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Imaging in Circulatory Arrest: Lessons to be Learned

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ABSTRACT

Objective: This study describes the computed tomography (CT) features in patients with cardiac or circulatory arrest.

Methods: We retrospectively reviewed the CT of 5 patients (age range – 6–50 years) who had circulatory arrest while undergoing imaging, within a 12 month period in our Trauma and Emergency Centre. The presence or absence of contrast in the right and left chambers of heart, venous and arterial system, contrast density, and layering were assessed.

Results: Contrast pooling and layering in superior vena cava, inferior vena cava, and right heart chambers were common (5/5 patients). Left heart chambers and systemic arteries were non-opacified. Reflux of contrast was seen in hepatic veins (4/5), portal vein, and renal veins (2/5 patients). Three patients showed pooling in lumbar and posterior external venous plexus. One patient showed contrast in splenic and superior mesenteric vein and two patients had dense opacification of pelvic veins. All patients had a dismal prognosis and died within 24 h.

Conclusion: The absence of left-sided chamber opacification and layering and pooling of dense contrast in the venous system is specific imaging signs of circulatory arrest. These features need to be recognized immediately, scanning terminated, and resuscitation initiated.

Keywords: Circulation, Arrest, Cardiac, Computed tomography, Contrast, Layering

INTRODUCTION

It is not uncommon to image a patient who has cardiac arrest or is in imminent cardiogenic shock.

Heart failure causes circulatory stasis seen as contrast pooling and layering within the venous system with the absence of left heart chamber or arterial opacification.[1]

Computed tomography (CT) features are typical and must be recognized immediately by the resident and technician on duty. Active clinical and electrophysiological monitoring of unstable patients referred to the radiology department both before and during CT scans is essential. As CT scans have become an inevitable investigative modality in the triage of extremely sick and unstable patients, the incidence of adverse events during image acquisition is likely to increase. Sudden deterioration can also be mistaken for contrast-mediated reaction. Knowledge of imaging findings is required for prompt diagnosis and to avoid delay in resuscitation. We highlight contrast-enhanced CT (CECT) features in circulatory arrest. Radiologists and technicians should not only be trained to recognize the imaging features but also undergo regular training in basic and advanced life support to deal with such life-threatening situations appropriately.

METHODS

We retrospectively reviewed the CT scans of 5 patients (age range – 6–50 years) with circulatory arrest within a 12 month period in our Trauma and Emergency Centre (November 2016–October 2017). This center has a 64 slice CT scanner and performs around 40,000 CT scans per year. CT scans were performed on a 64 slice CT scanner (Lightspeed at GCT, GE Healthcare, Buckinghamshire, UK), collimation of 0.625 mm, and reconstruction interval of 1.25 mm. 100 ml of iohexol (Omnipaque at 300, GE Healthcare, Princeton, NJ, USA) was injected at 2.5 ml/s in the adult patients for CT chest and abdomen and 80 ml at 3.5 ml/s for CT pulmonary angiography and at 2ml/kg in the pediatric patients. All patients were hemodynamically unstable with hypotension and were on ventilator support at the time of being transferred for scanning and on inotropes and intravenous fluids. Three patients had CT pulmonary angiography to rule out pulmonary thromboembolism [Cases 1-3, Figures 1-3], and two patients had CT chest and abdomen for trauma evaluation [Cases 4 and 5, Figures 4 and 5].

RESULTS

Dense contrast pooling and layering in superior vena cava (SVC) and inferior vena cava (IVC) were present in 100% ($n = 5$).

Contrast layering was also seen in the right heart chambers with non-opacification of left heart chambers and arterial system in all patients ($n = 5$).

