64-detector row CT split-bolus techniques: body applications

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Purpose

CT is currently the method of choice for evaluation of oncologic patients, vascular emergencies, and urinary tract diseases. Multidetector-row CT allows shorter acquisition times, greater coverage, and high image resolution (1, 2). Conversely, in the clinical practice, the radiation dose to the patient and the large amount of image data produced represent the major disadvantages (3-7).

To optimize CT radiation dose to patient, various technologic and patient-based strategies has been proposed by radiologists, physicists and the CT industry (5).

Recently, the split-bolus technique has been reported for CT urography with a variability technique for the reduction of radiation dose by scanning the abdomen to obtain only at one phase nephrographic and excretory phase (8-11).

We designed the 64 detector-row CT with double and triple split-bolus intravenous contrast medium technique and the body applications.

The aim is twofold: 1) to reduce radiation dose to patient, and 2) to ensure an accurate diagnosis and images of high diagnostic quality with respect to the conventional CT (e.g. Angio-CT, bi- or triphasic CT).

Methods and Materials

We retrospectively reviewed the 64 detector-row CT performed at our institution in the last year by double and triple split-bolus intravenous contrast medium technique in 192 patients.

CT was performed for staging or follow-up of primary malignant tumor (n=120), thoracic and/or abdominal vascular disease (n= 53), and urinary tract disease (n= 19).

The median body weight was 59 kg (range, 51-75 kg).

The examinations were performed with a 64 slice CT scanner using the following parameters: 120 Kv, 200 mA, 512 x 512 matrix, 2.0-2.5 mm slice thickness, 1.0-1.25 mm reconstruction index, 0.7-s/rotation, 0.9 pitch, and 64 x 0.625 collimation.

The protocol diagram of 64 detector-row CT with double and triple split-bolus intravenous contrast medium technique in oncologic patients, in patients with suspected vascular disease, and urinary tract diseases are reported in Fig. 1, 2 and 3 respectively.
Nonionic contrast agent Iopromide 370 mgI/mL was injected in double bolus and Iobitridol 350 mgI/mL or Iodinaxol 320 mgI/mL was injected in triple bolus, in a quantity ranged from 115 mL to 150 mL.

For all split-bolus CT protocols the dose modulation in Z-direction (Z-DOM) was used.

Split-bolus MDCT techniques

In the **oncologic patients**, the contrast material was injected in two boluses; each one reduced of 15 mL because contrast material was followed by saline solution (12). First bolus: at the start of bolus injection [or time zero], 55-90 mL (1.4 mL/kg) were injected at 1.2-1.5 mL/sec followed by 20 ml of saline solution at the same flow rate to determine enhancement in the vascular system. Second bolus: 36-60 mL (1.0 mL/kg) at 3.5 mL/sec followed by 20 ml of saline solution at the same flow rate were injected to achieve the arterial phase. Scan begins after 6 seconds from the time of arrival of the contrast material into the aorta determined by bolus tracking. CT delayed phase at 5 minutes was performed in patients with focal liver lesions.

In the **thoracic and/or abdominal vascular diseases**, the contrast material was injected in two boluses; in the patients with suspect of aortic or mesenteric disease, pre-contrast low-dose CT scan was performed. First bolus: at the start of bolus injection [or time zero], 55-90 mL (1.4 mL/kg) were injected at 1.2-1.5 mL/sec followed by 20 ml of saline solution at the same flow rate to determine enhancement of the vascular system. Second bolus: 36-60 mL (1.0 mL/kg) at 3.5 mL/sec followed by 20 ml of saline solution at the same flow rate were injected to achieve the arterial phase. In patients with suspected aorta and mesenteric vessels disease, scan begins after 6 seconds from the time of arrival of the contrast material into the aorta determined by bolus tracking. In patients with high clinical probability of acute pulmonary embolism the second bolus is centered at pulmonary peak previously determined by bolus test.

In the **urinary tract diseases**, the protocol consists of two images acquisition series: pre-contrast low-dose CT scan and a single contrast material-enhanced set of images obtained after triple-bolus injection of contrast material from the diaphragm to the pubic symphysis.

The contrast material was injected in three boluses. First bolus: at the start of bolus injection [or time zero], 50 mL at 2 mL/sec were meant for the opacification of the urinary tract. Second bolus: 6-7 minutes after time zero and after scout view to verify opacification of the pielocaliceal system and ureters, 50 mL at 1.5 mL/sec to enhance the renal medulla and veins. Third bolus: after 6 seconds from the time of arrival of the contrast material into the aorta determined by bolus tracking, 55 mL at 3 mL/sec to enhance the renal cortex and arteries.
Dose Radiation Calculation

The radiation was measured in Sievert (Sv), which is the equivalent dose calculated in human tissue. The effective doses were calculated using dose-length-product (DLP) values in mSv by conversion factors of MDCT taken from the 2004 Quality Criteria for MDCT (6).

