Scenario-Based Approach

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Gil Joon Suh, Jae Hyuk Lee, Kyung Su Kim,
Hui Jai Lee, and Joonghee Kim

7.1 Hypovolemic Shock Due to Multiple Trauma

A 32-year-old man came to the emergency department (ED) for multiple trauma. He was found in a parking lot and was suspected to be fallen down from a nearby building. He was transferred to the ED by an emergency medical system with a cervical collar in place and strapped to a backboard. He was confused and anxious, and could not remember the situation at the time of injury, but he was able to follow commands at the ED arrival. His initial vital signs were 55/45 mmHg–124 bpm–22 cpm–32.6 °C with SpO2 at 96%. He was anxious

Q. Describe initial evaluation steps for this patient.

A. Initial assessment of a multiple trauma patient (primary survey) must be performed promptly. The Advanced Trauma Life Support (ATLS) guideline provides an organized approach focused on identifying life-threatening conditions. It consisted of the following components (ABCDEs). Any problems identified should be managed immediately before moving on to the next step:

1. Airway maintenance with cervical spine protection:
   - A. Ask the patient simple question.
   - B. Observe the patient for signs of respiratory difficulty.
   - C. Inspect oropharyngeal cavity.
   - D. Assess the neck for injuries.
   - E. Protect (immobilize) the C-spine.
2. Breathing and ventilation:
   - A. Assess the adequacy of oxygenation and ventilation.
   - B. Look for chest injuries.
3. Circulation with hemorrhage control:
   - A. Check for bleeding and hemodynamic abnormalities.
   - B. Secure IV lines and control bleeding.
   - C. Reversal of anticoagulation.

G. J. Suh (✉)
Department of Emergency Medicine,
Seoul National University College of Medicine,
Seoul, South Korea
e-mail: suhgil@snu.ac.kr

J. H. Lee · J. Kim
Department of Emergency Medicine,
Seoul National University Bundang Hospital,
Gyeonggi-do, South Korea

K. S. Kim
Department of Emergency Medicine,
Seoul National University Hospital,
Seoul, South Korea

H. J. Lee
Department of Emergency Medicine,
Seoul Nation University—Seoul Metropolitan
Government Boramae Medical Center,
Seoul, South Korea
e-mail: emdrlee@snu.ac.kr

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4. Disability:
   A. Check for neurologic abnormalities.
5. Exposure/environmental control:
   A. Undress the patient and examine the entire body.
   B. Avoid hypothermia.

Q. Which category of hemorrhagic shock does the patient belongs to? What is your initial volume resuscitation strategy?

A. Initial blood pressure of the patient was 55/45 mmHg and pulse rate was 124/min, and he was anxious and confused. Therefore, it is class III hemorrhagic shock. Therefore, the patient needs blood transfusion as well as crystalloid infusion. The colloid solutions (dextran or albumin) have not been demonstrated to be superior to crystalloids. If there is no evidence of significant brain injury, the target systolic blood pressure should be 80–90 mmHg. However, higher blood pressure is recommended in patients with traumatic brain injury (see page 25).

and confused. His right limbs and pelvis had open wounds and deformities. He was suspicious for multiple facial bone fractures, including mandible fracture with oral bleeding and dislodged teeth.

After administration of 2 L of 0.9% saline solution, his blood pressure was increased to 95/60 mmHg with heart rate of 110/min. However, after 10 min his blood pressure dropped to 60/40 mmHg again. During the fluid resuscitation, limb splint and pelvic immobilization were applied to control possible hemorrhages from fractures in the limbs and pelvis. There was involuntary muscle guarding in right upper quadrant area of the abdomen and the focused assessment with sonography in trauma (FAST) identified free fluid in the Morrison's pouch and pneumothorax in the right thorax (Figs. 7.1 and 7.2).

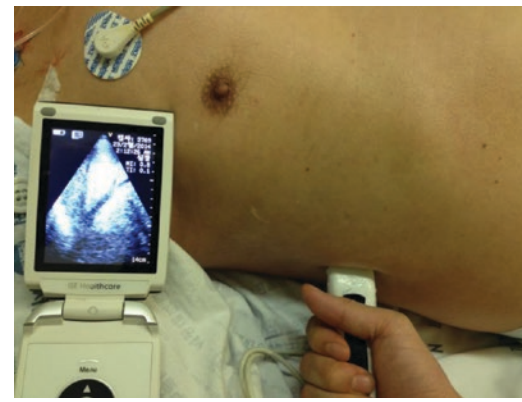


Fig. 7.1 Fast examination of the patient. Fluid collection in the Morrison's pouch (arrow) was observed

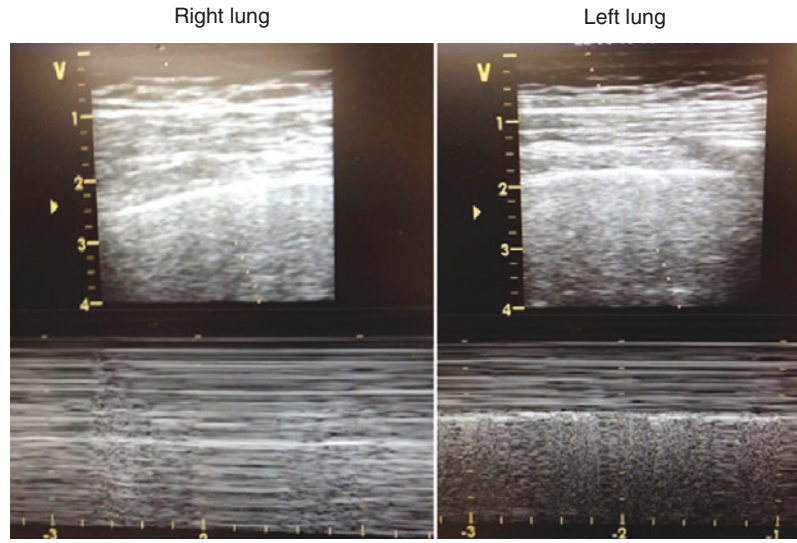


Fig. 7.2 Lung sonography findings of the patient. Right lung scan (left image) shows "barcode sign" while left lung scan (right image) shows "sandy beach sign" in M-mode

Arterial blood gas analysis			CBC			Chemistry			Cardiac enzyme			Coagulation panel			Urinalysis		
pH	7.36		WBC	22,130	/μL	Na	139.5	mmol/L	CK	650	ng/mL	PT (INR)	1.22	INR	WBC	1–4	/HPF
pCO2	37.9	mmHg	Hb	13.3	g/dL	K	3.7	mmol/L	CK-MB	11.2	ng/mL	aPTT	26.5	Seconds	RBC	5–9	/HPF
pO2	174.5	mmHg	Hct	38.8	%	Cl	105.8	mmol/L	TnI	0.3	pg/mL	D-dimer	35.2	μg/mL	Albumin	Negative	
HCO3-	20.9	mmol/L	Platelet	283,000	/μL	TCO2	20.4	mmol/L							Nitrite	Negative	
Base excess	−2.4	mmol/L				BUN	13	mg/dL							Bacteria	Negative	
Lactate	NA	mmol/L				Cr	1.18	mg/dL									
						AST	148	IU/L									
						ALT	87	IU/L									
						T.bil	1	mg/dL									
						ALP	68	IU/L									
						T.prot.	6.4	g/dL									
						Albumin	4	g/dL									

Q. His initial hemoglobin and hematocrit were 13.3 g/dL and 38.8%. Do you think they can represent the severity of acute blood loss?

A. Low hemoglobin and hematocrit are markers of severe bleeding, but normal hemoglobin and hematocrit may not reflect the volume of bleeding. Therefore, serial measurement combined with clinical and imaging study could help assess the volume of bleeding.

Meanwhile, the initial blood test results came out.

Initial chest X-ray was taken during resuscitation. Multiple rib fractures in the right thorax and hemopneumothorax in the right lung field were observed. Right-tube thoracostomy was performed (Fig. 7.3).

In CT angiography, liver laceration in S5 and 6 with active bleeding was identified (Fig. 7.4).

Q. Despite blood transfusion, the patient's blood pressure decreased and his pulse rate increased again after the CT angiography. What should you do next?

A. It is **suspected** that this patient has still ongoing bleeding. It is important to control bleeding immediately. Recently, angiographic embolization is gaining popularity for controlling arterial bleeding in patients with hemorrhage shock. However, it should not delay consultation for surgical bleeding control. In this case, surgical consultation for bleeding control should be done first. If surgical treatment is not possible, multidisciplinary approach should be considered, such as angiographic embolization (see page 29).

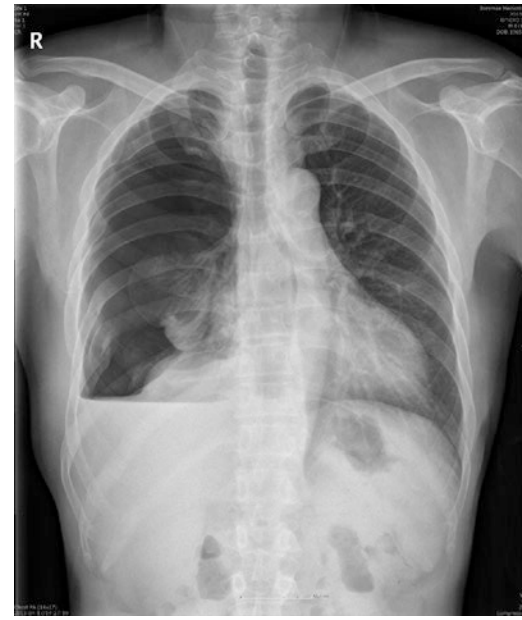


Fig. 7.3 Chest X-ray of the patient showing multiple rib fractures and hemopneumothorax in the right thorax

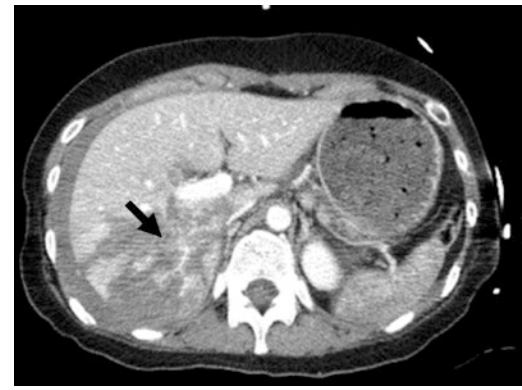


Fig. 7.4 An abdominal CT angiography imaging showing liver laceration in segments 5 and 6 with active contrast vacation (arrow)

7.1.1 Progression

The patient was transferred to the operating room for surgical control of arterial bleeding in the liver. After surgical treatment, he was admitted to the intensive care unit for close observation. Then, after 2 weeks of intensive care unit treatment, he was recovered and discharged home.

7.1.2 Summary

This is a case of hemorrhagic shock in multiple trauma. The estimated blood loss of this patient was about 30–40% according to hemorrhagic shock classification. He was initially resuscitated with crystalloid. However, the hemodynamic response was transient. Thus, immediate blood transfusion was performed. To assess bleeding focus, FAST exam was performed and it revealed intra-abdominal free fluid. For further assessment of bleeding focus, CT angiography was performed. The main bleeding focus was found to be liver laceration on CT angiography. The patient was moved to operating room for surgical bleeding control.

7.2 A Hemorrhagic Shock Case Treated with REBOA

A 46-year-old male without underlying disease came to the emergency department (ED) for falling from seventh floor of apartment for purpose of suicide. His initial vital signs were 110/60 mmHg–102 bpm–20 cpm–36.4 °C with saturation at 95%. He was slightly drowsy but able to move arms by following doctor's instructions. He complained of pain in pelvis and back and deformity in right forearm at the arrival time, but there was no definite open wound on his body.

Q. What is the first step of assessing the patient?

A. Primary survey (ABCDEs) should be accompanied by appropriate resuscitations:
   1. Airway maintenance with cervical spine protection.
   2. Breathing and ventilation.
   3. Circulation with hemorrhage control.
   4. Disability: neurologic status.
   5. Exposure/environmental control (see page 93).

In primary survey, there was no tender point in face, cervical spine, and upper trunk and his respiration was stable. No definite open wound or external bleeding was observed. He could move both hands and feet but could not flex both hip joints because of pain.

FAST was performed to assess injury of internal organs and bleeding during initial evaluation and it showed that there was no definite fluid collection at pericardium and intra-abdominal spaces.

In secondary survey, he looked a little pale. Lung sound was clear in both lung fields and there was no definite painful area during palpating chest wall. When his abdomen was palpated, he complained of pain at the right side of abdomen. Multiple bruises and swellings were shown at his back and buttocks after changing position with logrolling manners. He could not flex both legs because of severe pelvic pain, but could move both knees and ankles. Deformity of right forearm was also observed.

During the secondary survey, he became confused and his skin was pale and wet. His blood pressure dropped (VS: 56/36 mmHg–108 bpm–23 cpm–36.0 °C).

Q. According to the Advanced Trauma Life Support (ATLS) guidelines, in which class is this patient included?

A. He had tachycardia, hypotension, and altered mentality (confusion). These indicate that the patient is in class III hemorrhagic shock. Estimated volume of blood loss is 1500–2000 mL in 70 kg male (see page 21).

Fluid resuscitation with 0.9% saline solution of 2000 mL was performed and endotracheal intubation was performed to protect airway. However, his blood pressure was still low at 65/40 mmHg and heart rate was 128 bpm. A repeated FAST was performed to find delayed internal hemorrhage which showed free fluids in the Morrison's pouch and pelvic cavity (Fig. 7.5).

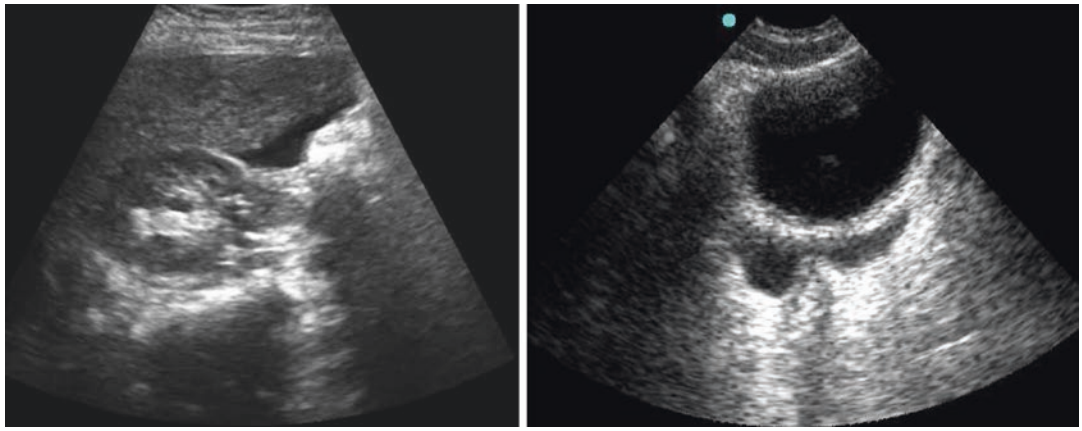


Fig. 7.5 Free fluid in the Morrison's pouch and pelvic cavity

Q. Does he need massive transfusion? If so, what is your rationale for massive transfusion?

A. He requires massive transfusion according to ABC score. The ABC score has four parameters including penetrating torso injury, systolic blood pressure ≤90 mmHg, heart rate ≥120 bpm, and positive focused assessment with sonography for trauma (FAST). His ABC score was three and massive transfusion would be necessary for this patient (see page 27).

Q. What is your initial plan for transfusion and how much for initial transfusion?

A. Resuscitation with FFP, platelets, and RBCs at 1:1:1 unit ratios has been recommended for massive transfusion for trauma patients. If you are going to transfuse the patient with 1:1:1 ratio, minimal 4 units of p-RBC, 4 units of FFP, and 4 units of platelet are necessary (see page 27).

Q. Which antifibrinolytic agent can be used for the patients who need massive transfusion?

A. Tranexamic acid and the recommended dose is a loading dose of 1 g over 10 min, followed by infusion of 1 g over 8 h (see pages 27–28).

Pelvic X-rays and CT scan were performed. Multiple pelvic bone fractures and right retroperitoneal hematoma were identified (Fig. 7.6).

Massive transfusion protocol was initiated, but his blood pressure remained low at 85/48 mmHg with a heart rate of 107 bpm. Norepinephrine was started and titrated up to 40 μg/min. Meanwhile his initial laboratory report came out (Fig. 7.7).

Arterial blood gas analysis			CBC			Chemistry			Cardiac enzyme			Coagulation panel			Urinalysis		
pH	7.306		WBC	18,700	/μL	Na	138	mmol/L	CK	24.4	ng/mL	PT (INR)	1.98	INR	WBC	<1	/HPF
pCO2	30.3	mmHg	Hb	6.8	g/dL	K	3	mmol/L	CK-MB	1.73	ng/mL	aPTT	50.3	Seconds	RBC	<1	/HPF
pO2	79.9	mmHg	Hct	20.1	%	Cl	105	mmol/L	TnI	NA	pg/mL	D-dimer	>20	μg/mL	Albumin	Negative	
HCO3-	17.3	mmol/L	Platelet	129,000	/μL	TCO2	19	mmol/L							Nitrite	Negative	
Base excess	−4.2	mmol/L				BUN	19	mg/dL							Bacteria	Negative	
Latate	5.8	mmol/L				Cr	1.81	mg/dL									
						AST	82	IU/L									
						ALT	39	IU/L									
						T.bil	0.6	mg/dL									
						ALP	50	IU/L									
						T.prot.	3.5	g/dL									
						Albumin	4	g/dL									

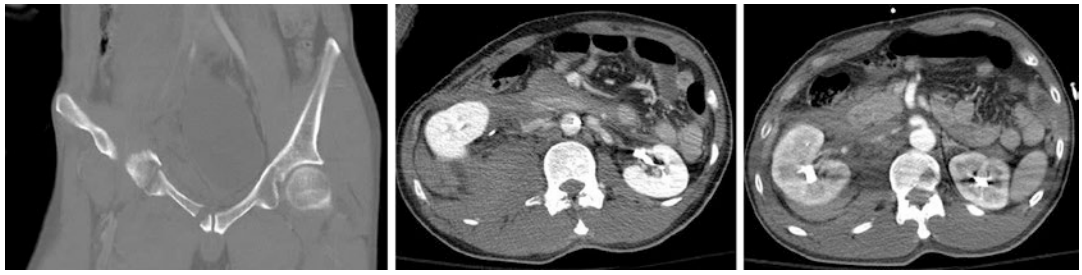


Fig. 7.6 Abdominopelvic CT showing multiple pelvic fractures and hematoma in the right retroperitoneum

Fig. 7.7 ROTEM results of the patient. $A10_{EX}$ and $A10_{FIB}$ were decreased to 40 mm and 4 mm, respectively. $A10_{EX}$, amplitude 10 min after coagulation time in EXTEM; $A10_{FIB}$, amplitude 10 min after coagulation time in FIBTEM

Q. What is your strategy for assessment and management of trauma-induced coagulopathy?

A. Thromboelastography (TEG) and rotational thromboelastometry (ROTEM) can be used to monitor trauma-induced coagulopathy rapidly at bedside. These examinations show important variables such as clotting time, clot formation/kinetics, clot strengthening, amplitude/maximal firmness, and lysis, by analyzing clot formation kinetics (see pages 23–24).

