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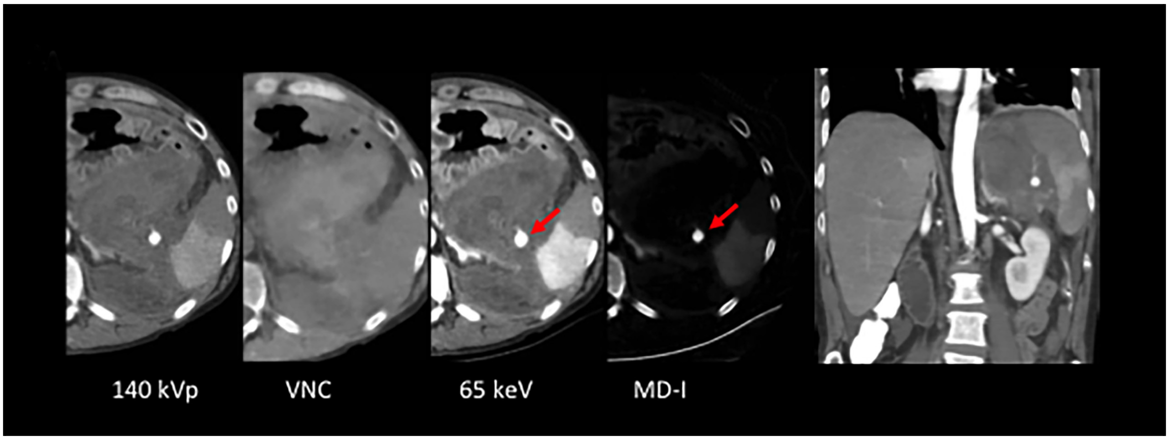

Contrast Optimization in Low Radiation Dose Imaging

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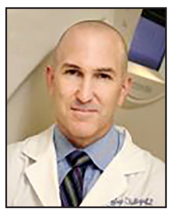

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CE Accreditation Information

Contrast Optimization in Low Radiation Dose Imaging

Program Information

Date of Release: 07/01/16
Date of Expiration: 06/30/18
Estimated time to complete: 1 Hour

Target Audience

Radiologic Technologists

Learning Objectives

At the end of this educational activity, the participant (learner) will be able to:

- Review the need for strategies that minimize radiation exposure due to medical imaging in general, and to computed tomography (CT) examinations in particular;
- Define the key CT acquisition and postprocessing protocol parameters that impact radiation dose;
- Discuss the use of low kVp and high-concentration contrast media (HCCM) to maximize quality and consistency, and minimize radiation dose; and,
- Explain the synergistic impact of HCCM and iterative reconstruction (IR) post-processing techniques to increase CTA signal-to-noise ratios and image quality recovery.

Accreditation

Radiologic Technologists

This course meets all criteria and has been approved by the AHRA, The Association for Medical Imaging Management, for one (1) ARRT Category A CE Credit.

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Introduction

Medical exposure is currently one of the largest sources of radiation exposure in the United States, and computed tomography (CT) imaging is the largest source of medical exposure.[1,2] Governmental and regulatory agencies, as well as professional radiologic societies and equipment manufacturers, are all invested in balancing the estimated risk of radiation exposure with the potential diagnostic benefit of CT imaging. Radiation exposure reduction is important to consider in all patients, particularly in pediatric patients and in those who may have a diagnosis requiring multiple CT scans during their lifetime.

According to Image Wisely®, the American College of Radiology and the Radiological Society of North America Joint Task Force on Adult Radiation Protection, a stepwise approach to minimizing radiation dose is recommended.[3,4] Preliminary steps include confirming the exam is indicated and has not been performed elsewhere recently, and also ensuring that equivalent information cannot be obtained from an alternative imaging exam associated with less exposure. Once these criteria have been met, there are several steps that can be taken for all exams, regardless of the specific protocol. These include scanning only the requested and required region of interest, eliminating any unnecessary acquisition phases, and ensuring that the patient is carefully centered on the gantry table, all of which will reduce overall radiation exposure.

