, CPR was given by bystanders. Five patients were male and eight were female, with ages ranging from 31 to 83 years old. Unfractionated heparin was administered to ten patients as a treatment for embolism or indication of veno-arterial extra corporeal membrane oxygenation (VA-ECMO), and other cases suffered from amniotic fluid embolisms or disseminated intravascular coagulation (DIC). All cases had problems with refractory coagulopathy. While twelve cases survived surgery or non-surgical management, one could not survive with non-surgical management.

Two patients were admitted to our emergency department due to pulmonary thromboembolism following CPA. The patients received CPR with chest compression and adrenaline. VA-ECMO was administered and spontaneous circulation was restored. After resuscitation, contrast-enhanced computed tomography (CE-CT) revealed massive hemorrhages in the abdominal cavities and liver injuries induced by chest compression. One case could survive with damage control surgery (DCS), but the other case could not survive with non-surgical management.

When we encounter patients with unstable vital signs after return of spontaneous circulation, complications from chest compression such as organ injury may be hidden. Anti-coagulant drugs could turn a minor fissure into a severe hemorrhage. As emergency clinicians, we should be aware of the complications from chest compression and the risk of anti-coagulant therapy; hence, we examined and evaluated these cases in Japan.

### Introduction

On one hand, chest compression is a useful, life-saving emergency technique for patients suffering from cardiopulmonary arrest (CPA). On the other hand, complications associated with chest compression, such as rib fracture, sternal fracture, and thoracic and abdominal organ injuries, have been widely reported.

We reviewed and summarized fifteen cases associated with liver

### Japanese Literature Review

#### Method and baseline characteristics

On September 2015, we authors searched for all reported cases of liver laceration associated with chest compression on several databases including English and Japanese literature. First author performed screening with databases. We examined cases reported from 1993 to 2015 in Japan, which were extracted from the Ichushi and

Pubmed library by searching for the keywords "chest compression", "complication" and "liver injury" (Table 1). We excluded traumatic CPA patients. Thirteen cases were found and examined in detail. We examined data related to cardiac arrest such as patient age, sex, initial electro cardiogram (ECG) rhythm, CPR information, usage of anticoagulant drugs, liver injury site, treatment, and prognosis. Time from cardiac arrest to return of spontaneous circulation was unknown. Five cases were male and eight were female, with ages ranging from 31 to 83 years old. Median age was unknown because one case was in their fifties.

## Diagnosis

Almost all cases were diagnosed as liver injuries associated with chest compression or intra-abdominal hemorrhage by ultrasound or CE-CT. Five cases were defined as pulmonary thromboembolism leading to CPA; therefore, unfractionated heparin was administered as a treatment after resuscitation and diagnosis. Dosage of unfractionated heparin was unknown. Our two cases were also diagnosed as pulmonary thromboembolism after resuscitation and indication of ECMO. In both cases 5,000 units of unfractionated heparin were administered rapidly following diagnosis.

Five cases had suffered from acute coronary syndrome (ACS), while the other cases involved amniotic embolism, cardiac sarcoidosis, and hyperkalemia during esophageal surgery, respectively.

## Initial ECG and CPR performer

All cases were assessed as CPA and CPR was administered immediately. Five cases (four of the ACS cases and one cardiac sarcoidosis case) revealed ventricular fibrillation (VF) in ECG. Two cases with pulmonary thromboembolism and hyperkalemia showed pulseless electrical activity (PEA). Initial ECG was unclear in the other cases because the data was not included in the publications.

CPR, including chest compression, was performed by bystanders in four cases. Medical technicians and doctors performed CPR in the other seven cases. In the one case admitted with poor prognosis, CPR was administered by a medical technician. Because of liver injury associated with chest compression, Meron et al. reported no differences between CPR performed by medical professionals and CPR performed by lay bystanders secondary to visceral hemorrhage. In our two cases, medical technicians and doctors experienced in

CPR performed chest compression. Although some previous reports have demonstrated that inappropriate chest compression site had the potential for complications, results of this review cannot indicate no association.

