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Review

Split Bolus Method in Computerized Tomography

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Abstract

The split-bolus method in computed tomography (CT) is the method used in the evaluation of renal dynamic enhancement stages and in the detection of pathologies. When designing the CT urography technique, there are several important options such as single-bolus and split bolus techniques. The single-bolus method consists of three separate post-contrast phases: arterial, nephrographic, and excretory (pyelogram), as a result raising the total radiation dose imparted to patients. On the other hand, in the split-bolus technique, the contrast dose is divided into several separate administrations to obtain the nephrographic and excretory phases simultaneously. With the split-bolus technique, by reducing the radiation dose and the number of phases that the patient will be exposed to, urinary system evaluation and the whole abdomen pathological evaluations can be performed. The device to be used in imaging must be a tomography device with at least 16 Multidetector CT sections. The bolus tracking method is one of the most accurate contrast delivery methods for renal dynamics and the split-bolus technique. Automatic dose calibration is used.

Keywords: Bolus tracking, computed tomography, computed tomography urography, contrast injections, dose, excretory phase (urographic phase), kidney, nephrogenic phase (parenchimal), renal arterial phase, renal dynamics, split-bolus method, urinary system, venous phase

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What is Split-Bolus Method?

Excretory urography (EU) has been used for the evaluation of the upper urinary tract. Although EU remains a good method for imaging uroepithelium, it is inferior to cross-sectional imaging techniques such as computed tomography (CT) for evaluating the renal parenchyma.[1] CT study termed "computed tomography urography (CTU)" which depicts both the renal parenchyma and the collecting system and ureters. When designing the CT urography technique, several important options exist, such as single-bolus and split bolus techniques. The techniques' primary purposes are to maximize opacification of the collecting systems and ureters in the delayed excretory phase for maximizing sensitivity. Nevertheless, there must be a balance between maximizing image quality and minimizing radiation dose. The dose length product (DLP) and the computed tomography dose index (CTDI) vol are the two most commonly used CT dose descriptors, which describe the radiation dose in a very standardized way.[2] In a large-scale study that collected data from 20 countries, median CTDIvol and DLP values for 2-phase ct urography were significantly lower than other multi-phase ct urography.(p=0.02)[3] Our institution use 2–4 phase CT urography protocols which has a similar result (Fig. 1). CTU examinations are considered safe, but it is essential to implement a protocol optimized according to the As Low as Reasonably Achievable (ALARA) principle. Split-bolus method CT is a technique used in the diagnosis and characterization

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of renal neoplasms, detection of urolithiasis, and evaluation of multiple organs such as the ureter and bladder (Fig. 1).

What is Single-Bolus Method?

The single bolus technique is the most common technique used in different clinical applications. Following the administration of contrast material at 1 time, arterial, nephrographic, and excretory (pyelogram) images are obtained.

When non-contrast images are obtained, 4 phases are acquired. Easy to apply and simple is one of the reasons for its widespread use. Renal dynamic; It is an examination technique used in tumor, mass, and lesion research (Fig. 2).

Renal Arterial Phase

This phase is in which the contrast media concentration is maximum in the descending aorta. The examination be-

Ward:
Physician:
Operator:

Total mAs 3039 Total DLP 417 mGycm

	Scan	kV	mAs / ref.	CTDIvol* mGy	DLP mGycm	TI s	cSL mm
Patient Position H-SP							
Topogram	1	100	20 mA	0.03 L	1.6	3.4	0.6
Non Contrast	2	100	90	3.57 L	167.8	0.5	1.2
PreMonitoring	3	100	23	0.81 L	0.8	0.5	10.0
Contrast Monitoring	4	100	23	3.22 L	3.2	0.5	10.0
Split Bolus	8	100	130	5.13 L	243.1	0.5	0.6

Medium	Type	Iodine Conc. mg/ml	Volume ml	Flow ml/s	CM Ratio
Contrast		0	0	0.0	100%
Saline			0	0.0	

Figure 1. Patient split-bolus protocol dose chart.