Optimizing specific CT protocol parameters can also contribute to lowering radiation dose exposure. For example, reducing both tube current (mA) and tube voltage (kV) will result in reductions in radiation dose; however, it is important to note that small reductions in kV have a more substantial effect on radiation dose reduction.[5,6] Moreover, for iodinated contrast-enhanced exams, lower kVp values result not only in lower radiation dose exposure, but also higher contrast enhancement, especially when employed with high-iodine–concentration contrast media (HCCM).[7-9] Modern postprocessing iterative reconstruction (IR) techniques start with the original filtered back-projection (FBP) and then iteratively refine the data, resulting in reduced noise within the CT images. These techniques help "recover" image quality at lower tube currents and voltages, and in doing so help to substantially reduce net radiation doses while producing high-quality CT images.[10]

When implemented appropriately, the core radiation-dose reduction strategies discussed above can greatly reduce patient exposure while maintaining acceptable image quality. Ensuring appropriate indications and scan coverage, as well as using the lowest possible mA and kV, should always be the cornerstones of a thoughtful and responsible approach to diagnostic CT; tube current modulation, low-kV imaging, and IR allow increased contrast enhancement at lower doses with acceptable noise levels. Using HCCM to achieve high-iodine flux contributes to improved diagnostic performance. Designing protocols for each indication in the context of acceptable radiation exposure and diagnostic image quality allows for overall radiation doses to be contained while CT use continues to advance. Here we present four cases that utilize HCCM protocols to produce high-quality images while reducing radiation dose exposure.

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Enterocolonic fistula with exacerbation of Crohn's disease

Khalid W Shaqdan, MD; Manuel Patino, MD; Dushyant Sahani, MD

SUMMARY

A 41-year-old male with a history of Crohn's disease presented with abdominal cramps and discomfort. Physical examination revealed distended abdomen. Labs showed CRP elevated to 61. Colonoscopy was performed and prematurely aborted due to a benign-appearing likely inflammatory stricture in the mid sigmoid. Patient was admitted, and computed tomography enterography (CTE) with IV and oral contrast was ordered.

CT was performed with a 128-section multidetector row dual-energy CT (DECT) scanner (Somatom Definition Flash, Siemens Medical Solutions; Forchheim, Germany). The patient was administered 90 mL of Isovue 370 (iopamidol, Bracco Diagnostics) via 20 gauge IV catheter by power injection (Empower CTA) at a rate of 4 mL/s. The patient was also given 0.1% barium suspension (VoLumen, E-Z-EM) as neutral oral contrast medium (total of 1350 mL prior to the scan; 450 mL at 60 minutes, 450 mL at 40 minutes, 450 mL at 15 minutes followed by 8 oz of water at 5 minutes). Dual energy data was acquired using the following parameters: tube potential of 140/100 kVp, mA ref 88/160 and 72/124, pitch of 0.95, rotation speed of 500msec, and a slice thickness of 5 mm. The images were reconstructed using SAFIRE level 3.

DIAGNOSIS

Enterocolonic fistula with exacerbation of Crohn's disease

IMAGING FINDINGS

There is mucosal hyperenhancement and mild wall thickening involving a long segment of the terminal ileum (Figure 1). There is fat stranding within the deep pelvis between the terminal ileum and the sigmoid colon with adjacent trace of free fluid (Figure 1). These findings likely represent active inflammation. In addition, there is an associated enterocolonic fistula likely between the terminal ileum and cecum without the presence of an abscess (Figure 1).

DISCUSSION

CTE has become the preferred method for initial imaging of the small bowel, as the image quality is superior to other modalities and the exam is well tolerated by patients.[1,2] However, the prevalent use of CTE has become concerning in terms of radiation exposure, since patients are often young and will likely undergo multiple imaging studies to monitor their disease.[3,4] The use of low-dose CT techniques have, therefore, been developed preserving diagnostic yield at considerably reduced radiation exposure.[5] Low CT tube voltage and the administration of high-concentration contrast media (HCCM) yields greater contrast enhancement for a given injection of contrast medium, lowering the iodinated contrast medium requirements. Additionally, the ability to generate a virtually nonenhanced scan with DECT removes the need for a separate nonenhanced scan. Several studies have also shown considerable radiation dose reduction using iterative reconstruction algorithms in abdominal CT.[6-8]

