Split-bolus MDCT urography technique: clinical applications, imaging findings and radiation dose exposure.

Poster No.: C-1618
Congress: ECR 2017
Type: Educational Exhibit
Authors: C. Valle¹, P. A. Bonaffini¹, A. Barletta¹, S. FAENZA¹, F. Invernizzi¹, A. Pappini¹, S. Sironi²; ¹Desio/IT, ²Bergamo/IT
Keywords: Urinary Tract / Bladder, Radioprotection / Radiation dose, Kidney, CT, Contrast agent-intravenous, Dosimetric comparison
DOI: 10.1594/ecr2017/C-1618

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR's endorsement, sponsorship or recommendation of the third party, information, product or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method ist strictly prohibited.

You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys' fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.

www.myESR.org
Learning objectives

The purpose of this educational exhibit is:

- to present the split-bolus MDCT-urography (CTU) technique;
- to show clinical applications, imaging findings and main limitations of split-bolus CTU, also in comparison to the standard CTU protocol;
- to report the main differences in terms of radiation dose exposure between the two protocols.

Background

The evaluation of kidneys, ureters and bladder relies on several imaging techniques. Conventional excretory urography (EU) is a radiographic examination in which anatomic and physiologic abnormalities of the urinary tract are detected through a timed series of images of the abdomen and pelvis after the intravenous (IV) injection of iodinated contrast medium (CM) (Fig. 1 on page 4).

EU has been for many decades the reference standard for the imaging evaluation of the urinary tract but -due to its low sensitivity and specificity- actually plays an occasional role in the clinical practice with some specific indications, according to ACR (American College of Radiology) [1].

Multidetector Computed Tomography (MDCT) represents the main imaging technique for the evaluation of renal diseases and pathologies affecting the urinary tract, particularly in the relation to the prevalent excretion of iodinated CM through the kidneys. Robust and recent improvements in MDCT technology have also enabled the acquisition of high-resolution CT urography (CTU) scans and allowed multiplanar reconstructions (MPRs) of isotropic images.

Unenhanced CT scan has high diagnostic accuracy for stones detection and hemorrhage content of cystic lesions, while arterial, parenchymal/nephrographic and excretory phases enable the proper evaluation of renal masses or parenchymal alterations (Fig. 2 on page 4) and upper urinary tract urothelial cell carcinoma, respectively.

Therefore, CTU is the preferred initial imaging investigation for patients presenting with various symptoms (i.e. hematuria) or suspected lesions of the urinary tract. In particular, the optimum diagnostic imaging strategy for patients with hematuria at high-risk for upper urinary tract urothelial cell carcinoma (UUT-UCC) involves the use of CTU as a replacement for other imaging tests (US, intravenous urography, retrograde ureteropyelography) and as a triage test for cystoscopy, resulting in earlier diagnosis.
and improved prognosis of bladder cancer, UUT-UCC, renal cell cancer and urinary tract stones [2].

The standard dynamic CTU study protocol, following the intravenous administration of iodinated CM, is mainly based on the acquisition of venous and excretory phases (C and D of Fig. 2 on page 4) of the volume of interest (upper and whole abdomen, respectively) for most of the pathologies affecting the urinary tract, such as stones or infections. The arterial phase (B of Fig. 2 on page 4) is acquired in cases of renal masses characterization or for clear cell carcinoma follow up [3].

Since the last years it has been a significant concern about the radiation dose exposure of CT examinations (including CTU scans) and its potential long-term consequences. Radiation dose first of all depends on the number of phases acquired, the scanning parameters employed and the patient size. According to the underlying diagnostic question and to the subsequent protocol employed, the reported radiation dose exposure for CTU examinations ranges from 20 to 66 mSv [4], compared with a mean effective dose of 5-10 mSv for intravenous urography [5]. This may represent the biggest concern tampering the widespread use of CT urography in the daily clinical practice, particularly when performed in young patients (i.e. stones, infections) or for follow-up purposes (i.e. complex renal cysts, treated renal cell carcinomas).