Total mAs 7809 Total DLP 1311 mGycm

	Scan	kV	mAs / ref.	CTDIvol* mGy	DLP mGycm	TI s	cSL mm
Patient Position H-SP							
Topogram	1	100	20 mA	0.03 L	1.6	3.5	0.6
Non Contrast	2	100	180 / 295	7.07 L	378.3	0.5	1.2
PreMonitoring	3	100	23	0.81 L	0.8	0.5	10.0
Contrast Monitoring	4	100	23	6.44 L	6.4	0.5	10.0
Arterial Phase	12	120	260	17.45 L	325.7	0.5	0.6
Nefrojenik 100s	13	120	200	13.49 L	257.9	0.5	0.6
Pyelo 10.dk	14	100	164 / 270	6.45 L	340.0	0.5	1.2

Medium	Type	Iodine Conc. mg/ml	Volume ml	Flow ml/s	CM Ratio
Contrast		0	0	0.0	100%
Saline			0	0.0	

Figure 2. Patient Single bolus technique protocol dose chart.

gins after 20–35 s after the contrast media infusion started. Maximum renal parenchymal cortical enhancement occurs in this phase (Fig. 3). İt is the best phase for evaluating hypervascular, hypertrophic berthini colon, focal renal cortical hypertrophy, and pre-operative vascular mapping for partial nephrectomy (Fig. 3).[4]

Nephrogenic (Parenchimal) Phase

It is the phase in which the renal medulla becomes isodense with the renal cortex or slightly hyperdense compared to the cortex, and it takes 80–100 s from the start of contrast agent infusion. It is the phase in which solid mass enhancement is best observed (Fig. 4). Delay in this phase is indicative of renal dysfunction (Fig. 4).[5]

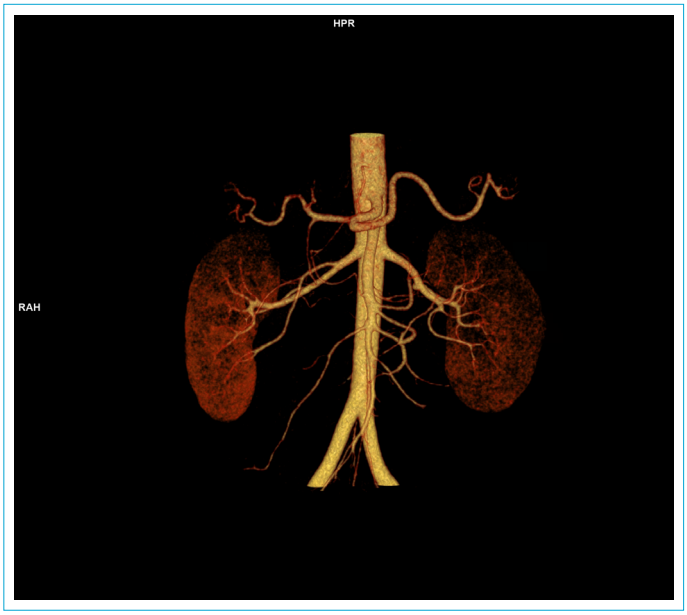

Figure 3. Renal arterial phase volume rendering technique (VRT).