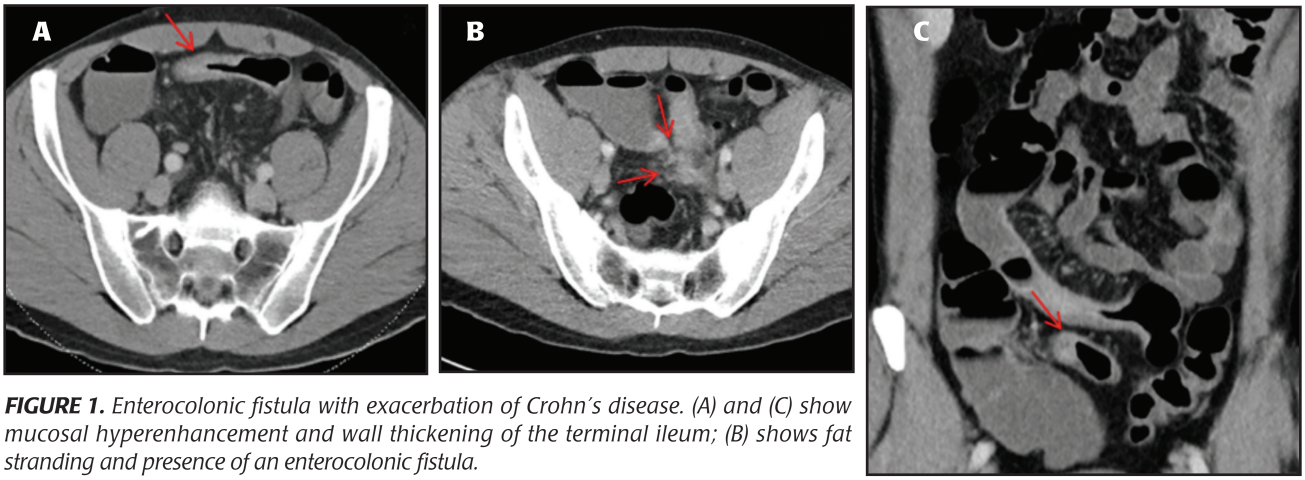

FIGURE 1. *Enterocolonic fistula with exacerbation of Crohn's disease. (A) and (C) show mucosal hyperenhancement and wall thickening of the terminal ileum; (B) shows fat stranding and presence of an enterocolonic fistula.*

These techniques are collectively used to maintain high diagnostic image quality at considerably reduced radiation exposure.

With the use of our contrast media and scanning protocol we can easily appreciate the location of the fistula, and the extent of bowel inflammation in this patient. After the patient was managed he was discharged on oral steroids and antibiotics, with a close GI-follow up plan.

CONCLUSION

With routine use of dose reduction techniques and appropriate protocols for CTE, the radiation safety profile for patients can be improved without compromising image quality.

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Questions To Consider

It is important to consider radiation exposure when performing CTE since:

a. Patients are often young and will likely undergo multiple imaging studies to monitor their disease
b. CTE is most commonly performed in pregnant women
c. Many patients requiring CTE have metal implants
d. Patient motion results in more artifacts

CT enterography (CTE) has become the preferred method for initial imaging of the small bowel because:

a. It provides higher quality images compared to other modalities
b. The exam is well tolerated by patients
c. A and B
d. None of the above

The use of low-radiation–dose CT techniques have been developed that:

a. Reduce diagnostic yield at considerably reduced radiation exposure
b. Preserve diagnostic yield at considerably reduced radiation exposure
c. Preserve diagnostic yield at considerably increased radiation exposure
d. Preserve diagnostic yield without affecting radiation exposure

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Splenic artery pseudoaneurysm

Khalid W. Shaqdan, MD; Manuel Patino, MD; Dushyant Sahani, MD

SUMMARY

A 53-year-old male with a history of alcoholism and chronic pancreatitis presented to the emergency department with an acute episode of abdominal pain. Physical examination revealed a distended abdomen with epigastric tenderness radiating to the suprapubic region. Due to the uncertain nature of his clinical findings, the patient was admitted to the hospital, treated medically for his pancreatitis, and further investigation with a computed tomography (CT) scan of the abdomen was ordered.

Dual phase CT was performed with a fast kVp switching 64-section multidetector row dual-energy CT scanner (DECT; Discovery 750 HD; GE healthcare, Milwaukee, WI). The patient was administered 90 mL of Isovue 370 (iopamidol, Bracco Diagnostics) via 18 gauge IV catheter by power injection (Empower CTA) at a rate of 3 mL/s. Arterial phase contrast-enhanced CT scanning was initiated after an enhancement threshold of 150 was reached. Dual energy data was acquired using the following parameters: tube potential of 140/80 kVp, tube current of 600 mA, pitch of 1.375:1, rotation speed of 0.8, and a slice thickness of 2.5 mm. The images were reconstructed using ASiR 50%.

IMAGING FINDINGS

There is a hyperdense soft tissue abnormality/collection in the left upper quadrant that extends along the paracolic gutters into the pelvis (Figure 1). Within the collection, there is a well-defined 8 mm homogenous lesion showing enhancement that was isoattenuating to the splenic artery consistent with the appearance of a pseudoaneurysm (Figure 1). There is also a differential enhancement of the spleen, likely related to an evolving splenic infarct from compromised splenic artery flow (Figure 1).