Along with the employment of alternative imaging modalities (MRI), several techniques are generally used to reduce the radiation dose exposure of CTU examinations. One of the most common tool is lowering the tube voltage [6] but this may lead to low/middle-quality images [7]. Very promising and increasingly employed in the last years is the application of several iterative reconstruction algorithms [5]. When not available, a common and feasible approach simply relies on the reduction of the number of phases acquired. The urinary tract evaluation generally requires at least an excretory phase that rarely responds entirely to the underlying diagnostic question, if performed alone [8]. CTU protocols have the main goal to obtain fully opacified and distended collecting systems up to the bladder, along with an adequate image quality of renal parenchyma, tumor enhancement and vascular anatomy. According to the ALARA principle, this has to be obtained with the lowest number of phases as possible; however, to the best of our knowledge, no standard CTU protocols have been widely accepted for patients with renal or urinary tract diseases [9]. Therefore, the need to acquire, in most of the clinical settings, at least both the nephrographic and the excretory phase is the main clinical and diagnostic background for considering the Split Bolus-MDCT urography (CTU) technique.

Basically the Split Bolus CTU is based on the consecutive IV administration of two boluses of CM doses at a given time (seconds), with the acquisition of a combined venous/nephrographic and excretory phase. The CM dose fractionation inevitably lead to a slightly higher overall dose as compared to that used in a traditional multiphasic study; however, the radiation dose exposure is accordingly reduced, with a reported comparable diagnostic efficacy of the traditional protocols in terms of imaging quality [10]. Split Bolus
technique has been employed in several clinical settings, such as in the characterization of focal liver lesions [11], in acute pulmonary embolism [12] and in polytraumatized patients [13]. In the evaluation of kidneys and urinary tract pathologies, although Split Bolus CTU has been suggested for reducing scans number, protocol features are not yet standardized [10].

Images for this section:

Fig. 1: Two plain radiographs of the abdomen, before (A) and after the intravenous injection of iodinated contrast medium (B). The whole collecting system, from caliceal cavities to bladder through ureters, is delineated being opacified by the contrast medium itself. In this case a proximal bilateral ureteric kink is recognizable.

© Case courtesy of Dr Aditya Shetty (Radiopaedia.org, rID: 27486).
Fig. 2: Standard multiphasic axial CE-MDCT images acquired for the characterization of a renal cyst in a middle-aged woman. Before the IV injection of CM (A) the presence of parenchymal or vascular calcification can be excluded and the baseline densitometric values of the renal cyst can be obtained. After IV contrast media, the arterial phase (B) shows the typical cortico-medullary differentiation while in the portal venous phase (C) the renal parenchyma homogeneously enhances, helping to better define any alteration within the parenchyma itself (such as simple renal cysts). The excretory phase (D), generally performed 10 minutes after CM injection, highlights the collecting system.

© - Desio/IT
Findings and procedure details

1. SPLIT BOLUS CTU PROTOCOL

A prior unenhanced study of the abdomen and pelvis is performed before the dynamic study, mainly for stone detection and in cases of first examinations (especially in oncologic or traumatic patients). Then, considering a standard patient with a body weight of 70 kg, a total dose of 130 mL of iodinated CM is intravenously administered, fractionating it in two consecutive boluses, with a standard infusion flow of 3.0-3.5 mL/s: 50 mL and, after about 8-10 minutes, 80 mL. Approximately 80-90 seconds after the second bolus, a single combined nephro-urolraphic phase is acquired. When needed (i.e. oncologic patients), the arterial phase is additionally acquired about 13 seconds after the administration of the second bolus, by using the bolus tracking technique (ROI placed within the aortic lumen; threshold 120-150 HU). The main acquisition parameters of Split Bolus CTU protocol are listed in Table 1 on page 10.

The dynamic study of Split Bolus CTU allows obtaining -in a single image acquisition- both the nephrographic and the renal excretory phases. At the same time we can achieve information of parenchymal organs in the abdominal cavity as in the portal/nephrographic phase of a standard CT protocol (Fig. 3 on page 11).

The high-resolution acquisitions then allow performing additional post-processing images such as multiplanar (MPR), maximum intensity projection (MIP) and three-dimensional (3D) reconstructions (Fig. 4 on page 11, Fig. 5 on page 12, Fig. 6 on page 12).

