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Research Article

Split-Bolus versus Single-Bolus CT Urography: A Comparative Study of Radiation Dose and Scan Time.

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Abstract: Background: This study was done to calculate and compare the Radiation dose between the Single-bolus and Split-bolus CT-urography technique and calculate and compare the time taken for the study of single-bolus and split-bolus CT-urography technique. **Material and Methods:** This study included 39 patients. Twenty-two were males (56.4%) and females were 17(43.6%). 19 patients were done by using single-bolus CT-Urography protocol and 20 patients by the split-bolus protocol. **Results:** In SB1 (Single-bolus CT Urography), CTDI vol had a mean ±SD value of 17.9711 and SB2 (Split-bolus CT Urography), CTDI vol had a mean ±SD value of 10.7400, with p value of < 0.001, which is statistically significant. In SB1 (Single-bolus CT Urography), DLP (dose-length product) had a mean ±SD value of 739.68 and SB2 (Split-bolus CT Urography), DLP (dose-length product) had mean ±SD value of 531.65, with p value of < 0.001, which is statistically significant. Scan time for SB1 had mean ±SD value of 64.47sec and SB2 had a mean ±SD value for scan time of 56sec. There was no significant difference in the image quality between SB1 and SB2. **Conclusion:** Split-bolus CT urography is a reasonably better alternative to single bolus technique in terms of radiation dose and scan time.

Keywords: Urography; single-bolus; split-bolus.

INTRODUCTION

Computed tomography urography (CTU) is a relatively new diagnostic imaging examination providing comprehensive evaluation of the upper and lower urinary tract. Multidetector CT (MDCT) enables isotropic or near-isotropic high-quality multi-planar image reconstruction. As MDCT has become more widely available, CTU has begun to replace other imaging techniques, especially intravenous urography (IVU).

CTU is currently performed for a variety of indications using different protocols (Nolte-Ernsting, C., & Cowan, N. 2006; Morcos, S.K. 2007) for which purely CT-based techniques as well as hybrid CT-radiography techniques (Kawashima, A. *et al.*, 2004; Sudakoff, G. S. *et al.*, 2005) have been utilised. Multi-detector computed tomography urography (MDCTU) offers considerable advantages in the evaluation of the upper urinary tract compared to excretory urography due to higher contrast resolution and ability to perform high quality three dimensional rendering of the urinary tract (Dillman, J.R. *et al.*, 2007). A variety of CT urography techniques have been evaluated for producing adequate opacification of the urinary tract at the lowest radiation exposure (Nawfel, R. D. *et al.*, 2004). Due to multiphase scanning, with some CT urography protocols patients undergoing MDCTU may receive a radiation dose as much as three or four times higher than that with a single phase abdominal CT examination. Nawfel *et al.*, (2004) reported a mean effective dose of 14.8 ± 3.1 mSv with three phase MDCTU protocols, which was about 1.5 times higher than the conventional excretory urography dose of 9.7 ± 3 mSv.

The most commonly described MDCTU protocol comprises a three-phase protocol, which typically consists of non-contrast (for the detection of hemorrhage and stones), nephrographic (for renal parenchymal evaluation), and excretory phases (for assessing the collecting system, ureters and urinary

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bladder). The double excretory or corticomedullary phase is optionally acquired instead of the nephrographic phase. Some studies have described acquiring arterial phase images for patients who may require surgery (Lang, E. K. *et al.,* 2003).

High radiation exposure and increased scanning time are amongst the major disadvantages of the multi-phase scanning procedures which in addition require more time to study the larger number of images. To rectify these issues, Chai *et al.,* (2001) devised split-bolus technique which reduces radiation dose as well as reduces the number of phases of scanning thereby reducing the radiation exposure. The technique involved injection of a small bolus of contrast agent (30mL) after non-contrast scan. This was followed by injection of a larger bolus (100mL) after 5 to 10 minutes. This allowed two phases to be demonstrated in single scan (nephrographic phase from the second bolus and excretory phase from the first bolus).

