

# Triphasic Single Bolus and Biphasic Split Bolus Techniques in Computed Tomography Urography: A Pilot Study

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## ABSTRACT

**Aim and objective:** Our study's objective is to examine the image quality, radiation dose, and scan time of the split bolus technique in computed tomography (CT) to evaluate urinary tract diseases.

**Background:** Computed tomography is one of the commonly preferred medical imaging modalities in diagnostic radiology for visualizing several diseases with higher resolution images. However, radiation dose reduction is one of the most crucial causes of a CT examination. Multidetector CT (MDCT) has updated several technical advancements of CT scanner for clinical purposes. The excretory system's radiological investigation is called urography, which is done in conventional radiography in the old days. Urolithiasis is considered a common disease affecting 12% of the global population in their lives.

**Materials and methods:** In our study, 10 patients underwent a split bolus technique for CT urography (CTU) examination at the Mahatma Gandhi Medical College and Research Institute, Puducherry. Among the 10 patients, 6 patients are adult male, 1 patient is a pediatric male, and 3 patients are adult female. The study was conducted in an MDCT (GE optima 660) scanner. The split bolus technique protocol followed in this study is an initial bolus of 40 mL contrast media given intravenously at 3.5 mL/second flow rate with an interbolus delay of 8–10 minutes to allow the contrast media opacify the ureter and urinary bladder. After 8–10 minutes, the remaining 50 mL of contrast media and 20 mL saline chaser are given, and images were acquired at 25 seconds for the arterial phase and 70 seconds for the venous phase, nephrogenic and excretory images in a single acquisition, which eliminates the need of separate acquisition.

**Results:** The image quality of the split bolus technique provides comparable results with a single bolus technique for interpretation. The total dose length product (DLP) of the split bolus technique is less than the single bolus technique. So, as a result, the radiation dose is reduced in the split bolus technique. The entire procedure from patient preparation to postprocedure care ranges from 35 to 55 minutes, and the scan time is similar for both the techniques. In our study, various pathologies were also diagnosed, such as, renal cyst was reported in 40% of the patients, and other diseases like hydronephrosis, renal calculus, contracted, a lesion in the kidney, and pyelonephritis were diagnosed in the rest of the patients.

**Conclusion:** The split bolus technique can be considered for reducing radiation exposure to the patient for the CTU examination. The split bolus technique has some limitations compared to the single bolus technique. Nevertheless, split bolus gives comparable image quality with the less patient dose, making the technique considered for various contrast-enhanced CT investigations.

**Keywords:** Computed tomography, Split bolus, Urography.

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## INTRODUCTION

Computed tomography (CT) is one of the commonly preferred medical imaging modalities in diagnostic radiology for visualizing several diseases with higher resolution images.<sup>1,2</sup> The reformatted three-dimensional (3D) image and various postprocessing software were used to enhance the specific anatomy or vasculature diagnostic information, enabling the doctors to evaluate pre- and postsurgical mapping.<sup>3</sup> The reduction of radiation dose is the most crucial cause for a CT examination because of the radiation-induced consequences and the probability of cancer occurrence.<sup>4,5</sup> In CT, the radiation dose depends on the significant factors like X-ray tube operating parameters, patient thickness, and acquisitions in different phases.<sup>4</sup> Also, decreasing the X-ray tube voltage may decrease the resolution of images, and change in the X-ray tube current reduces the radiation dose level. The iterative reconstruction algorithm reduces the radiation dose from 40 to 87% in routine clinical use.<sup>1</sup> In the case of the unavailability of dose reduction algorithms, reducing the number of acquisitions in different phases may also reduce the radiation dose.<sup>4</sup> The alternative method for reducing the radiation dose is reducing the field of view, which significantly decreases the radiation dose as it is

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directly proportional to scan time and scanning field of view.<sup>6</sup> It is implemented in clinical practice by reducing the scan coverage area for noncontrast examinations and excretory phase from kidneys to the urinary bladder, which eventually decreases the radiation

dose without compromising the image quality.<sup>6</sup> The International Commission on Radiation Protection (ICRP) has prescribed a thumb rule called As Low As Reasonably Achievable (ALARA), which insists the medical practitioners implement several strategies to reduce the radiation dose to the patient.<sup>5</sup>

Also, there is a possibility to decrease the individual effective dose by adhering to the ALARA principle while performing CT urography (CTU) examination.<sup>7</sup> The spontaneous development of CT technology led to multidetector computed tomography (MDCT), which enabled higher resolution CT examinations.<sup>8</sup> Nowadays, dual energy computed tomography (DECT) is used for the imaging, which enables noncontrast virtual imaging with an iodine subtraction protocol to extract noncontrast images from contrast instilled CT images to eliminate the need for multiple phases scan.<sup>9</sup>