2. MAIN SPLIT BOLUS CTU FINDINGS

2a. Unenhanced phase

- Lithiasis (Fig. 7 on page 14): presence, number, location in urinary tract (kidneys, urethers, bladder)
- Presence of calcification of various nature (i.e. vascular, tumoral, etc.), maybe not easily recognizable after the CM injection
- Baseline values of renal cysts (hemorrhage), lesions and collections (Fig. 2 on page 14)

2b. Arterial phase

- Arterial vascular anatomy (Fig. 5 on page 12)
• Hypervascular lesions detection (i.e. renal cell carcinoma, urothelial tumors), staging and/or characterization (Fig. 8 on page 15)
• Arterial traumatic blushing

2c. Combined nephrographic and urographic phase

• Typical findings of nephrographic phase, with better parenchymal lesions definition (cysts, tumors, infections), homogeneous renal vein and inferior vena cava opacification (Fig. 9 on page 16 and Fig. 11 on page 19);
• Typical findings of excretory phase (opacification of calyces, renal pelvis, ureters and bladder) for better urinary tract evaluation (anatomy, variants, filling defects), hydronephrosis grading and urinary traumatic blushing (Fig. 9 on page 16 and Fig. 11 on page 19);
• Collateral evaluation of other abdominal parenchymal organs (especially liver, spleen and pancreas) and of portal-splenic-mesenteric venous system (variants, caliper, filling defects).

3. LIMITS

According to some Authors [10], there are some limits to consider while approaching a Split Bolus CTU protocol and that, however, might be partially shared with standard CTU studies:

• If not planned before, an arterial phase displaying findings such as the cortico-medullary differentiation or lesions with increased enhancement, is not routinely obtained, according to the underlying clinical question; in this sense the protocol may be suboptimal for an accurate staging of tumors once they are occasionally detected, so that such patients may require an additional contrast study or a different imaging technique (MRI) for staging;
• Although MDCT has a reported sensitivity up to 90-95% in visualizing bladder tumors, small ones at the ureteral orifices may be missed, possibly due to the normal protrusion that is often seen in that region and also due to the mixing artifacts within the bladder that can result either in false-positive or false-negative interpretations. An exclusively anatomic imaging approach will not provide a secure identification of flat bladder tumors (such as carcinoma in situ) and a conventional cystoscopy still remains the gold standard for evaluation of the bladder urothelium;
• Additional reconstructions (particularly MIP) can add further useful information (to convey overall anatomic features) but has to be interpreted along with native axial images and with standard MPR; indeed, the main evaluation is based on axial images analysis and appropriated window and level settings should be used for collecting system and ureters evaluation so that dense intraluminal contrast material does not obscure urothelial details and, potentially, small lesions;
• The proper timing of double CM bolus is essential in order to avoid partial/inhomogeneous opacification of urinary tract or bladder (see Fig. 12 on page 19 below);

• The reduced amount of the first CM bolus may lead to reduced HU values of iodinated urine as compared to a standard CTU protocol; however, the overall opacification (on which the final evaluation generally relies) tends to be qualitatively similar among the two techniques.

4. DOSE REPORTS

The main advantage of Split Bolus CTU is undoubtedly the significant saving of radiation dose delivered to the patient; this is basically related to the reduction of number of phases acquired. Traditional protocols require multiple image acquisitions (generally unenhanced, nephrographic and excretory phases) and the average effective radiation dose has been estimated to be even higher than 60 mSv [4]. Diagnostic imaging must ensure that benefits of a radiologic examination exceed the corresponding risk, especially for CT examinations that, with the ongoing advances, will continue to be the most important contributor to medical given doses [15].

MDCT protocol information (such as mAs, kV peak, pitch) and selected dosimetry values, particularly the volume CT dose index (CTDIvol) and the dose-length product (DLP) are included on the protocol phage summary sheet and reported for each scan series. CTDIvol specifies the amount of radiation in CT examinations, being the metric used by the ACR for CT practice accreditation [16]. For a certain CT scanner and a certain acquisition protocol, the CTDIvol is established and independent of patient size and scan length. Considering equal technical parameters, doses are lower in large patients because of the greater X-rays attenuation than in small ones [17]. The CTDIvol does not represent the actual dose delivered but indicates the intensity of radiation directed to the patient. On the other hand, the DLP is the CTDIvol multiplied by the scan length and is independent of what is actually scanned. The effective dose (ED) is the risk of developing cancer in a certain tissue. The amount of radiation used, expressed through the CTDIvol and the DLP, is directly proportional to the patient's ED.