Images for this section:

Fig. 1: Protocol diagram of 64 detector-row CT with double split bolus intravenous contrast medium technique in oncologic patient. The contrast material is injected in two boluses; each one reduced of 15 mL because contrast material was followed by saline solution. First bolus: at the start of bolus injection [or time zero], 55-90 mL (1.4 mL/kg) were injected at 1.2-1.5 mL/sec followed by 20 ml of saline solution at the same flow rate to determine enhancement in the vascular system. Second bolus: 36-60 mL (1.0 mL/kg) at 3.5 mL/sec followed by 20 ml of saline solution at the same flow rate were injected to achieve the arterial phase.
Fig. 2: Protocol diagram of 64 detector-row CT with double split bolus intravenous contrast medium technique in patients with suspected vascular disease. The contrast material is injected in two boluses; each one reduced of 15 mL because contrast material was followed by saline solution. In patients with suspect of aortic or mesenteric disease, pre-contrast low-dose CT scan was performed. First bolus: at the start of bolus injection [or time zero], 55-90 mL (1.4 mL/kg) were injected at 1.2-1.5 mL/sec followed by 20 ml of saline solution at the same flow rate to determine enhancement in the vascular system. Second bolus: 36-60 mL (1.0 mL/kg) at 3.5 mL/sec followed by 20 ml of saline solution at the same flow rate were injected to achieve the arterial phase.
Fig. 3: Protocol diagram of 64 detector-row CT urography with triple split bolus intravenous contrast medium technique. The contrast material is injected in three boluses. The first bolus (at the start of bolus injection [or time zero], 50 mL at 2 mL/sec) was meant for the opacification of the urinary tract. The second bolus: (6-7 minutes after time zero) 50 mL at 1.5 mL/sec) to enhance the renal medulla and veins. The third bolus: 55 mL at 3 mL/sec to enhance the renal cortex and arteries.

Note - The protocol consists of two image acquisition series: unenhanced images and a single contrast material–enhanced set of images obtained after triple-bolus injection of contrast material from the diaphragm to the pubic symphysis. The second bolus (6-7 minutes after time zero) is initiated after scout view to verify opacification of the pielocaliceal system and ureters. The third bolus begins 6 seconds from the time of arrival of the contrast material into the aorta determined by bolus tracking.
Results

Single-pass with double split-bolus 64-detector-row CT technique allowed an accurate staging and follow-up in patients with primary malignant tumor (n=120); in the characterization of the focal liver lesions similar patterns were demonstrated in all cases with respect to bi- or triphasic CT (Fig. 4-8). In evaluating the patients with a high clinical probability of acute pulmonary embolism, the double split-bolus MDCT technique demonstrated a simultaneous adequate enhancement of pulmonary veins and arteries and diagnosis of acute pulmonary embolisms in 29/33 cases (Fig. 9). Accurate diagnosis of thoracic aneurysms and/or dissection (n=5), abdominal aortic aneurysms (n=13), and mesenteric ischemia (n=2) (Fig. 10-13) was assessed. Pyelonephritis (n=3), lithiasis (n=5), aneurysms (n=1), malformations (n=2) and tumors (n=8) of the urinary tract (Fig.14-18) were accurately evaluated by triple split-bolus CT technique in all cases.

A significant reduction of the radiation dose was obtained by split-bolus CT technique when compared to bi- or triphasic CT (Fig. 19).

Images for this section:
**Fig. 4:** Axial (a) and coronal MPR (b) 64 detector-row CT with double split-bolus intravenous contrast medium technique in the staging of lung adenocarcinoma. The simultaneous homogeneous enhancement of the veins and arteries allows an accurate assessment of the tumor extension and of the relationships with adjacent superior vena cava and right pulmonary vein.