The primary criteria for CTU image interpretation are appropriate urinary tract distension and opacification. Various techniques can be applied to achieve optimal urinary tract distension and contrast media opacification. McNicholas et al. (1998) observed a higher opacification of the mid ureter to distal ureter while applying abdominal compression. However, compression is contraindicated in some patients having an abdominal aortic aneurysm. For the contraindicated patients, McNicholas et al. applied for the prone position as an alternative for higher mid ureter opacification.<sup>10</sup> For the pelvicalyceal system's overall opacification, the supine position shows more significant opacification than the prone position.<sup>11</sup> As per the American Urological Association (AUA) guidelines in 2012 and the American College of Radiology (ACR) appropriateness criteria in 2014, CTU is considered as the choice of study for evaluation of gross hematuria and microscopic hematuria in adult patients.<sup>6</sup> The European Society of Urogenital Radiology had prescribed the MDCT split bolus technique as an adequate diagnostic imaging examination to rule out macroscopic hematuria.<sup>12</sup> Brenner et al. have argued that an increase in CT use may lead to radiation-induced malignancies, especially while examining children and young populations, particularly women.<sup>7</sup> Hence, modalities like ultrasonography (USG) and magnetic resonance imaging (MRI) can be considered for patients suspected with a high risk of developing radiation-induced malignancies.<sup>7</sup> In recent days, MRI has been considered a choice of investigation for performing urography procedure, but due to its inability to detect renal calcifications, higher cost, and contraindications limit the use of MRI in evaluating urinary tract pathologies.<sup>13</sup> Apart from urography investigations, various other examinations also show increased recommendations for the split bolus technique. Apart from urographic investigations, split bolus spectral CT shows equal opacification and image quality in evaluating the pancreas with a reduced radiation dose of 43% compared to multiphasic CT acquisitions.<sup>14</sup> For evaluating hepatic focal nodular hyperplasia, MDCT split bolus technique shows equivalent image quality compared to triphasic image acquisition.<sup>15</sup> Multidetector computed tomography is successfully replacing the conventional urography technique by effective visualization of the urinary tract and excretory system that detects various urinary tract abnormalities, neoplasm, and congenital abnormalities.<sup>16</sup> Using the CTU examinations, various benign etiologies of hematuria, benign prostate enlargement, traumatic urine leaks, and additional postsurgical follow-up investigations can also be diagnosed using this protocol.<sup>6</sup>

Among the renal system pathologies, urolithiasis is considered a common disease affecting 12% of the global

population at some day in their life.<sup>17</sup> Urography is the radiological investigation of the excretory system with intravenous contrast media injection to image the urinary tract. The single bolus technique is a 3-phase study, i.e., arterial phase, venous phase, and excretory phase, whereas the split bolus technique is a 2-phase study, i.e., arterial and venous phase combined with excretory phase. During the past, intravenous urography (IVU) was the urographic examination performed to evaluate the excretory system.<sup>18</sup> Even though IVU is considered a golden standard to evaluate the urothelium, it is remarkably inferior in evaluating the renal parenchyma by acquiring cross-sectional 3D images in CT.<sup>19</sup> The CT's technical advancements had paved the way for performing urography examination in CT to increase diagnostic accuracy. In the beginning era of CT, urography was performed in a single acquisition, resulting in inappropriate opacification of both upper and lower ureter. Various techniques, like altering the position of the patient (prone position), abdominal compression, and diuretics, were followed to overcome this issue, resulting in increased patient discomfort, time, and cost.<sup>18</sup> Then, CTU is done with a single bolus technique, which gives entire ureter opacification in a single run, whereas split bolus technique is a unique approach to radiation dose reduction compared to a single bolus technique, a conventional technique.<sup>20</sup> Multidetector computed tomography is considered a choice for evaluating urolithiasis and classifying the renal mass stages.<sup>21</sup> However, IVU can be done to diagnose the excretory system pathology. CT urography examination is considered because of the post-processing and reconstruction software used, especially for the coronal reformatted images, which enhance the diagnostic visualization of the bilateral renal excretory system in a single image.<sup>21</sup> The split bolus technique decreases the radiation dose; the opacification of the urinary tract can be diminished due to the lower amount of intravenous contrast media injection in the first bolus than the second bolus.<sup>22</sup> However, the split bolus technique notably reduces the radiation dose to the patient. It gives comparable image quality with a single bolus technique.<sup>20</sup> In evaluating the excretory system, DECT has a clinical application of renal calculi quantification and auto bone extraction. The bone may obscure the volume-rendered CTU images that can be overcome using DECT by auto bone extraction, reducing post-processing time.<sup>9</sup> Also, for calculi quantification, DECT distinguishes non-uric acid stones from uric acid stones by color-coding so that uric acid stones can be treated with uric alkalization instead of an interventional procedure. This present study examines the various pathological conditions in urinary tract diseases, such as, hydronephrosis, renal calculus, contracted kidney, lesion, and pyelonephritis.

## MATERIALS AND METHODS

### Patient Data

In our study, 10 patients were selected for the split bolus technique for CTU examination at the Mahatma Gandhi Medical College and Research Institute, Puducherry. Among the 10 patients, 6 patients are adult male (60%), 1 patient is a pediatric male (10%), 3 patients are adult female (30%) as shown in Figure 1. For our understanding, we have categorized patients based on their age groups, as shown in Figure 2.