In Fig. 10 on page 17, dose reports of two different protocols (performed at our Institution for suspected urologic cancers) are reported as CTDIvol and DLP values.

MAIN APPLICATIONS OF CTU SPLIT-BOLUS CTU PROTOCOL

1. LITHIASIS
Obstructing ureteral calculi are most commonly located at or near the uretero-vescical junction. Other common locations include the uretero-pelvic junction and where the ureter crosses the iliac vessels. Acute ureteral obstruction causes severe flank pain, also known as renal or ureteral colic. Renal colic is due to sudden distention of the proximal collecting system and edema of the kidney, exacerbated by ureteral hyperperistalsis. The combination of severe flank pain accompanied by hematuria is seen in approximately 50% of patients with ureterolithiasis.

For renal colic evaluation, unenhanced CT or the first scan of a triphasic CTU is the study of choice; however, contrast-enhanced CT scans are rarely needed (Fig. 7 on page 14). In acute obstruction caused by a ureteral calculus, CT usually shows the obstructing calculus as well as secondary signs of obstruction, including hydro-ureter/-nephrosis, perinephric stranding and renal enlargement [19].

It has been reported that the baseline scan might allow recognizing the different composition of urinary calculi, according to their density (calcium salts calculi: 400-1000UH; struvite: 200-400UH; urate and cystine calculi: 100-200UH) and therefore may contribute to treatment choice. MDCT also allows to accurately measure calculi’s size, useful for prognostic purposes since in 80-90% of cases ureteral stones < 4 mm are ejected spontaneously, while the spontaneous expulsion is recorded only in 50% of 4-6 mm calculi and in 20% of calculi > 8 mm, respectively [19].

The potential associated acute urinary tract obstruction, because of intraluminal pression increasing, can determinate a liquid oozing, detectable on CT images as bands and streaks of thickening in the fatty soft tissue around the kidney and the ureters [8]. Often the complications of urolithiasis are a result of obstruction or infection. Renal enlargement and perinephric stranding are signs of obstruction, infection or both. In these cases it is useful to complete the baseline acquisition with one or more contrast phases. Contrast-enhanced images may allow excluding parenchymal concomitant complications, such as pyelonephritis or demonstrating the regular parenchimal enhancement of kidneys.

2. TUMORS

MDCT is useful for an accurate topographic assessment of tumors, necessary for the selected type of surgery (radical or conservative) and for local and distant staging. For a comprehensive assessment of urinary tract tumors it is essential a multiphasic CECT study. The arterial phase defines the vascular arterial anatomy, the presence of newly formed vessels and the increased enhancement of several histotypes such as renal cell carcinoma. The nephrographic phase allows evaluating the possible venous involvement, better defining and visualizing the lesion itself in relation to the surrounding renal parenchyma or excluding the presence of distant parenchymal metastases. Finally, the excretory phase is helpful to detect filing defects (Fig. 12 on page 19) and to better delineate obstruction grade [19].
The main advantage of Split Bolus CTU protocol is once again the reduction of radiation dose exposure since it allows the acquisition of three phases (baseline, arterial, nephrographic) as compared to a standard CTU study of an oncologic patient (four phases).

2. INFECTIONS

Pyelonephritis and its sequelae, such as inter-renal abscess, are common in patients with obstructing calculi, and when the clinical history and CT findings are appropriate, the diagnosis of pyelonephritis can be suggested. Acute pyelonephritis is clinically characterized by fever, flank pain, bacteriuria, and pyuria. CT may show global enlargement of the affected kidney and patchy or wedge-shaped areas of decreased contrast enhancement. These finding are best seen on nephrographic phase images [19].