## Hemostasis and anti-coagulant drugs

Unfractionated heparin was used to treat embolization or maintain ECMO in ten cases. Dosage was unknown in each case due to no statement in manuscript. In both of our cases, 5,000 units of unfractionated heparin was given immediately following diagnosis and activated clotting time was adjusted from 150 to 200 seconds to keep ECMO running smoothly. The other two cases were characterized as obstetric DIC and hemorrhagic DIC, respectively. Transfusion, including fresh frozen plasma, was the key treatment.

## Location of liver injury

CT or intra-operative findings showed subcapsular hematoma of the liver in seven cases. Liver fissure appeared in six cases at the left lobe, both lobes and the falciform ligament. Some cases were complicated, with multiple liver injuries.

According to anatomical features, the left lobe or falciform ligament of the liver are easy to injure because these sections are located immediately below the xiphoid process. Therefore, compression of the rib cage leads to liver damage around the ligament and left lobe. Gallbladder injury was rarely reported at the injury site, whereas hematoma or bleeding arising from the nearby falciform ligament or lateral site of liver were cited more frequently. A damaged posterior segment of the liver due to chest compression as in our cases had never been reported previously in the literature. Although some reasons such as inadequate positioning for chest compression, right heart strain resulting from pulmonary hypertension, and damage from the diaphragm were hypothesized, no obvious cause was established.

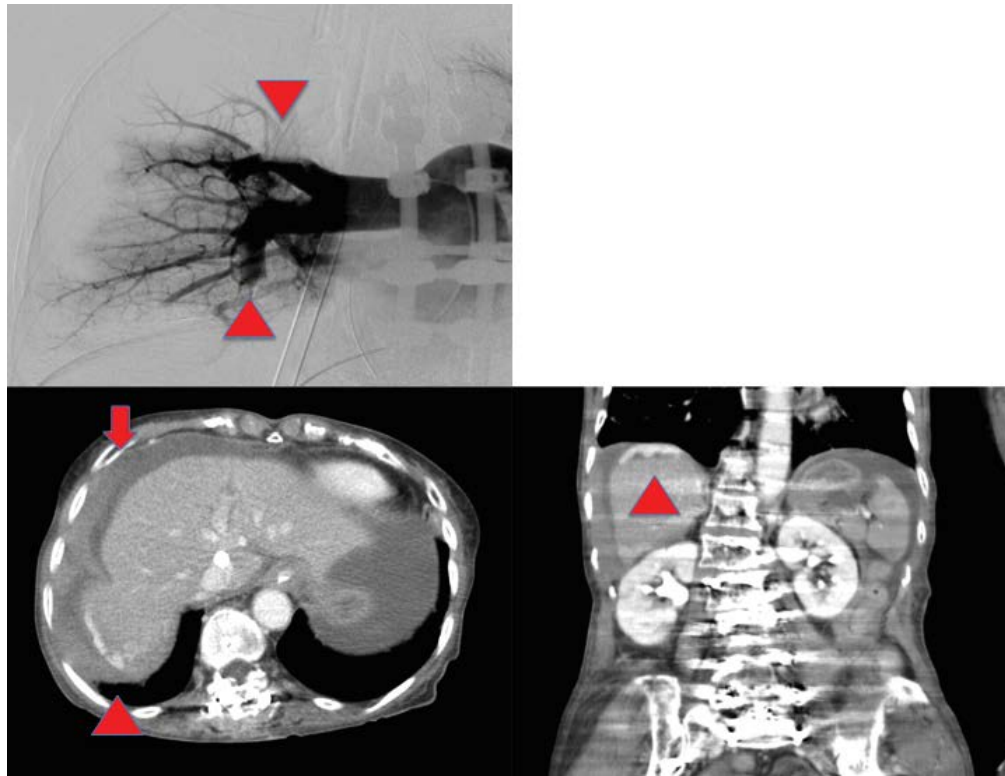
## Treatment and Results

In a previous study in 1993, liver injury was treated by hepatic resection. Since 2010, as the concept of trauma surgery has become more widespread, DCS, including peri-hepatic gauze packing, was performed in four cases. Our surgical team also administered DCS in case 2. Although inadequate gauze packing contributed to re-