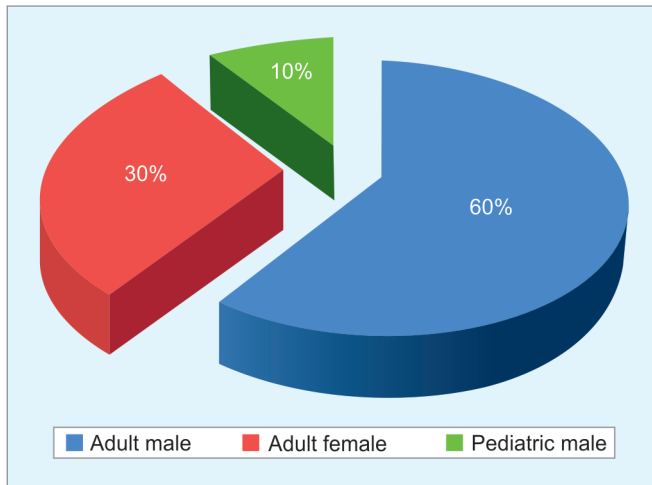


Fig. 1: Gender classification

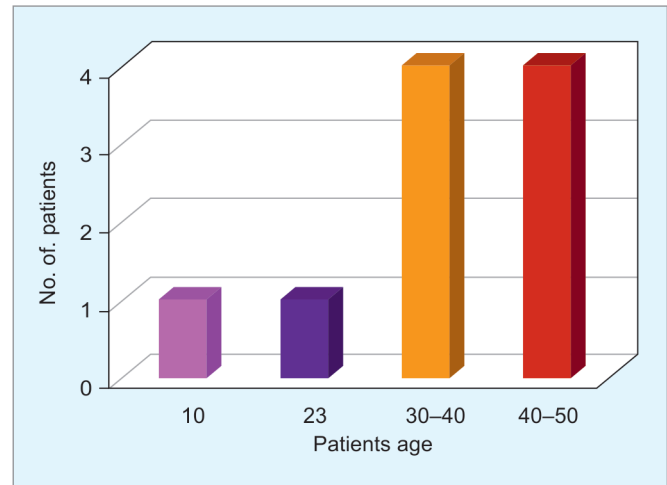
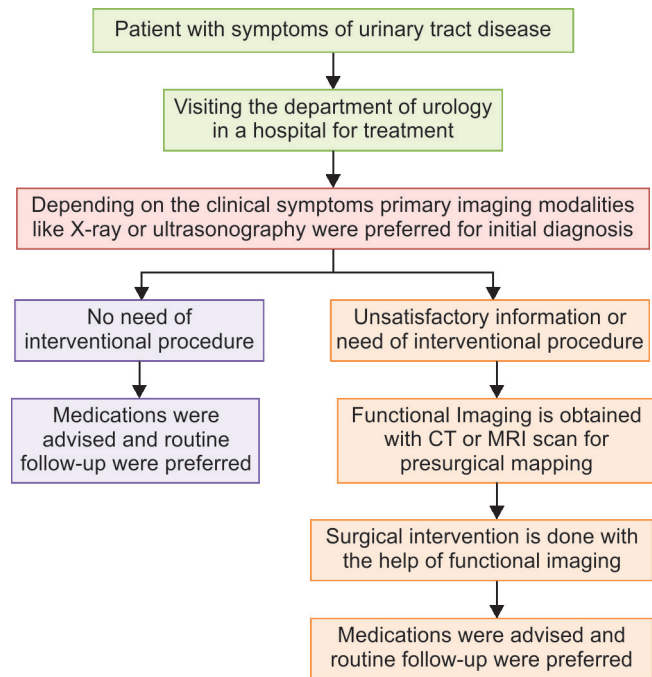


Fig. 2: Age group classification

Flowchart 1: Patient flow in the hospital for urological diseases



### Patient Preparation

This study is performed as a regular clinical examination in our department, and the ethical committee was not formed for conducting this study. The patient flow in the hospital is mentioned in [Flowchart 1](#). The patients considered for this study are with flank pain symptoms, presence of any urinary tract pathology previously diagnosed by any initial diagnostic imaging modality, hematuria, postsurgical follow-up, and urinary tract obstruction. The exclusion criteria for patient consideration were allergic to iodinated contrast media, pregnant patients, elevated blood urea, and serum creatinine levels. Fasting overnight or 6 hours before the study is preferred. For overnight fasting patients, mostly, the study is conducted in the morning for patient comfort. All the patients are instructed to drink 500–800 mL of water 30–45 minutes before the study and advised not to void after drinking water.