Q. Which management is needed to correct the value of ROTEM?

A. Amplitude 10 min after coagulation time in EXTEM ($A10_{EX}$) was decreased to 40 mm, and amplitude 10 min after coagulation time in FIBTEM ($A10_{FIB}$) was decreased to 4 mm, so he needed to get fibrinogen concentrates or cryoprecipitate till $A10_{FIB}$ reached 12 mm. Coagulation time in INTEM (CT_{IN}) and coagulation time in EXTEM (CT_{EX}) were within normal limit and correction is not needed.

Despite the massive transfusion, the patient was still in hypotension with BP at 70/45 mmHg. While waiting for angiographic intervention for embolization, the treating ED physicians decided to use resuscitative endovascular balloon occlusion of the aorta (REBOA) to control active bleeding. The device was introduced via femoral artery under the fluoroscopic guidance and the blood pressure increased rapidly to 134/51 mmHg after inflation of its balloon. Infusion of norepinephrine was titrated down to 4 μg/min.

He was moved to angiography room. Hypervascular staining was supplied by engorged both internal iliac arteries with vascular spasm of distal branches in aortography and both internal iliac arteriogrphy. Embolization of both internal iliac arteries using glue and gelfoam was done. The REBOA was removed from patient after balloon deflation (Fig. 7.8).

His vital sign became stable after embolization. Additional radiography showed fracture of ulnar proximal shaft with dislocation of radius head in right arm. He was admitted to surgical intensive care unit for 10 days. He got open reduction and external screw fixation of multiple pelvic bone fracture, right radius, and ulnar fractures at the hospital day 9. Neuropsychiatric consultation was done after recovery of mental status and he was diagnosed with schizophrenia with major depressive disorder. He was discharged and transferred to local hospital for rehabilitation at the hospital day 33.

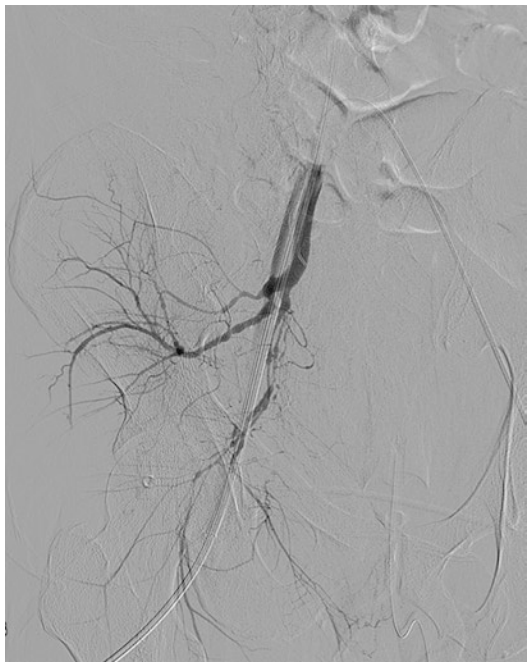


Fig. 7.8 Embolization of both internal iliac arteries using glue and gelfoam

7.2.1 Summary

This was a case of uncontrolled hemorrhagic shock in multiple trauma. In this case, initial resuscitation for refractory hemorrhagic shock was not possible despite aggressive intravenous crystalloid hydration and massive transfusion. Additional bridging intervention was needed to hold out blood pressure during transferring patient to angiography room. REBOA is an endovascular technique that can temporarily control bleeding from the branches of descending aorta. It can be a useful tool in critical situations like this case.

7.3 A Cardiogenic Shock Case due to ST-Elevation Myocardial Infarction

A 63-year-old male patient came to the emergency department (ED) with chest pain and dyspnea started 3 h ago. He had underlying diabetes mellitus. His initial vital signs were 82/34 mmHg–99 bpm–22 cpm–36.3 °C (saturation at 81%). Physical examination revealed jugular vein engorgement and crackle in both basal lung fields. His initial ECG was as above (Fig. 7.9):

Q. What do you see in the initial ECG? Which type of MI do you suspect?

A. (1) Regular heart rate without evidence of arrhythmia; (2) ST elevation in lead III and V1–5 and reciprocal changes in lead I, aVL, and V6, which is suggestive of STEMI involving anterior wall.

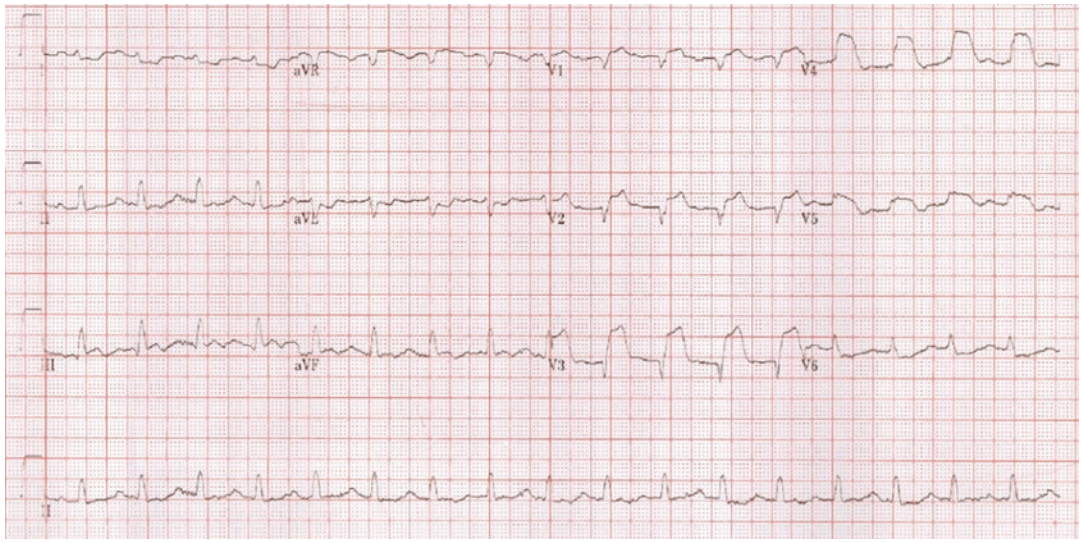


Fig. 7.9 Initial electrocardiography of the patient

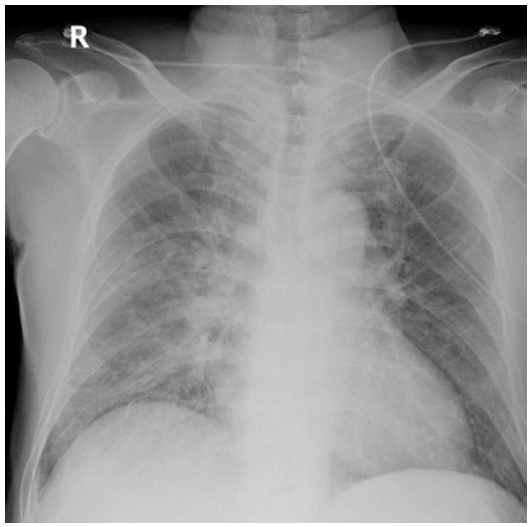


Fig. 7.10 Initial chest X-ray of the patient

Q. What do you see in the initial chest X-ray? Please discuss about the clinical significance of the finding.

A. Chest X-ray showed pulmonary congestion. Fluid resuscitation should be avoided if there is pulmonary congestion. In this case, patient complained dyspnea and SpO_2 was low. In addition, chest X-ray showed pulmonary edema. Thus, administration of fluid should be cautious not to compromise respiration.

Continuous monitoring of blood pressure, heart rate, and SpO2 was started. Rapid crystalloid infusion with 500 mL of normal saline and oxygen administration were also started. Cardiologist was called in and the patient was given aspirin, clopidogrel, and cholesterol-lowering statin drug. During fluid resuscitation, chest X-ray was taken (Fig. 7.10).

Bedside echocardiography revealed low ejection fraction (estimated as less than 30%) and hypokinesia in mid-anteroseptal and whole apical wall. Meanwhile his initial laboratory results came out.

Arterial blood gas analysis			CBC			Chemistry			Cardiac enzyme			Coagulation panel			Urinalysis		
pH	7.366		WBC	19,820	/μL	Na	134	mmol/L	CK		ng/mL	PT (%)	89	%	WBC	1–4	/HPF
pCO2	42.6	mmHg	Hb	15.9	g/dL	K	4.1	mmol/L	CK-MB	7.1	ng/mL	PT (INR)	1.09	INR	RBC	1–4	/HPF
pO2	56.1	mmHg	Hct	48.6	%	Cl	100	mmol/L	TnI	0.283	pg/mL	aPTT	31.4	Seconds	Albumin	Negative	
HCO3-	22.8	mmol/L	Platelet	232,000	/μL	TCO2	22	mmol/L	BNP	163.5	pg/dL	D-dimer	0.76	μg/mL	Nitrite	Negative	
Base excess	NA	mmol/L				BUN	23	mg/dL				Fibrinogen	463	mg/dL	Bacteria	Negative	
Lactate	2.4	mmol/L				Cr	1.21	mg/dL									
						AST	150	IU/L									
						ALT	127	IU/L									
						T.bil	1.4	mg/dL									
						ALP	385	IU/L									
						T.prot.	5.8	g/dL									
						Albumin	3.5	g/dL									

After initial administration of isotonic crystalloid (500 mL), blood pressure was 85/44 mmHg.

Q. What is your resuscitation plan for hypotension?

A. Since the contractility of left ventricle was decreased and return of blood from lungs was impaired, fluid administration would cause more congestions. The amount of blood returning to the heart should be reduced and vasopressors are preferred to fluid resuscitation.

Vasopressors like dopamine, norepinephrine, and epinephrine can be used to maintain adequate blood pressure. The target mean blood pressure for adequate splanchnic and renal perfusion is based on clinical indices of organ function (MAP ≥ 65 mmHg). Dopamine increases myocardial contractility and constricts blood vessel, but increases myocardial oxygen demand. Dobutamine does not increase myocardial oxygen demand, but can increase heart rate and peripheral vasodilation. Thus, dobutamine can be used to increase cardiac output if blood pressure is maintained.

Intravenous infusion of dopamine was started at a rate of 5 μg/kg/min and was titrated up to 20 μg/kg/min to maintain mean blood pressure over 65 mmHg. He was transferred to cath lab and CAG and primary PCI were performed. Coronary angiography showed total occlusion in proximal left anterior descending (LAD) artery and diffuse stenosis at distal LAD and proximal left circumflex (LCX) artery. Thrombosuction and ballooning was followed by stenting which was performed into LAD (Fig. 7.11).

His diagnosis was made as acute myocardial infarction caused by two coronary diseases (LAD and LCX).

During coronary catheterization, blood pressure dropped gradually and norepinephrine infusion was started. Immediately after coronary catheterization, saturation decreased to 81% despite oxygen supply with a rate of 12 L/min. Repeated chest radiography showed aggravation of pulmonary edema (Fig. 7.12).

High-flow nasal cannula was applied at a flow of 50 L/min with FiO_2 of 60%, but blood pressure decreased to 82/32 mmHg and the patient complained shortness of breath. His SpO_2 was dropped to less than 80% despite increased FiO_2 up to 80% (Fig. 7.13).

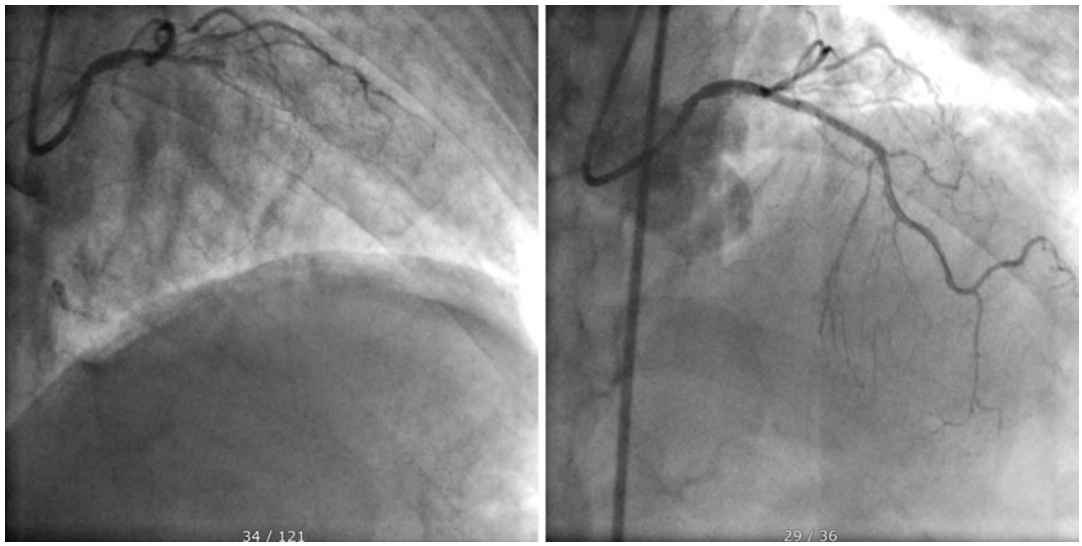


Fig. 7.11 Total thrombotic occlusion of LAD (left). Reperfusion after PCI (right)

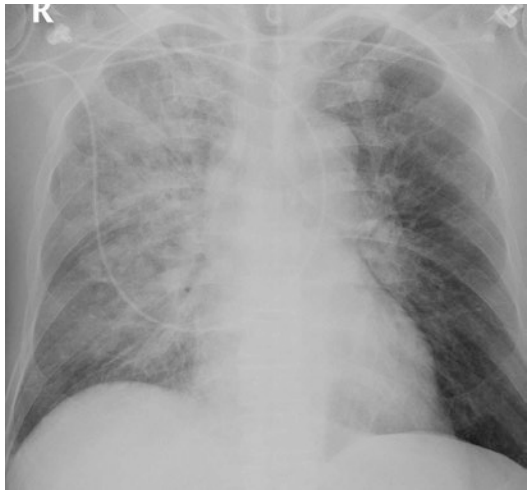


Fig. 7.12 A repeated chest X-ray of the patient showing significant pulmonary edema

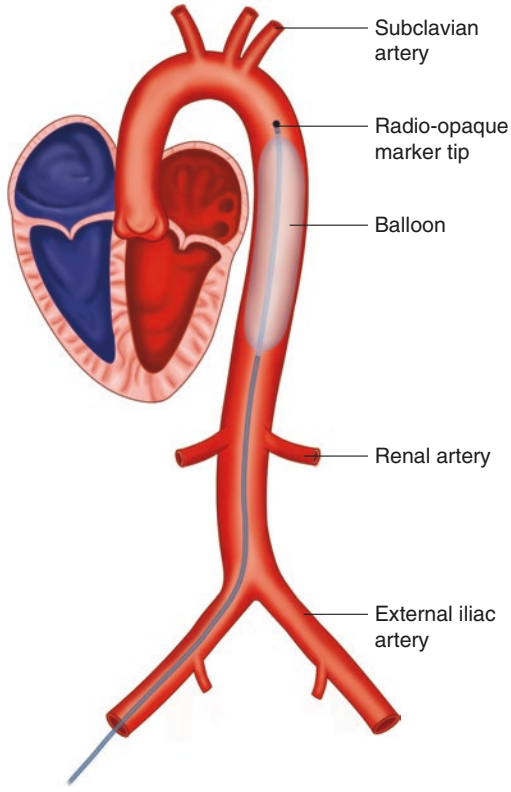


Fig. 7.13 Intra-aortic balloon pump (IABP) placement. The usual route is common femoral artery. The radio-opaque distal end is positioned in the proximal descending aorta

Q. What is your strategy for refractory shock and desaturation in LV failure?

A. Advanced airway placement and application of mechanical ventilation should be considered in the case of desaturation and patient deterioration. Intra-aortic balloon pump (IABP) may be considered as a temporizing measure in complicated myocardial infarction. This device can increase cardiac output, reduce afterload cardiac contractility and oxygen demand, and improve coronary artery blood flow.

He was admitted to coronary intensive care unit (ICU) for hemodynamic monitoring and application of ventilator. After 5 h of reperfusion therapy, ST segment and T wave of ECG were normalized (Fig. 7.14).

After stabilization of blood pressure, furosemide was administrated intravenously to control pulmonary edema. After 24 h of the reperfusion therapy, chest radiography showed decreased pulmonary edema. IABP was weaned off (Fig. 7.15).

He was treated with furosemide till improvement of pulmonary edema. He gradually improved over several days of hospital stay and discharged with prescriptions of dual-antiplatelet agents, beta-blocker, and cholesterol-lowering statin.