Dense contrast reflux was seen in hepatic veins (4/5) and in renal veins in patients who underwent CT of the abdomen (2 patients). Two patients who underwent CT chest and abdomen had dense hepatic parenchymal opacification,

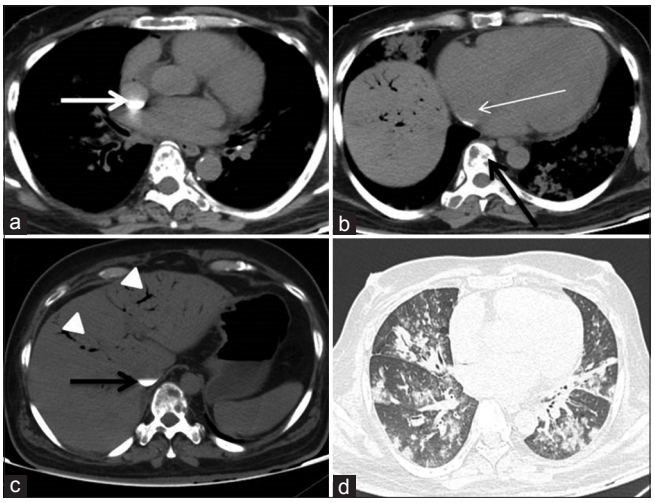

Figure 2: A 50-year-male patient with a history of myeloma presented with hypotension, shock, and feeble pulses. Computed tomography pulmonary angiography axial images show contrast pooling and layering in superior vena cava (2a; thick white arrow), right atrium (2b; thin white arrow), and inferior vena cava (2c; thick black arrow). Air is seen in portal branches (2c; arrowheads). Lung window image (2d) shows patches of consolidation with centrilobular nodules in both lungs. Lytic vertebral lesions seen (2b; long black arrow).

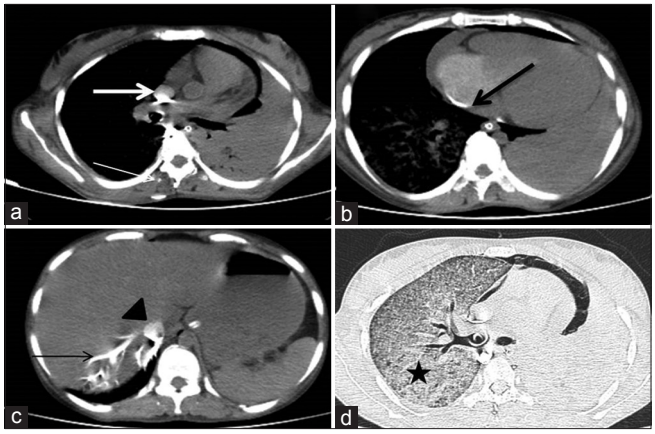

Figure 1: A 25-year-old female with a history of tuberculosis presented with sudden-onset dyspnea and shock. Computed tomography pulmonary angiography axial images show contrast pooling and layering in superior vena cava (1a; thick white arrow), right atrium (1b; thick black arrow), pooling in posterior external vertebral plexus (1a; thin white arrow), inferior vena cava (1c; arrow head), and right hepatic veins (1c; thin black arrow). Lung window images (1d) shows miliary nodules in left lung (star) with left pneumothorax and collapse of left lung with left pleural effusion. Endotracheal tube tip is noted in the right bronchus.