Images for this section:

<table>
<thead>
<tr>
<th>Unenhanced Acquisition</th>
<th>Dynamic Study</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Arterial phase</td>
</tr>
<tr>
<td><strong>Voltage (kV)</strong></td>
<td>120</td>
</tr>
<tr>
<td><strong>Tube current (mAs)</strong></td>
<td>Automatic Tube Current Modulation</td>
</tr>
<tr>
<td><strong>Scan range</strong></td>
<td>From diaphragm down to the trochanter minor</td>
</tr>
<tr>
<td><strong>Slice Thickness</strong></td>
<td>2-3 mm</td>
</tr>
<tr>
<td><strong>Scan timing after CM administration</strong></td>
<td>/</td>
</tr>
<tr>
<td><strong>Standard Post processing</strong></td>
<td>/</td>
</tr>
<tr>
<td><strong>Additional post processing</strong></td>
<td>/</td>
</tr>
</tbody>
</table>

**Table 1**: Split Bolus CTU protocol main parameters. BT: bolus tracking. MPR: multiplanar reconstruction. MIP: maximum intensity projection. MIP and 3D are performed in selected cases, in order to better visualize the vascular (arterial phase) and the whole urinary tract anatomy (nephro-urographic phase), along with the relation of a renal mass with
the collecting system. MIP are generally performed with a slice thickness of 10 mm and 7 mm interval.

© - Desio/IT

Fig. 3: Axial images (A, B) of a combined nephrographic and excretory phase of a Split Bolus CTU acquisition, demonstrating the homogeneous opacification of the renal cortex, the right renal pelvis, the left proximal ureter (A) and the bladder (B), also characterized by a irregular wall thickening (curved arrow, B) and postero-lateral left diverticulum (white arrow, B). In the upper abdomen (A) a homogeneous enhancement of liver and spleen parenchyma, as in the portal venous phase of a standard CECT examination, can also be appreciated.

© - Desio/IT
**Fig. 4:** 3D reconstructions (A-C) obtained by a combined nephro-urographic acquisition of a Split Bolus CTU, showing the whole anatomy of the urinary tract, from kidneys to the bladder.

© - Desio/IT

**Fig. 5:** Axial (A) and coronal (B) Maximum-Intensity-Projections (MIP) of an additional arterial phase acquisition of a Split Bolus CTU (performed for hematuria), properly displaying the abdominal aorta and both the renal arteries up to the hilar regions of kidneys (as in standard CTU protocol with an arterial phase).

© - Desio/IT
Fig. 6: Axial (A) and coronal (B) MIP of a CTU performed for suspected bladder lesion in a 60 years old man with a hematuria. The MIP images highlight the contours of the bladder, enhance its content (A and B) and allow the visualization of the distal and intramural portions of both ureters (A, white arrows).

© - Desio/IT

Fig. 7: Unenhanced MDCT images (A-C axial, D coronal) showing multiple calcified stones (white arrows) of different sizes in both renal calyces (A-D) and in the right pelvis (C-D) in two different patients. In A and B a 58 years old female patient, with a functional exclusion of the left kidney, underwent a CT examination for left renal lithiasis; an ipsilateral ureteral double J catheter was also present (curved arrow, B). In C and D a 50 years old female patient performed a CT study for lithiasis and recurrent urinary tract infections (UTI) In both cases a combined nephro-urographic phase was also performed (images not shown).

© - Desio/IT
Fig. 2: Standard multiphasic axial CE-MDCT images acquired for the characterization of a renal cyst in a middle-aged woman. Before the IV injection of CM (A) the presence of parenchymal or vascular calcification can be excluded and the baseline densitometric values of the renal cyst can be obtained. After IV contrast media, the arterial phase (B) shows the typical cortico-medullary differentiation while in the portal venous phase (C) the renal parenchyma homogeneously enhances, helping to better define any alteration within the parenchyma itself (such as simple renal cysts). The excretory phase (D), generally performed 10 minutes after CM injection, highlights the collecting system.

© - Desio/IT
Fig. 8: Axial arterial image of a Split Bolus (CTU) in a 83 years old male patient. The right anterior wall of the bladder is characterized by an irregular solid lesion, protruding in the lumen, partially enhancing and with multiple peripheral vessels (white arrow), of about 6.4x2.4x3 cm; a minimal exophytic component protruding in the Retzius cave is also present (curved white arrow).

© - Desio/IT
Fig. 9: Axial combined nephrographic and excretory images of a Split Bolus CTU performed for follow-up of endometrial carcinoma in a 68 years old female patient. In presence of left ureteral double J catheter (B) is appreciable ipsilateral hydroureteronephrosis, associated to inflammatory thickening of the pelvis and ureter wall (white arrows, B and C). A right known renal cysts causes compression of the ipsilateral caliceal cavities and ureter (B). Symmetric and homogeneous the parenchymal enhancement and the urinary opacification of both kidneys and caliceal cavities, respectively (A).