DIAGNOSIS

Splenic artery pseudoaneurysm

DISCUSSION

Splenic artery pseudoaneurysms (SAAs) are found in approximately 1% of the population, and account for almost 60% of all visceral arterial aneurysms.[1] The importance of diagnosing and treating SAA lies in the possible risk for fatal complications. SAAs are usually asymptomatic, but when a rupture occurs, the patient commonly presents with epigastric pain and hypovolemic shock. Ruptured SAA has a mortality rate of 25–70 %, but with current CT technology, patients can be imaged quickly to detect such lesions, preventing fatal complications.[2,3]

Contrast-enhanced CT scanning is useful to illustrate the anatomic details of the aneurysm, associated retroperitoneal hemorrhage, and associated underlying disease. The administration of HCCM and low CT tube voltage yields greater contrast enhancement for a given injection of contrast medium, lowering the iodinated contrast medium requirements. Additionally, the ability to generate a virtually nonenhanced scan with DECT removes the need for a separate nonenhanced scan. These techniques have been individually or jointly used to achieve the least radiation dose possible to the patient while maintaining high diagnostic image quality. According to the dose index registry (DIR), the median size-specific dose estimate (SSDE) for CT abdomenangio with IV contrast at all DIR sites is 17.6 mGy.[4] The SSDE dose to the patient in this study was 11.7 mGy.

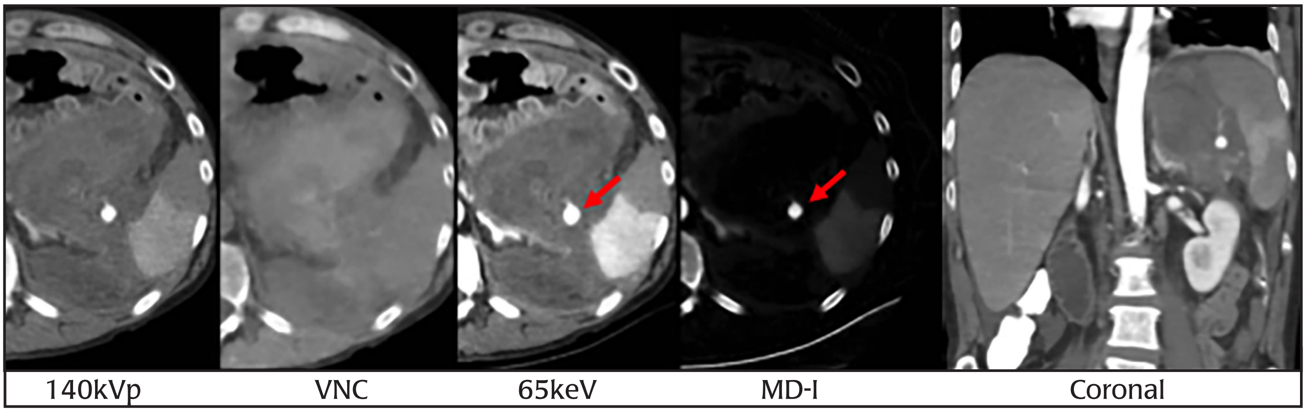

FIGURE 1. *Arterial phase contrast-enhanced DECT showing the splenic artery pseudoaneurysm and hematoma. VNC images show the hematoma as hyperdense. The contrast between the aneurysm (arrows) and the background hematoma is increased in the MD-I image. Additionally MD-I image better delineates the gastric mucosa. Differential enhancement of the spleen is well appreciated in the coronal image.*

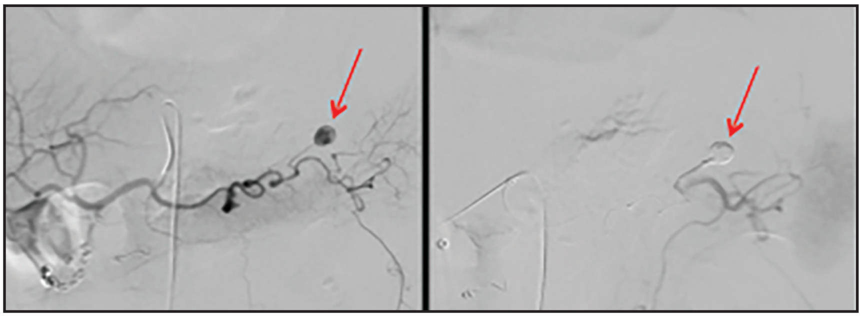

FIGURE 2. *Spleen angiogram shows pre- and post-coil embolization of the splenic artery pseudoaneurysm.*

With the use of our contrast media and scanning protocol, we can easily appreciate the location and extension of the pseudoaneurysm, and its relationship to associated blood vessels. Once the diagnosis was made the patient was managed with coil embolization by an interventional radiologist (Figure 2). The patient was then transferred to the ICU for close observation.