Table 1: Contrast enhancing phases of computed tomography (CT) with corresponding abnormalities

S. no.	CT phase	Visualization of anatomy and defects
1	Unenhanced plain CT	Calculus, hemorrhage content of cystic lesion, <sup>4</sup> calcification, fat, and baseline density masses. <sup>20</sup>
2	Arterial phase	Arterial vasculature and hypervascular lesions.
3	Venous phase	Venous vasculature and hypovascular lesions.
4	Nephrogenic phase	Tumors in the renal system like renal cell carcinoma, etc., and most urological abnormalities. <sup>20</sup>
5	Excretory phase	Fibrotic lesions, excretory system filling defects, etc. <sup>20</sup>

### Equipment Operating Parameters

The study was conducted in an MDCT (GE optima 660) 128 slice CT scanner with X-ray tube potential of 120 kVp, mAs was fixed by automatic tube current modulation, zero degree gantry tilt and couch laser alignment were fixed based on patient thickness. The image is acquired by serial axial images in helical scan mode. The images are acquired in a 5-mm thick slice thickness and retro reconstructed to 0.625 mm thin slice thickness. In this study, most of the post-processing was done with multiplanar reconstruction (MPR), maximum intensity projection (MIP), especially the coronal plane, and volume rendering (VR) images.

### Image Acquisition Technique

The primary image characteristics of CTU are visualization of fully opacified and distended urinary bladder and renal parenchymal enhancement with opacification of vasculature and enhancement of pathology.<sup>4</sup> The acquisition phases and its corresponding pathological visualization are represented in [Table 1](#).

Generally, a noncontrast computed tomography (NCCT) was obtained before CTU, but in our study, depending on the physician's need, it is decided to perform NCCT. In a single bolus technique, we inject 90 mL of contrast media with 20 mL saline chaser at 3.5 mL/second flow rate in a single run and acquire three different phases with three different consecutive times like 25 seconds for



the arterial phase, 70 seconds for venous/nephrogenic phase, and 8 to 10 minutes for delayed or excretory phase as illustrated in Figure 3 and clinical image as represented in Figure 4.

Whereas in the split bolus technique, we initially give 40 mL of intravenous contrast media at 3.5 mL/second flow rate as the first bolus and interbolus delay of 8–10 minutes allows the contrast media to opacify the ureter and urinary bladder. After 8–10 minutes, the remaining 50 mL of contrast media with a 20 mL saline chaser as a second bolus obtain rapid image acquisition in 25 seconds for arterial phase imaging and 70 seconds for venous phase imaging. Whereas, in 70 seconds, we will acquire both nephrogenic and excretory phases in a single acquisition, which eliminates the need for separate acquisition for excretory phases like the single bolus technique, as illustrated in Figure 5 and the clinical image represented in Figure 6. The arterial phase's scanning field starts from the diaphragm to the iliac crest, and the venous phase starts from the diaphragm to the ischium. During the split bolus technique, after the first 40 mL bolus instillation, the patient may be rolled on the couch to allow the blending of contrast media and urine.<sup>12</sup>

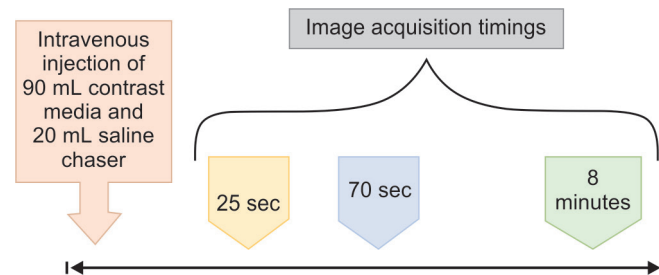


Fig. 3: Schematic representation of single bolus 3 phase CTU protocol

## RESULTS

### Image Quality

The image quality is mainly evaluated based on the urinary tract opacification and distension. Four radiologists with 3–5 years of experience independently reviewed the split bolus technique for CTU examination in the axial and coronal images along with MPR, MIP, and VR 3D reconstruction images. The details about the protocol used for image acquisition were not discussed with the radiologist. For the evaluation of image quality, the degree of contrast media opacification was recorded as; 0 for no opacification noted, 1 for 25% of opacification, 2 for 50% of opacification, 3 for 75% of opacification, and 4 for 100% opacification. The radiologist interpreted the images in the picture archiving and communication system (med synaptic private limited) server. The urinary tract distension is measured using the digital cursors to evaluate the renal collecting system in the axial acquired plane on a wider CT window instead of a narrow CT window to avoid obscuring the urothelial details by contrast media opacification. The maximum noted short-axis values were marked as the measurements. The urinary