**Table 1:** This table shows the review of cases with liver injury caused by chest compression including our cases.

Patient	Diagnosis	ECG	CPR	Haemostasis	Injury site of Liver	Treatment	Result	Author	Year
49F	PTE	Unknown	Medical technician	Heparin	left lobe fissure	Resection	Successful	Mitsuru Kunihiro	1993
64F	PTE	Unknown	Unknown	Heparin	Liver S4	TAE	Successful	Masaki Nishida	1996
41F	PTE	Unknown	Medical technician	Heparin	Subcapsular hematoma around fusiform ligament of liver	NOM	Death	Masato Fujita	2005
60F	ACS	Vf	Bystander	Heparin	Subcapsular hematoma in both lobe	TAE, NOM	Successful	Koichiro Suekichi	2008
31F	Amniotic embolism	Unknown	Medical technician	Obstetric DIC	Subcapsular hematoma in both lobe Injury of lateral segment, S5 segment, and fissure around fusiform ligament of liver	DCS	Successful	Horoyoshi Matsukawa	2010
50'sF	Cardiac sarcoidosis	Vf	Bystander	Heparin	Subcapsular hematoma in lateral segment	DCS	Successful	Hiroki Kuwata	2011
70F	PTE	PEA	Medical technician	Heparin	Fissure around fusiform ligament of liver	TAE, NOM	Successful	Horoyuki Suzuki	2011
62M	ACS	Vf	Bystander	Heparin	Injury of left lobe (peeling of omentum)	Coagulation	Successful	Masahito Suzuki	2012
53M	ACS	Vf	Medical technician	Heparin	Hematoma in right lobe	TAE	Successful	Hidemichi Kouzu	2012
50M	ACS	Vf	Mechanical compression	Heparin	Laceration of right lobe	Coagulation	Successful	Hidemichi Kouzu	2012
34M	PTE	Asystole	Medical technician	Heparin	Subcapsular hematoma of right lobe Deep injury of left lobe	DCS	Successful	Manabu Yamasaki	2014
76M	ACS	unknown	Bystander	Heparin	Fissure around fusiform ligament of liver Peeling of gallbladder serosa	DCS	Successful	Yuuki Fujiwara	2015
83F	Hyperkalemia	PEA	Surgeon	Surgical DIC	Subcapsular hematoma in both lobe	NOM	Successful	Jun Kan	2015
81F	PTE	PEA	Doctor	Heparin	Infra-phragmatic liver injury	DCS	Successful	Takeshi Nishimura	2015
78F	PTE	PEA	Doctor	Heparin	Infra-phragmatic liver injury	NOM	Death	Takeshi Nishimura	2015

ECG: electrocardiogram; CPR: cardio pulmonary resuscitation; PTE: pulmonary thromboembolism; ACS: acute coronary syndrome; Vf: ventricular fibrillation; DIC: disseminated intravascular coagulation; TAE: transcatheter arteriography embolization; NOM: non operative management; DCS: damage control surgery.



**Figure 1:** (Left upper) Arrowheads show obstruction of the upper and lower branches of the pulmonary artery in right pulmonary angiography; (Left lower) Arrow demonstrates fluid collection in the abdominal cavity in CE-CT. Arrowhead shows extravasation at the posterior segment in CE-CT at axial figure; (Right lower) Arrowhead shows extravasation at the posterior segment in CE-CT at coronal figure.

admission to the operating room, tertiary surgery allowed closure of the patient's abdomen after a 40 hour interval from onset.

Our one case could not be successfully treated with non-surgical management. The fact that all cases with surgical procedures could survive with DCS indicates that early indication of surgical procedure might have the potential to dramatically change the prognosis of a patient with liver injury treated with anti-coagulant agents or DIC associated with chest compression.

### Case Presentation

We present 2 cases of liver injury secondary to chest compression which we recently experienced in addition to the Japanese case series.