**Small hepatic hemangioma with rapid flow**

![Images of small hepatic hemangioma with rapid flow](image)

**Fig. 5:** Triple phase CT of a small atypical hepatic hemangioma with rapid flow in arterial phase (a), venous phase (b), and delayed phase (c)(13). Single-pass 64 detector-row CT with double split-bolus intravenous contrast medium technique demonstrates a similar pattern (d).
Fig. 6: Triple phase CT of a typical hepatic hemangioma with a peripheral globular enhancement in arterial phase (a) and venous phase (b). Single-pass split-bolus CT technique (c) demonstrates a similar pattern (peripheral enhancement that extends toward the center).
**Fig. 7:** Triple phase CT of a hepatic cysts in arterial phase (a), venous phase (b), and delayed phase (c). 64 detector-row CT with double split-bolus intravenous contrast medium technique (d) and delayed phase at 5 minutes (e) shows a similar pattern.
**Fig. 8:** Triple phase CT of a hypodense liver metastasis in patient with GIST of the stomach in arterial phase (a), venous phase (b), and delayed phase (c). Single-pass 64 detector-row CT with double split-bolus intravenous contrast medium technique (d) shows a similar appearance.
**Fig. 9:** Axial (a, b), coronal (c, d), and sagittal MPR (e) 64 detector-row CT with double split-bolus intravenous contrast medium technique show bilateral acute pulmonary embolism in the lobar and segmental pulmonary arteries.
**Fig. 10:** Axial (a, b) and coronal MPR (c) 64 detector-row CT with double split-bolus intravenous contrast medium technique show thoraco-abdominal dissection.
**Fig. 11:** Sagittal (a), coronal MIP (b), and Volume Rendering reconstruction (c) 64 detector-row CT with double split-bolus intravenous contrast medium technique show aneurysm in the ascending thoracic aorta.
Fig. 12: Axial (a), coronal (b), sagittal MPR (c), and Volume Rendering reconstruction (d) 64 detector-row CT with double split-bolus intravenous contrast medium technique show abdominal aortic aneurysm.
Fig. 13: Axial (a) and coronal MPR (b) 64 detector-row CT with double split-bolus intravenous contrast medium technique show superior mesenteric vein thrombosis.
**Fig. 14:** 64 detector-row CT in acute focal pyelonephritis of the left kidney before (a) and after double bolus injection of contrast medium (b). Note hypodense linear enhancement with a pattern of radial distribution along the cortico-medullary region.
Fig. 15: 64 detector-row CT after US performed for hematuria and hydroureteronephrosis. CT before (a, b) and after double bolus injection of contrast medium (c). Split-bolus Volume Rendering reconstruction (d). Note the ureteral stone in the right side (a, b) and omolateral hydroureteronephrosis (c).
**Fig. 16:** Volume Rendering reconstruction 64 detector-row CT with triple split-bolus intravenous contrast medium shows a small aneurysm of the right renal artery (arrow in b).
Fig. 17: Axial (a), coronal (b), sagittal MPR (c) and Volume Rendering reconstruction (d) 64 detector-row CT after double bolus injection of contrast medium show hypovascular renal cell carcinoma in the upper pole of the left kidney.
Fig. 18: 64 detector-row CT in urothelial carcinoma in the right intrarenal collecting system before (a) and after double bolus injection of contrast medium (b). Coronal MPR (c).
Fig. 19: Dose reduction to patient: split-bolus CT technique versus bi- and triphasic MDCT.

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<thead>
<tr>
<th></th>
<th>BIPHASIC CT Protocol A</th>
<th>TRIPHASIC CT Protocol B</th>
<th>SPLIT-BOLUS CT Protocol C</th>
<th>% OF DOSE REDUCTION</th>
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<tr>
<td>Abdomen and pelvis</td>
<td>43.53 mSv ± 10.97</td>
<td>47.2 mSv ± 13.26</td>
<td>20.21 mSv ± 6.7</td>
<td>C vs A = 53.58</td>
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<td>C vs B = 57.19</td>
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<td>Chest and Abdomen</td>
<td>42.92 mSv ± 11.73</td>
<td>52.55 mSv ± 16.84</td>
<td>17.85 mSv ± 5.52</td>
<td>C vs A = 57.8</td>
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<td>C vs B = 66.4</td>
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<td>MDCT Urography</td>
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<td>55.41 mSv ± 12.41</td>
<td>38.77 mSv ± 10.74</td>
<td>C vs B = 30</td>
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Note - The effective doses were calculated using dose-length-product (DLP) values in mSV by conversion factors of MDCT taken from the 2004 Quality Criteria for MDCT.
Conclusion

The main goal in optimizing body CT examinations is to reduce the radiation dose and at the same time to maintain or even to improve diagnostic accuracy.

In the clinical practice, 64-detector row CT with double and triple split-bolus intravenous contrast medium technique represents an accurate and innovative method for evaluation of oncologic patients, vascular and urinary tract diseases, allowing a significant reduction of radiation dose to patient.

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