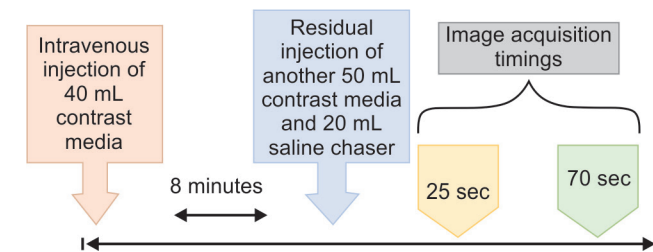
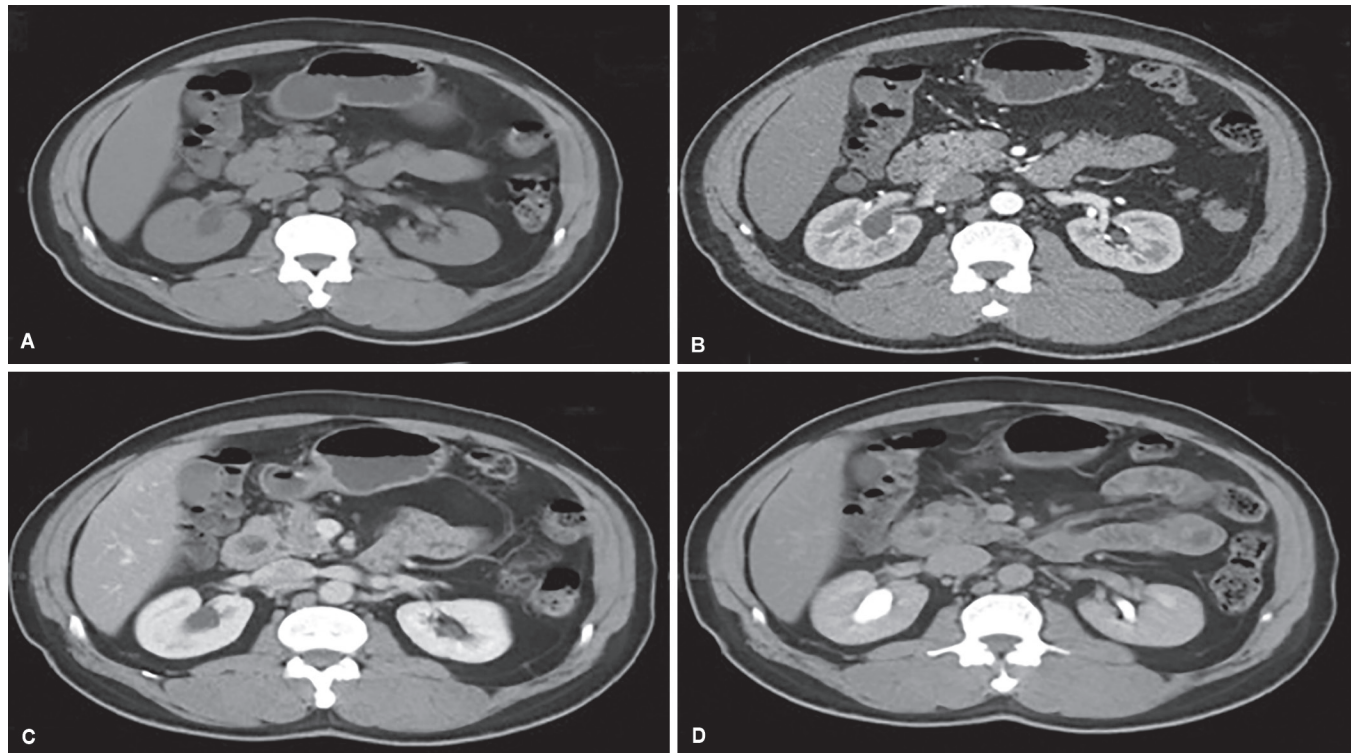
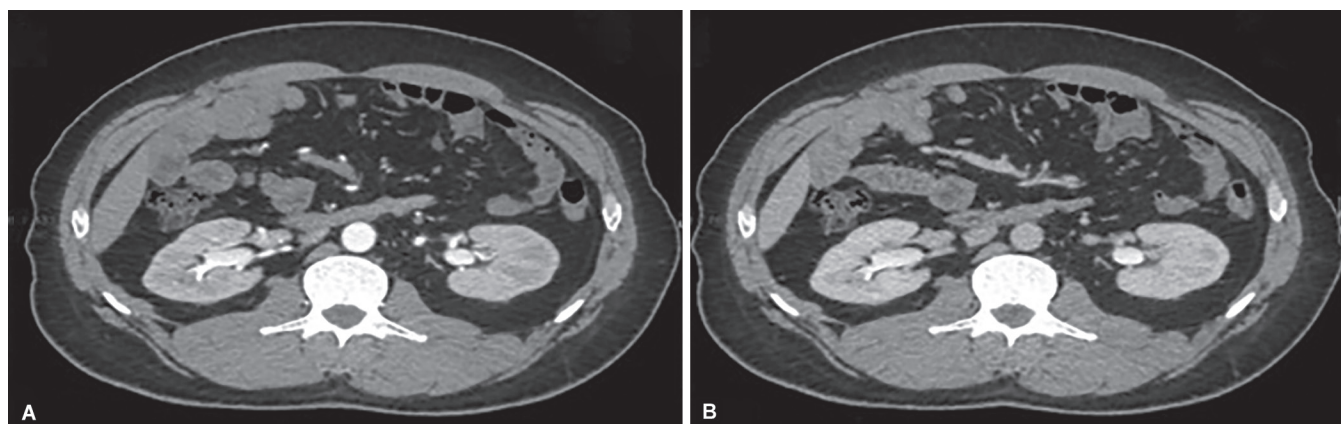


Fig. 5: Schematic representation of split bolus 2 phase CTU protocol



Figs 4A to D: Single bolus multiphasic MDCT urography imaging: (A) Unenhanced CT or NCCT; (B) Arterial phase image acquired at 25 seconds delay after administration of intravenous contrast media shows arterial vasculature enhancement; (C) Venous phase image acquired at 70 seconds (25 sec + 45 sec) shows nephrogenic phase; (D) Excretory phase image acquired at 8 minutes delay shows enhancement of renal pelvis