7.3.1 Summary

This case represents cardiogenic shock caused by left ventricular failure. Initial resuscitation of cardiogenic shock includes adequate oxygenation, fluid administration to correct hypovolemia, and hemodynamic optimization using vasopressors or inotropes. Adequate oxygenation to prevent further myocardial and systemic ischemia is

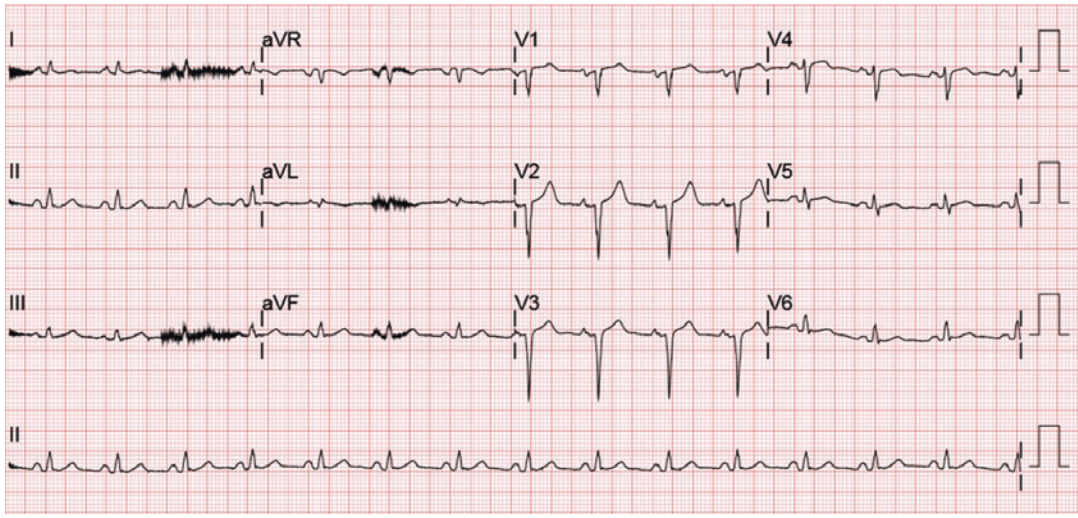


Fig. 7.14 Normalized ST elevation after reperfusion therapy

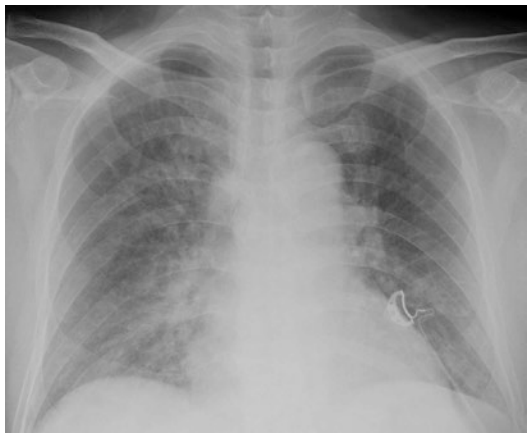


Fig. 7.15 Decreased pulmonary edema after diuresis

important. Usually, patients with cardiogenic shock caused by LV failure present with pulmonary edema and it can complicate adequate oxygenation. Thus, continuous monitoring of pulse oximetry is required. Intubation and mechanical ventilation are often required in severe cases. Positive pressure ventilation can improve pulmonary edema, but compromise venous return resulting in diminished LV preload.

In most patients with cardiogenic shock, fluid resuscitation is required. However, it can compromise respiration and care must be taken not to administer fluid excessively. Vasopressors or inotropes are used to preserve organ perfusion. The target mean blood pressure to maintain adequate splanchnic and renal perfusion is mean arterial pressure ≥65 mmHg, which is based on clinical indices of organ function. Patients with organ hypoperfusion require inotropic and/or vasopressor therapy. Dopamine increases myocardial contractility and constricts blood vessels. On the other hand, dopamine may increase myocardial oxygen requirement, which results in further myocardial ischemia. Dobutamine also increases myocardial contractility, dilates peripheral blood vessels, and augments peripheral perfusion. However, it can increase heart rate and result in myocardial oxygen requirement.

In this case, dopamine was used to elevate and maintain blood pressure but failed to maintain blood pressure and oxygen saturation was dropped. Additional vasopressors like norepinephrine or addition of dobutamine can be used. Intra-aortic balloon pump (IABP) can also be used because IABP reduces LV afterload and augments coronary perfusion pressure, which can increase cardiac output and coronary blood flow. IABP is a useful adjunctive treatment to stabilize patients with cardiogenic shock. It is not a definitive treatment of myocardial infarction, but just a bridging therapy. Definitive diagnostic and therapeutic interventions should be performed after stabilization of patients using IABP.

7.4 A Cardiogenic Shock Case Due to RV Infarction

An 83-year-old female visited the emergency department (ED) complaining of ongoing chest discomfort which began 1 h before. The pain was somewhat severe (7 in NRS scale) and located at lower substernal area without radiation. Her initial vital signs were 95/37 mmHg–62 bpm–18 cpm–37.3 °C and oxygen saturation was 96%. Physical examination revealed mild tenderness on palpation of right upper quadrant in the abdomen. Because of her chest pain, she was given a tablet of nitroglycerin sublingually by the triage nurse. After 2 min, she became drowsy with BP of 56/33 mmHg.

Her 12-lead ECG taken during the triage was reviewed retrospectively by the ED staff and is presented below (Fig. 7.16).

Right precordial lead ECG was taken thereafter. There were ST elevations in lead V3R-6R which is suggestive of right ventricular involvement (Fig. 7.17).

Q. What are the abnormal findings of this ECG?

A. ST elevation in lead II, III, and aVF and reciprocal changes in lead I and aVL. ST depression in precordial lead (lead V2–6) → indicates inferior wall STEMI; irregular heart rate indicates atrial fibrillation; and subtle ST elevation in lead V1 and STE in lead III > II may suggest RV infarction.

Q. Was the use of nitroglycerin appropriate?

A. Giving nitroglycerin to those with possible RV infarction (including those with ST changes in the inferior leads) should be avoided because RV infarction causes decreased preload. Nitroglycerin can further decrease the preload and can cause profound shock.

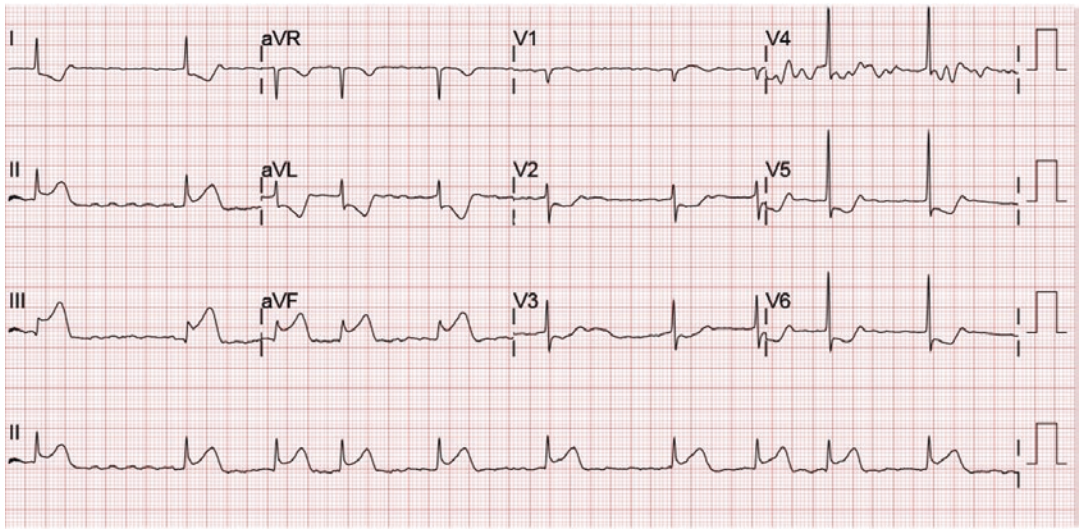


Fig. 7.16 Initial ECG of the patient, ST elevation in the inferior leads, and reciprocal changes in the anterolateral leads

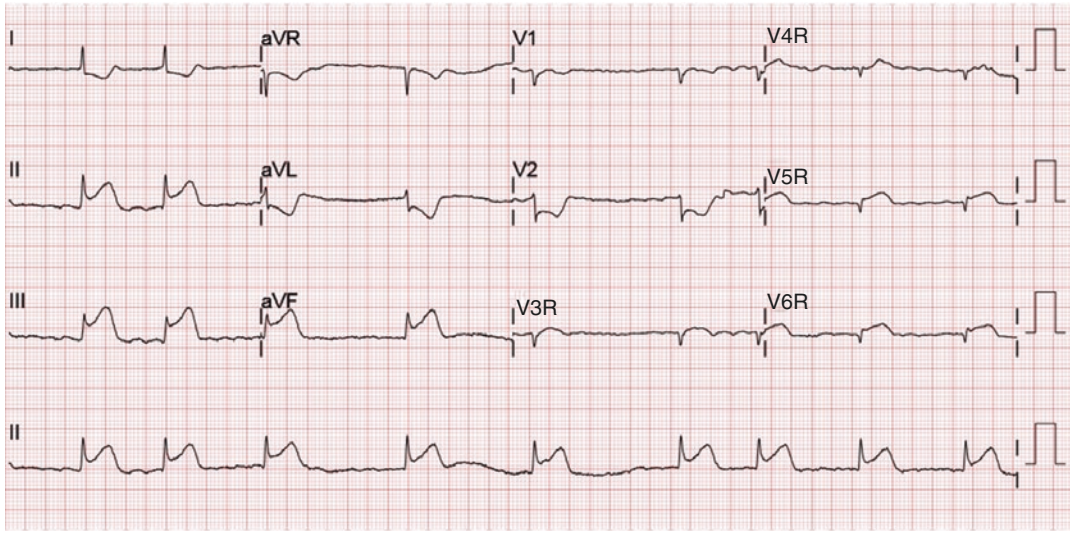
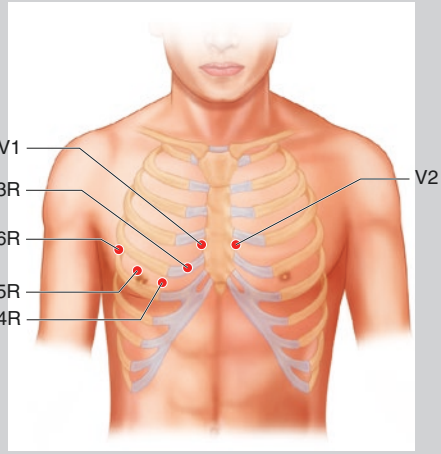


Fig. 7.17 Reverse electrocardiography of the patient. V3R-6R ST elevation suggests RV infarction

Q. Please describe how to interpret "reverse" ECG.

A. The reverse ECG is obtained by placing the precordial lead on the right anterior chest as shown in the following figure.



These right-sided precordial leads provide electrical information about the right side of the heart that is difficult to obtain from conventional ECG. The most useful lead is V4R, which is obtained by placing the V4 electrode in the fifth right intercostal space in the midclavicular line. ST elevation in V4R has a sensitivity of 88%, specificity of 78%, and diagnostic accuracy of 83% in the diagnosis of RV MI.

Meanwhile, her initial laboratory results were reported. The troponin I level was in normal range and initial chest X-ray showed no significant lung lesion.

Arterial blood gas analysis			CBC			Chemistry			Cardiac enzyme			Coagulation panel			Urinalysis		
pH	7.38		WBC	10,700	/μL	Na	138	mmol/L	CK	35	ng/mL	PT (INR)	1.14	INR	WBC	NA	/HPF
pCO2	28	mmHg	Hb	10.8	g/dL	K	4.4	mmol/L	CK-MB	<1.0	ng/mL	aPTT	35.5	Seconds	RBC	NA	/HPF
pO2	59	mmHg	Hct	31.3	%	Cl	102	mmol/L	TnI	<0.035	pg/mL	D-dimer	3.47	μg/mL	Albumin	NA	
HCO3-	19	mmol/L	Platelet	251,000	/μL	TCO2	22	mmol/L	Pro-BNP	430.7	pg/dL				Nitrite	NA	
Base excess	NA	mmol/L				BUN	20	mg/dL							Bacteria	NA	
Lactate	NA	mmol/L				Cr	1.01	mg/dL									
						AST	160	IU/L									
						ALT	56	IU/L									
						T.bil	0.7	mg/dL									
						ALP	112	IU/L									
						T.prot.	NA	g/dL									
						Albumin	3.4	g/dL									

Initially she was in shock (defined by SBP <90 mmHg); thus, resuscitation with isotonic crystalloid and primary PCI was planned. After administration of isotonic crystalloid (1500 mL), she was still in shock (BP 82/43 mmHg) and bedside echocardiography revealed dilated RV and normal systolic function of LV. Interventricular septum was deviated to the left side.

Q. What is your fluid resuscitation plan at this time?

A. RV failure limits Lt heart filling through the mechanism of decreased RV CO. Thus, fluid administration is critical to adequate RV filling to maintain adequate LV filling. However, vigorous fluid administration can result in very high RV end-diastolic pressure, and thus can shift interventricular septum to LV cavity, which can result in impairment of LV filling. Thus, fluid administration should be careful and frequent assessment of CO with fluid administration is required.

Administration of fluid was stopped and then dobutamine was administered at a dose of 10 μg/kg/min. Her blood pressure was elevated to 95/50 mmHg and heart rate was increased to 95 bpm.

Q. If the patient's blood pressure is not adequately elevated after administration of fluid and inotropes, what will you do next?

A. If hypotension was persisted even after administration of adequate amount of fluid and inotropes, one should consider the possibilities of mechanical complications such as ventricular wall rupture. A quick bedside echocardiography may be useful to rule out it.

The patient was prepared for primary PCI (including administration of dual-antiplatelet agents), and then was transferred to cath lab. Coronary angiography revealed total occlusion of right coronary artery (left). Primary PCI was performed (right) (Figs. 7.18 and 7.19).

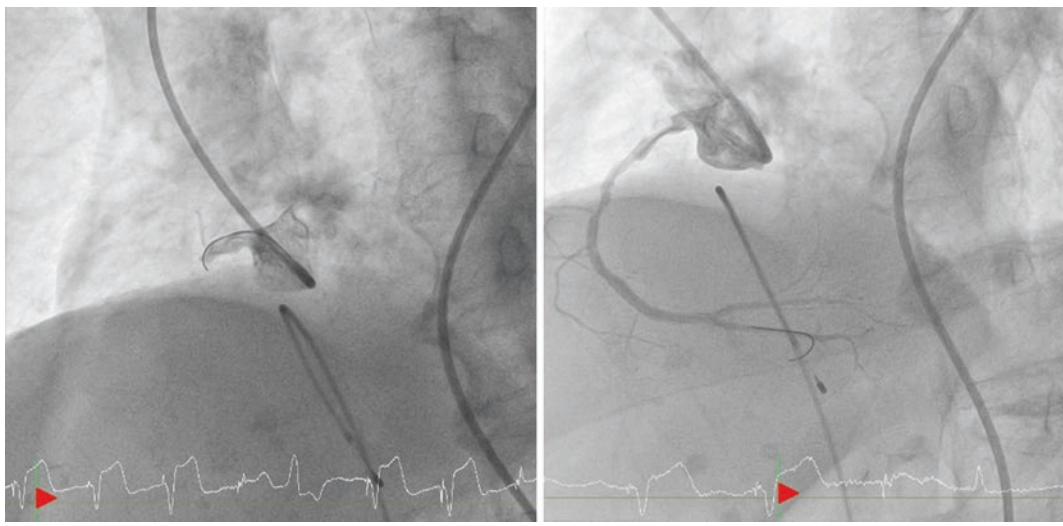


Fig. 7.18 Occluded right coronary artery (left) reperfused after PCI (right)

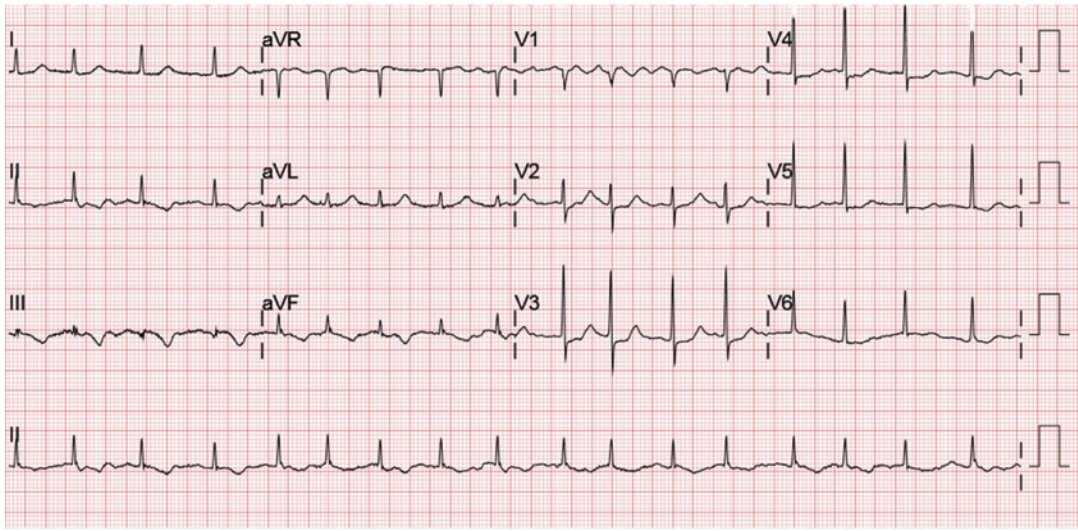


Fig. 7.19 The ECG taken after PCI, the ST elevations were resolved

After PCI, her blood pressure increased to 110/80 mmHg and the dobutamine infusion was tapered off. Her ECG showed complete resolution of ST elevation. The patient was treated for 3 days in ICU and then was discharged after additional 2 days of stays in general ward.

7.4.1 Summary

This is a case of cardiogenic shock resulted from RV infarction. Acute myocardial infarction is the most important cause of cardiogenic shock. RV infarction usually has different pathophysiology of shock. Failure of RV stroke work results in diminished LV filling, and thus diminished LV preload. Thus, initial resuscitation of shock caused by RV failure requires relatively large amount of fluid to increase and maintain LV preload, which is different with cardiogenic shock caused by LV failure. Usually vigorous fluid resuscitation in LV failure increases LV workload and aggravates myocardial ischemia and pulmonary edema. However, excessive fluid administration in RV infarction results in increased RV end-diastolic pressure, which can deviate interventricular septum to left ventricle and results in impairment of LV filling. Thus, frequent assessment of cardiac output during initial fluid resuscitation should be performed. If cardiac output and blood pressure are not maintained after administration of adequate amount of fluid (adequate RV end-diastolic pressure), inotropic therapy can be considered. Dobutamine, milrinone, levosimendan, norepinephrine, and low-dose vasopressin can be used. When the patient is still hemodynamically unstable after administration of adequate fluid and inotropics, mechanical complication of RV infarction (ventricular wall rupture, cardiac tamponade, etc.) should be considered. Bedside echocardiography is a useful tool to assess mechanical complication of myocardial infarction. For definite treatment of RV infarction, percutaneous coronary intervention

should be performed as early as possible if the patient presents within 6 h of onset. There are scant data regarding improvement in patients who present after 12 h of onset and these patients are more likely being well with conservative management.