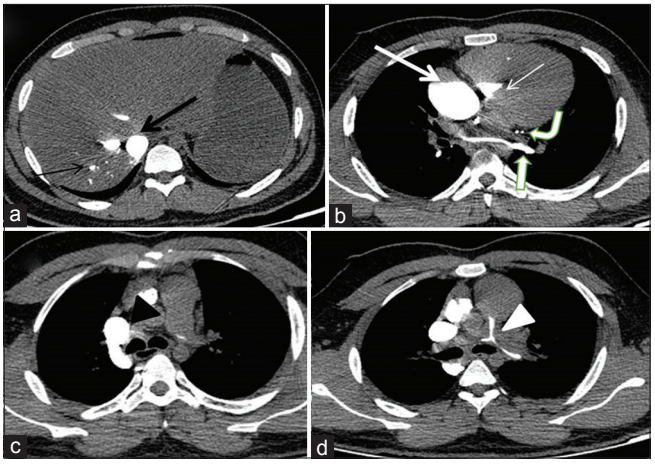

Figure 3: A 28-year-male with no prior known history presented with shortness of breath and shock. Computed tomography pulmonary angiography axial images show dense contrast in inferior vena cava (3a; thick black arrow), right hepatic veins (3a; thin black arrow), pooling and layering in RA (3b; thick white arrow), RV (3b; thin white arrow), superior vena cava and azygous vein (3c; black arrow head), and pulmonary artery (3d; white arrow head). Opacification of cardiac veins (3b; curved arrow) and accessory hemiazygs vein is seen (3b; short arrow).

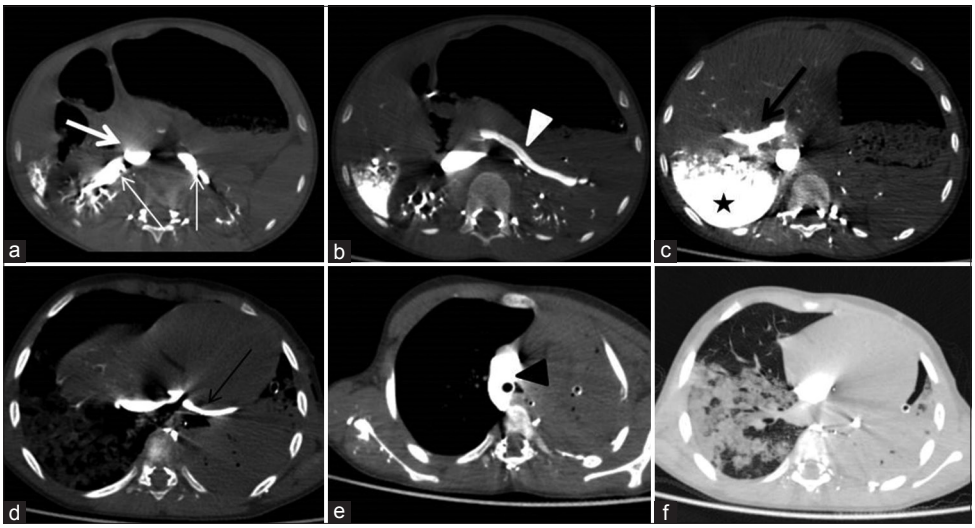

Figure 4: A 10-year-male with a history of polytrauma presented with shock. Contrast-enhanced computed tomography chest and abdomen axial images show dense contrast pooling and layering in inferior vena cava (4a; thick white arrow), renal veins and renal sinusoids (4a; thin white arrows). Dense hepatic parenchymal opacification (*) with retrograde filling of right portal vein (4c; thick black arrow) and splenic vein (4b; white arrow head), coronary sinus (4d; thin black arrow), superior vena cava and azygos vein (4e; black arrow head) is seen. Lung window images (4f) show contusions in both lungs with left pneumothorax and intercostal drainage tube.

