CT-UROGRAPHY STUDY PROTOCOL: SPLIT-BOLUS TECHNIQUE

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ABSTRACT

CTU represents the natural technical and instrumental evolution of urography. The multidetector technology, with the possibility of retro-reconstruction of the images, has allowed the direct representation of the excretory tract with a significant reduction in acquisition times, decreasing motion artifacts and increasing the definition of the processed images. Split-Bolus CT dynamic study allows us to obtain, in a single image acquisition, both the nephrographic and the renal excretory phases; at the same time, we can obtain information of the parenchymal organs in the abdominal cavity as in the portal/nephrographic phase of a standard CT protocol. The main advantage of Split-Bolus CTU is undoubtedly the significant saving of the radiation dose administered to the patient, related to the reduction in the number of phases acquired, with a reported diagnostic efficacy comparable to traditional protocols in terms of imaging quality. The Split Bolus technique has been used in several clinical contexts, such as in the characterization of focal liver lesions, in acute pulmonary embolism and in polytrauma patients.

INTRODUCTION

CTU represents the natural technical and instrumental evolution of urography. The multidetector technology, with the possibility of retro-reconstruction of the images, has allowed the direct representation of the excretory tract with a significant reduction in acquisition times, decreasing motion artifacts and increasing the definition of the processed images. It represents the main imaging technique for the evaluation of renal diseases and diseases affecting the urinary tract, particularly in relation to the prevalent excretion of iodinated contrast agents through the kidneys.

CT without contrast agent has a high diagnostic accuracy for the detection of stones and hemorrhagic content of cystic lesions, while contrastographic phases (arterial, parenchymal/nephrographic, and excretory) allow the correct evaluation of renal masses or parenchymal changes. On CT, the kidneys present sharp and defined contours due to the high natural contrast with the surrounding fatty tissue. On examination without mdc, the renal parenchyma presents homogeneous parenchymatous density of about 30-60 Hounsfield Units (HU); contrast agent administration allows to distinguish the different parenchymal components, which present variable behavior depending on the study phase:

- In the arterial or angio-cortical phase, the renal cortical shows intense enhancement. In this phase it is also possible to study the renal arteries and is acquired in cases of characterization and follow-up of renal masses.;
- In the venous or nephrographic phase, enhancement of the medullary pyramids increases, so that the renal parenchyma appears homogeneous. In this phase it is possible to study the renal veins;
- In the late or urographic phase, opacification of the urinary excretory pathway is detected with reduced parenchymal enhancement.

On CT, it is possible to easily detect bladder walls that exhibit muscle-like density in the pre-contrast study, with moderate and homogeneous impregnation after contrast agent, nicely delineated by perivesical pelvic fat, externally, and urine hypodensity, internally.

Significant is the concern about the radiation dose exposure of CT examinations and its potential long-term consequences. The radiation dose depends primarily on the number of steps acquired, the scanning parameters used, and the size of the patient. Depending on the diagnostic question and subsequent protocol employed, the reported radiation dose exposure for uro-CT examinations varies from 20 to 66 mSv, compared with an average effective dose of 5 to 10 mSv for intravenous urography. This may be the major concern hindering the widespread use of uro-CT in daily clinical practice, particularly when performed in young patients or for follow-up purposes. Along with the use of alternative imaging modalities (e.g., MRI or ultrasound), several techniques are generally used to reduce radiation dose exposure in CT examinations. One of the most common tools is lowering the tube voltage, but this can lead to low/medium quality images. Increasingly employed in recent years is the application of various iterative reconstruction algorithms, but when this is not available, a common approach is based simply on reducing the number of steps acquired.

Urinary tract evaluation generally requires at least one excretory step, which rarely fully answers the underlying diagnostic question when performed alone. The main goal of uro-CT protocols is to obtain fully opacified collection systems lying down to the bladder, along with adequate image quality of renal paren-

	Unenhanced Acquisition	Dynamic Study	
		Arterial phase	*Combined Nephro-Urographic phase*
Voltage (kV)	120		
Tube current (mAs)	Automatic Tube Current Modulation		
Scan range	From diaphragm down to the trochanter minor	From diaphragm down to the upper border of the iliac crests (or to pelvis in cases of known/suspected urothelial tumors or hematuria)	From diaphragm down to the trochanter minor
Slice Thickness	2-3 mm		
Scan timing after CM administration	/	13 sec after second CM bolus (BT technique)	80-90 sec after second CM bolus
Standard Post processing	/	Coronal and sagittal 2-3 mm MPR	
Additional post processing	/	MIP, 3D	

Tab. 1

chyma, tumor enhancement, and vascular anatomy. According to the ALARA (As Low As Reasonably Achievable) principle, this should be achieved with as few steps as possible; however, to the best of our knowledge, no standard uro-CT protocol has been widely accepted for patients with renal or urinary tract disease.