7.5 A Case of Obstructive Shock Due to Acute Pulmonary Thromboembolism

A 42-year-old female came to the emergency department (ED) through EMS for syncope during defecation. She had no underlying disease, but her right lower leg had been immobilized for 5 days due to ankle sprain. At the time of ED arrival, blood pressure was 75/40 mmHg, heart rate was 127 bpm, respiratory rate was 28 cpm, and body temperature was 35.7 °C. The pulse oximetry revealed SpO2 of 92% while maintaining oxygen supply at 6 L/min via nasal prong. She was alert, but complained of dizziness and dyspnea.

Physical examination revealed no abnormal breathing sound, but slightly engorged jugular vein and right-leg swelling. Continuous monitoring of blood pressure, heart rate, and SpO2 was started, fluid bolus was administered, and oxygen was administered via nasal prong at a rate of 6 L/min.

Q. What is your different diagnoses?

A. The patient was afebrile and there was no abnormal breathing sound. However, she had dyspnea, profound hypotension, and tachycardia. Considering her recent immobilization of right lower leg, pulmonary embolism should be the first differential diagnosis. Other conditions causing profound hypotension and desaturation such as pneumonia, myocardial infarction, and heart failure should also be ruled out.

After administration of fluid bolus (1000 mL), blood pressure was slightly elevated up to 85/50 mmHg, and heart rate was decreased to 105 bpm. Her arterial blood gas analysis results were pH 7.39, pCO2 32 mmHg, pO2 65 mmHg, HCO3 20 mmol/L, and SaO2 92% while maintaining oxygen supply at 6 L/min via nasal prong.

The A-aDO2 was 59.0 mmHg assuming that the atmospheric pressure was 760 mmHg which indicates increased A-a DO2 that usually results from ventilation-perfusion mismatch or right-to-left shunt.

Q. What is A-aDO2? Please describe how to calculate it and interpret the results.

A. The alveolar–arterial gradient (A-aO2, or A–a gradient) is a measure of the difference between the alveolar concentration (A) of oxygen and the arterial (a) concentration of oxygen. It is used in diagnosing the source of hypoxemia.

PA-aO2 = PAO2 - PaO2 (normal range: 10–25 mm Hg in room air, 30–50 mm Hg with 100% O2).

Elevated value of A-aDO2 means that oxygen is not effectively transferred from the alveoli to the blood. This includes V/Q mismatches such as PTE or R-L shunt.

Her first ECG was taken. The ECG showed sinus tachycardia and S wave in lead I, Q wave in lead III, and T wave inversion in lead III (S1Q3T3) (Fig. 7.20).

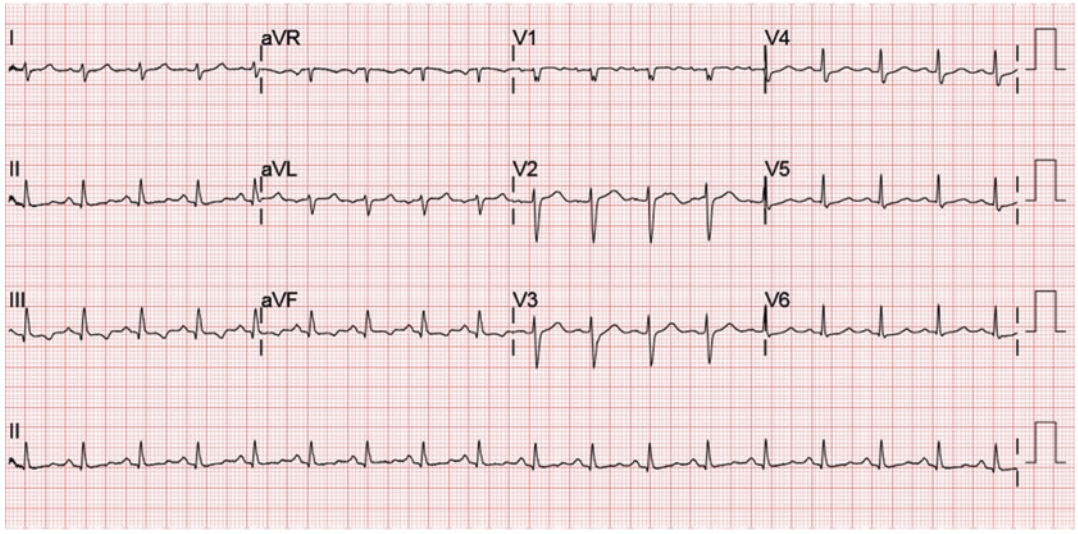
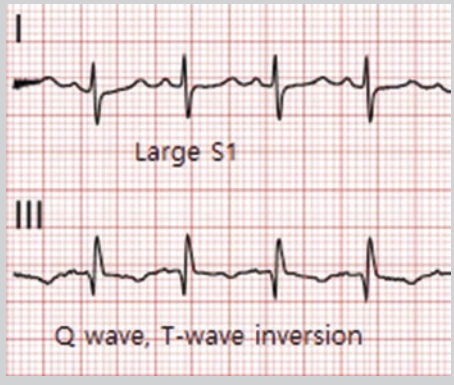


Fig. 7.20 Initial ECG of the patient, RV strain pattern (S1Q3T3) was observed

Q. What does the result of the ECG indicate?

A. The most common ECG finding in the setting of a pulmonary embolism is sinus tachycardia. However, the "S1Q3T3" pattern can be observed in patients with significant RV strain. The sign consists of a large S wave in lead I, a Q wave in lead III, and an inverted T wave in lead III. This pattern only occurs in about 10% of people with pulmonary embolisms.



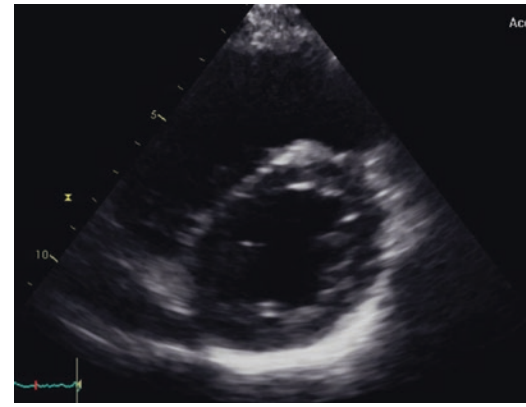


Fig. 7.21 The large RV cross-sectional area and the flattened interventricular septum ("D-shape" of LV) indicate RV strain

Bedside echocardiography was performed during initial resuscitation. It revealed dilated RV and severe TR, and D-shape LV (Fig. 7.21).

Meanwhile her initial laboratory results came out.

Arterial blood gas analysis			CBC			Chemistry			Cardiac enzyme			Coagulation panel			Urinalysis		
pH	7.390		WBC	16,910	/μL	Na	140	mmol/L	CK		ng/mL	PT (%)	84	%	WBC	NA	/HPF
pCO2	32	mmHg	Hb	14.7	g/dL	K	4.5	mmol/L	CK-MB	2.1	ng/mL	PT (INR)	1.11	INR	RBC	NA	/HPF
pO2	65	mmHg	Hct	43.6	%	Cl	104	mmol/L	TnI	0.772	pg/mL	aPTT	37.1	Seconds	Albumin	NA	
HCO3-	20	mmol/L	Platelet	153,000	/μL	TCO2	21	mmol/L				D-dimer	>20	μg/mL	Nitrite	NA	
Base excess	NA	mmol/L				BUN	13	mg/dL				Fibrinogen	299	mg/dL	Bacteria	NA	
Lactate	NA	mmol/L				Cr	1.01	mg/dL									
						AST	405	IU/L									
						ALT	306	IU/L									
						T.bil	0.7	mg/dL									
						ALP	109	IU/L									
						T.prot.	8.0	g/dL									
						Albumin	4.0	g/dL									

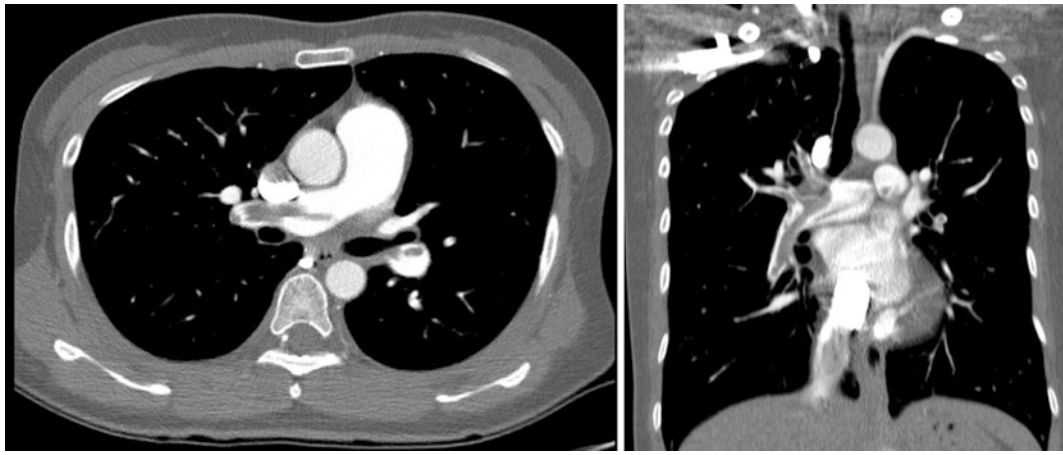


Fig. 7.22 Thrombotic occlusion of right main pulmonary trunk

It confirms RV strain and is suggestive of RV outflow obstruction. Therefore, massive pulmonary embolism was suspected. To confirm the presumptive diagnosis, contrast-enhanced chest CT scan was done while continuing fluid resuscitation and shown below (Fig. 7.22).

Q. What is your management plan considering the pulmonary thromboembolism, RV strain, and obvious shock?

A. Acute thrombolysis using IV thrombolytics should be considered because of her obvious hemodynamic instability.

Thrombolysis Therapy for Acute Pulmonary Embolism

1. Indications
   - The only widely accepted indication for systemic thrombolysis: Persistent hypotension or shock (i.e., a systolic blood pressure <90 mmHg or a decrease in the systolic blood pressure by ≥40 mmHg from baseline)
2. Potential indications for thrombolytic therapy in venous thromboembolism
   - High-risk (massive) PE, i.e., presence of hypotension related to PE*
   - Presence of severe hypoxemia (particularly in those with a contribution from concomitant cardiopulmonary disease)
   - Patients with acute PE who appear to be decompensating but are not yet hypotensive
   - Patients with severe right ventricular dysfunction and tachycardia due to PE
   - Clot in transit (i.e., right atrium or ventricle)
   - Extensive deep vein thrombosis
3. Absolute contraindications
   - Prior intracranial hemorrhage
   - Known structural cerebral vascular lesion
   - Known malignant intracranial neoplasm
   - Ischemic stroke within 3 months (excluding stroke within 3 h*)
   - Suspected aortic dissection
   - Active bleeding or bleeding diathesis (excluding menses)
   - Significant closed-head trauma or facial trauma within 3 months
4. Relative contraindications
   - History of chronic, severe, poorly controlled hypertension
   - Severe uncontrolled hypertension on presentation (SBP > 180 mmHg or DBP > 110 mmHg)
   - History of ischemic stroke more than 3 months prior

- Traumatic or prolonged (>10 min) CPR or major surgery less than 3 weeks
- Recent (within 2–4 weeks) internal bleeding
- Noncompressible vascular punctures
- Recent invasive procedure
- For streptokinase/anistreplase: Prior exposure (more than 5 days ago) or prior allergic reaction to these agents
- Pregnancy
- Active peptic ulcer
- Pericarditis or pericardial fluid
- Current use of anticoagulant (e.g., warfarin sodium) that has produced an elevated international normalized ratio (INR) >1.7 or prothrombin time (PT) >15 s
- Age > 75 years
- Diabetic retinopathy

5. Regimen
   - Alteplase: 10 mg bolus infusion → followed by 90 mg (+NS500 mL) over 2 h

After confirming the diagnosis of pulmonary thromboembolism, 10 mg of rtPA was infused over 10 min, followed by 90 mg over 2 h. After thrombolysis infusion, she was admitted to ICU for 1 day. Her vital signs were stabilized gradually and then transferred to general ward (Fig. 7.23).

She was discharged with a prescription of rivaroxaban (NOAC) to maintain anticoagulation.

7.5.1 Summary

This case is an example of obstructive shock. Pulmonary thromboembolism causes RV outflow tract obstruction, resulting in diminished LV filling. As a consequence, cardiac output decreases and hypotension occurs. As a result of decreased preload, tachycardia can be occurred as a compensatory mechanism. In addition, increased cardiac workload in right ventricle results in RV strain, which can result in ECG change of RV strain (typically S1Q3T3 pattern). Initial resuscitation includes correction of hypovolemia and respiratory support. Although angiographic CT scan of chest can make a confirmative diagnosis of PTE, it is sometimes hard to perform due to hemodynamic instability. Bedside echocardiography is a useful tool to identify the cause of shock and it can detect the findings of RV strain, deviation of interventricular septum (D-shape LV), and sometimes thrombus in pulmonary trunk. The treatment of PTE includes anticoagulation for preventing further formation of thrombus and resolution of thrombus by thrombolytics or mechanical thrombectomy. Usually, mechanical thrombectomy is hard to perform in hemodynamically unstable patients, because it requires transport of patients to operation room or angiography room. In addition, there are many case reports that ECMO can be a temporizing measure in refractory cardiac arrest due to pulmonary embolism.

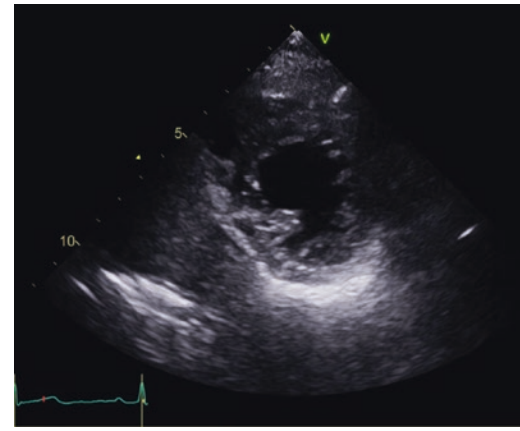


Fig. 7.23 The axial view of left ventricle at hospital day 7, the D-shape appearance has disappeared

7.6 A Case of Obstructive Shock Due to Cardiac Tamponade

An 81-year-old female with a history of hypertension and dyslipidemia came to the emergency department (ED) for chest pain. Before the ED visit, she had visited oriental medicine clinic because of headache and epigastric discomfort. Her chest pain began after the practitioner at the clinic performed an acupuncture to her chest. She fainted after the onset of chest pain and was promptly brought to the ED by EMS vehicle. On physical examination, there was a long acupuncture needle deeply inserted at the fourth left intercostal space of sternal border (the photo could not be taken because the clerk from the oriental medicine clinic removed it without permission from ED staffs). She was confused and diaphoretic. Her initial vital signs were 71/52 mmHg–106 bpm–24 cpm–36.3 °C. Lung sounds were clear and symmetric. Heart sound was a little muffled without a murmur or gallop. There was no abdominal tenderness.

Q. What will you do for initial resuscitation?

A. Rapid accumulation of fluid in the pericardial space, which increases pressure of pericardial space and impairs relaxation and filling of the ventricles, resulting in reduced ventricular filling and hemodynamic compromise. Higher filling pressure and large amount of venous return will overcome increase in intrapericardial pressure.

Therefore, volume infusion using crystalloid or blood products to provide higher filling pressure would be the most important step.

Q. What is the most likely diagnosis?

A. She had hypotension, confusion, and diaphoresis which indicate hemodynamic unstability. Because her symptoms developed after chest trauma (deep needle insertion), both cardiac tamponade and tension pneumothorax should be considered as possible diagnoses. The patient had muffled heart sound without decrease in lung sound; the most likely diagnosis would be acute cardiac tamponade.

After initial fluid administration, her blood pressure was increased a little, but after a while became low again as 67/42 mmHg. Meanwhile, her initial laboratory reports came out.

Arterial blood gas analysis			CBC			Chemistry			Cardiac enzyme			Coagulation panel			Urinalysis		
pH	7.502		WBC	9630	/μL	Na	138	mmol/L	CK		ng/mL	PT (%)	87.6	%	WBC	<1	/HPF
pCO2	23.4	mmHg	Hb	11.7	g/dL	K	3.6	mmol/L	CK-MB	0.7	ng/mL	PT (INR)	1.07	INR	RBC	<1	/HPF
pO2	109.7	mmHg	Hct	35.0	%	Cl	104.4	mmol/L	TnI	0.131	pg/mL	aPTT	30.0	Seconds	Albumin	Negative	
HCO3-	17.9	mmol/L	Platelet	290,000	/μL	TCO2	16.8	mmol/L				D-dimer	1.15	μg/mL	Nitrite	Negative	
Base excess	NA	mmol/L				BUN	18	mg/dL				Fibrinogen	NA	mg/dL	Bacteria	Negative	
Lactate	3.38	mmol/L				Cr	0.89	mg/dL									
						AST	35	IU/L									
						ALT	34	IU/L									
						T.bil	0.5	mg/dL									
						ALP	74	IU/L									
						T.prot.	6.1	g/dL									
						Albumin	3.6	g/dL									

There was no active lung lesion or cardiomegaly on her initial chest X-ray. There was also no significant abnormality except sinus tachycardia in her initial electrocardiogram. Her bedside echocardiography found moderate amount of pericardial effusion and diastolic RV collapse. The treating physician made a presumptive diagnosis of traumatic cardiac tamponade due to hemopericardium and a cardiac surgeon was consulted promptly (Figs. 7.24 and 7.25).

