Optimisation of CT protocols in abdominal emergencies

Poster No.: ESI-0052
Congress: EuroSafe Imaging 2018
Type: EuroSafe Imaging
Authors: M. R. Onur, I. Idilman, E. Akpınar, M. N. Özmen, D. Akata; Hacettepe University Faculty of Medicine Department of Radiology Ankara/TR
Keywords: Action 3 - Optimisation, diagnostic reference levels, image quality, Action 9 - Development of criteria for safe imaging procedures, Abdomen, CT, Radiation safety, Acute
DOI: 10.1594/esi2018/ESI-0052

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Background/introduction

Learning Objectives

1. General dose reduction techniques in CT examination of abdominal emergencies.

2. Awareness of CT protocols defined for reducing radiation dose in abdominal emergencies.

3. Most effective CT parameters which play a major role in radiation burden of emergency abdominal CT.

- Non-traumatic abdominal emergencies account for 5-10% of emergency department (ED) admissions and 20-22% of urgent CT scans (1).
- Understanding the individual patient's clinical data and laboratory findings is essential to determine CT protocol.
- Multiple CT dose reduction techniques can be used to reduce radiation dose in abdominal CT.
Description of activity and work performed

We present main factors affecting radiation dose in abdominal emergencies. Appropriate protocol considerations for most encountered abdominal emergencies are also summarized.

1. Abdominal CT protocol parameters

a. Oral contrast administration - radiation dose considerations

- Positive enteric contrast agents cause increased radiation exposure in abdominopelvic CT compared to those with oral water whether automatic exposure control (AEC) is utilized (Fig. 1).

b. Multiphasic imaging

- Multiphasic imaging is usually required for assessment of abdominal vascular emergencies. Unenhanced CT images may be helpful to detect gastrointestinal haemorrhage or haemorrhagic ischemia in bowel wall.
- Arterial and venous phases of multiphasic abdominal CT examinations reveal enhancement features of arterial and venous vasculature. Unenhanced CT part of multiphasic CT can be avoided by depicting CT examination as dual CT. Unenhanced CT images can be acquired without performing a separate unenhanced CT scanning.

5. Most encountered abdominal emergencies

a. Bowel emergencies

- Most frequently presenting aetiologies of bowel emergencies are inflammatory, infectious or obstructive bowel conditions.
- In the setting of inflammatory and infectious conditions lowering the tube voltage may be helpful to detect involved segments by revealing increased enhancement at decreased k.V. levels.
- It is unnecessary to administer oral or IV contrast agent in patients with suspicion of perforation.
- Obstructive bowel disorders may necessitate repeat scanning however scanning area in the repeated scan can be limited to region which is suggestive of transition point according to topogram.
- Applying low tube voltage is a good option in patients undergoing abdominal CT due to specific bowel pathologies such as Crohn disease and recurrent obstruction. This manner prevents high cumulative radiation doses especially in young patients.
• Intravascular contrast enhancement increases by lowering tube voltage which may be helpful in assessment of vascular pathology such as bleeding or stenosis.
• Lowering tube voltage would increase the image noise which can be solved by using iterative reconstruction.

b. Acute appendicitis

• CT imaging is commonly used for the diagnosis of acute appendicitis. Low tube voltage images can reveal inflammatory enhancement of appendix vermiformis (Fig. 2).
• Dose reduction is essential for this indication as many patients with suspected diagnosis of acute appendicitis are young or paediatric patients.
• Avoidance of oral contrast agent administration may be a good recommendation as a first step of dose reduction since administration of oral contrast increases radiation dose.
• Low section thickness (1-3 mm) is not usually required for assessment of appendicitis. Acquisition of thick sections with high gantry rotation speed may be helpful to obtain low dose CT examinations.
• Lowering tube voltage according to the patient size is crucial. By the way, it was shown that limited scan area including right quadrant especially in pediatric patients reduces the dose by approximately 23-46% (2,3).

c. Acute pancreatitis

• CT protocol in acute pancreatitis include early arterial and venous phases.
• Avid iodine enhancement in pancreas parenchyma at arterial phase results in increased contrast resolution allowing reduced tube voltage and hence decreased radiation dose. Tube voltage in arterial phase can be lower than venous phase (Fig. 3).