Protocol

Prior to image acquisition, preliminary patient preparation is very important, consisting of:

- oral hydration, in which the patient should drink 1 liter of water 40-60 minutes prior to the examination, allowing optimal distension of the collector system so as to improve visualization;
- The administration 15-20 minutes before the start of the examination of 500 ml of intravenous saline;
- administration of an intravenous diuretic (0.1 mg/kg up to 10 mg furosemide) immediately before contrast agent administration as it promotes fluid elimination from the urinary system;
- Because of the administration of the contrast agent, the patient must observe a fast of at least 6 to 8 hours.

A preliminary study without contrast agent administration of the abdomen and pelvis is performed before the dynamic study, mainly in cases of first examinations (especially in oncological or traumatic patients) and for the possible evaluation of cystic lesions and calcifications of various nature (perhaps not recognizable due to mdc injection). The standard patient position at all stages of the study is supine, with arms raised above the head. Occasionally, the ready position may be necessary if opacification of the upper excretory tract is to be improved, especially in the presence of hydro-uretero-nephrosis and bladder. Considering a norm type patient, a total dose of 120-130 ml of water-soluble iodinated contrast agent is administered intravenously, fractionating it into

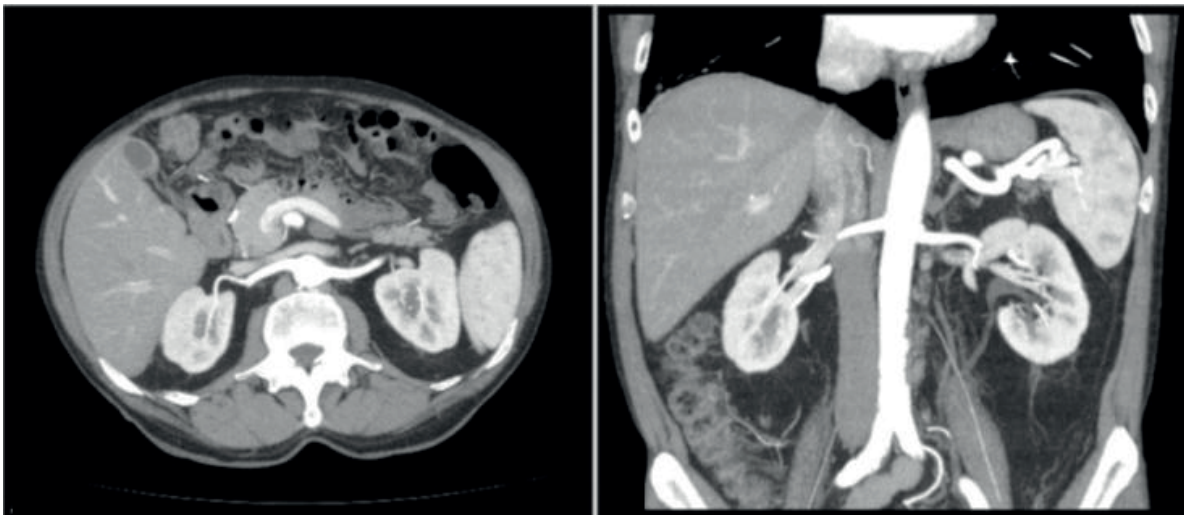

Fig. 1 - *Axial image (left) and coronal MIP image (right) of an additional arterial phase acquisition in a Split Bolus uro-CT, in which the abdominal aorta to both renal arteries to the hilar regions of the kidneys are visible.*