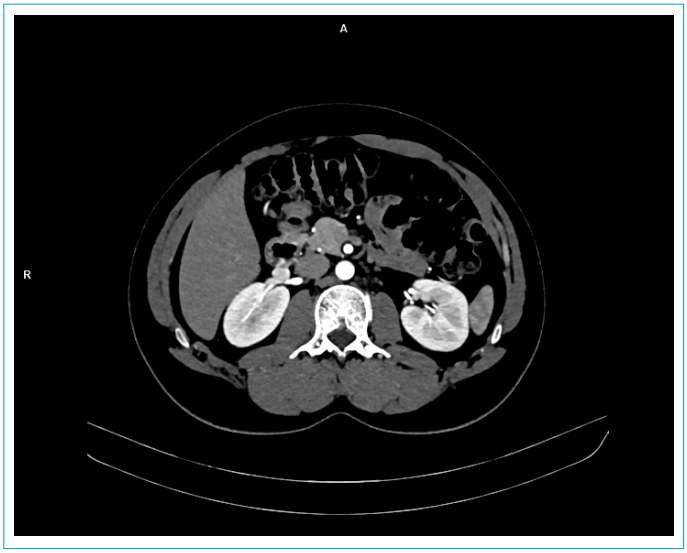

Figure 4. Nephrogenic (Parenchimal) phase study CT.

Excretory Phase (Urographic Phase)

This phase is taken after injection of contrast media through the upper extremity after 7–12 min. The ureters, the entire collecting system, and the bladder are evaluated in the filtration phase (Fig. 5). This phase helps in the detection of masses and stones or other filling defects such as clots (Fig. 5).

Split Bolus Technique (Fig. 6)

Considering the total number of phases taken in renal dynamic imaging, the split-bolus technique is accepted as a three-phase combined bolus technique by administering a single dose to the patient. It provides retrospective evaluation of renal parenchyma and renal collecting system with a single image with arterial, nephrogenic, and excretory (pyelogram) phases (Fig. 7). In addition, perfusion defects can be demonstrated reliably by performing contrast-enhanced examinations in the transplanted kidney.[6] The split-bolus technique is especially beneficial for children, young women, and patients with the possibility of benign disease or with chronic symptomatic stone disease, urinary diversions, or risky patients with clinical exposure to radiation[7] (Fig. 7).

What is A Split-Bolus CT Examination Done For?

1. Examination of kidney, ureter, and urinary bladder
2. Mass, cyst, and tumor diagnosis
3. Congenital urinary anomalies
4. Evaluation of urinary stenoses and stones

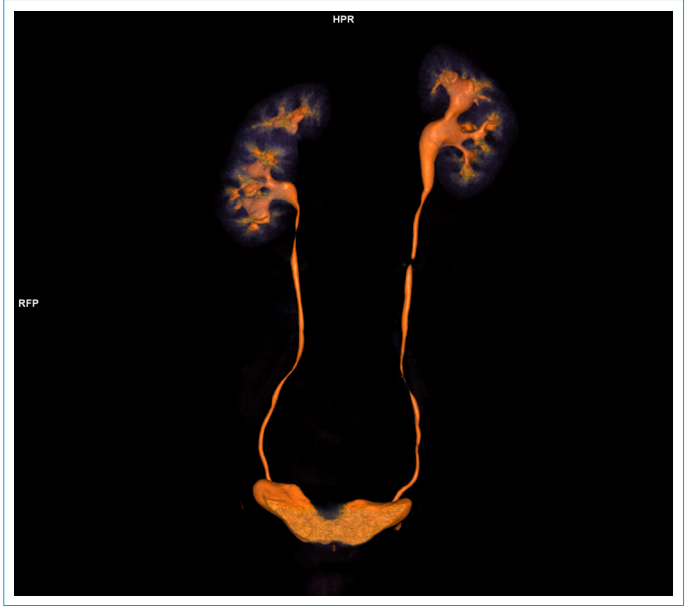

Figure 5. Excretory phase (Urographic phase) VRT.