#### Case 1

A 78-year-old woman was admitted to our emergency department complaining of losing consciousness. She was not feeling well since the beginning of the day. She was losing consciousness when standing up, so her family requested an emergency room visit. Her past medical history included vertebral compression fracture, hypertension, rheumatoid arthritis, and diabetes mellitus. On arrival, her vital signs were as follows: Glasgow Coma Scale score (GCS) was E1V1M1, and her pupils were not dilated with rapid light reflex; heart beat was 130 beats per minute; blood pressure was 95/60 mmHg; respiratory rate was 16 breaths per minute; arterial blood saturation was 80%; and pulmonary artery oxygen 56 mmHg with 10 liters of oxygen. Echocardiography demonstrated dilation of the right ventricle and exclusion of the left ventricle. These findings supported the diagnosis of pulmonary thromboembolism, so the patient was transferred to the CT suite. Suddenly, her vital signs became unstable during radiography scanning and she had PEA. During chest compressions and infusion of adrenaline, VA-ECMO was administered under radiography. After a 10 minute interval of PEA, her spontaneous circulation was restored. Angiography revealed an embolism at the pulmonary artery, which was diagnosed as pulmonary thromboembolism. The patient received an infusion of 5,000 units of unfractionated heparin following hypothermia therapy

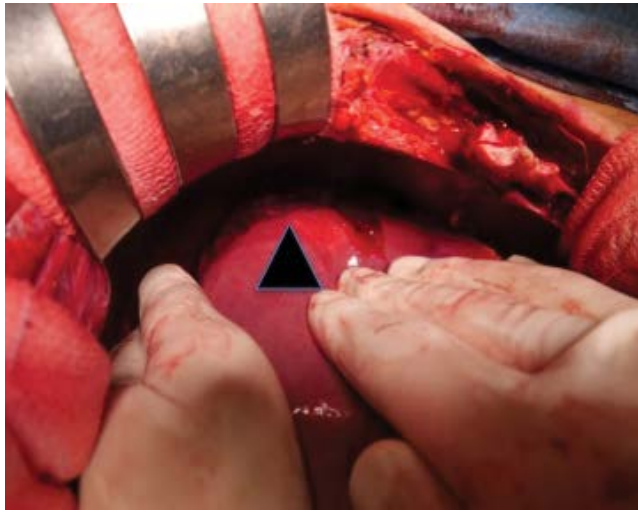
in the intensive care unit (ICU).

Twenty-four hours after admission, because of worsening anemia and instability of circulation, contrast-enhanced CT (CE-CT) revealed intra-abdominal fluid collection, infra-diaphragmatic liver injury, and extravasation at the injury site. Without an episode of trauma and abdominal fluid collection at the emergency room, it was hypothesized that chest compression induced the lethal liver injury during CPR. Although conservative therapy was continued including transfusion, she died on the third day after hospitalization.

#### Case 2

An 81-year-old woman had been hospitalized due to surgery for scoliosis. A few days after the operation, when she was practicing walking in the rehabilitation room, she suddenly fainted. Our rapid response team soon arrived at the rehabilitation room and recognized her unstable vital signs and lack of coma. She was transferred to the emergency room with the following vital signs: GCS: E3V1M6; heart rate: 79 beats per minute; blood pressure: 73/46 mmHg; arterial saturation under 12 liter oxygen: 99%. Electrocardiogram revealed a complete right bundle branch block of the pulmonary artery, as well as something floating at the right ventricle and dilation of the right ventricle. D-dimer was remarkably elevated (D-dimer: 45.0 mcg/ml).

Unexpectedly, she fell into PEA and CPR was started. Chest compressions contributed to the start of VA-ECMO under radiography. Arterial angiography revealed thromboembolism of the right upper and lower pulmonary artery branches. The patient received an immediate infusion of 5,000 units of unfractionated heparin. We diagnosed her with pulmonary thromboembolism due to deep vein thrombosis resulting from spinal surgery (Figure 1). Although her vital signs stabilized, VA-ECMO could not work smoothly due to hypovolemic state. Ultrasonography revealed an echo-free space in the abdominal cavity. CE-CT revealed an intra-abdominal fluid collection and liver injury at the posterior area (Figure 1). No bone fractures near the liver were found. Transfusion could not improve the patient's unstable state, and angiography could not detect the injured vessels; therefore, we performed laparotomy for hemostasis.



**Figure 2:** Intra operative findings revealed liver injury at the posterior segment (black arrowhead). Continuous bleeding flowed from the injury site.

Massive bloody ascites were found and the infra-diaphragmatic area of liver was found to be damaged (Figure 2). We decided to perform DCS to control massive hemorrhage. Peri-hepatic gauze packing and transient abdominal closure were performed. In the ICU, the patient was treated with a massive transfusion. Despite transfusion and warming, hemorrhage was not controllable, and therefore the patient was re-admitted to the operating room for confirmative peri-hepatic gauze packing. With stabilization of her vital signs, abdominal wall closure was performed after a 40 hour interval from laparotomy. After tracheotomy at 22 hospitalized days, continuous rehabilitation could contribute to improvement of her of activities of daily living.