© - Desio/IT
**Fig. 10:** The first scan (A-D) was performed in a 52 years old female patient employing a traditional CTU protocol with four phases (including the baseline scan); the final diagnosis was a papillary renal carcinoma (white arrows A-D). The second examination (F-H) was performed in a 84 years old male patient employing a Split Bolus CTU with three phases (including the baseline scan); the final diagnosis was bladder cancer (white arrows, F-H). As shown (E and I), the second protocol allowed a significant reduction of CTDIvol and DLP values.

© - Desio/IT

**Fig. 11:** Axial (A), coronal (B) and sagittal (C) images of the nephro-urographic phase of a Split Bolus CTU scan, showing the presence of right pelvic stone (white arrow, A and B) and the proper renal parenchyma enhancement along with concomitant urinary homogeneous opacification (A-C). Note in the coronal reconstruction (C) the optimal and homogeneous opacification of a suprahepatic vein and hepatic parenchima.

© - Desio/IT
Fig. 12: Axial (A), sagittal (B) and coronal (C) images of a Split Bolus CTU study (same patient as Figure 8). The combined nephro-urographic phase demonstrates (despite the sub-optimal bladder opacification) a hypodense expansive lesion in the right antero-inferior wall, developing mainly in the bladder's lumen (white arrows, A-C).

© - Desio/IT
Conclusion

Split-bolus CTU may couple in a single post-contrast acquisition (combined nephrourographic phase) the main information required for a proper evaluation of patients with renal/urologic diseases. This technique involves a slightly higher amount of CM volume injected as compared to the traditional multiphasic CTU scans but can significantly reduce the radiation dose exposure. Therefore, the knowledge of this feasible technique, its applications and main limitations represents a powerful additional tool for radiologists. The reported benefits of the Split Bonus CTU technique can surely be extended to other clinical settings (oncology, trauma, emergency, etc), as also suggested in literature [11-13, 20, 21].

Personal information

- **C. Valle**, Department of Radiology, Desio Hospital, Via Mazzini 1, 20832, Desio; Post Graduate School of Diagnostic Radiology, University of Milano Bicocca, via Cadore 48, 20900, Monza.
- **P. A. Bonaffini**, Department of Radiology, Desio Hospital, Via Mazzini 1, 20832, Desio; Post Graduate School of Diagnostic Radiology, University of Milano Bicocca, via Cadore 48, 20900, Monza.
- **F. Invernizzi**, Department of Radiology, Desio Hospital, Via Mazzini 1, 20832, Desio.
- **A. Barletta**, Department of Radiology, Desio Hospital, Via Mazzini 1, 20832, Desio; Post Graduate School of Diagnostic Radiology, University of Milano Bicocca, via Cadore 48, 20900, Monza.
- **S. Faenza**, Department of Radiology, Desio Hospital, Via Mazzini 1, 20832, Desio; Post Graduate School of Diagnostic Radiology, University of Milano Bicocca, via Cadore 48, 20900, Monza.
- **A. S. Casiraghi**, Department of Radiology, San Gerardo Hospital; Post Graduate School of Diagnostic Radiology, University of Milano Bicocca, via Cadore 48, 20900, Monza.
- **A. Pappini**, Department of Radiology, Desio Hospital, Via Mazzini 1, 20832, Desio.
- **S. Sironi**, Department of Radiology, Papa Giovanni XXIII Hospital, Piazza OMS, 1, 24127, Bergamo; Post Graduate School of Diagnostic Radiology, University of Milano Bicocca, via Cadore 48, 20900, Monza.

References
1. ACR&SAR practice parameter for the performance of excretory urography, American College of Radiology, 2014
7. Iezzi R, Santoro M, Marano R et al. Low-dose multidetector CT angiography in the evaluation of infrarenal aorta and peripheral arterial occlusive disease
8. Dal Pozzo G, Compendio di Tomografia Computerizzata e TC Multistrato
15. Huda W, Mettler FA, Volume CT Dose Index and Dose-Length Product Displayed during CT: what good are they? Radiology, 2010