CONCLUSION

A combination of low-kVp CT and HCCM administration can obtain high diagnostic image quality with substantially reduced radiation dose.

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Questions To Consider

In the case of SAA, contrast-enhanced CT scanning is useful to illustrate:

a. The anatomic details of the aneurysm
b. Associated retroperitoneal hemorrhage
c. Associated underlying disease
d. All of the above

One of the advantages of dual-energy CT (DECT) is:

a. The ability to generate a virtually nonenhanced scan, negating the need for a separate nonenhanced scan
b. The lack of ionizing radiation
c. The ability to perform filtered back-projection (FBP) postprocessing
d. None of the above

Splenic artery pseudoaneurysms (SAAs) are important to diagnose and treat because although typically asymptomatic, if rupture occurs, they are potentially fatal. SAAs are found in approximately what percent of the population?

a. 50%
b. 10%
c. 5%
d. 1 %

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CTA and perfusion CT following stroke

Lawrence N. Tanenbaum, MD, FACR

CASE SUMMARY

An 80-year-old male presented to the emergency room (ER) sometime after onset of right hemispheric stroke symptoms. An unenhanced CT of the head revealed no evidence of stroke or hemorrhage (Figure 1A); thus, he was a candidate for intravenous thrombolytic therapy. Inspection of the intracranial vasculature led to detection of a hyperdense (ie, denser than other arteries of similar or larger size) right internal carotid artery (ICA) and middle cerebral artery (MCA) – a finding strongly suggestive of thrombosis (Figure 1B). While eligible patients should still receive intravenous recombinant tissue plasminogen activator (rTPA), endovascular therapy is now the standard of care for cardiovascular accident (CVA) caused by large vessel occlusion. Because of uncertainty as to the time since symptom onset, a combined time-resolved CT angiography (CTA) and perfusion CT (PCT) was performed.

IMAGING FINDINGS

The early and late phases of the time-resolved CTA reveal occlusion of the right ICA, with markedly delayed filling and draining of the right MCA and its branches via collaterals (Figure 1C). The delayed phase from the time-resolved CTA correlates well with the conventional angiogram (Figure 1D) with respect to the site of occlusion. Note also the higher density of the later filling and yet-to-drain right MCA branches, suggesting poor collateralization (Figure 1E). The concomitant PCT parametric maps reveal reduced blood flow. There is a striking prolongation of transit times evidenced by mean transit time (MTT) and time to drain (TTD) images. In general, cerebral blood volumes increase in the setting of ischemia due to intact autoregulatory mechanisms. In this case, there is a subtle reduction in blood volume consistent with failure of autoregulation. This suggests infarction within the right MCA territory (Figure 1F). Serial CT examinations over the next two days manifest progressive evidence of the infarction with no subsequent development of hemorrhage (Figure 1G).

DIAGNOSIS

Occlusion of the right ICA; infarction within the right MCA territory

DISCUSSION

The technique for hybrid CTA-PCT examinations leverages the interaction between iodine and the X-ray beam. In general, when designing a contrast-enhanced exam, optimizing the opacity created by iodine is critical to quality and consistency. Maximizing iodine flux by using an HCCM (370 mgI/mL in this example) and a high injection rate (4 mL/sec here) is a powerful way to accomplish this.[1] Lowering the energy of the X-ray to more closely match the unique characteristics (k-edge) of iodine is another way to maximize tissue and vascular contrast. By using 70 kVp, as opposed to the traditional 80 kVp used for PCT or 100 kVp used for CTA, radiation dose is substantially reduced and image quality is improved, even at low tube current (150 mAs).[2]

CONCLUSION

Readily available CT, CTA, and PCT techniques facilitate the modern treatment of acute stroke. Refined techniques such as low kVp and HCCM use maximize quality and consistency and minimize radiation dose.