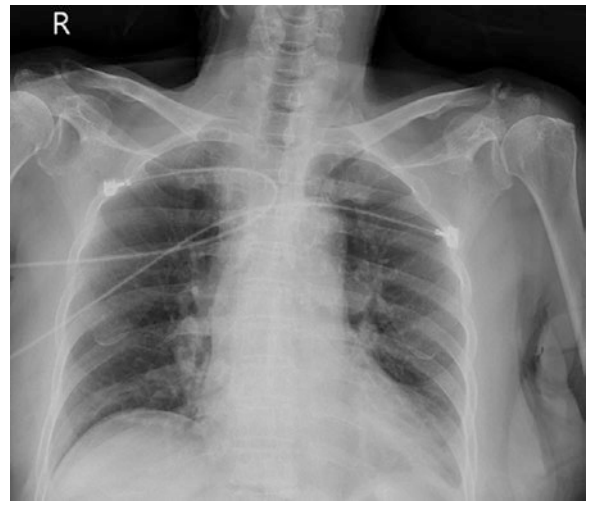


Fig. 7.24 Initial chest X-ray of the patient. Significant increase in heart size was not observed

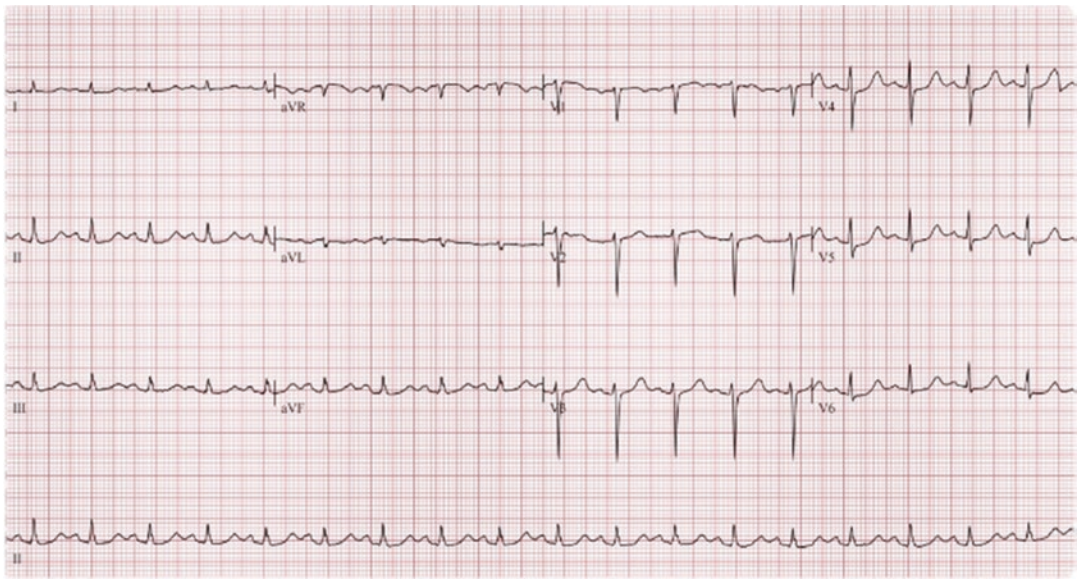
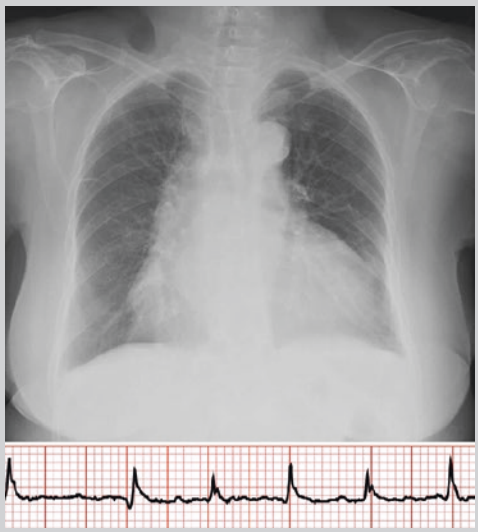


Fig. 7.25 Initial electrocardiogram of the patient which was nonspecific

Q. The chest image and electrocardiogram showed no signs of cardiac tamponade (e.g., enlarged cardiac silhouette, low voltage, or electrical alternans). Discuss about the diagnostic performances of chest PA and ECG in cardiac tamponade.

A. Both chest X-ray and electrocardiogram are not sensitive to cardiac tamponade. One of the reasons is the dependence of the development of cardiac tamponade on the rapidity of pericardial fluid accumulation. With chronic accumulation of a pericardial effusion, pericardial compliance increases gradually. However, rapid accumulation does not allow such increase in compliance and, in acute trauma like this case, small accumulation of blood in pericardial space can significantly increase intrapericardial pressure and be complicated by cardiac tamponade without significant abnormalities in chest X-ray.

Upper, enlarged cardiac silhouette; Lower, electrical alternans and low-voltage sign.



Q. What is diastolic RV collapse? Discuss about the echocardiographic findings of cardiac tamponade.

A. In cardiac tamponade, RV diastolic collapse can be observed during echocardiography in early diastole when the RV volume is still low. It is less sensitive but very specific compared to RA collapse.

After fluid resuscitation and monitoring with arterial line insertion, the patient was transferred to OR for emergency operation. In the operation room, the surgeons evacuated 300 cc of pericardial hematoma and repaired the small perforation at the right ventricle. The patient remained stable after the surgery and was discharged home without complication (Fig. 7.26).

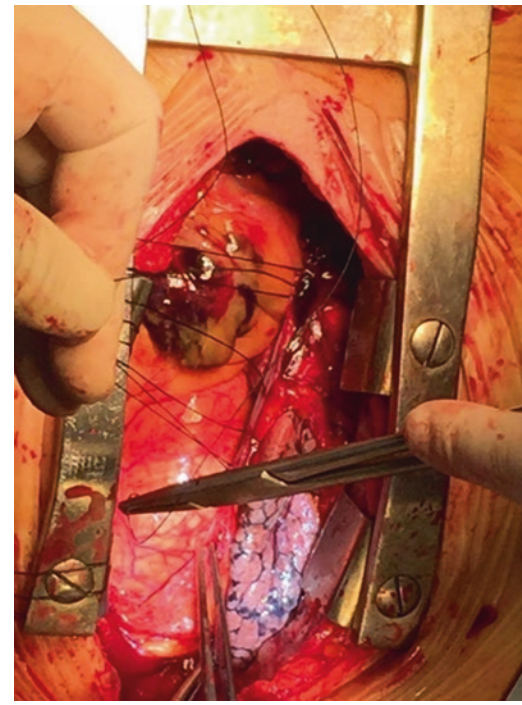


Fig. 7.26 After evacuation of 300 cc of pericardial hematoma, right ventricular perforation was identified and primary closure was done

7.6.1 Summary

Cardiac tamponade is one of the lethal causes of shock. The incidence of cardiac tamponade is two cases per 10,000 populations in the United States. The most common causes are malignant diseases and it accounts for 30–60% of the overall incidence. Although it is not a relatively common cause of shock, a physician should consider it as one of the many differential diagnoses of shock especially when malignancy, chronic kidney disease, and trauma are present. In this case, the cardiomegaly and characteristic ECG changes were not present. This could be due to the fast progression of pericardial filling by blood because the severity of the condition is also dependent on the speed of its development. This is commonly observed in traumatic cardiac tamponade. Approximately 2% of penetrating injuries are reported to result in cardiac tamponade. In this case, percutaneous drainage was not performed in the ED. It was because rapid operation by a thoracic surgeon was available. However, if prompt surgical intervention is impossible or delayed, emergency subxiphoid percutaneous drainage or echocardiographically guided pericardiocentesis must be performed.

7.7 A Septic Shock Case Due to Pneumonia

A 56-year-old woman visited the emergency department (ED) with chief complaint of vomiting. She had fever, chill, and yellowish sputum which began at the morning of her visit. She had underlying disease of hypertension and osteoporosis. Her initial vital signs were 69/47 mmHg–120 bpm–32 cpm–34.7 °C with sPO2 level of 92%. Two weeks ago, she had cough and whitish sputum which had spontaneously resolved. Her physical examination revealed decreased lung sound at left lower lung field.

Q. Describe your assessment of the patient based on the initial presentation.

A. The first symptoms the patient experienced were fever, chill, and productive cough which suggest respiratory infection. At the ED presentation, she had hypotension (SBP 69 mmHg) and tachypnea (32 bpm) and thus positive for two qSOFA components. Therefore, she was screened to be positive for sepsis. To determine whether this patient is in septic shock, we need to know the response to adequate fluid resuscitation and blood lactate measurement (see pages 59–61).

Q. What is your initial fluid resuscitation plan?

A. Patients with sepsis are often in relative hypovolemia. It is recommended to infuse at least 30 mL/kg of crystalloids within the first 3 h. It would be considerate to infuse the fluid in predefined size of bolus (e.g., 300–500 cc) while monitoring the response to the sequential boluses. For this patient, four 500 cc boluses of normal saline (65 × 30 = 1950 mL) were rapidly administered (see page 65).

During the fluid resuscitation, ceftriaxone and azithromycin were administered with a presumptive diagnosis of pneumonia after obtaining specimens for blood and respiratory cultures. After the initial fluid infusion, her blood pressure increased, but was still low as 72/54 mmHg. On bedside echocardiography, her IVC diameter of 2.0 cm and its respiratory collapse with forceful inspiration were less than 50% (Fig. 7.27).

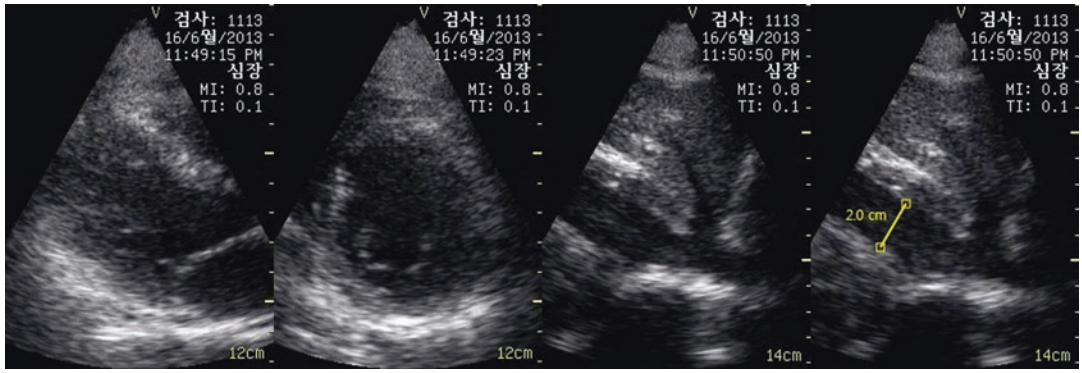


Fig. 7.27 Bedside ultrasonography findings

Q. Do we need further fluid resuscitation? If so, how will you do it?

A. Some patients with sepsis may require larger volume of fluid to achieve optimal hemodynamic status. Therefore, further fluid resuscitation should be considered. However, too much fluid can result in pulmonary edema. Therefore, fluid resuscitation for sepsis should be guided by hemodynamic assessment. SSC guideline recommends frequent reassessment of hemodynamic status using static or dynamic measurement.

- Static: CVP, PCWP, LV end-diastolic area by echocardiography, IVC diameter.
- Dynamic: Stroke volume variation, pulse pressure variation, passive leg raising (aortic blood flow, pulse pressure change, stroke volume change, cardiac output change), IVC collapsibility.

Bedside ultrasonography is a useful tool in monitoring volume status. The test identified "IVC plethora" in this patient. This suggests that adequate fluid resuscitation was achieved and there is a significant risk of pulmonary edema with further fluid administration. Because the patient is still hypotensive, initiation of vasopressors is required to achieve target mean arterial pressure of 65 mmHg.

Norepinephrine was started at the infusion rate of 8 μg/min. Meanwhile, her initial laboratory test results came out. The laboratory results indicate combined metabolic acidosis and respiratory alkalosis. The high CRP level indicates underlying inflammatory process.

Arterial blood gas analysis			CBC			Chemistry			Cardiac enzyme			Coagulation panel			Urinalysis		
pH	7.47		WBC	5200	/μL	Na	137	mmol/L	CK	NA	ng/mL	PT (Sec)	14.2	Seconds	WBC	<1	/HPF
pCO2	29	mmHg	Hb	10.7	g/dL	K	3.3	mmol/L	CK-MB	1.2	ng/mL	PT (INR)	1.31	INR	RBC	<1	/HPF
pO2	63	mmHg	Hct	32.3	%	Cl	102	mmol/L	TnI	0.01	pg/mL	aPTT	26.9	Seconds	Albumin	Trace	
HCO3-	23	mmol/L	Platelet	203,000	/μL	TCO2	23	mmol/L				D-dimer	1.63	μg/mL	Nitrite	Negative	
Base excess	NA	mmol/L				BUN	137	mg/dL				Fibrinogen	689	mg/dL	Bacteria	Negative	
Lactate	3.0	mmol/L				Cr	1.28	mg/dL									
						AST	94	IU/L									
						ALT	211	IU/L									
						T.bil	1.5	mg/dL									
						ALP	96	IU/L									
						T.prot.	5.6	g/dL									
						Albumin	2.9	g/dL									

Her electrocardiogram showed no significant arrhythmia or ST-T change. Her initial chest X-ray showed left lower lung field haziness (Fig. 7.28).

Her chest CT revealed airspace consolidation at her left lower lung field confirming the initial diagnosis of pneumonia (Fig. 7.29).

For infusion of vasopressors, central line was inserted through internal jugular vein. CVP was measured as 24 mmHg. ScvO2 was 59% and lactate level sampled in radial artery was 2.8 mmol/L. After starting norepinephrine at 8 μg/min, her blood pressure increased to 122/78 mmHg. However, her respiratory rate also increased to 33 cpm and the saturation was decreased to 85% with O2 flow rate of 6 L/min via facial mask. In follow-up echocardiography, decreased cardiac contractility was observed and IVC diameter was increased to 2.4 cm, with lesser proportion of collapse by respiration than before. Myocardial depression was suspected and dobutamine infusion was started at the rate of 5 μg/kg/min and O2 was increased to 10 L/min via facial mask (Fig. 7.30).

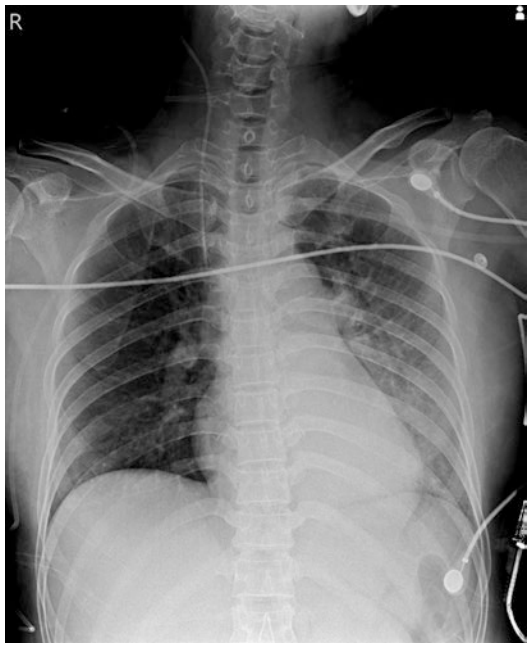


Fig. 7.28 There is haziness on left lower lung field

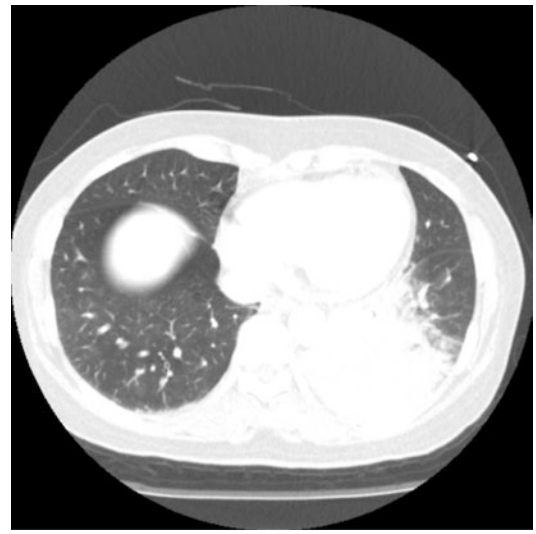


Fig. 7.29 There is dense consolidation located in the left lower lobe

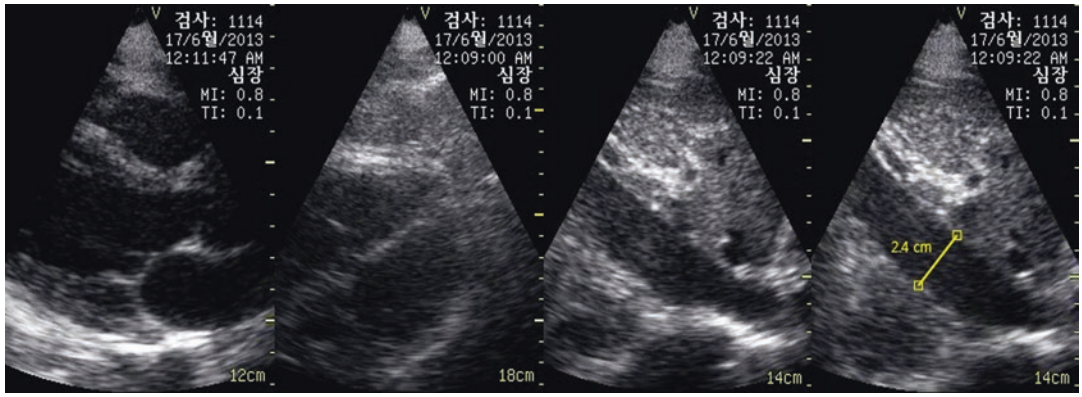


Fig. 7.30 Follow-up bedside (HD 2) ultrasonography showing increased IVC plethora and myocardial depression

Adrenergic Agents in Sepsis

Based on the SCC 2016 guideline, the first choice for the initial vasopressor should be norepinephrine in most cases. Dopamine can be used as an alternative agent in highly selected patient (low risk of tachyarrhythmia and absolute or relative bradycardia). Dobutamine can be used in case when there is persistent hypoperfusion.