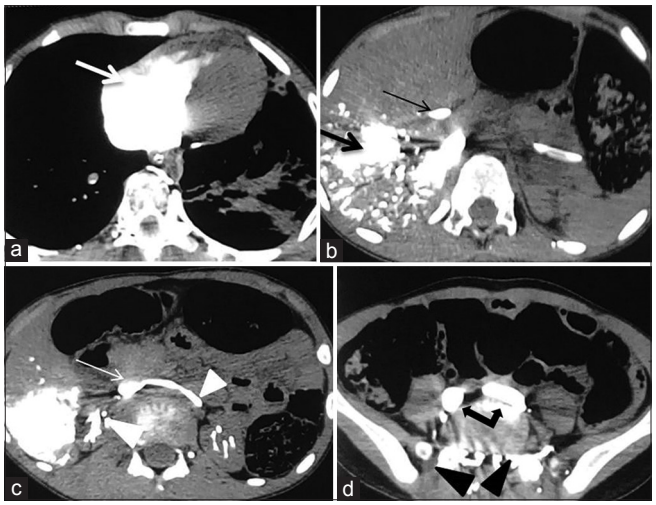

Figure 5: A 6-year-male with a history of polytrauma presented with shock and feeble pulses. Contrast-enhanced computed tomography chest and abdomen axial images show dense contrast pooling in right atrium and right ventricle (5a; thick white arrow), portal vein (5b; thin black arrow), hepatic veins and sinusoids (5b; thick black arrow), inferior vena cava (5c; thin white arrow), renal veins (5c; white arrow heads), common iliac veins (5d, curved arrow) and lumbar venous plexus (5d; black arrow heads).

the right lobe of liver with a branching pattern resembling tree-in-bud opacities and portal vein opacification [Figures 4 and 5]. One patient had splenic vein and superior mesenteric vein (SMV) opacification [Figure 4].

Three patients showed pooling in lumbar or posterior external venous plexus in the back [Figure 5] two patients had opacification of common, internal and external iliac veins [Figure 5].

The radiological diagnosis was missed by the resident on call in 4 out of 5 cases.

The clinical and imaging findings and the outcome are summarized in Table 1.

DISCUSSION

It is a common occurrence to image sick and hemodynamically unstable patients in a busy Emergency and Trauma Centre with the advent of multidetector CT scanners with rapid acquisition and quick information provided which may be vital for patient management. Controversy remains about the need for imaging in extremely unstable patients. However, such patients are often sent for imaging after primary stabilization and ventilator assistance. These patients always remain in danger of sudden deterioration leading to cardiac or circulatory arrest, during the time interval between the patient being shifted and taken for the scan.

Circulatory arrest leads to reduced perfusion of vital organs due to decreased cardiac output secondary to pump failure. It carries a very high mortality. A vast number of causes have been attributed to this phenomenon; common causes are hypovolemia, hypoxic injury, metabolic causes, hypothermia, pulmonary thromboembolism, massive or tension pneumothorax, and toxins.[2]

Electrophysiological features are well described and recognized. However, electrocardiogram (ECG) features may

Table 1: Clinical and imaging findings of patients with circulatory arrest.

Case	Sex	Age	Primary disease	Imaging findings suggestive of circulatory arrest	Other imaging findings	Outcome
1	F	25	Tuberculosis	Contrast pooling in SVC,§ IVC,* right hepatic veins, RA†, RV‡ and posterior external vertebral plexus in the back [Figure 1]	Collapse of the left lung, miliary nodules in the right lung, left pneumomediastinum, left pleural effusion	Died within 24 h
2	M	50	Multiple myeloma	Pooling and layering of contrast in SVC, IVC, and RA [Figure 2]	Patches of consolidation and nodules both lungs, Air in portal vein, lytic lesions in vertebra	Died within 24 h
3	M	28	Not known	Pooling of contrast in SVC,‡ IVC* and hepatic veins. Layering of contrast in RA, RV and pulmonary arteries [Figure 3]	No other significant finding	Died immediately after the scan
4	M	10	Trauma	Pooling of contrast in SVC, IVC, hepatic veins, renal veins, splenic vein, portal vein, posterior external and lumbar venous plexus [Figure 4]	Bilateral lung lacerations, left pneumothorax, multiple left rib fractures	Died immediately after the scan
5	M	6	Trauma	Pooling of contrast in IVC, hepatic veins, renal veins, portal vein, and lumbar venous plexus [Figure 5]	Left lung contusion	Died immediately after scan

*IVC, †RA, ‡RV, §SVC. IVC: Inferior vena cava, RA: Right atrium, RV: Right ventricle, SVC: Superior vena cava

also be misleading with pulseless electrical activity simulating normal ECG in the presence of pump failure.[2]

Imaging features

Patients with impending circulatory arrest have typical imaging characteristics on CECT. CT scan frequently demonstrates contrast pooling independent areas commonly seen in IVC, SVC, right heart chambers (right atrium [RA] and right ventricle [RV]), and vertebral venous plexus.[2,3]