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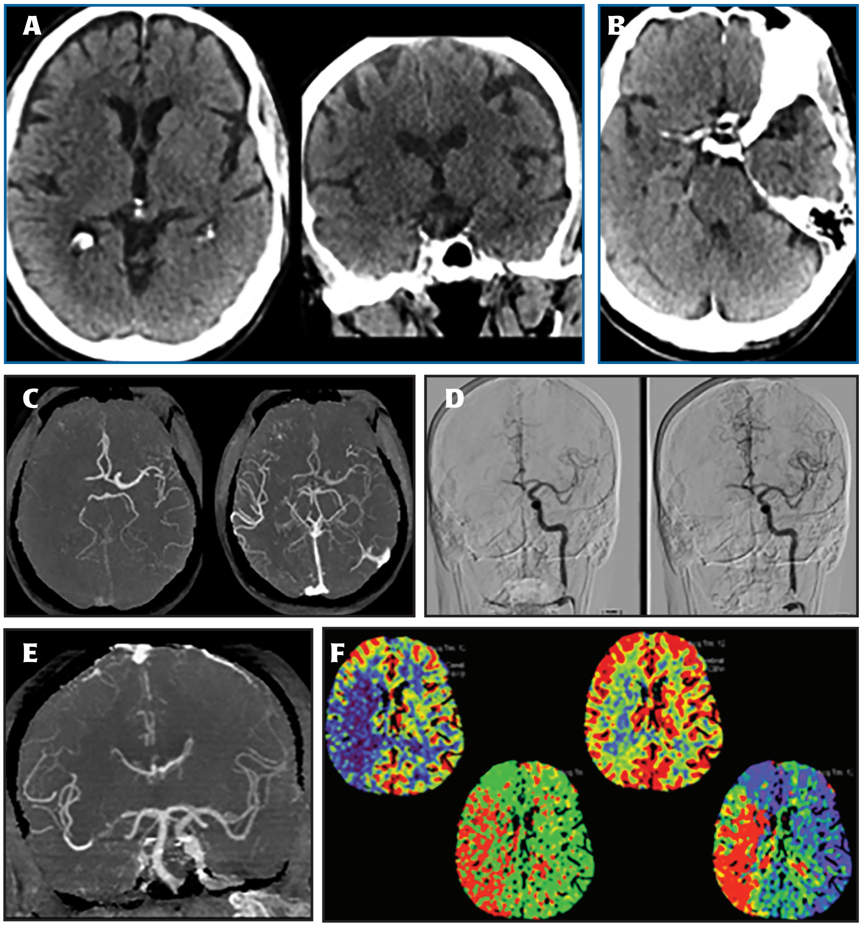

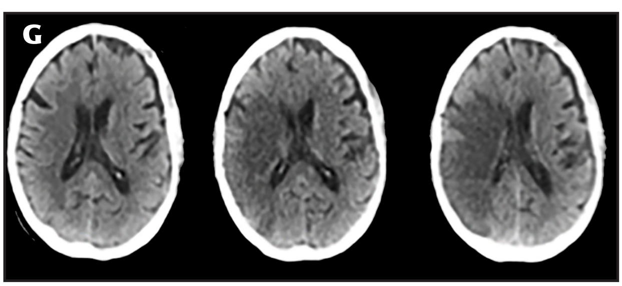

FIGURE 1. *CTA and perfusion CT following stroke. (A) Unenhanced CT of the head reveals no evidence of hemorrhage or stroke; (B) hyperdense right internal carotid and middle cerebral artery suggesting thrombosis; (C) early and late phases of a time-resolved CTA reveal occlusion of the right ICA with markedly delayed filling and draining of the right middle cerebral artery and its branches via collaterals; (D) early phases of the conventional angiogram show occlusion of the right internal carotid artery and poor collateral filling of the intracranial vasculature; (E) delayed phase from the time-resolved CTA correlates well with the conventional angiogram with respect to the site of occlusion. Note also the higher density of the later filling and yet to drain right MCA branches; (F) perfusion CT (clockwise from upper left) CBF, CBV, TTD and MTT parametric images. Note the striking reduction in blood flow and prolongation of transit times associated with a more subtle reduction in blood volume; (G) note the evolution of infarction over the next two days.*

Questions To Consider

In order to maximize iodine flux, one should:

a. Use HCCM and a low injection rate
b. Use HCCM media and a high injection rate
c. Use low-concentration contrast media (LCCM) and a low injection rate
d. Use LCCM and a high injection rate

Lowering the kVp from 80 to 70 results in:

a. Radiation dose reduction
b. Radiation dose increase
c. No effect on radiation dose exposure
d. A decrease in mAs

The technique for hybrid CT angiography and perfusion CT examinations leverages the interaction between:

a. Gadolinium and the X-ray beam
b. Iodine and iterative reconstruction (IR)
c. Iodine and the X-ray beam
d. All of the above

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Coronary CTA for evaluation of chest pain

Jeffrey C. Hellinger, MD, MBA

SUMMARY

A 54-year-old female (BMI 28) presented to the emergency room (ER) with acute chest and left arm pain following a 2-month duration of exercise intolerance and a recent equivocal nuclear cardiac stress test. Cardiovascular risk factors included hypertension, hypercholesterolemia, and a family history for coronary artery atherosclerotic disease. Electrocardiogram, cardiac enzymes, and 2-view chest radiographs were normal at the time of ER presentation.