## Discussion

The American Heart Association recommends that CPR be used to potentially save the lives of patients who suffer from CPA [1]. Even non-medical staff can perform CPR without any device. However, while CPR skills can be learned by ordinary people, complications related to chest compression such as rib and sternal fractures have been reported, occurring at a rate of approximately 21-67% [2]. Liver injury happens rarely (at a rate of about 2%), but when these injuries do occur, they can be lethal and life-threatening [3,4]. Particularly, CPR with anti-coagulant drugs as a treatment might change a minor injury to a life-threatening situation.

In our two cases, paramedics and doctors with CPR expertise performed chest compression. CE-CT revealed only liver injury without any other visceral injuries. Clinical signs, including instability of circulation, progression of anemia and dropping hematocrit, and swelling of the abdominal wall, indicate hemorrhage in the abdominal cavity. Ultrasonography or CE-CT might detect an injury associated with chest compression. According to anatomical features, hematoma tends to arise around the falciform ligament or the lateral segment of the liver.

In case 1, stabilization of the circulatory system was gained with VA-ECMO. Hypothermia treatment was implemented because of cardiac arrest about ten minutes after ICU admission. On the next day, abdominal fluid collection accounted for the exacerbating anemia. Focused assessment of sonography revealed no fluid collection in the abdominal cavity immediately following resuscitation; therefore, we diagnosed the patient with visceral injury resulting from chest compression. We assumed that anti-coagulant drugs and hypothermia might promote a visceral minor injury to a lethal condition. Despite rapid and massive transfusion, the patient's blood pressure deteriorated gradually. Her family did not want more invasive treatment, so the patient died on post-admission day three.

In case 2, VA-ECMO did not work smoothly due to hypovolemia. CT revealed fluid collection in the abdominal cavity; hence, we performed laparotomy to stop the bleeding immediately. The first surgery could not confirmatively work; therefore, we re-attempted peri-hepatic gauze

packing. The abdomen was closed after 60 hours from onset. Since angiography could not detect an injured vessel, we decided to perform surgery for hemorrhage due to venous injury. Early recognition of hemoperitoneum and early decision to perform laparotomy, based on our experience with case 1, rescued the patient in case 2.

Few cases of patients able to survive after liver injury due to chest compression have been reported [5]. We summarized cases of liver injury associated with chest compressions in Japan (Table 1). Yamasaki et al. described successful cases associated with pulmonary embolization and liver injury in Japan [6]. Matsukawa et al. reported a pregnant woman with refractory DIC resulting from an amniotic fluid embolism [7]. A case of cardiac sarcoidosis leading to liver injury with chest compression was also described [8].

Although twelve of thirteen cases survived, one case could not survive secondary to refractory hemorrhage. While four of twelve successful cases had angiography, a bleeding point was not found in three cases. Four cases were treated with transfusion and non-surgical management. Seven cases had laparotomy due to unstable vital signs. Of seven cases, four cases were treated with DCS, two cases were treated with electrocoagulation, and one was treated with left lobe resection. Hence, all cases suffered refractory coagulopathy, and a strategy including DCS in the early phase was recommended.

Sakamoto et al. compared interventional radiology and laparotomy treatments in traumatic cases with liver injury [9]. However, cases involving anti-coagulant drugs, ECMO, obstetric DIC, and similar situations are more complicated. Although a systematic review is difficult to establish, early recognition of a patient's condition and deciding on a strategy including laparotomy and DCS in the early phase have the potential to improve a patient's prognosis, even when they are treated with anti-coagulant agents and coagulopathy.

## Conclusion

We examined and evaluated cases of liver injury associated with chest compression for CPA. Our experiences and review reveal that CPR has the unintended potential to result in liver injury for patients with these severe conditions. In cases of exacerbating anemia with unstable vital signs after resuscitation following chest compression, early recognition of visceral injury and appropriate choice of treatment might be able to dramatically improve a lethal condition.

## Conflict of Interests

No conflicts of interest were declared.

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