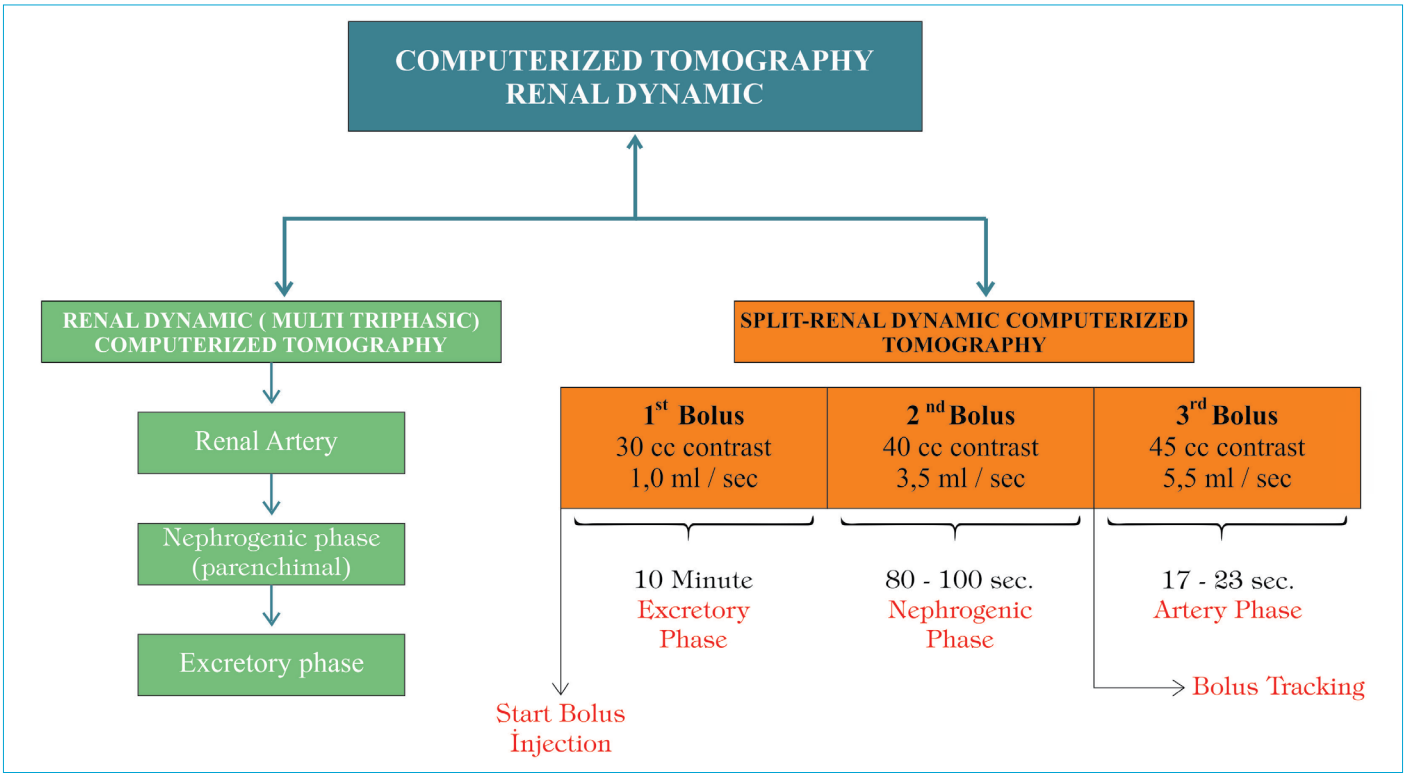

Figure 6. When compared with the multitriphasic technique, the Split-bolus technique reduces the patient's exposure to excess radiation by 40–45%.