Within 1 hour of the initial ER presentation, isotropic resolution (0.75 mm images), low radiation dose (70 kV) coronary computed tomographic angiography (CCTA) was performed on a 128-channel multidetector-row scanner (Siemens Medical Solutions; Forchheim, Germany) with tube current modulation (mean 160mA). Prior to the study, heart rate optimization (57–62 bpm) was achieved with 7.5 mg of intravenous metoprolol, while nitroglycerin 0.4 mg was administered sublingually for coronary artery vasodilatation. 80 mL of high-concentration contrast media (HCCM; Isovue 370; iopamidol, Bracco Diagnostics) was injected at a rate of 5 mL/s through an 18 g antecubital intravenous catheter. Images were reconstructed with 30% and 50% iterative techniques. CCTA radiation exposure was 0.34 mSv.

IMAGING FINDINGS

CCTA demonstrated a right-dominant coronary circulation with nonobstructive coronary atherosclerotic disease (CAD; Figure 1) in the left anterior descending (LAD) and left circumflex coronary (LCX) arteries. Focal calcified plaques with less than 30% stenosis were present in the proximal LAD, while intermittent minimal noncalcified atheroma (<15%) was present in the mid LAD and proximal LCX. Cardiac chambers were normal in size; myocardium had normal enhancement. The imaged central pulmonary arteries and thoracic aorta were patent and normal in caliber, without acute or chronic abnormalities. Noncardiovascular viscera in the imaged thorax and abdomen were unremarkable.

DIAGNOSIS

Nonobstructive CAD

DISCUSSION

Based upon the CCTA, a diagnosis of nonobstructive CAD was rapidly made, with minimal radiation exposure. Acute coronary syndrome was excluded based upon the initial ER evaluation and the CCTA findings. With continued stability in the ER after the CCTA, the patient was discharged home. Follow-up care has focused on CAD risk factor modification (eg, blood pressure and cholesterol control), as well as initiation of low-dose antiplatelet therapy. At 7 months since the ER presentation, the patient has not had recurrent chest pain or new cardiac symptoms warranting additional cardiac and/or coronary artery imaging.

Although the stakes are high with ER imaging, there should never be a sacrifice made with respect to patient safety to achieve high image quality and rapid diagnosis. This cardiac CTA case highlights that patient-centric CTA protocols can successfully be employed in the ER setting to effectively balance radiation exposure and diagnostic image quality without hindering patient safety or timely care.[1] Given the patient's low BMI and the ability to pharmacologically control the patient's heart rate to an acceptable target range, 70 kV was selected. The decision to use this tube voltage parameter (as opposed to 120, 100, or 80 kV) in conjunction with tube current modulation was crucial to achieving ultra-low radiation exposure (0.34 mSv) – equivalent to slightly more than a single chest radiograph. HCCM was delivered at a high rate through an appropriate-size IV catheter to achieve high intraluminal density. Iterative reconstruction was utilized to reduce background noise, which is inherent and increases with low- and ultra-low dose CTA. Together, HCCM and iterative reconstruction (IR) had a combined effect to improve the signal to noise ratio (SNR) and optimize image quality. Source images were readily interpretable and, as illustrated in the Figure 1, advanced 2- and 3-dimensional imaging techniques could easily be applied. An accurate and rapid diagnosis was made, leading to efficient and appropriate patient triage.

