

## Computed tomography of acute heart failure: A novel case and literature review

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Computed tomography (CT) is used in patients whose conditions span the gamut from healthy to critically ill. In the specific subset of patients with cardiac arrest or imminent cardiac failure who receive contrast-enhanced CT, extant literature illustrates a set of imaging findings that include inferior vena cava and hepatic parenchymal contrast reflux, pooling, and layering in a dependent fashion. We review the literature and present a case in which these findings are demonstrated along with renal venointerstitial reflux, a finding that has not been previously described.

### Introduction

Computed tomography is widely used in inpatient, outpatient, and emergency settings. Patients who undergo CT span the gamut of conditions, with asymptomatic, healthy individuals who may be scanned for candidacy as living kidney or partial liver donors at one extreme. At the other extreme are critically ill patients who either sustain cardiac arrest during the imaging procedure or shortly thereafter. In the subset of patients with either cardiac arrest or imminent cardiac failure who undergo a CT study with intravenous contrast, a number of specific imaging findings have been described by previous authors, including inferior vena cava and hepatic parenchymal contrast reflux, pooling, and layering in a dependent fashion. In this paper, we review the literature of CT imaging in the setting of cardiac arrest or imminent cardiac failure. We also present a case that demonstrates both these previously described imaging findings as well as a novel finding of venointerstitial reflux: that is, forced reflux of contrast from the renal veins into the renal interstitium in a manner analogous to pyelointerstitial

reflux (described in the voiding cystourethrography literature).

### Literature review

We performed searches on PubMed and Google Scholar for the query terms “cardiac arrest” and “computed tomography.” These general search terms produced a surplus of results, as there has been much scholarly activity regarding the imaging appearance of the heart itself and the brain in the setting of cardiac arrest. Manual parsing of the results to those relevant to our intended query revealed five groups that have described imaging findings of contrast-enhanced CT performed in patients with imminent or actual cardiac arrest.

We summarize the findings of previous authors in order of publication. Ko, et al. initially described imaging findings of “strikingly dense abdominal veins, variable degrees of arterial enhancement, and poor abdominal visceral enhancement.”<sup>(1)</sup> Singh, et al. in a nearly contemporaneous publication, described “reflux of contrast into the abdomen as indicated by opacification of renal veins, hepatic veins, inferior vena cava, and hepatic and renal parenchyma,” and additionally described a case of reflux into the portal vein <sup>(2)</sup>. Roth, et al. refined the description in their later work, noting dependent pooling and layering of contrast within the superior vena cava and right atrium as well as “a contrast-blood interface and pooling in [...] the IVC, dependent hepatic veins, right renal vein, lumbar veins, and iliac veins.” Jana, et al. echoed these findings in their own small case series <sup>(3, 4)</sup>. Most recently, Sami, et al. have described a case of complete cardiac arrest in which no opacification of the left heart was seen, and in which

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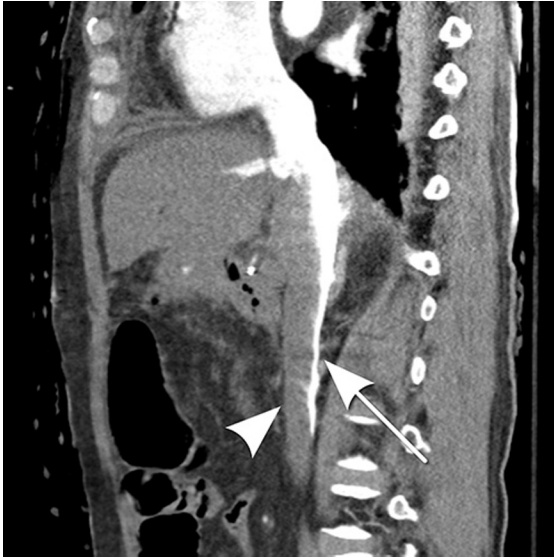


Fig. 1. Right parasagittal reformatted image from a contrast-enhanced CT of the abdomen and pelvis obtained 75 seconds after contrast injection shows reflux of contrast from the right atrium into the dependent portion of the IVC (arrow), without opacification of blood pool within the non-dependent portion of the IVC lumen (arrowhead).

there was “regurgitation of contrast medium from the right atrium into the inferior vena cava and hepatic veins”(5).

From these extant works, a number of common imaging features are readily evident, including reflux of contrast into the inferior vena cava, hepatic, and occasionally renal veins; layering of contrast in a dependent manner; and parenchymal enhancement in the dependent portion of the liver. Some authors describe reflux even more distally, to the level of the pelvis, while others do not, likely reflecting heterogeneity in the cardiac output of the patients being examined, as these series include patients in both frank present and imminent cardiac arrest.

Building on this published literature, we present the case of a patient who received a CT scan during a brief period of marginal cardiac function, flanked by periods of cardiac arrest. This case both illustrates the previously described imaging findings, including that of pooling and layering as described by Roth, et al. and additionally depicts a novel, previously undescribed finding of renal interstitial contrast reflux via the renal vein.