d. Urinary emergencies

• Most frequent urinary emergency in ED is obstructive urinary stone disease. Since urinary stones are almost always hyperdense and presents with great contrast difference with neighbouring tissues low tube voltage can be preferred to detect urinary stone at CT.
• Acquisition of CT images on prone position was shown to load lower radiation dose than CT acquisition in supine position (4) (Fig. 4).
• Traumatic injury of lower urinary system should be assessed with a pelvic CT scan including bladder and urethra. Upper urinary system may be excluded from the scan area if no doubt about kidney or urethra injury exists (Fig. 5).

e. Vascular emergencies
• Split-bolus CT technique can be used in assessment of mesenteric occlusive diseases such as mesenteric ischemia. This technique enables single-phase acquisition instead of multiphasic study by exploiting two contrast boluses separated by a time delay. Early arterial and portal venous phases can be visualized in single scan with reduced radiation dose (Fig. 6).
**Fig. 1:** Abdominal CT topogram images of a 54-year-old male before and after positive oral contrast administration. Radiation dose values automatically measured by CT equipment after topogram scanning yielded DLP values as 488 mGy cm and 514 mGy cm before and after positive oral contrast agent administration, respectively.

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Fig. 2: Dual-energy CT images of a 33-year-old female with acute appendicitis. Contrast enhancement is more prominent at 80 kV CT image than 140 kV image. Lowering tube voltage resulted in avid enhancement at inflammation region.

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**Fig. 3:** Abdominal CT examinations of a 69-year-old male performed in different 64-slice CT scanners with an interval time period of 20 days. The DLP values of CT examinations were 660 mGy cm and 518 mGy cm, respectively. High tube voltage (120 kV for upper row, 110 kV for lower row) and tube current reference values (128 mAs for upper row, 83 mAs for lower row) and low section thickness (0.8 mm for upper row, 1.2 mm for lower) resulted in increased radiation dose in first CT exam.

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**Fig. 4:** Unenhanced CT topograms performed in prone and supine positions of patient yielded estimated CTDIvol values as 2.92 mGy and 3.28 mGy, respectively.

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**Fig. 5:** CT examination performed in a 32-year-old female with abdominal pain and history of cystoscopy four days ago. Bladder was filled with iodinized contrast agent via urinary catheter. Topogram image (A) shows that scanning area was wider than required in this clinical condition which suggests iatrogenic injury after urinary tract intervention. Radiation exposure would be lower whether scanning region was limited to pelvis. Sagittal CT image (B) demonstrates leakage of iodinized contrast agent through the defect at dome of the bladder.

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Fig. 6: CT angiography images obtained with split-bolus technique in a 43-year-old female suspected to have mesenteric ischemia reveal concurrent enhancement in arterial and venous vasculature in a single phase image. This technique reduces the radiation dose by avoiding two separate CT scanning dedicated to demonstrate arterial and venous vasculature.

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Conclusion and recommendations

• Appropriate management of CT radiation dose in abdominal emergencies relies on awareness of CT technology advances which allow reducing radiation dose without impairment in image quality. Avoidance from unnecessary multiphasic studies and implementation of dose lowering techniques are mainstay principles in lowering radiation dose of CT examinations performed in abdominal emergencies.
Personal/organisational information

1. Mehmet Ruhi Onur (submitting author), Associate Professor, e-mail:ruhionur@yahoo.com, Hacettepe University Faculty of Medicine, Department of Radiology, Ankara, Turkey

2. Ilkay Idilman, Associate Professor, Hacettepe University Faculty of Medicine, Department of Radiology, Ankara, Turkey

3. Erhan Akpinar, Professor, Hacettepe University Faculty of Medicine, Department of Radiology, Ankara, Turkey

4. Mustafa Nasuh Ozmen, Professor, Hacettepe University Faculty of Medicine, Department of Radiology, Ankara, Turkey

5. Deniz Akata, Professor, Hacettepe University Faculty of Medicine, Department of Radiology, Ankara, Turkey
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