**Figs 6A and B:** Split bolus multiphasic MDCT urography imaging: (A) Arterial phase image acquired at 25 seconds after administration of second bolus shows arterial vasculature enhancement combined with excretory phase opacification; (B) Venous phase image acquired at 70 seconds shows nephrogenic phase combined with excretory phase opacification

tract opacification is evaluated by placing the Hounsfield unit (HU) measuring circular region of interest (ROI) on the contrast-enhanced region of the renal cortex and medulla in the axial acquired images or reformatted coronal images of 0.625 mm slice thickness for better visualization of bilateral urinary tracts.

Among the 10 patients, 6 patients were given an opacification score of 2, and 4 patients were given an opacification score of 3, which is considered more or less enough for reconstruction and reporting the final diagnosis. As a result of our study, the split bolus technique had provided a minimum of 50% urinary tract and urinary bladder opacification. Hence, the split bolus technique's image quality provides comparable results with a single bolus technique for interpretation in reduced radiation exposure.

### Radiation Dose Reduction

The detector of the CT scanner measures the radiation dose. The radiation dose report is generated at the end of the examination after the successful completion of the retrospective reconstruction of the acquired phases. The radiation dose reports of two patients who underwent a single bolus and split bolus technique were given below. Table 2 shows the radiation dose report of the triphasic single bolus technique, and Table 3 shows the dose report of the biphasic split bolus technique.

The dose report is exclusive of plain CT as the radiologist decides it at the time of examination. If a plain CT scan was

performed, it might increase the total dose length product (DLP) of both the techniques. The DLP of the split bolus technique is less than the single bolus technique. As a result, the radiation dose is reduced in the split bolus technique compared to a single bolus technique.

### Scan Time

The total duration of the CTU on table procedure ranges from 12 to 15 minutes, which may increase or decrease depending on the patient's cooperation, intravenous vasculature accessibility of the patient, protocol of the institution, scanner configurations, etc. Before the examination, the oral hydration time is 25–40 minutes, depending on the patient's tolerability to restrict urine. The time duration is similar to both the techniques. So, as a total, the entire procedure from patient preparation to postprocedure care ranges from 35 to 55 minutes.

### Various Diagnosis Made by the Split Bolus Technique

In our study, apart from image quality, radiation dose, and scan time, we diagnosed renal cyst as a significant disease for 40% of the patients, and various other diseases were interpreted. The diseases diagnosed were hydronephrosis, renal calculus, contracted kidney, the lesion in the kidney, and pyelonephritis was diagnosed in the rest of the patients, as shown in Figure 7.

From our study, two patients with surgical implants like bilateral DJ stent and spinal metal screw implant were imaged by this split bolus technique with optimal image quality. The renal cortical cyst

**Table 2:** Radiation dose report received by a patient in a triphasic single bolus examination

S. no.	Phase	Scan range (mm)	CTDI vol (mGy)	DLP (mGy—cm)	Phantom (cm)
1	Arterial phase	I 51.750–I 421.750	12.70	551.29	Body (32)
2	Venous phase		12.69	551.20	
3	Delayed phase	I 55.000–I 420.000	21.03	902.66	

Total exam DLP: 2005.15

**Table 3:** Radiation dose report received by a patient in a biphasic split bolus examination

S. no.	Phase	Scan range (mm)	CTDI vol (mGy)	DLP (mGy—cm)	Phantom (cm)
1	Arterial phase with excretory phase	S 20.000–I 245.000	25.28	786.56	Body (32)
2	Venous phase with excretory phase	S 20.000–I 450.000	21.05	1086.61	

Total exam DLP: 1873.17

is noted in the right kidney for two patients measuring  $10 \times 7$  mm in the interpolar region,  $6 \times 6$  mm in the upper pole. Three patients were diagnosed with BOSNAIK type-1 cyst noted in the right kidney measuring  $1.4 \times 1.1$  cm,  $2.2 \times 1.5$  cm in the interpolar region, and  $7.2 \times 8$  cm cyst in the left kidney. One patient is diagnosed with a cortical cyst measuring  $10 \times 8$  mm in the left kidney's mid pole. Two patients were diagnosed with enlarged left kidney measuring  $19.5 \times 8.5$  cm,  $11 \times 4$  cm, and enlarged right kidney is noted in one patient measuring  $14.2 \times 7.4$  cm. One patient is diagnosed with contracted left kidney measuring  $6 \times 3.4$  cm. Partial renal staghorn calculus is noted in one patient measuring  $3.5 \times 2.5$  cm in the right kidney's upper calyx. Left renal vein thrombosis was noted in one patient due to incomplete opacification of the renal vein. One patient is diagnosed with an ill-defined collection measuring  $9 \times 12 \times 7$  cm and approximately  $390 \text{ cm}^3$  in the perirenal space. One patient is diagnosed with diffuse urinary bladder wall thickening measuring approximately 12 mm with mild trabeculations.