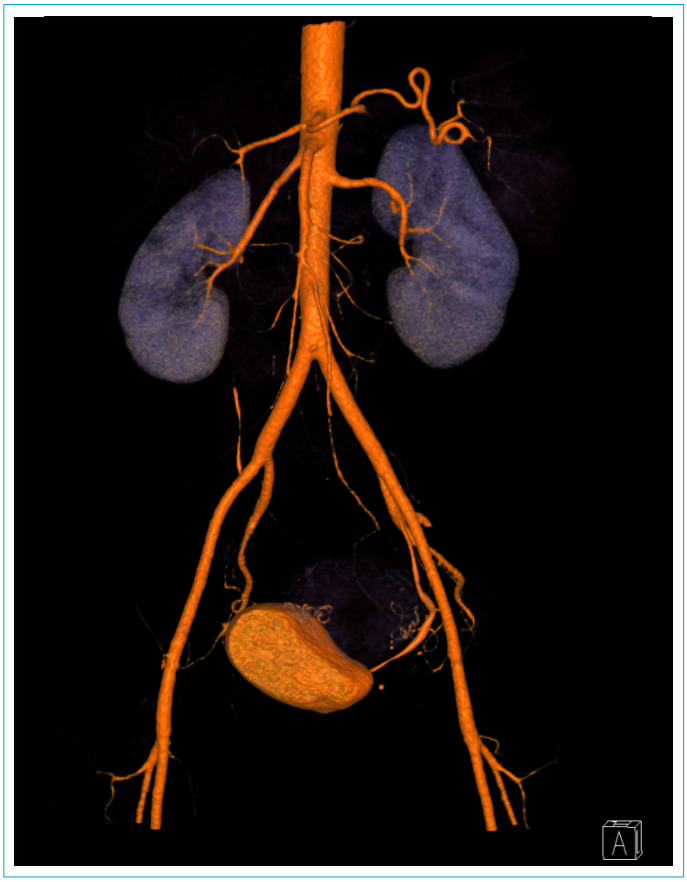

Figure 7. Triple-bolus technique view.

5. Microscopic hematuria
6. Renal artery stenosis.

Split-Bolus Computer Tomography (CT) Shooting Protocol and Techniques

Patient Preparation

1. The patient consent form must be filled out
2. The creatinine value should be checked
3. If possible, oral food intake should be interrupted for 7–8 h before the examination
4. All items that may cause metal artifacts in the abdomen should be removed
5. The patient should be placed on the table in a head-first position in the supine position, and vascular access should be provided through the right or left median cubital vein for contrast agent injection
6. Both arms of the patient should be raised above the head to avoid artifacts

The patient should be told that complications such as temperature feeling and nausea may occur during contrast material injection and that he/she should comply with the "breath commands" given by the device during shooting.

Shooting Protocol

The device to be used in imaging must be a tomography device with at least 16 Multidetector computer tomography (MDCT) sections. A front view should be taken from the patient on a 600 mm long AP scanogram (Topogram, Localizer), including the region from the upper part of the diaphragm domes to the end of the symphysis pubis.

Then a pre-contrast image of the entire abdomen (from the upper part of the liver dome to the end of the symphysis pubis) should be taken with appropriate FOV adjustment. The aim is to shoot a pre-contrast scan is distinguish between situations stone, calcification, cystic lesion, etc. Furthermore, the image taken here guides us through bolus tracking and the split-bolus phase.

Time bolus, bolus tracking, or test bolus methods can be used to capture the enhancement in the arterial phase at a more accurate time.

Note: In the CT examination of renal pathologies, there should be two main protocols as "pre-contrast phase" and "contrast phase." Only in patients with a pre-diagnosis of non-complicated stone disease, the examination can be terminated by taking the non-contrast (pre-contrast) phase with the "stone protocol" in CT or MDCT.[5]

What is Bolus Tracking

The bolus tracking method, which has been produced in parallel with the developments in computerized tomography technology, can be determined in accordance with the previously targeted threshold staining level, with the help of software programs, the patient-specific delay time.[8]

Split-Bolus Technique (Fig. 8)

A pre-contrast image of the entire abdomen is taken. After the contrast agent application, the excretory (pyelogram) phase and the venous phase are obtained and the kidneys, ureters, and bladder are examined with a single image. The arterial phase is not required in this technique.

Then, 50 cc of contrast material is injected into the patient at a rate of 1 mL/s. After a waiting period of 10–15 min, 45 cc of contrast material is injected for the venous phase and takes approximately 20–25 s. Finally, shooting starts the shot is performed with a single shot and splitting the contrast.

After the contrast media, saline application artifacts decrease, and the effectiveness of contrast agent use increases.