### Case report

A 65-year-old man with a distant history of coronary artery disease requiring angioplasty and stenting (as well as pancreatic adenocarcinoma resected several weeks earlier) presented in ventricular fibrillation that progressed rapidly to pulseless electrical activity. Emergency medical services performed cardiopulmonary resuscitation en route to the emergency department, with return of spontaneous circulation after four rounds of intravenous epinephrine and defi-

brillation shocks. Upon arrival in the emergency room, a new right bundle branch block was diagnosed with electrocardiography and, given this finding, CT, pulmonary angiography, and nonangiographic imaging of the abdomen and pelvis were emergently performed. Almost immediately after performance of these CT studies, the patient sustained another cardiac arrest, with 30 minutes of cardiopulmonary resuscitation performed during pulseless electrical activity. The patient was pronounced deceased after cardiac activity could not be revived.

### Findings and diagnosis

CT and pulmonary angiography revealed no pulmonary embolus, but did demonstrate rib and chondral fractures consistent with prolonged cardiopulmonary resuscitation. Imaging of the abdomen and pelvis performed at a 75-second delay from initial contrast bolus injection revealed dense opacification of the aorta as well as retrograde opacification, layering, and pooling of contrast within the dependent aspects of the inferior vena cava, hepatic veins, and right renal vein (Fig. 1). Contrast opacified the dependent aspect of the right hepatic lobe parenchyma (Fig. 2). Furthermore, contrast also was seen exclusively within the right renal parenchymal interstitium, contiguous with the opacified renal veins, without contrast within either the left or right renal collecting system to suggest excretion (Fig. 3).

The imaging findings indicative of right heart failure, along with the clinical scenario of known coronary artery disease, new right bundle branch block, and pulseless electrical activity immediately before and after (but not during)

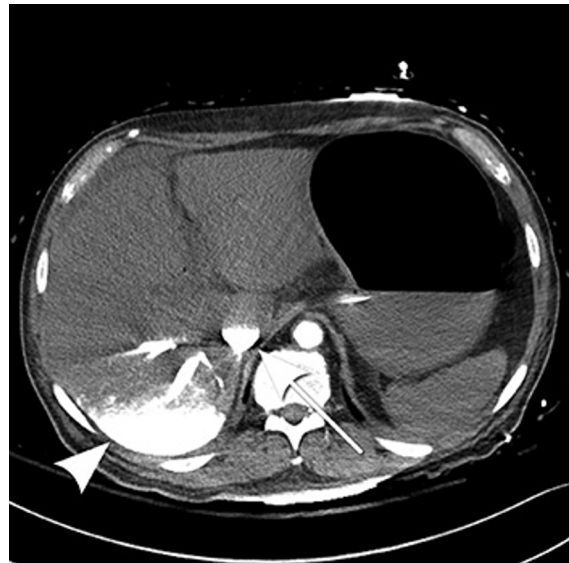


Fig. 2. Axial image from a contrast-enhanced CT of the abdomen and pelvis obtained 75 seconds after contrast injection shows reflux of contrast into the dependent portion of the IVC (arrow) as well as reflux of and pooling of contrast within the dependent hepatic veins and parenchyma (arrowhead).

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the performance of the CT exams were consistent with a clinical diagnosis of myocardial infarction. No autopsy was performed.



Fig.3. Axial image from a contrast-enhanced CT of the abdomen and pelvis obtained 75 seconds after contrast injection shows reflux of contrast into the right renal vein as well as interstitial reflux within the right renal parenchyma (arrow).

### Discussion

This constellation of imaging findings has no differential diagnosis, and is indicative of acute right heart failure requiring emergent clinical intervention. The dependent layering of injected iodinated contrast material reflects the higher specific gravity of the injected contrast material relative to blood. In particular, the iopamidol injection 76% contrast used (Isovue 370; Bracco, Inc; Monroe Township, NJ, USA) has a specific gravity of 1.405, while whole blood at body temperature has been reported as 1.0506 (6). In most clinical scenarios where a patient may receive an injection of iodinated contrast, this difference in specific gravity does not result in a dependent distribution of contrast due to the mixing effect of cardiac output, which typically is one to two orders of magnitude greater than contrast injection rates as measured by right heart catheterization (7, 8). This patient's heart rate was noted to be in the 50s and systolic blood pressure in the 80s, at the time of the computed tomography exams. Iodinated contrast was injected at a relatively high rate of 5 mL/second, as the first study performed sequentially was a pulmonary angiogram. Assuming a mean male body surface area of 1.9 square meters as per Smorenburg, et al.'s published data, and normalizing to a resting heart rate of 70, we thereby indirectly estimate that this patient's cardiac output to be 1/15th that expected by the norms established by Stead, et al., concordant with the clinical scenario of marginal cardiac func-

tion, wherein the patient was in pulseless electrical activity immediately before and after the exam.