Additional diagnostic information of nearby organs was also obtained for each patient in our study. Both adrenal glands appear normal in all the patients of our study. A duplex collecting system is observed in two patients. Two patients were diagnosed with mild to moderate pelvicalyceal dilatation. Two patients were

diagnosed with delayed excretion in the right kidney. One patient is diagnosed with an umbilical hernia, and one patient is suspected of pancreatitis. One patient is diagnosed with a cyst in bilateral ovaries measuring  $2.5 \times 2.4$  mm in the right ovary and  $3 \times 1.8$  mm in the left ovary. One patient diagnosed with a hyperdense lesion measuring  $7.1 \times 6.4 \times 6.2$  cm in left adnexa, probably arising from the left ovary, displaces the uterus anteriorly to the right side and the rectum toward the right side. As a result, our study split bolus technique has ruled out various diagnostic pathologies.

## DISCUSSION

In this study, we examined the split bolus technique for urography in the aspects of accuracy, image quality, and radiation dose consideration. All the patients in our study had reduced radiation exposure than single bolus techniques incomparable image quality. The purpose of drinking water is to distend the urinary tract and urinary bladder. It also has the effect of filling renal calyces and decreasing the contrast-enhanced urine density due to lower concentration.<sup>23</sup> During the excretory phase, the oral hydration decreases the urinary tract's attenuation values and improves the constant opacification of the ureter.<sup>24</sup> In case of emergency or intolerable to restrict urine flow, the patient may empty half of the bladder for convenience.<sup>12</sup> For CTU and IVU, the radiation dose for skin is similar, whereas the total effective dose is double in CTU than IVU.<sup>25</sup> Images acquired in the split bolus technique for a pediatric patient are represented in Figure 8, which shows a post-processed VR image acquired using a split bolus technique. The images acquired at different phases, as represented in Figure 9, show ruptured and infected hydronephrosis of the left kidney with an extensive collection noted in the perirenal space, greater sac, and left the subdiaphragmatic region. The right kidney shows grade-II hydronephrosis with multiple cortical scars in all three poles of the kidney and minimal adjacent free fluid noted in perirenal space. There is no evidence of excretion on the left kidney in the excretory phase.

While comparing all the frequently performed 11 different CT examinations types, multiphasic CT of the abdomen and pelvis significantly contributes to delivering a more significant effective radiation dose with a higher number of acquisitions and images. The physician's primary need for the excretory phase is to attain

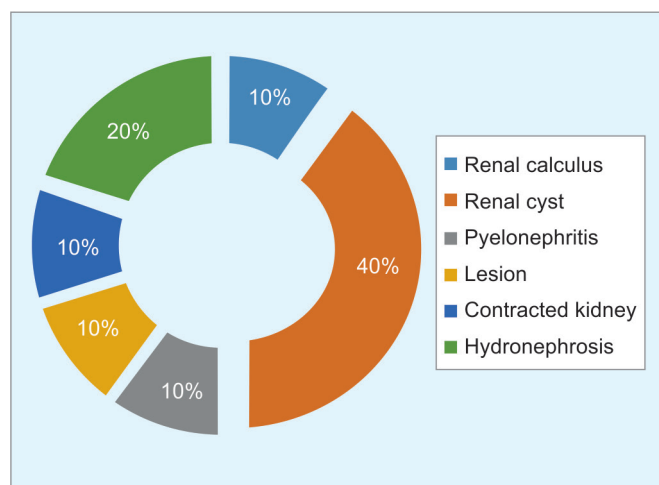
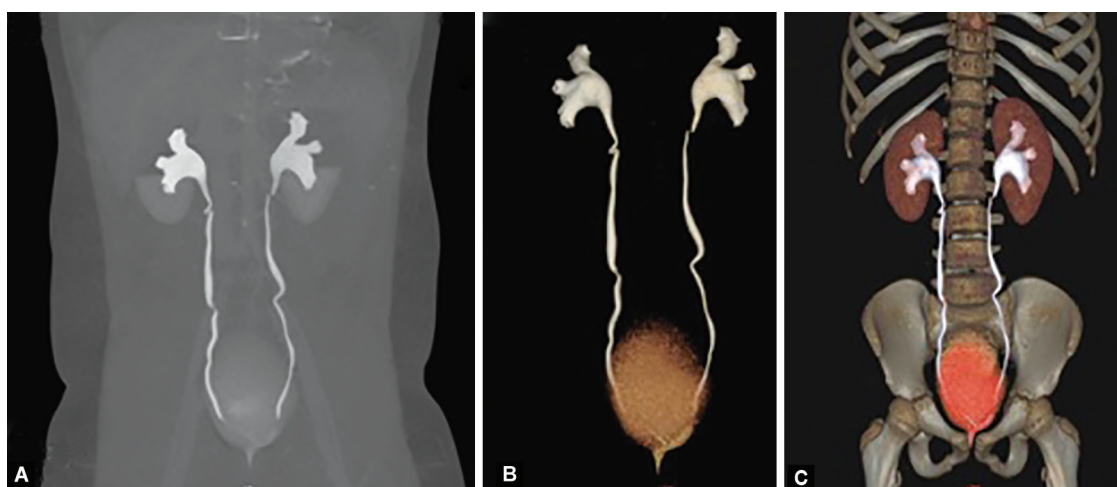
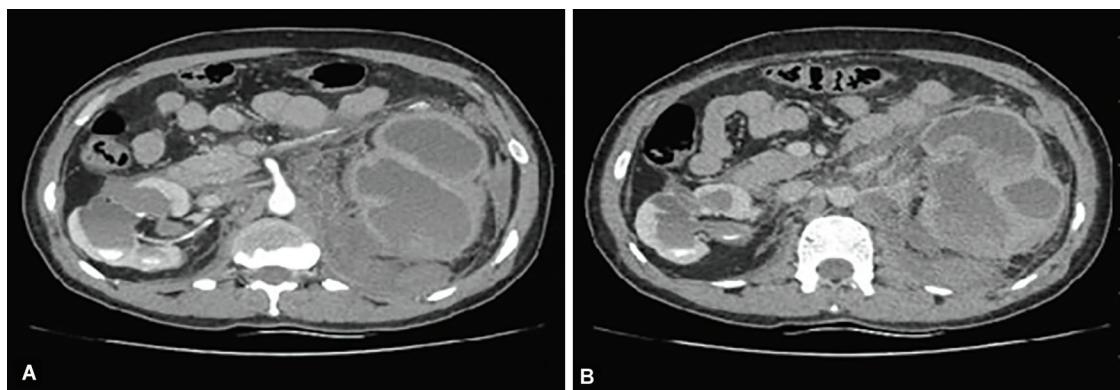