Triple-Bolus Technique (Fig. 9)

After all these stages, 30 cc of contrast material is injected at a speed of 1 mL/s, then 20 cc of serum physiology is injected and a waiting time of approximately 10–15 min is determined. This period constitutes the pyelography phase. 30 cc of contrast agent for the nephrographic phase at the end of 10–15 min injected with a speed of 3.5 mL/s. The average duration of time for the nephrographic phase is 80–100 s. To calculate the time needed for the nephrographic phase, the injection time of the contrast agent, the delay scan time, and the arrival time of the drug in the artery should be calculated as 17 s and these should be subtracted from the nephrographic phase. The time to start bolus tracking is calculated with the resulting time (Time calculations and the amount of contrast material vary depending on the device and patient).

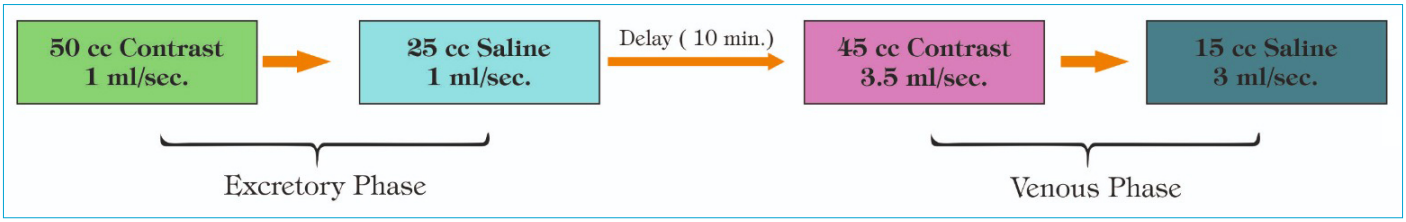

Figure 8. The split-bolus technique contrast schema.

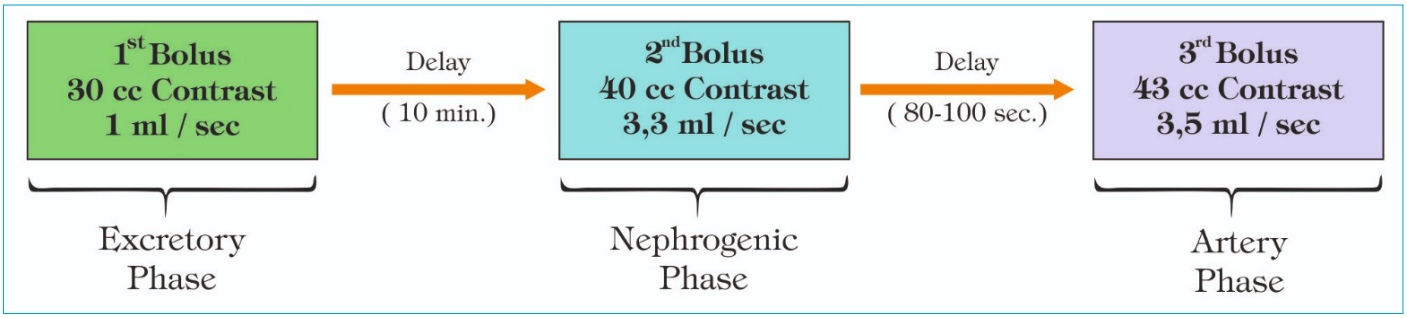

Figure 9. Triple-bolus technique contrast schema.

After the nephrogenic phase, a region of interest is placed in the descending aorta to view the arterial phase. Then, with the bolus tracking technique, 45 cc of contrast material is given at a rate of 5.5 mL/s (followed by 25 cc of physiological saline at 5 mL/s) while images are taken at certain intervals at the same time. When the density measured on the aortic surface reaches the predetermined Hounsfield unit value, shooting is started. Thus, the three phases are presented in one image with a single shot (Fig. 10).

Note: Factors related to contrast agent injection; injection time, injection speed, contrast media volume, contrast media concentration, and saline use after contrast media.