(Surviving Sepsis Campaign: International Guidelines for Management of Sepsis and Septic Shock: 2016)

1. SSC guideline recommends norepinephrine as the first-choice vasopressor (strong recommendation, moderate quality of evidence).
2. SSC guideline suggests adding either vasopressin (up to 0.03 U/min) (weak recommendation, moderate quality of evidence) or epinephrine (weak recommendation, low quality of evidence) to norepinephrine with the intent of raising MAP to target, or adding vasopressin (up to 0.03 U/min) (weak recommendation, moderate quality of evidence) to decrease norepinephrine dosage.
3. SSC guideline suggests using dopamine as an alternative vasopressor agent to norepinephrine only in highly selected patients (e.g., patients with low risk of tachyarrhythmias and absolute or relative bradycardia) (weak recommendation, low quality of evidence).
4. SSC guideline recommends against using low-dose dopamine for renal protection (strong recommendation, high quality of evidence).
5. SSC guideline suggests using dobutamine in patients who show evidence of persistent hypoperfusion despite adequate fluid loading and the use of vasopressor agents (weak recommendation, low quality of evidence).

Remarks: If initiated, vasopressor dosing should be titrated to an end point reflecting perfusion, and the agent reduced or discontinued in the face of worsening hypotension or arrhythmias.

After 2 h, her vital sign was improved to 112/60 mmHg–98 bpm–28 cpm–36.7 °C with CVP at 18 mmHg (Sat: 99%). O2 flow rate was decreased to 8 L/min, and norepinephrine infusion rate was decreased to 2 μg/min. O2 flow rate was further decreased to 4 L/min via nasal prong, and norepinephrine infusion was stopped. Her vital signs remained stable thereafter and her oxygen requirements gradually decreased. Dobutamine infusion was gradually tapered off. Later, her urine test for pneumococcus urine antigen was revealed to be positive. She was treated for 8 more hospital days with antibiotics. Her chest X-ray was improved during the hospital stay (Fig. 7.31).

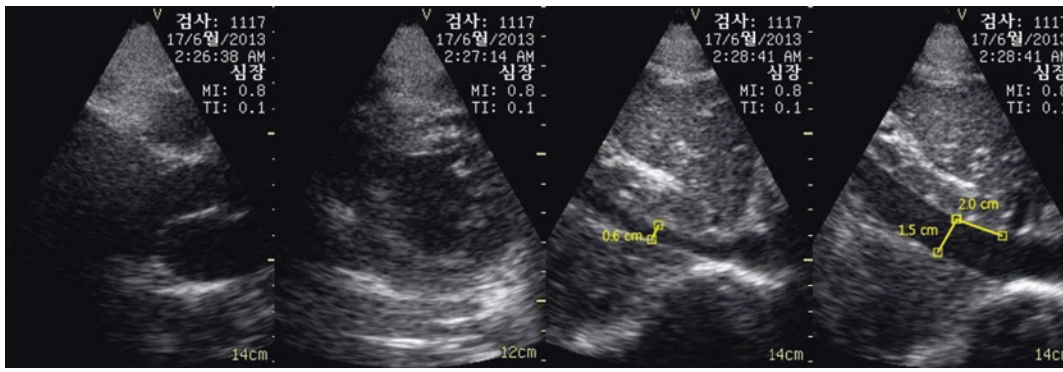


Fig. 7.31 Third bedside ultrasonography (HD 2) showing clear improvement in volume overload

7.7.1 Summary

This was a case of pneumococcal pneumonia septic shock. Since myocardial depression was combined, pulmonary edema and progression of hypoxemia were followed after initial fluid resuscitation. CVP was 24 mmHg and bedside echocardiography revealed dilated IVC diameter. Fluid was withheld and dobutamine was added to increase myocardial function. Her cardiac output was increased and norepinephrine was tapered. Pulmonary edema was improved with stabilization of vital sign. Bedside echocardiography and CVP provided important information to guide initial fluid administration and vasopressor and inotropic use in this patient.

7.8 A Septic Shock Case with Acute Cholangitis

A 79-year-old female came to the emergency department (ED) for abdominal pain. She was diagnosed with pancreatic head cancer with vascular invasion and peritoneal seeding diagnosed 6 months ago. She had biliary stent insertion procedure 5 months ago and was being treated with chemotherapy. Her initial vital signs were 77/59 mmHg–112 bpm–28 cpm–38.2 °C. The abdominal pain started with nausea and vomiting 2 days ago and, as time went by, the pain worsened. Physical examination revealed right upper quadrant tenderness.

Q. Please describe her current condition.

A. Infectious process should be considered because she is febrile. She can be in sepsis, because her initial qSOFA score was 2 (SBP 77 mmHg with increased respiratory rate at 28 cpm). Her blood pressure is very low at 77/59 mmHg. However, diagnosis of septic shock should be based on the response to adequate fluid resuscitation and serum lactate level.

Q. List your differential diagnoses and their rationales.

A. She has pancreatic cancer with prior history of biliary stent insertion for biliary obstruction. As she had right upper quadrant tenderness on physical examination without any other localizing sign, an infection involving hepatobiliary system should be at the first of the differential diagnosis list. Another possible explanation for her fever could be neutropenic fever because she was on chemotherapy until recently.

Q. Describe your initial management plan.

A. Clinically, she is suspected to be in sepsis and possibly in septic shock. SSC guideline recommends adequate fluid resuscitation, early administration of appropriate antibiotics, and source control in this condition. Fluid resuscitation should be guided by patients' volume status and empirical antibiotics should be administered within 1 h. Source control usually requires anatomic assessment of the patient which requires further evaluation (abdominal CT or sonography) in this patient (see page 68).

Because of initial RUQ pain and tenderness and underlying pancreatic head cancer with recent biliary stent procedure, the treating physician made initial presumptive diagnosis of acute cholangitis. After collection of culture specimens, the treating physician ordered piperacillin/tazobactam as initial empirical antibiotics to cover bacteria of biliary origin including pseudomonas.

Antibacterial Regimen for Acute Cholangitis

The most common bacteria isolated are as follows:

Gram negative

- *Escherichia coli* (most common, 25–50%) > Klebsiella (15–20%) > Enterobacter (5–10%).

Gram positive

- Enterococcus species (most common, 10–20%).

Anaerobes

- Bacteroides and Clostridia, usually present as a mixed infection.
- Rarely sole infecting organism, and not clear if they play a role in acute cholangitis (Nancy Misri Khardori, 2012).

Because of bacteriology as above, empiric antibiotic therapy for ascending cholangitis should include broad-spectrum parenteral antibiotics based upon the probable source of infection until culture results are available. The first-choice regimen of empiric therapy for gram negative and anaerobes was recommended to be monotherapy with a beta-lactam/beta-lactamase inhibitor such as piperacillin/tazobactam or combination third-generation cephalosporin such as ceftriaxone plus metronidazole.

Reference: Nancy Misri Khardori, Interventions in infectious disease emergencies, Medical clinics of north America, Medical Clinics of North America, Volume 96, Issue 6, Pages 1033–1272 (November 2012).

After fluid resuscitation as recommended by SSC guideline, her blood pressure increased, but was still low as 80/40 mmHg. Meanwhile, her initial laboratory results came out. The laboratory results can be summarized as leukocytosis, coagulopathy, metabolic acidosis (lactic acidosis), azotemia, and cholestasis. Her initial electrocardiogram showed no significant arrhythmia or ST-T change. Her chest X-ray showed no active lesion in both lung fields (Fig. 7.32).

Arterial blood gas analysis			CBC			Chemistry			Cardiac enzyme			Coagulation panel			Urinalysis		
pH	7.302		WBC	12,390	/μL	Na	142.9	mmol/L	CK	NA	ng/mL	PT	16	Seconds	WBC	5–9	/HPF
pCO2	22.9	mmHg	Hb	11.9	g/dL	K	3.5	mmol/L	CK-MB	NA	ng/mL	PT (INR)	1.42	INR	RBC	1–4	/HPF
pO2	70.6	mmHg	Hct	37.8	%	Cl	112.4	mmol/L	TnI	NA	pg/mL	aPTT	32.1	Seconds	Albumin	1+	
HCO3-	22.9	mmol/L	Platelet	55,000	/μL	TCO2	9.4	mmol/L				D-dimer	23.4	μg/mL	Nitrite	Negative	
Base excess	NA	mmol/L				BUN	25	mg/dL				Fibrinogen	NA	mg/dL	Bacteria	Many	
Lactate	10.53	mmol/L				Cr	1.76	mg/dL									
						AST	562	IU/L									
						ALT	316	IU/L									
						T.bil	3.5	mg/dL									
						ALP	127	IU/L									
						T.prot.	5.6	g/dL									
						Albumin	3.2	g/dL									

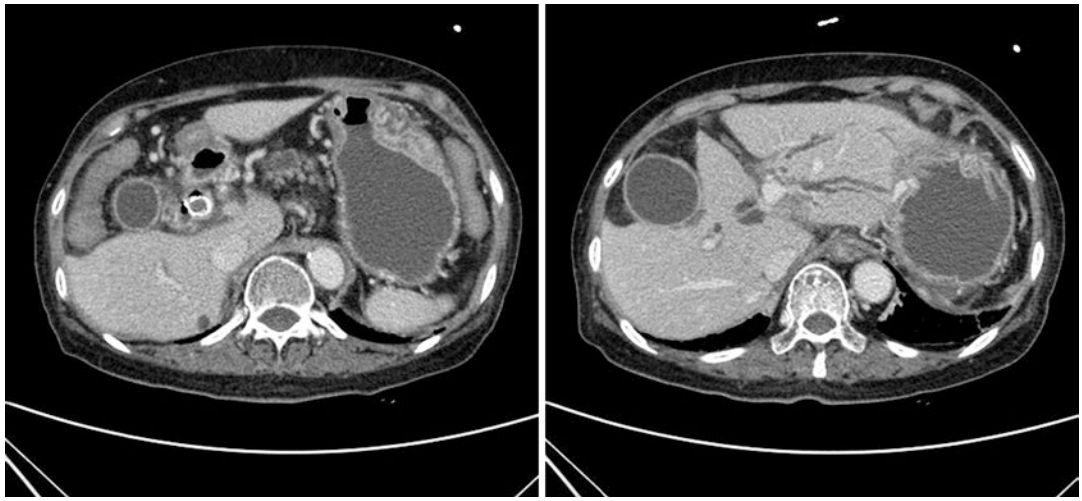


Fig. 7.32 Abdominal CT scan images of the patient. There were intrahepatic duct dilatation and GB distension with wall enhancement

Q. Her initial coagulation results were not normal. Do the findings indicate disseminated intravascular coagulation (DIC)?

A. Because DIC syndrome manifests in various forms by the etiology and disease process, there are no established diagnostic criteria and it should be diagnosed clinically. The International Society for Thrombosis and Hemostasis (ISTH) DIC scoring system provides objective measurement of DIC as follows:

Platelet count:
>100,000/μL = 0
50,000/μL–100,000/μL = 1
<50,000/μL = 2

Elevated fibrin-related markers such as soluble fibrin monomers and fibrin degradation products:
No increase = 0.
Moderate increase = 2.
Strong increase = 3.

Prolonged prothrombin time:
3 s or less = 0
>3 s but <6 s = 1
>6 s = 2

Fibrinogen level:
Greater than 100 mg/dL = 0.
<100 mg/dL = 1

Calculate score:
A total score ≥5 is compatible with overt DIC. It is recommended to repeat scoring daily.
Total score <5 suggests non-overt DIC, and the tests should be repeated in the next 1–2 days.

Reference: Levi M, Toh CH, Thachil J, Watson HG. Guidelines for the diagnosis and management of disseminated intravascular coagulation. Br J Haematol. 2009 Apr;145(1):24–33.

Q. Current SSC guideline recommends that a specific anatomic diagnosis of infection requiring emergent source control should be identified or excluded as rapidly as possible in patients with sepsis or septic shock. Please describe your initial plan for source control for this patient.

A. The patient is suspected of having acute cholangitis or other infections involving hepatobiliary system. The usual source control method for acute cholangitis is PTBD- or ERCP-guided biliary drainage. In case the patient has liver abscess, percutaneous drainage of the abscess should be arranged. In this case, abdominal enhanced CT was chosen over liver sonography for comprehensive assessment of whole abdominopelvic cavity.

During initial hemodynamic resuscitation, a total of 1.5 L of saline was administered intravenously. After the initial resuscitation, her blood pressure was 106/60 mmHg, and heart rate was 120. For further evaluation of her biliary system as well as to find other possible fever focus, the treating physician ordered an abdominal CT scan. The abdomen CT scan revealed intrahepatic duct dilatation and GB distension with wall enhancement which supports initial presumptive diagnosis of cholangitis (Fig. 7.33).

PTBD insertion was done after the resuscitation. However, her blood pressure gradually decreased. To maintain mean blood pressure over 65 mmHg, norepinephrine infusion was started and titrated up to 16 μg/min which increased her MBP to 80 mmHg (systolic/diastolic blood pressure was 114/62 mmHg). After 12 h of continuing treatment, the MBP remained stable at the rate of 12 μg/min of norepinephrine infusion which was gradually tapered thereafter.

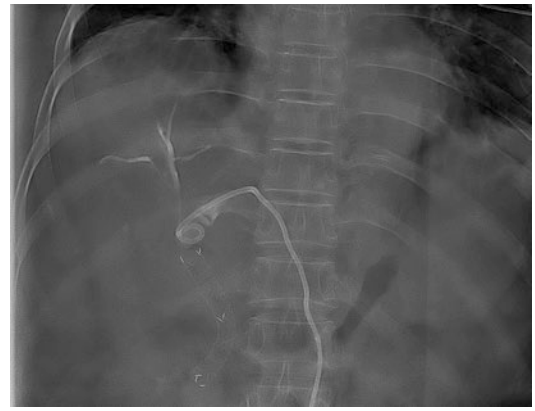


Fig. 7.33 PTBD insertion of the patient

Her blood and PTBD fluid cultures revealed ESBL-negative *K. pneumoniae* that was susceptible with cephalosporin, carbapenem, and aminoglycosides on fourth admission day. Therefore, antibiotic regimen was changed to ceftriaxone because current SCC guideline recommends that empiric antimicrobial therapy should be narrowed once pathogen identification and sensitivities are established and/or adequate clinical improvement is noted. Follow-up blood and PTBD fluid cultures were done after 1 week from the day of the first microbial cultures, and the result of blood and PTBD fluid cultures was negative. She was safely discharged to home with oral antibiotics at hospital day 10.

7.8.1 Summary

Cholangitis is one of the deadliest causes of sepsis. Prompt diagnosis, early antibiotics administration, and appropriate source control are critical as is true in other sepsis syndromes. Source control methods for biliary sepsis can be summarized as follows:

First of all, broad-spectrum antibiotics should be administered to the patient who is suspected of sepsis as soon as possible after microbial culture study. And it should be considered to take the imaging test first such as CT scan or ultrasound to make a decision whether or not to perform source control procedure. If there is an evidence of biliary tract obstruction such as biliary tract dilatation or tense gallbladder dilatation, it should be considered that the patients need urgent biliary decompression procedures. Especially, the patient who has persistent abdominal pain, hypotension despite adequate fluid resuscitation, fever greater than 39 °C, or mental confusion due to infection should be considered to receive urgent biliary decompression procedure such as ERCP, PTBD, or PTGBD appropriately.

7.9 A Septic Shock Case Due to *Klebsiella pneumoniae* Liver Abscess

A 72-year-old male patient came to the emergency department (ED) for visual loss on his left eye which began 1 day before the ED visit. His initial vital signs were 81/49 mmHg–79 bpm–18 cpm–38.7 °C.

Because the initial chief complaint of patient was visual loss, the physician focused on patient's eye problem and the initial decision was to arrange ophthalmologist examination. Patient was sent to the ophthalmology department at 1 h after ED arrival, and came back to the ED after staying for 3 h at the ophthalmology department for exam. Septic shock was recognized after the patient came back from the ophthalmology department; his blood pressure was 64/41 mmHg at that time.

Additional history finding revealed that the patient complained of myalgia for 5 days and watery diarrhea for 3 days. His physical examination revealed abdominal tenderness on right upper quadrant and pitting edema in both lower extremities.

Q. What has gone wrong with the initial management?

A. This patient should be suspected of having a sepsis because initial vital signs show low systolic blood pressure and increased body temperature. The treating physician did not notice the abnormalities and sent the patient to ophthalmological examination. The patient should be on monitor and getting appropriate management for suspected sepsis from the beginning. To avoid this mistake, routine implementation of a screening tool (e.g., qSOFA) to ED patients would be helpful.

After the recognition that patient is in septic shock state, which was 4 h past from ED arrival, the physician started to administer normal saline rapidly up to 2 L. His initial chest X-ray showed no active lung lesion and electrocardiogram showed no significant ST-T change nor arrhythmia. Routine laboratory tests were ordered including CRP and lactate to evaluate severity. After 2 h, his initial laboratory results came out as follows.

Arterial blood gas analysis			CBC			Chemistry			Cardiac enzyme			Coagulation panel			Urinalysis		
pH	7.34		WBC	8290	/μL	Na	132	mmol/L	CK	NA	ng/mL	PT (INR)	1.16	INR	WBC	NA	/HPF
pCO2	28	mmHg	Hb	12.9	g/dL	K	3.8	mmol/L	CK-MB	NA	ng/mL	aPTT	33.9	Seconds	RBC	NA	/HPF
pO2	86	mmHg	Hct	38.9	%	Cl	94	mmol/L	TnI	NA	pg/mL	D-dimer	NA	μg/mL	Albumin	NA	
HCO3-	NA	mmol/L	Platelet	49,000	/μL	TCO2	18	mmol/L							Nitrite	NA	
Base excess	−10.7	mmol/L				BUN	107	mg/dL							Bacteria	NA	
Lactate	NA	mmol/L				Cr	4.27	mg/dL									
						CRP	23	mg/L									
						AST	125	IU/L									
						ALT	99	IU/L									
						T.bil	1.5	mg/dL									
						ALP	73	IU/L									
						T.prot.	5.7	g/dL									
						Albumin	3.3	g/dL									

Bedside ultrasonography revealed hepatic mass in S6 area suspicious of liver abscess and collapsed inferior vena cava. Estimated ejection fraction of LV was above 60%.

Q. Does this patient have evidences of organ dysfunction?

A. The high creatinine level indicates azotemia and the high CRP level indicates underlying inflammatory processes in this patient. Organ dysfunction can be identified as an acute change in total SOFA score ≥2 points consequent to the infection. The baseline SOFA score can be assumed to be zero in patients not known to have preexisting organ dysfunction. We calculate SOFA score to evaluate the severity of organ dysfunction. The SOFA score was 7 (renal 3, cardiovascular 1, and hematologic 3). A SOFA score ≥2 reflects an overall mortality risk of approximately 10% in a general hospital population with suspected infection. The lactate level was 3.9, which is greater than the threshold for definition of shock (>2 mmol/L). However, we need to check the response to the fluid resuscitation to confirm septic shock (see page 60).