Fig. 7: Various diseases diagnosed with split bolus CTU technique



Figs 8A and C: CTU obtained from MDCT split bolus technique for a pediatric patient: (A) Reformatted coronal plane MIP image shows enhanced contrast flow density in the urinary tract; (B) Coronal plane reformatted VR image with bone extraction shows 3D visualization of urinary tract; (C) Coronal reformatted VR image shows anatomical location of the urinary tract in detail without bone subtraction





**Figs 9A and B:** Images acquired by using split bolus technique of bilateral DJ stent *in situ* patient: (A) Arterial phase obtained at 25 seconds after instillation of second bolus; (B) Shows venous phase obtained at 70 seconds

maximum opacification of the urinary tract that causes an additional phase in a single bolus technique, which increases radiation dose and scans time to the patient.<sup>20</sup> Hence, the biphasic split bolus technique reduces radiation dose to the patient and decreases scan time with comparable image quality than the multiphasic single bolus technique. Several researchers have reported that radiation dose can be reduced by eliminating the plain unenhanced NCCT examination or acquiring the excretory phase with abdomen radiography or localizer radiography.<sup>26</sup>

In some cases, the upper urinary tract may not be well opacified, which can be overcome by abdominal compression, diuretics administration, and investigation performed with the patient in a prone position.<sup>12</sup> Also, there is no remarkable difference between administering a higher volume of the first bolus, followed by a lower second bolus volume and *vice versa*. The reduced amount of first bolus administration leads to a decreased HU value of iodinated urine, and an enormous amount of bolus administered second shows higher enhancement of the renal cortex and other abdominal visceral organs.<sup>27</sup> However, the overall opacification of the urinary tract is similar to both the techniques.

## LIMITATIONS

In our study, we have some limitations as follows:

- Only fewer patient populations were evaluated in this study, which decreases the number of diseases diagnosed and the evaluation of urinary tract opacification.
- The single bolus and split bolus techniques were not performed for the same patient as it increases radiation exposure, which is ethically unacceptable. Hence, we cannot evaluate the superiority and inferiority of the techniques in our study.
- The radiation dose is calculated by the CT scanner's displayed dose level, and we have not measured the dose by the individual dosimetry.

Also, the split bolus technique has some disadvantages compared to the single bolus technique such as:

- Reduced urinary tract distension and opacification compared to single bolus, especially in the excretory phase, which insists on using an additional volume of contrast media depending on the patient's height and weight compared to a single bolus technique that results in contrast-induced toxicity for patients. Though techniques like abdominal compression and diuretics infusion may be done to improve opacification and distension,

it will not have equivalent accuracy like a single bolus technique instead increases discomfort to the patient.

- Reduced accuracy in diagnosing lower urinary tract pathologies and minute renal cell carcinoma as there are only a few post-contrast phase acquisitions.

Hence, we had instructed oral hydration before the study, which significantly improved the entire urinary tract's opacification with appreciable distension for the imaging of both upper and lower urinary tracts. This resulted in increased accuracy of image interpretation. The protocol is different for both the techniques, whereas the image quality is more or less comparable for interpretation.

## CONCLUSION

Our study concluded that the split bolus technique could be considered one of the growth strategies for reducing radiation exposure to the patient for CTU examination and various other contrast-enhanced CT investigations. Even though the split bolus technique has some disadvantages compared to the single bolus technique, split bolus gives comparable image quality with the less patient dose, making the technique to be considered for evaluating various pathologies in the human body.

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