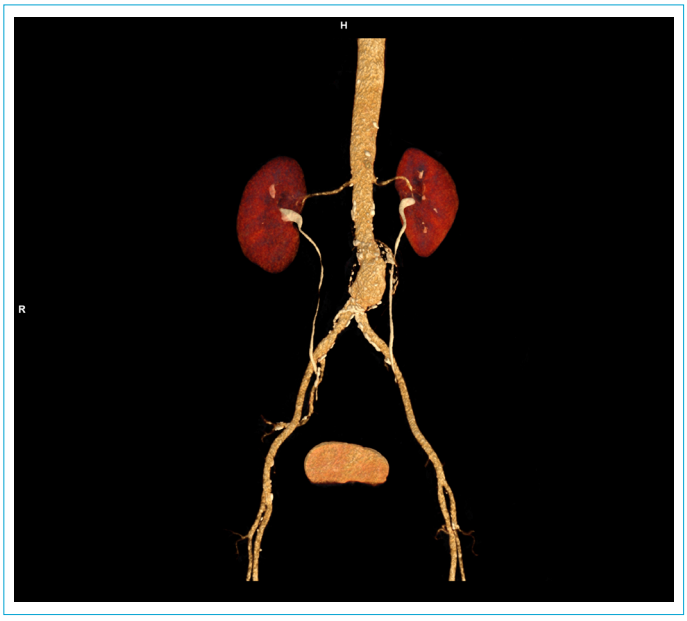

Figure 10. Vascular general VRT and angio view in CT.

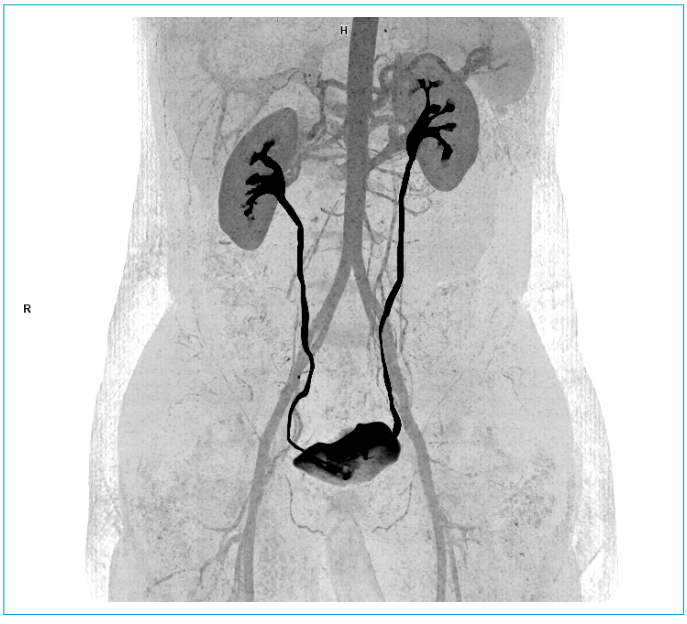

Figure 11. Angio view in CT.

Since the injection time directly affects the peak enhancement time of an organ or vessel, it is considered the most important factor in determining the scan times in CT examinations.[4]

The Importance of Serum Physiological: In a study comparing the use of contrast material alone and the administration of saline in a decreasing amount immediately after the contrast, it was shown that the decrease in the amount of contrast media/saline did not affect the liver parenchyma contrast or the lesion visibility. With the administration of physiological saline after the contrast agent, the amount of contrast media and related artifacts decrease, and the efficiency of the use of contrast agents increases[4] (Fig. 11).

Sample Reconstruction Parameters

Automatic dose calibration is used (CAREDose4D and CARE kV). But as sample dose parameters;

eff. MAs:195, Kv:100, scan time:11.6 s, Rotation time:0.5 s, Delay:5 s, Pitch:0.6, Maxtrix Size: 512 Detector Collimation: 128*0.6 mm, Tilt: 0, CTDIvol: 7.72 mGy, DLP: 396 mGy*cm

Kernel: Body Regular 38(Br38) Window: Abdomen, *IBHC (Iterative Beam Hardening Correction): Lodine, Slice: 1.0 mm–3.0mm (coronal and axial plane), *Increment: 0.75 mm, Safire Strength: 3.

split-bolus/urography vrt reconstructıon samples (Fig. 12).