A modification of split-bolus technique was proposed by Raptopoulos, V., & McNamara, A. (2005) wherein they combined arterial and excretory by injecting 30 mL of contrast agent for urinary tract opacification followed byre-injection of 70-100 mL contrast approximately 2-3 min later and scanning for the corticomedullary phase, 60 s after the start of the last contrast injection. This split-bolus technique reduces the radiation exposure by reduction the number of scans to two (Chow, L.C., & Sommer, F.G. 2001; Nawfel, R.D. *et al.,* 2004).

The present study was conducted to see the scan time and radiation dose differences between single-bolus and split-bolus techniques CT urography.

AIM AND OBJECTIVES

- To calculate and compare the Radiation dose between the Single-bolus and Split-bolus CT-urography technique.
- To calculate and compare the time taken for the study of single-bolus and split-bolus CT-urography technique.

MATERIAL AND METHODS

After due approval from the Institutional Ethics Committee vide no. SIMS/IEC/238 dated 15/04/2015, CT-Urography of the patients was done using 64 slice Somatom Sensation CT scanner (Siemens Healthcare, Germany). In all cases informed consent was taken from the patient or his/her attendants.

INCLUSION CRITERIA

- Patients more than 20 years of age were included in the study.
- Patients with nephrolithiasis and, orureterolithiasis.
- Patients with painless hematuria.
- Patients with pelvic masses causing obstructive uropathy.

EXCLUSION CRITERIA

- Patients less than 20 years
- Patients with hypersensitivity reaction to intravenous contrast.
- Patients in whom CECT is contraindicated (pregnancy, severely impaired renal function).
- Non cooperative patients.
- Patients who refuse to give consent.

EXAMINATION TECHNIQUES AND IMAGING PROTOCOLS:

In this study we included 39 patients. Twenty-two were males (56.4%) and females were 17(43.6%). 19 patients were done by using single-bolus CT-Urography protocol and 20 patients by the split-bolus protocol. Patients fitting in the inclusion criteria were evaluated by using MDCT 64 slice Somatom Sensation CT scanner (Siemens Healthcare, Germany) was performed after fasting of 8 hours. Patients were advised to fill the bladder. The technical parameters for unenhanced phase included a collimation of 1.25 mm, a table speed of 1.4 mm/sec, 250–300 mAs, and 120 kVp. It included from the top of kidneys up to the bladder. The technical parameters for nephrographic phase in single-bolus technique and combined phase of split-bolus protocol included 120 kV and 175 reference effective mAs.

Excretory phase of single-bolus protocol was obtained with 120 kV and 175 reference effective mAs. In our study we used IOHEXOL GE (omnipaque) (350mgI/ml) injection as Contrast medium.

By using the single bolus technique, Unenhanced phase was acquired by breath-hold, abdominal phase followed One hundred millilitres of a non-ionic iodinated contrast agent (Omnipaque) was administration via the antecubital vein at 3.5 ml/sec by using a 20-gauge cannula and an automatic injector. CT was performed in the late arterial phase (start delay, 40 seconds). Another scan was taken after a delay of 10 minutes, yielding images of excretory phase. Raw data sets were reconstructed at 1.25-mm section thicknesses and 0.9-mm reconstruction intervals. We used a 5-mm section thickness for transverse CT images.

In split-bolus technique, Contrast-medium (omnipaque) was given in two boluses. After taking an unenhanced phase, a bolus of 40ml of contrast medium was administered via the antecubital vein at 3 ml/sec by using a 20-gauge cannula manually. After 11 minutes of delay, an additional 60ml contrast medium was administered via the antecubital vein at 3.5 ml/sec by using a 20-gauge cannula and an automatic injector to the patient. The contrast- enhanced ,breath-hold abdominal phase images were acquired 40 seconds after the second contrast bolus, yielding images in synchronous nephrographic and excretory phases of enhancement. No compression was used in this study. Dose parameters with AEC system, displayed on the console of the CT scanner were recorded in all patients.