Contrast pooling is seen as a result of pump failure against gravity with reflux into IVC and hepatic veins due to the right heart failure and absence of dilution with flowing blood lead to dense appearance.[3]

A blood-contrast level is described in these patients, with contrast due to its high-density lying in the dependent part.[3,4] A blood-fluid level has been documented in half of the patients with CT performed within 2 h of death.[5]

The pressure injector injects contrast into the antecubital veins at rates of 2.5–3.5 ml/s. This causes contrast opacification of not only the venous structures close to the chest or heart but also distal opacification of pelvic and vertebral veins. The positive pressure ventilation may also aid in distal propulsion of contrast to the pelvic venous system and into hepatic sinusoids due to increased intra-abdominal pressure.

Retrograde filling through sinusoids and parenchymal opacification leading to contrast in the portal, SMV, and splenic veins has been described in previous studies.[1,3]

The final distribution of injected contrast material and resultant imaging findings depends on the injector pressure and the density of contrast material.[6]

Medico-legal significance

The radiologist and CT technician should be aware of these findings and recognize them immediately to initiate prompt resuscitative measures. Real-time monitoring of the CT acquisition is necessary by radiologists in trauma and emergency service areas to avoid delay in management. This has medicolegal significance in the era of PACS and teleradiology with off-site image transfers and reporting. The sudden deterioration in the patients' condition can also mimic contrast-mediated reaction. An absence of arterial and left heart opacification should be carefully evaluated to avoid misdiagnosis.

Misleading features

Certain imaging features may be misleading. The venous opacification and opacification of pelvic structures may be mistaken for a technical error causing delayed scan. Opacification of hepatic sinusoids with parenchymal retrograde opacification as well as renal venous opacification may further add to diagnostic confusion. In post-traumatic patients, such dense contrast opacification of the liver can mimic contrast extravasation within lacerations. However, the absence of even faint arterial and left-sided chamber opacification of the heart, dense contrast pooling within the veins with blood-contrast levels should alert the radiologist.

Arterial opacification

Tsai *et al.* and Roth *et al.* described similar findings with contrast pooling, layering, and reflux within abdominal and pelvic veins with persistent opacification of the left heart chambers and aorta due to cardiac failure in patients with aortic dissection and myocardial infarction.[4,6]

Contrast stasis and layering in the venous system in the presence of the left chamber and arterial opacification implies cardiac failure and impending arrest with an equally poor prognosis.

Root cause analysis

A root cause analysis of every adverse event in the radiology department is needed. Improper triage of patients by clinicians for radiological investigation is difficult to ascertain and prove in the setting of widespread utilization of this modality in trauma and emergency. Long waiting periods of such patients with suboptimal monitoring can hasten clinical deterioration. Better communication is warranted between the referring physician and the radiologist especially in a busy department where average waiting time exceeds several minutes. An unstable patient must be accompanied by a referring clinical resident who should constantly be monitoring vital parameters. Triage must also be done by the radiologist in the radiology suite to avoid unnecessary delay.

Training

In 5 patients, the radiological diagnosis was missed by the resident on call but was recognized clinically by the accompanying clinical resident. In one patient, the radiology resident who had seen a similar finding before immediately alerted the accompanying physician. This further highlights the need for widespread awareness. Regular training and updates in resuscitation and life support protocols are needed in every radiology setting, not only for radiologists but also for technical and support staff.

CONCLUSION

It is not uncommon to image patients with circulatory arrest as more and more hemodynamically unstable, and polytrauma patients are imaged with CT scan. Imaging findings are fairly specific and include dense contrast pooling and layering in SVC, IVC, and right heart chambers with non-opacified left heart chambers. Hepatic venous and retrograde parenchymal and portal venous splenic vein opacification is also seen in few cases and should not be mistaken for a contrast-enhanced scan. The radiologist and technician performing the scan should be aware of these findings and be prepared for immediate resuscitation.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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