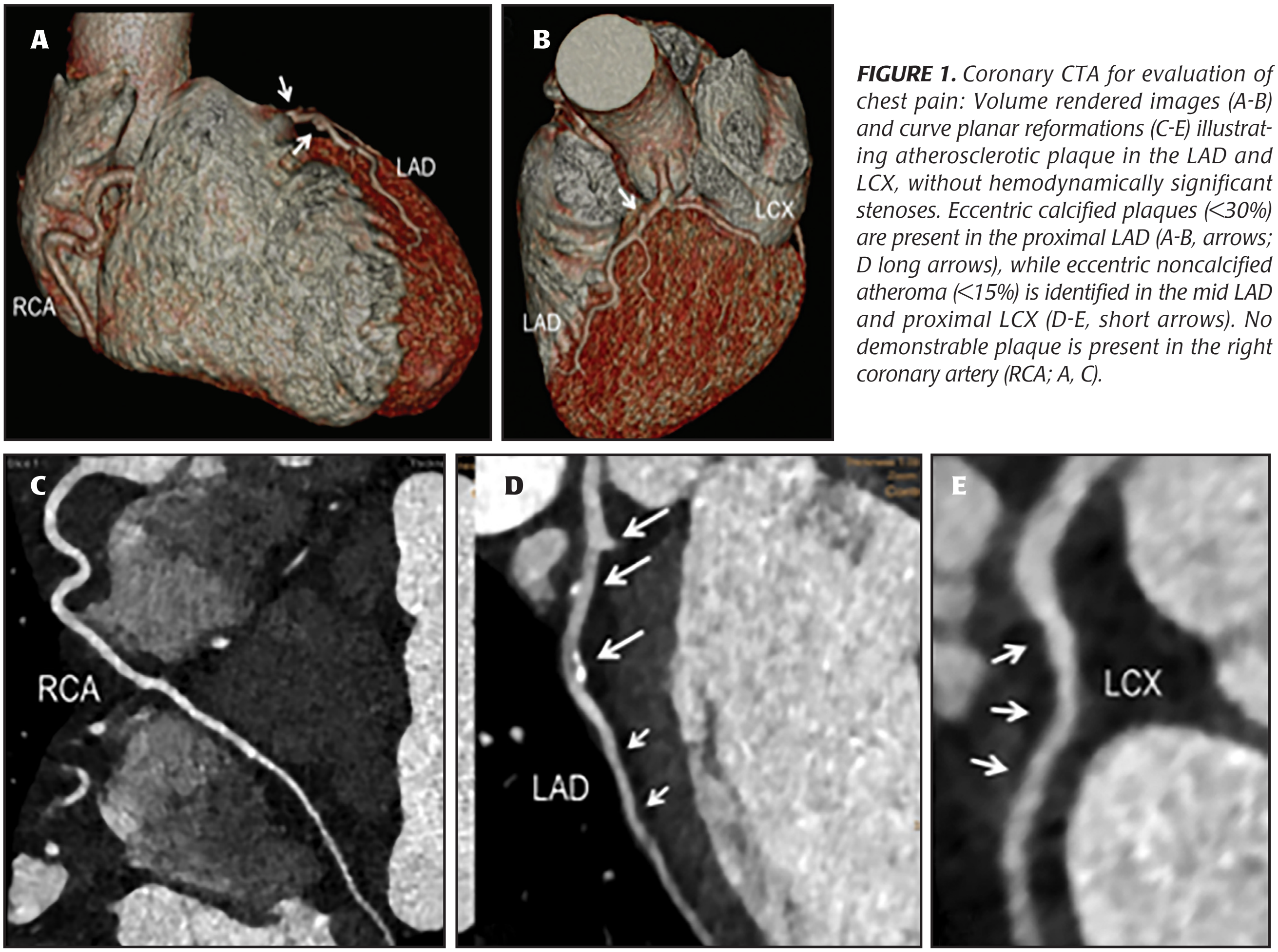

FIGURE 1. *Coronary CTA for evaluation of chest pain: Volume rendered images (A-B) and curve planar reformations (C-E) illustrating atherosclerotic plaque in the LAD and LCX, without hemodynamically significant stenoses. Eccentric calcified plaques (<30%) are present in the proximal LAD (A-B, arrows; D long arrows), while eccentric noncalcified atheroma (<15%) is identified in the mid LAD and proximal LCX (D-E, short arrows). No demonstrable plaque is present in the right coronary artery (RCA; A, C).*

CONCLUSION

Patient-centric, low-dose CTA protocols incorporate primary and secondary strategies for managing radiation exposure and image quality. Of these strategies, as demonstrated in this case study, tube voltage and current parameter selection, use of HCCM, and use of IR are essential. Based upon a patient's physiology and biometrics, low radiation parameters are selected to achieve exposure as low as reasonably possible. HCCM and IR techniques are selected for their synergistic impact to increase the CTA SNR and recover image quality.

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Questions To Consider

The use of low-radiation–dose CT techniques have been developed that:

a. Reduce diagnostic yield at considerably reduced radiation exposure
b. Preserve diagnostic yield at considerably reduced radiation exposure
c. Preserve diagnostic yield at considerably increased radiation exposure
d. Preserve diagnostic yield without affecting radiation exposure

For iodinated contrast-enhanced exams, lower kVp values result in

a. Lower radiation dose exposure, but also lower contrast enhancement
b. Lower radiation dose exposure and also higher contrast enhancement
c. Higher radiation dose exposure and lower contrast enhancement
d. Higher contrast enhancement, but also higher radiation dose exposure

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