two boluses: the first bolus at bed flow infusion of 40-50 ml of mdc, followed by a second injection of the remaining 70-80 ml of mdc, 5-15 minutes after the first injection. 80-90 seconds after the second administration, images are acquired in a single combined nephro-urographic phase.
This phase allows to obtain the typical results of the nephrographic phase (with better definition of parenchymal lesions such as cysts, tumors, infections, homogeneous opacification of the renal vein and inferior vena cava) and of the excretory phase (opacification of calyces, renal pelvis, ureters and bladder for a better evaluation of the anatomy variants and filling defects of the urinary tract and a possible classification of hydronephrosis and redness of the urinary tract) allowing in turn a collateral evaluation of other abdominal parenchymal organs (especially liver, spleen and pancreas) and the portal-splenic-mesenteric venous system (variants, caliber, filling defects). In the case of oncological patients, for the evaluation of hypervascularized lesions (such as in renal carcinoma or urothelial cancer) the arterial phase is further acquired approximately 15-20 seconds after the administration of the second bolus (**Fig.1**), using the bolus tracking technique (**Table 1**).

Split Bolus-CT dynamic study allows to obtain, in a single image acquisition, both the nephrographic and the renal excretory phases; at the same time, we can obtain information of the parenchymal organs in the abdominal cavity as in the portal/nephrographic phase of a standard CT protocol (Fig.2). High-resolution acquisitions then allow for additional post-processing images such as multiplanar reconstructions (MPR), maximum intensity projections (MIP), and three-dimensional (3D).

Main limitation of the protocol

According to some authors, there are some limitations to consider in the use of a Split Bolus uro-CT protocol and which, however, could be partially shared with standard uro-CT studies:

- Although CT has a reported sensitivity of up to 90-95% in visualizing bladder tumors, small ones at the ureteral orifices may not be visualized, likely due to both the normal protrusion often present in that region and the blending artifacts within the bladder that can lead to false-positive or false-negative interpretations. An anatomic-only imaging approach will not provide confident identification of flat tumors of the bladder (such as carcinoma in situ), and conventional cystoscopy still remains the gold standard for evaluation of the bladder mucosa;
- Additional reconstructions (particularly MIP) may add additional useful information, but should be interpreted in conjunction with native axial images and with standard MPR; in fact, the main evaluation is based on analysis of axial images. Appropriate window and level settings should be used for evaluation of the collecting system and ureters so that dense intraluminal contrast material does not obscure urothelial details and, potentially, small lesions;
- Correct timing of the double bolus of contrast agent is essential to avoid partial/uneven opacification of the urinary tract or bladder;
- The reduced amount of the first contrast agent bolus may lead to reduced HU values of iodinated urine compared with a standard CT protocol; however, the overall opacification (on which the final assessment is generally based) tends to be qualitatively similar between the two techniques.

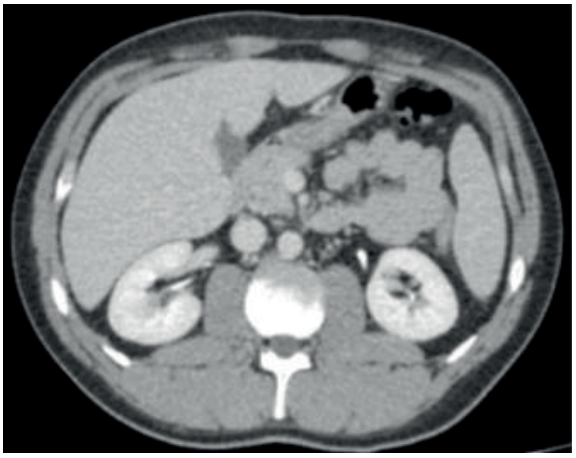

Fig. 2 - *Image of a Split Bolus uro-CT acquisition in which both the nephrographic and excretory phases are represented; the homogeneous opacification of the renal cortical, right renal pelvis, and left proximal ureter is clearly visible in this image.*

CONCLUSIONS

One of the limitations of this technique is in the evaluation of neoplasms that produce minimal thickening of the bladder wall, where a sensitivity of 74% has been reported. However, patients with hematuria and risk factors for urothelial neoplasia should be considered for conventional cystoscopy, which remains the gold standard for evaluation of the bladder mucosa. The main advantage of Split Bolus uro-CT is undoubtedly the significant savings in the radiation dose administered to the patient; this is basically related to the reduction in the number of phases acquired. Traditional protocols require multiple image acquisitions (usually non-contrast images, nephrographic and excretory phases) and the average effective radiation dose has been estimated to be even higher than 60 mSv. Radiation dose exposure is consequently reduced, with reported diagnostic efficacy comparable to traditional protocols in terms of imaging quality.

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