The most used index today for measuring the dose from MDCT equipment is theCTDIvol*. The DLP (dose length product) is the CTDIvol multiplied by the scan length (slice thickness × number of slices). There are conversion factors to estimate the corresponding effective dose(ED). To decide the effective dose more accurately, individual organ doses must be determined and then the effective dose is the sum of the organ doses multiplied by the corresponding weighting factor. The scanning time was calculated as the total no. of seconds during which the actual scanning was performed adding all the phases in SB1 and SB2.

Image quality was compared by the degree of opacification of the upper urinary tract in axial and coronal images in the excretory phases of single bolus and the combined phase of the split bolus technique by calculating mean opacification score for each kidney. For the purpose of this study, upper urinary tract was divided into 4 parts- pyelocalyceal system, upper, middle and distal ureter.

STATISTICAL ANALYSIS:

The results were compiled and analysed using standard statistical methods. The continuous variables of the study have been shown in terms of descriptive statistics & categorical variables in terms of frequency and percentages. The data analysed with the help of statistical test like Wilcoxon-Mann Whitney U test (Non-Parametric tests) on the data follows Non-Gaussian distribution. All the results so obtained discussed on 5% level of significance. i.e. P-value less than 0.05 considered significant.

OBSERVATIONS AND RESULTS

In our study, age ranged from 20-60 years with a mean ± SD of 46.54 ± 10.03 and with a median of 48.00. The predominant age group was in the age range of 40-50 years with 16 (41.0%) patients falling in this age group followed by age range of 50-60 years with 12 (33.3%) patients falling in this age group, followed by 30-40 years with 7(17.9%) patients falling in this group. Minimum patients were in 20-30 years of age group with 3(7.7%). (Table 1, and Table 1:1)

Table 1: Age Distribution of CT Urography

AGE (in yrs)	Frequency (n)	Percent (%)
20-30 yrs	3	7.7
30-40 yrs	7	17.9
40-50 yrs	16	41.0
50-60 yrs	12	33.3
TOTAL	**39**	**100.0**

Table 1.1: Age distribution

Variable	Mean	Median	S. Deviation	Minimum	Maximum	Range
Age	46.54	48.00	10.031	20	60	40

Out of total 39 patients 22 (56.4%) were males and 17 (43.6%) were females. With a male to female ratio of1.3:1 (Table 2).

Table 2: Gender distribution

Variable (sex)	Frequency(n)	Percent (%)
Male	22	56.4
Female	17	43.6
Total	**39**	**100**

Patients with urological disorders were included in this study. Maximum patients were presented with Hematuria 17(43.65%).5(12.8%) patients had Renal calculus and 5 pat cortical cysts. Minimum patients had HDN, Flank pain, Renal Mass and ureteric calculus having same no. Of patients 3 each (7.7%). (Table 3).

Table 3:Clinical indications for CT Urography

Symptom	No. Of patients(n)	Percent (%)
URETERIC CALCULUS	3	7.7
RENAL CALCULUS	5	12.8
CORTICAL CYSTS	5	12.8
HDN	3	7.7
HEAMATURIA	17	43.6
FLANK PAIN	3	7.7
RENAL MASS	3	7.7

RADIATION DOSE AND TIME COMPARISON IN SINGLE-BOLUS AND SPLIT-BOLUS CT UROGRAPHY:

In SB1 (Single-bolus CT Urography), CTDIvol had a mean ±SD value of 17.9711 and SB2 (Split-bolus CT Urography), CTDIvol had a mean ±SD value of 10.7400, with p value of < 0.001, which is statistically significant.

In SB1 (Single-bolus CT Urography), DLP (dose-length product) had a mean ±SD value of 739.68 and SB2 (Split-bolus CT Urography), DLP (dose-length product) had mean ±SD value of 531.65, with p value of < 0.001, which is statistically significant.

Scan time for SB1 had mean ±SD value of 64.47sec and SB2 had a mean ±SD value for scan time of 56sec, with p value of < 0.001, which is statistically significant. (Table 4, 5).

Table4: Data representing the CT Urography radiation dose, dose-length product and time acquired in the study.