Until this time point, a total of 2300 mL of crystalloid was administered and central venous catheter was inserted. The Surviving Sepsis Campaign guideline recommends frequent reassessment of hemodynamic status to guide additional fluid administration. After initial fluid administration, his blood pressure increased, but was still low at 80/40 mmHg. To maintain mean blood pressure over 65 mmHg, norepinephrine was started and titrated up to 8 μg/min.

Q. Is this patient confirmed as septic shock?

A. According to the definition of the Sepsis-3, septic shock is a subset of sepsis in which underlying circulatory and cellular/metabolic abnormalities are profound enough to substantially increase mortality. This patient had persisting hypotension requiring vasopressors to maintain MAP ≥65 mmHg and having a serum lactate level >2 mmol/L despite adequate volume resuscitation. Therefore, this patient can be confirmed as septic shock. With these criteria, hospital mortality is reported to be in excess of 40%.

Because his initial physical examination showed right upper quadrant tenderness, and bedside ultrasound showed abscess like hepatic mass, an abdominal CT scan was taken to identify possible infection focus. Even though his creatinine level was 4.2 mg/dL, to evaluate abscess like lesion, physician at the site decided to order contrast abdomen CT (Fig. 7.34).

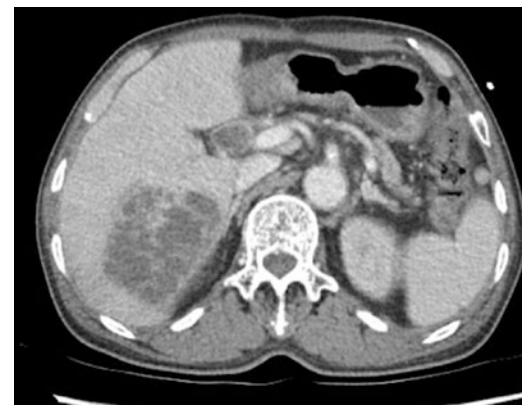


Fig. 7.34 A large abscess in the right posterior section of the liver

His abdomen CT revealed 8.5 cm pyogenic abscess in the right posterior section of the liver without a stone in his common bile duct (Fig. 7.34). He was assessed as septic shock due to pyogenic liver abscess with possible acute septic kidney injury.

The consulted ophthalmologist's diagnosis for the left eye visual loss was endogenous endophthalmitis due to metastatic infection. Considering that he had both liver abscess and endophthalmitis, *Klebsiella pneumoniae* liver abscess syndrome was highly suspicious. Biliary obstruction due to CBD stone may have played a significant role in this process.

Q. What is the *Klebsiella pneumoniae* liver abscess syndrome?

A. *Klebsiella pneumoniae* primary liver abscess (KLA) occurs in the absence of hepatobiliary disease and is almost always monomicrobial. Most cases have been reported from Asia or in patients of Asian origin. In addition to the manifestations typical of pyogenic liver abscess, such as fever, leukocytosis, right upper quadrant tenderness, and elevated liver enzymes, a minority of patients with primary KLA can develop metastatic infections at other sites. A high index of suspicion for metastatic spread to various other organs including the eye is necessary. Early detection of Klebsiella-associated endophthalmitis and prompt treatment with aggressive intravenous antibiotics may be the only method to salvage visual acuity and decrease the incidence of overall morbidity and mortality.

7.9.1 Progression

At 5 h after presentation, meropenem was started as initial empirical antibiotics after blood culture test. At the second hospital day, 1% vancomycin 1.0 mg/0.1 mL and 2.25% ceftazidime 2.25 mg/0.1 mL intraocular injections were done by the ophthalmology consultant. Despite the aggressive hemodynamic management, there was no urine output. So, continuous renal replacement therapy (CRRT) was started. Percutaneous catheter drainage (PCD) insertion in liver abscess was done. At hospital day 3, atrial fibrillation with rapid ventricular rate appeared and mental state of the patient was deteriorated to drowsy state. Intubation was done and mechanical ventilator support was started. At hospital day 4, his vital signs began to stabilize and norepinephrine was tapered off. At hospital day 5, culture reports came back. The *Klebsiella pneumoniae* (ESBL negative) was isolated in his blood and PCD fluid. Because current guidelines recommend empiric antimicrobial therapy be narrowed once pathogen is identified and sensitivities are established and/or adequate clinical improvement is noted; his antibiotics were stepped down to ceftriaxone 2 g bid (a dose for CNS infection) considering endophthalmitis. At hospital day 6, brain MRI imaging was done. There was no evidence of metastatic infection to CNS. The patient's overall conditions eventually got better and CRRT and mechanical ventilation were tapered off. The patient was transferred to general ward for further treatment.

7.9.2 Summary

This was a case of invasive syndrome of *Klebsiella pneumoniae* liver abscess. The patient came to the ED with visual loss and was found to have septic shock. Despite prompt assessment and aggressive treatment, he developed ARDS and acute kidney injury which made him to require CRRT and mechanical ventilation. *Klebsiella pneumoniae* is a well-known human pathogen, and recently a distinct invasive syndrome caused by *K. pneumoniae* serotypes K1 and K2 has been recognized in Southeast Asia. The syndrome is defined by the following criteria: (1) definite invasive syndrome: *Klebsiella pneumoniae* liver abscess with extrahepatic complications, especially CNS involvement, necrotizing fasciitis, or endophthalmitis and (2) probable invasive syndrome: *K. pneumoniae* liver abscess as the sole presenting clinical manifestation.

It is recommended that in patients with diabetes mellitus who present with *K. pneumoniae* bacteremia, endophthalmitis, meningitis, or other extrahepatic infections, especially those who are Asian or of Asian descent, a search for an occult liver abscess is indicated.

As current guidelines recommend, source control has utmost importance once initial hemodynamic stabilization and initiation of antibiotics are achieved. In cases where initial infection source is not clear, detailed history taking and physical examination as well as imaging workup such as CT can be revealing.

7.10 A Septic Shock Case Due to Acute Pyelonephritis

A 78-year-old woman being cared in a nursing hospital came to the emergency department (ED) for hypotension and altered mental status. She has been hemiplegic because of a stroke event 30 years ago. She was also treated for pulmonary tuberculosis 7 years ago. Her initial vital signs were 60/38 mmHg–106 bpm–18 cpm–39 °C. She developed fever and myalgia developed 2 days ago. Physical examination revealed left costovertebral angle tenderness (CVAT). There were no other historical clues to get because she was too drowsy for verbal communication. The Glasgow coma scale was E2M5V2. Bedside echocardiography examination was done and found collapsed IVC.

Q. Is she septic?

A. She had altered mental status and hypotension (SBP: 60 mmHg) which indicate possible sepsis according to qSOFA.

After fluid administration as recommended by the SCC guideline, her blood pressure increased, but was still low as 80/40 mmHg. Meanwhile, her initial laboratory test results came out.

Arterial blood gas analysis			CBC			Chemistry			Cardiac enzyme			Coagulation panel			Urinalysis		
pH	7.345		WBC	12,260	/μL	Na	136.4	mmol/L	CK	NA	ng/mL	PT (Sec)	12.9	Seconds	WBC	>100	/HPF
pCO2	32.7	mmHg	Hb	9.3	g/dL	K	4.4	mmol/L	CK-MB	4.7	ng/mL	PT (INR)	1.10	INR	RBC	5–9	/HPF
pO2	75.9	mmHg	Hct	27.2	%	Cl	102.8	mmol/L	TnI	0.066	pg/mL	aPTT	27.3	Seconds	Albumin	2+	
HCO3-	17.4	mmol/L	Platelet	135,000	/μL	TCO2	19.2	mmol/L	Pro-BNP	721.3	pg/dL	D-dimer	2.37	μg/mL	Nitrite	Positive	
Base excess	NA	mmol/L				BUN	38	mg/dL				Fibrinogen	467.5	mg/dL	Bacteria	Many	
Lactate	5.0	mmol/L				Cr	2.91	mg/dL									
						AST	28	IU/L									
						ALT	17	IU/L									
						T.bil	0.9	mg/dL									
						ALP	59	IU/L									
						T.prot.	6.2	g/dL									
						Albumin	3.6	g/dL									

Her initial laboratory findings indicated azotemia, lactic acidosis, and significant pyuria with bacteriuria. Her initial chest X-ray showed no active lesion in the lung compared with previous X-ray and electrocardiogram showed sinus tachycardia.

Q. What is your presumptive diagnosis of this patient and its rationale?

A. Considering CVAT, pyuria, and positive nitrite on her urinalysis, acute pyelonephritis should be considered as a primary diagnosis.

After obtaining specimens for blood and urinary cultures, meropenem was administered as the initial empirical antibiotics. The choice was based on the culture results of her previous admission when a drug-resistant bacterial strain (ESBL-positive *E. coli*) was cultured from her urine.

During the initial resuscitation, over 2 L of crystalloid fluid was administered. However, the patient remained hypotensive with BP of 92/30 mmHg. To maintain mean blood pressure over 65 mmHg, norepinephrine was started and titrated up to 8 μg/min. During initial resuscitation, the patient's oxygen saturation was decreased to 86%. Thus, follow-up chest X-ray was performed. Chest X-ray showed bilateral pleural effusion and pulmonary edema (Fig. 7.35).

Oxygen supply at the rate of 3 L/min was started using nasal prong. Although urine output had increased to 0.5 mg/kg/h, intravenous furosemide (20 mg) was administered to the patient because of her pulmonary edema.

To rule out other possible infection focuses as well as to find any evidence of complicated UTI, a non-contrast abdominal CT was taken. Contrast dye was not used because of the decreased renal function (Fig. 7.36).

Abdomen CT revealed left perirenal fat stranding with small amount of fluid collection which is

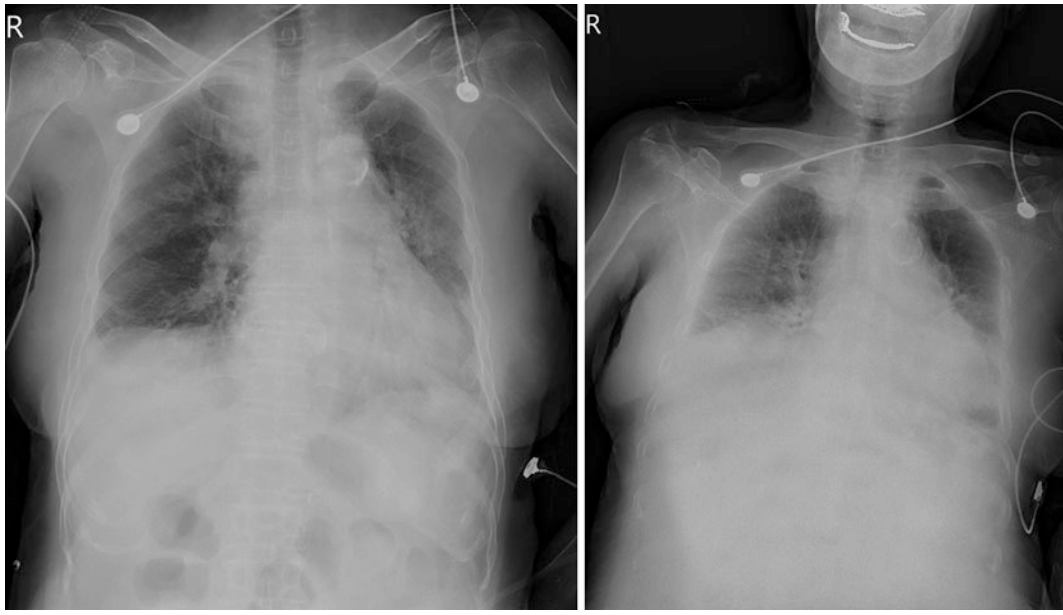


Fig. 7.35 Development of pleural effusion and pulmonary edema after fluid resuscitation

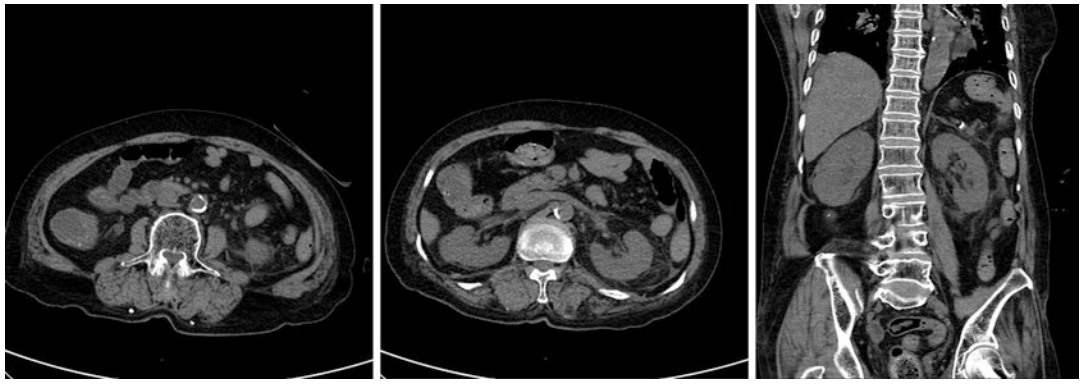


Fig. 7.36 Left: perirenal fat stranding with small amount of fluid collection suggesting acute pyelonephritis

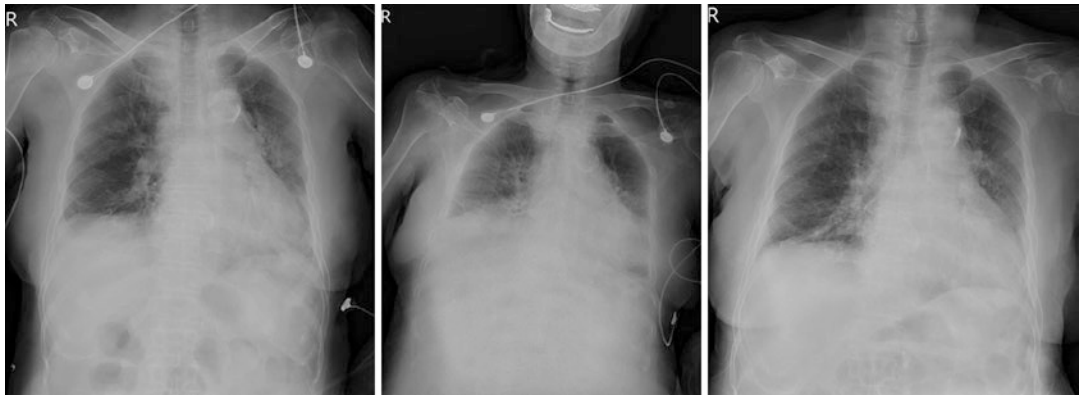


Fig. 7.37 Chest X-ray changes during fluid resuscitation. Left, 11 AM: no change; middle, 2 PM: increased pulmonary edema, bilateral atelectasis; right, next day 6 AM: decreased pulmonary edema, subsegmental atelectasis in the right lower lobe

Q. Would you recommend CT scan for this patient? What is your rationale if so?

A. Acute pyelonephritis is relatively a common infection. The grave presentation of the patient indicates that there could be complicated APN. Unenhanced abdominal CT can detect ureter stone and hydronephrosis both of which frequently warrant further evaluation and interventions for source control. Ultrasound can be an alternative choice.

suggestive of left pyelonephritis. Otherwise no other septic focus was found. Therefore, her ED diagnosis was made as septic shock caused by acute pyelonephritis.

After 24 h of treatment, mean blood pressure was maintained over 65 mmHg while maintaining norepinephrine infusion at 8 μg/min. Blood pressure was 128/50 mmHg, and heart rate was 120 bpm after 24 h from treatment start. Norepinephrine was tapered during the second hospital day. At the hospital day 2, the follow-up chest X-ray showed improvement of pulmonary edema and decreased extent of pleural effusion (Fig. 7.37).

Her blood and urine culture reports came out at hospital day 4. They were positive for ESBL(+) *E. coli* and the initial choice of antibiotics was maintained until her discharge. She was fully recovered and discharged at hospital day 11.

7.10.1 Summary

Acute pyelonephritis is a relatively common systemic infection. According to the report that Czaja CA wrote, overall annual rates are 15–17 cases per 10,000 females and 3–4 cases per 10,000 males Acute pyelonephritis develops in 20–30% of pregnant women (*Czaja CA, et al., Population-based epidemiologic analysis of acute pyelonephritis, Clin Infect Dis. 2007 Aug 1;45(3):273–80)*. Delia Scholes also reported that sexual behaviors, patient and family history of UTI, and diabetes are associated with increased pyelonephritis risk (*Delia Scholes, et al., Risk factors associated with acute pyelonephritis in healthy women, Ann Intern Med. 2005 Jan 4;142(1):20–7)*. In this patient, no significant risk factors for complicated pyelonephritis were found. However, although pyelonephritis responds well to antibiotics, it can turn into deadly infectious syndrome in some patients.

The antibiotics for complicated acute pyelonephritis include the following: cefepime, imipenem, meropenem, and piperacillin/tazobactam. This patient had previous history of ESBL(+) bacterial infection. The treating physician appropriately chose meropenem as the primary antibiotics. Because she was in shock and had been living in a nursing hospital and it means that she might have been exposed to drug-resistant bacterial strains. And that choice was right.

The initial fluid resuscitation had resulted in pulmonary edema which should have been avoided by multiple reassessment of volume status. Physicians treating shock should be vigilant on the patients' volume status to decide when to stop volume infusion and start to use vasopressors instead.

7.11 A Shock Case Due to Toxic Shock Syndrome

A 25-year-old male with tattoo on his back came to the emergency department (ED) with a 2-day history of myalgia, headache, chill, and cough. He was a nonsmoker and had no specific underlying disease before. His initial vital signs were 151/57 mmHg–140 bpm–23 cpm–38.7 °C. The tattooing had been done 3 days ago. On physical examination, there was diffuse erythroderma on his chest. At his back, where the tattoo was, redness, pustules, and tenderness were observed. One hour after the visit, he became drowsy with his vital signs of 73/36 mmHg–123 bpm–21 cpm–39.2 °C (Fig. 7.38).