The specific finding of interstitial reflux of contrast into the right kidney (Fig. 3) is one that we believe has not previously been described in the literature. Multiple authors have described the significance of inferior vena cava contrast reflux and nonhomogeneous hepatic parenchymal enhancement in association with right heart dysfunction (9-12). Additional findings of right atrial, renal vein, and hepatic parenchymal contrast pooling have been described in the specific setting of imminent or current cardiac arrest, as summarized above (1-5.) Intrarenal reflux, both pyelotubular and pyelointerstitial, has been long described in the voiding cystourethrography literature (13, 14). We posit that the reflux that we demonstrate in this case represents the same phenomenon, only achieved via increased pressure in the renal vein rather than in the renal collecting system, as in the case of vesicoureteral reflux, and therefore characterize this phenomenon as venointerstitial reflux.

### Conclusion

This case demonstrates multiple imaging features of heart failure, including renal venointerstitial reflux, a finding that we believe is novel in the literature. Knowledge of both the common and uncommon manifestations of heart failure, as well as our technique of estimated actual versus expected cardiac output, may aid radiologists in interpretation of CT studies performed on critically ill patients.

### References

1. Ko SF, Ng SH, Chen MC, Lee TY, Huang CC, Wan YL. Sudden cardiac arrest during computed tomography examination: clinical findings and "dense abdominal veins" on computed tomography. *Journal of Computer Assisted Tomography*. 2003;27(1):93-7. [PubMed]
2. Singh AK, Gervais D, Mueller P, Shirkhoda A, Sagar P, McCarroll K. Cardiac arrest: abdominal CT imaging features. *Abdominal Imaging*. 2004;29(2):177-9. doi: 10.1007/s00261-003-0120-0. PubMed [PubMed]
3. Roth C, Sneider M, Bogot N, Todd M, Cronin P. Dependent venous contrast pooling and layering: a sign of imminent cardiogenic shock. *AJR American Journal of Roentgenology*. 2006;186(4):1116-9. doi: 10.2214/AJR.04.1850. [PubMed]
4. Jana M, Gamanagatti SR, Kumar A. Case series: CT scan in cardiac arrest and imminent cardiogenic shock. *The Indian Journal of Radiology & Imaging*. 2010;20(2):150-3. doi: 10.4103/0971-3026.63037. [PubMed]
5. Sami KA AN, Osman T, Emine U, Seda O. Cardiac arrest during computed tomography scanning: Imaging findings. *Journal of Radiology & Radiation Therapy*. 2013;1(3):1018.
6. Trudnowski RJ, Rico RC. Specific gravity of blood and plasma at 4 and 37 degrees C. *Clinical Chemistry*. 1974;20(5):615-6. [PubMed]

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7. Stead EA, Warren JV, Merrill AJ, Brannon ES. The cardiac output in male subjects as measured by the technique of right atrial catheterization. Normal values with observations on the effect of anxiety and tilting. *The Journal of Clinical Investigation*. 1945;24(3):326-31. doi: 10.1172/JCI101609. [[PubMed](#)]
8. Smorenburg CH, Sparreboom A, Bontenbal M, Stoter G, Nooter K, Verweij J. Randomized cross-over evaluation of body-surface area-based dosing versus flat-fixed dosing of paclitaxel. *Journal of Clinical Oncology: Official Journal of the American Society of Clinical Oncology*. 2003;21(2):197-202. [[PubMed](#)]
9. Yeh BM, Kurzman P, Foster E, Qayyum A, Joe B, Coakley F. Clinical relevance of retrograde inferior vena cava or hepatic vein opacification during contrast-enhanced CT. *AJR American Journal of Roentgenology*. 2004;183(5):1227-32. doi: 10.2214/ajr.183.5.1831227. [[PubMed](#)]
10. Moulton JS, Miller BL, Dodd GD, 3rd, Vu DN. Passive hepatic congestion in heart failure: CT abnormalities. *AJR American Journal of Roentgenology*. 1988;151(5):939-42. doi: 10.2214/ajr.151.5.939. [[PubMed](#)]
11. Holley HC, Koslin DB, Berland LL, Stanley RJ. Inhomogeneous enhancement of liver parenchyma secondary to passive congestion: contrast-enhanced CT. *Radiology*. 1989;170(3 Pt 1):795-800. doi: 10.1148/radiology.170.3.2916031. [[PubMed](#)]
12. Gore RM, Mathieu DG, White EM, Ghahremani GG, Panella JS, Rochester D. Passive hepatic congestion: cross-sectional imaging features. *AJR American Journal of Roentgenology*. 1994;162(1):71-5. doi: 10.2214/ajr.162.1.8273693. [[PubMed](#)]
13. Rolleston GL, Maling TM, Hodson CJ. Intrarenal reflux and the scarred kidney. *Archives of Disease in Childhood*. 1974;49(7):531-9. [[PubMed](#)]
14. Hodson CJ. The effects of disturbance of flow on the kidney. *The Journal of Infectious Diseases*. 1969;120(1):54-60. [[PubMed](#)]