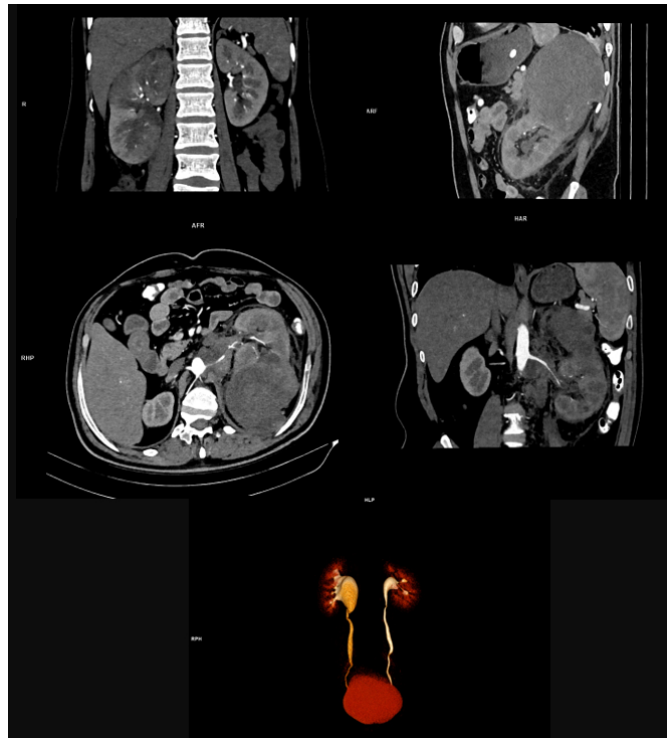

Figure 12. 3D reconstruction examples.

Conclusion

The purpose of this study is to compare the scan time, image quality, and radiation dose and describe the examination of the three-phase single bolus and split-bolus method. Due to the increasing demand for CT examinations in recent years, the amount of exposure to radiation dose has increased and it is an important source of concern considering the long-term damage of radiation to living organisms. Radiation dose first of all depends on the number of phases acquired, the scanning parameters employed, and the patient size.[9] In this study, the main difference between the split bolus method and the renal dynamic technique is the amount of dose delivered to the patient and the number of phases received. 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] Compared to renal dynamic technique, the main advantage of split-bolus CTU is that it is undoubtedly significantly saving radiation. The split-bolus technique is an imaging technique that combines arterial, nephrographic, and renal discharge phases in a single image and aims to minimize radiation dose. By decreasing the number of phases, the amount of radiation absorbed by the patient is directly proportional. Conventional protocols require multiple phase acquisition (arterial, nephrographic, and excretory phases) based on the results of the dose parameters received, the average radiation dose is estimated to be 50% higher.[3] Studies with MDCT can be performed by urinary system evaluation and other pathological assessments of the entire abdomen venous phase, reducing radiation dose, and patient exposure by combining the entire contrast bolus into three separate phases in one phase, rather than dividing it into three separate phases.

All CT images were taken at VRT, Curved MPR, Seyrantepe Hamidiye Etfal Training and Research Hospital, Radiology Clinic, Tomography-1 and Tomography-2 Departments, Siemens Somatom Deifinition Edge (2019), Germany, Collimation 128 x 1.0 mm device. Processed with Siemens Syngo Via30 and CT Vascular, Angio View, programs.

Disclosures

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Conflict of Interest: None declared.

Authorship Contributions: Concept – S.O.; Design – H.O., E.C.; Supervision – H.O.; Materials – H.O.; Data collection &/or processing – S.O., E.C.; Analysis and/or interpretation – H.O., S.O., E.C.; Literature search – S.O., E.C.; Writing – H.O., S.O., E.C.; Critical review – H.O.

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