After initial fluid resuscitation as recommended by SSC guideline, his blood pressure was increased, but still remained low as 80/40 mmHg. His initial chest X-ray showed no active lung lesion and electrocardiogram showed sinus tachycardia. Meanwhile, his initial laboratory test results came out.

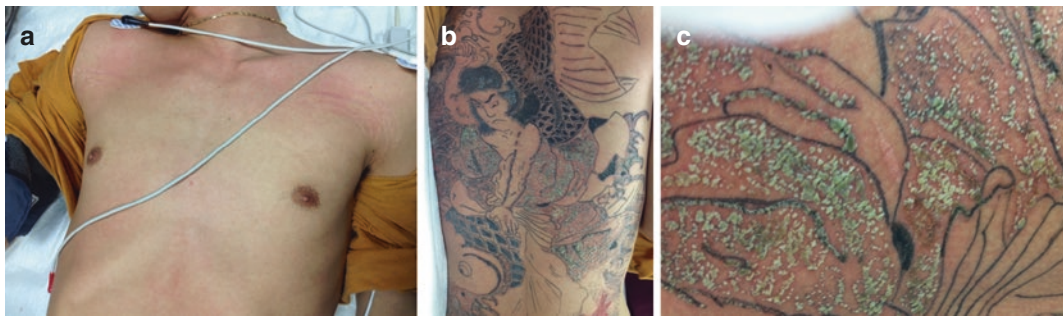


Fig. 7.38 The patient had diffuse erythroderma on his upper chest area (A). At his back, where the tattoo was, redness, pustules, and tenderness were observed

Arterial blood gas analysis			CBC			Chemistry			Cardiac enzyme			Coagulation panel			Urinalysis		
pH	7.45		WBC	25,940	/μL	Na	134	mmol/L	CK	NA	ng/mL	PT (%)	86	%	WBC	20–29	/HPF
pCO2	35	mmHg	Hb	13.8	g/dL	K	4.1	mmol/L	CK-MB	0.4	ng/mL	PT (INR)	1.12	INR	RBC	<1	/HPF
pO2	78	mmHg	Hct	38.7	%	Cl	94	mmol/L	TnI	0.001	pg/mL	aPTT	39.7	Seconds	Albumin	1+	
HCO3-	24.3	mmol/L	Platelet	154,000	/μL	TCO2	25	mmol/L				D-dimer	NA	μg/mL	Nitrite	Negative	
Base excess	NA	mmol/L				BUN	31	mg/dL				Fibrinogen	438	mg/dL	Bacteria	NA	
Lactate	2.2	mmol/L				Cr	1.77	mg/dL									
						AST	171	IU/L									
						ALT	170	IU/L									
						T.bil	1.3	mg/dL									
						ALP	74	IU/L									
						T.prot.	6.0	g/dL									
						Albumin	3.6	g/dL									

Q. What is your presumptive diagnosis and which evaluation steps are required to reach final diagnosis?

A. The patient is positive for two qSOFA criteria (SBP 73 mmHg, HR 123 cpm). Thus, he can be assumed to be in septic condition. Because he had high fever (≥38.9 °C), hypotension, elevated creatinine, skin rash (diffuse macular erythroderma on his chest and within tattoo), severe myalgia, drowsy mentality, and hepatic involvement (liver function test abnormality), azotemia, and coagulopathy, can also be assumed to be toxic shock syndrome. Blood, throat, or cerebrospinal fluid cultures are needed for final diagnosis and close observation for desquamation on his skin.

After 45 min of visiting the ED, antibiotics (vancomycin 1 g bid + clindamycin 4 mL tid + ceftriaxone 2 g qd) were started. Then immunoglobulin (monomeric purified polyspecific immunoglobulin G) was injected by intravenous route. During initial hemodynamic stabilization process, over 2 L of crystalloid was administered and central venous catheter was inserted. Follow-up vital signs were 98/57 mmHg–116 bpm–19 cpm–39.1 °C. To maintain mean blood pressure over 65 mmHg, norepinephrine infusion was started and titrated up to 12 μg/min.

Q. Why these antibiotics were chosen?

A. Broad-spectrum antibiotics should be administered as soon as possible in all suspected cases of TSS, preferably following collection of blood and other samples for culture. Current recommendations for empiric antibiotic treatment of suspected sepsis advocate the use of flucloxacillin and a third-generation cephalosporin. In settings where the rate of methicillin-resistant *S. aureus* (MRSA) is high, initial cover should include vancomycin. In our case, we decided to use antibiotics (ceftriaxone 2 g once daily + vancomycin 1 g twice a day + clindamycin 4 mL three times a day) to cover both *S. aureus* (including MRSA) and *S. pyogenes*.

Clindamycin has multiple activities that make it potentially useful as an adjunctive treatment in TSS. Clindamycin is a bacteriostatic lincosamide with efficacy unaffected by bacterial growth phase or inoculum size. Clindamycin has been shown to inhibit toxin production by both *S. aureus* and *S. pyogenes*. These include the ability to overcome the "Eagle effect," inhibition of superantigen toxin production, better tissue penetration and longer post-antibiotic effect than penicillin, and potentiation of phagocytosis. Clindamycin can also reduce bacterial superantigen toxin production through the inhibition of transcription of exoprotein genes, thereby potentially interrupting any ongoing stimulation of the inflammatory cascade. Clindamycin should not be used alone because it is only bacteriostatic rather than bactericidal and because of reports of rising resistance and improved outcomes have been reported with the combined use of a beta-lactam antibiotic and clindamycin.

Q. What is the role of immunoglobulin in TSS?

A. In TSS, the adjunctive use of intravenous immunoglobulin (IVIg) is supported on a theoretical basis by its anti-inflammatory and immunomodulatory properties, and on the evidence from many studies. IVIg contains

mainly monomeric purified polyspecific immunoglobulin G (IgG) and a smaller fraction comprising other immunoglobulin isotypes and additional immunological components. The beneficial anti-inflammatory and immunomodulatory activities of IVIg when used in TSS are thought to include the facilitation of antigen recognition, activation of the innate immune system, and counteraction of superantigen toxin activity by neutralizing antibody and blockade T-cell activation by staphylococcal and streptococcal superantigens.

Diagnosis of Staphylococcal Toxic Shock Syndrome Clinical Case Definition

1. Fever ≥38.9 °C.
2. Hypotension—systolic blood pressure ≤90 mm Hg for adults.
3. Rash—diffuse macular erythroderma.
4. Desquamation—1–2 weeks after onset of illness, especially of palms and soles.
5. Multisystem involvement—three or more of the following:
   (a) Gastrointestinal—vomiting or diarrhea at the onset of illness.
   (b) Muscular—severe myalgia or elevated creatine phosphokinase.
   (c) Mucous membranes—vaginal, oropharyngeal, conjunctival hyperemia.
   (d) Renal—blood urea nitrogen or creatinine twice upper limit of normal.
   (e) Hepatic—total bilirubin twice upper limit of normal.
   (f) Hematological—platelets ≤100/μL.
   (g) CNS—disorientation or alterations in consciousness without focal neurological signs.
6. Negative results on the following tests:
   (a) Blood, throat, or cerebrospinal fluid culture (blood culture may be positive for *S. aureus*).
   (b) Rise in titer to Rocky Mountain spotted fever, leptospirosis, or measles.

   Case classification.

   *Probable: case with five of the six clinical findings described

   *Confirmed: case with all six of the clinical findings described.

Treatment of Staphylococcal Toxic Shock Syndrome

1. Aggressive fluid replacement with normal saline to treat hypotension.
2. The prompt administration of appropriate antibiotics: In cases in which the causative organism is unknown, the antibiotic regimen should cover both *S. aureus* (including MRSA if indicated) and *S. pyogenes*.
   - Broad-spectrum antibiotics (flucloxacillin + third-generation cephalosporin) + clindamycin ~Then changes ~.
   - Cloxacillin or nafcillin or cefazolin + clindamycin (MSSA if indicated).
   - Vancomycin or teicoplanin (MRSA if indicated) + clindamycin.
3. Consider use of intravenous immunoglobulin (IVIg) in patients whom no clinical response within the first 6 h of aggressive supportive therapy:

   IV Ig G [high dose (1–2 g/kg) on day 1 followed by subsequent doses of 0.5 g/kg on days 2 and 3].
4. Source control (for staphylococcal TSS, source control may include removal of the tampon or drainage of a surgical site infection).
5. Extracorporeal membrane oxygenation (ECMO) and supportive management.

7.11.1 Progression

After 1 day, methicillin-sensitive *Staphylococcus aureus* was isolated from the skin wound culture. No organism was isolated from blood culture. Antibiotics were changed to cefazolin + clindamycin. Norepinephrine was tapered to 4 μg/min. After 2 days, norepinephrine was tapered off. He was transferred to general ward and antibiotic therapy was maintained until discharge. After 5 days, characteristic skin desquamation began at back, finger, and toe area which supports the initial diagnosis of TSS. After 14 days, he was discharged home (Fig. 7.39).

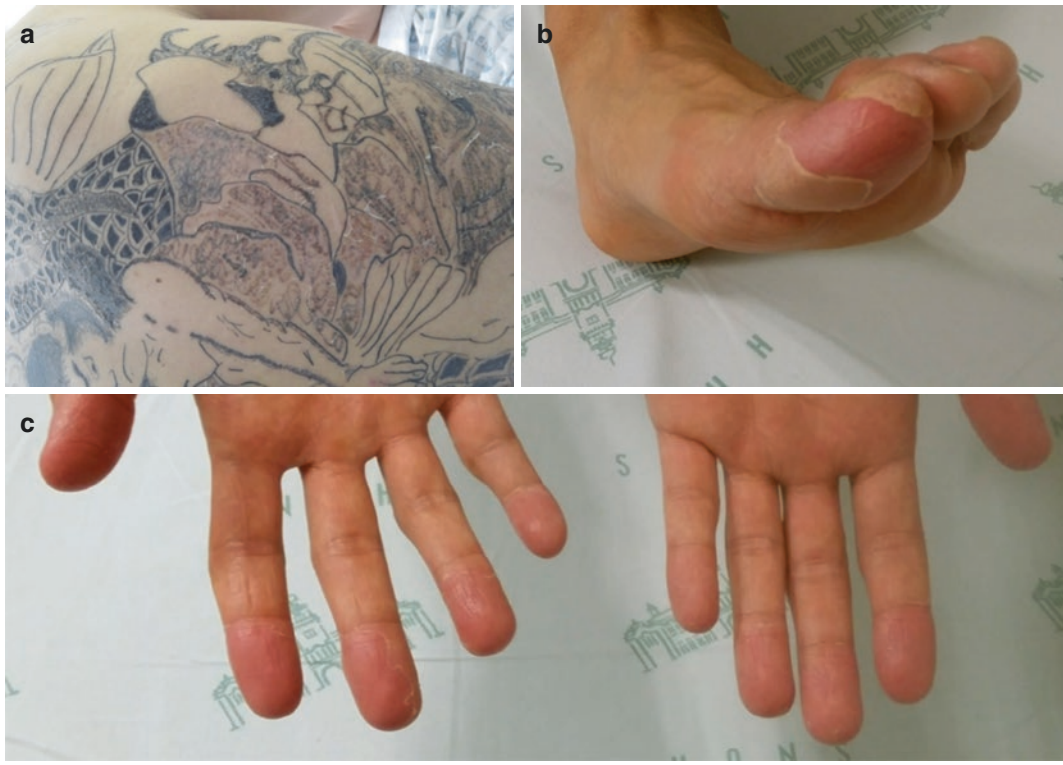


Fig. 7.39 Desquamation of skin occurred within tattoo on back (**a**), left toe (**b**), and both fingers (**c**) observed at outpatient department visit

7.11.2 Summary

This was a classic case of a toxic shock syndrome due to methicillin-sensitive *Staphylococcus aureus*. Patient came to the ED with fever, myalgia, and skin rash after tattooing. Toxic shock syndrome (TSS) is an acute, multisystem, toxin-mediated illness, often resulting in multi-organ failure. It is caused by toxin-producing strains of *Staphylococcus aureus* and *Streptococcus pyogenes* (group A streptococcus). In this case, the treating physician promptly identified possible TSS case and administered appropriate antibiotic regimen early, while initial hemodynamic resuscitation process was still ongoing. The readers should remember that this prompt assessment of patient and early administration of antibiotics are critical in the management of septic shock.

7.12 A Case of Anaphylactic Shock

A 74-year-old man (75 Kg) with underlying hypertension came to the emergency department (ED) for persistent vomiting. His blood pressure and pulse rate were 110/60 mmHg and 66 bpm. He had skin rash in face and extremity. He had swollen face and lip. But his respiration was 18 cpm and he had no dyspnea.

About 20 min before the symptom onset, patient took his wife's painkiller (Aceclofenac 100 g) for headache. He had no known allergies. On the physical examination, his lung sound was normal without wheezing or stridor.

Q. What is your presumptive diagnosis and its rationales?

A. He had persistent vomiting and skin rash after taking the nonsteroidal anti-inflammatory drug (NSAID). They involve both cutaneous and gastrointestinal system after exposure to likely allergen. Although he had no previous history of allergic reaction, anaphylaxis should be included in the differential diagnoses because of the definition of anaphylaxis criteria 1 or 2. Blood tests are not necessary for the diagnosis of anaphylaxis. However, measuring serum tryptase and histamine may help to distinguish anaphylaxis from other diseases with similar symptoms. Similarly, chest X-ray and electrocardiogram can also be helpful.

His chest X-ray showed no active lesion in the lung or significant cardiomegaly. Electrocardiogram showed no significant arrhythmia or ST-T change. Initial laboratory tests showed no significant abnormalities.

Arterial blood gas analysis			CBC			Chemistry			Cardiac enzyme			Coagulation panel			Urinalysis		
pH	7.313		WBC	7450	/μL	Na	139	mmol/L	CK	68	ng/mL	PT (INR)	1.01	INR	WBC	1–4	/HPF
pCO2	43.6	mmHg	Hb	13.4	g/dL	K	3.5	mmol/L	CK-MB	1.5	ng/mL	aPTT	23.6	Seconds	RBC	1–4	/HPF
pO2	63.4	mmHg	Hct	39.6	%	Cl	102.8	mmol/L	TnI	<0.01	pg/mL	D-dimer	1.13	μg/mL	Albumin	1+	
HCO3-	21.6	mmol/L	Platelet	170,000	/μL	TCO2	20.2	mmol/L							Nitrite	Negative	
Base excess	−4.6	mmol/L				BUN	17	mg/dL							Bacteria	NA	
Lactate	5.31	mmol/L				Cr	1.45	mg/dL									
						AST	31	IU/L									
						ALT	28	IU/L									
						T.bil	0.7	mg/dL									
						ALP	45	IU/L									
						T.prot.	6.0	g/dL									
						Albumin	3.8	g/dL									

Q. What is your initial management plan?

A. 1:1000 (1 mg/mL) epinephrine 0.01 mg/kg should be injected by the intramuscular route in the mid-anterolateral thigh as soon as possible. In this case, 0.5 mg IM injection would be appropriate because the maximum dose of epinephrine IM injection for anaphylaxis is 0.5 mg in adults.

Although H1-antihistamines cannot inhibit the release of mediators from mast cells and basophils, it can relieve itching, flushing, urticaria, angioedema, and nasal and eye symptoms. Thus chlorpheniramine 10 mg or diphenhydramine 25–50 mg can be administered intravenously.

Glucocorticoids can switch off transcription of a multitude of activated genes that encode pro-inflammatory proteins. They can potentially relieve protracted anaphylaxis symptoms and prevent biphasic anaphylaxis, even though these effects have never been proven. Therefore, glucocorticoids are not lifesaving in initial hours of an anaphylactic episode, but they can be considered as second-line medications. Hydrocortisone 200 mg or methylprednisolone 1 mg/kg can be administered intravenously.

His symptoms were completely resolved after 0.5 mg IM injection of epinephrine. The patient wanted to be discharged home.

Q. Will you discharge the patient?

A. Biphasic anaphylaxis can occur in about 5–10% of anaphylaxis patients. Patients should be monitored for at least 4 h and, if necessary, up to 24 h.

Two hours later, tachycardia (112 bpm) with desaturation (SpO2 at 90%) developed. Patient had dyspnea and his blood pressure was 78/40 mmHg. EKG monitoring showed sinus tachycardia with no ST-segment abnormality. There was no evidence of urticaria, flush, or facial edema.

Q. What happened and what is the appropriate treatment?

A. The patient had respiratory (dyspnea, hypoxemia) and cardiovascular system (hypotension) involvement after complete resolution of initial anaphylactic reaction without re-exposure to the trigger. Therefore, the presumptive diagnosis is biphasic anaphylaxis.

- The treatment of biphasic anaphylaxis is the same as the anaphylaxis.
- A 1:1000 (1 mg/mL) epinephrine 0.01 mg/kg should be injected by the intramuscular route in the mid-anterolateral thigh as soon as possible.
- Give high-flow supplemental oxygen (6–8 L/min) by face mask. Place patient on the back, or in a position of comfort if there is respiratory distress.
- Give 1–2 L of 0.9% (isotonic) saline rapidly.

Ten minutes later, dyspnea and hypoxemia improved but the patient was still hypotensive (80/42 mmHg).

Q. What should be the next step?

A. A repeat dose of 1:1000 (1 mg/mL) epinephrine 0.01 mg/kg should be the choice. One can also consider vasopressors such

as dopamine, norepinephrine, phenylephrine, or vasopressin. Administration of glucagon should also be considered when the patient is taking beta-adrenergic blocker or other medications that interfere with epinephrine effect. In case of cardiac arrest, the ECMO should be considered early in patients unresponsive to traditional resuscitative measures, before irreversible ischemic acidosis develops.

Patient's blood pressure gradually increased to 108/57 mmHg after another epinephrine injection. He was admitted to the short-stay unit for 24-h observation. Until the next day, there was no recurrent anaphylaxis. He was discharged with an Epi-pen prescription.

7.12.1 Summary

In this case, the patient with anaphylaxis involving cutaneous and gastrointestinal system was safely managed with early recognition of anaphylaxis. The most important component in the initial management of anaphylactic shock is giving epinephrine. Physicians should also recognize that anaphylaxis may not appear life threatening initially without respiratory or cardiovascular symptoms. During the observation period, he had lethal biphasic anaphylaxis and was appropriately managed with oxygen supply, epinephrine injection, and fluid resuscitation. The flowchart below points out a prompt diagnostic approach and management of anaphylaxis.