Variable	Group	Median	Interquartile Range	P. Value
DOSE (CTDIV)	SB1 SB2	17.64 10.74	5.62 1.35	<0.001
DLP	SB1 SB2	800 532	218 149	<0.001
TIME	SB1 SB2	65 56	4 2	<0.001

Table 5: Various statistical parameters for dose, DLP and time obtained in the study.

Variable	Group	Mean	Median	S.D	Min.	Max	Range
DOSE (CTDIVOL)	SB1	17.9711	17.6400	3.36649	13.75	25.09	11.34
	SB2	11.0275	10.7400	1.51974	8.91	15.49	6.58
DLP	SB1	739.68	800.00	151.755	570	1124	554
	SB2	531.65	532.00	196.899	389	732	343
TIME	SB1	64.47	65.00	2.970	58	68	10
	SB2	55.90	56.00	1.714	53	60	07

Table 6: Right kidney: percentage of urinary tract segments with opacification scores ≥ 2

	Single bolus protocol	Split bolus protocol
PCS	90%	94%
Proximal ureter	81%	82%
Middle ureter	77%	68%
Distal ureter	73%	70%

Table 7: Left kidney: Percentage of urinary tract segments with opacification scores ≥ 2

	Single bolus protocol	Split bolus protocol
PCS	88%	92%
Proximal ureter	80%	82%
Middle ureter	77%	66%
Distal ureter	79%	70%

Figures 1-7 show the CT images acquired during the study of various patients who underwent single and split-bolus CT urography.

There was no significant difference between the opacification of the upper urinary tract in SB1 and SB2 techniques and the quality of images was similar in both techniques. The percentage opacification show the comparative opacification scores of the upper urinary tract in both kidneys in single-bolus as well as split bolus techniques.

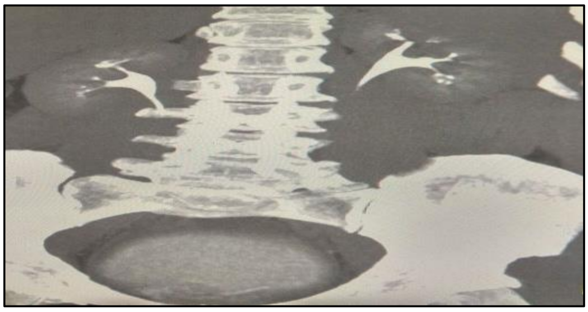

Figure 1: Coronal MIP Post Contrast CT Image showing synchronous Nephrographic phase and excretory phase by Split-Bolus protocol.

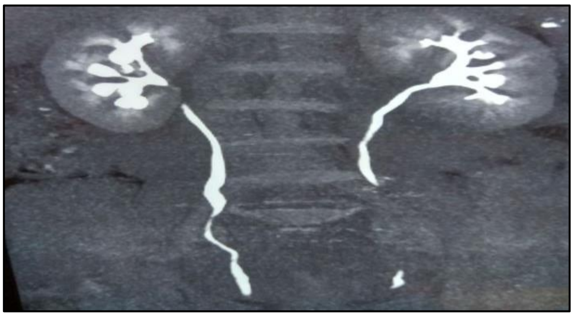

Figure 2: Coronal MIP image showing the well-delineated nephrographic and excretory phases of both kidneys in a split-bolus protocol.

Figure 3: Axial post-contrast CT Image showing normal Excretion on the left side and grade IV HDN on the right side.

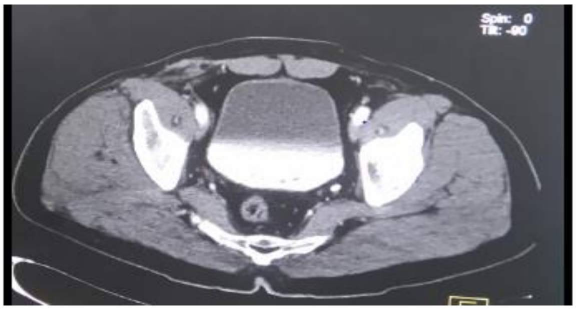

Figure 4: Axial post-contrast CT delayed image showing partial filling of the bladder with contrast.

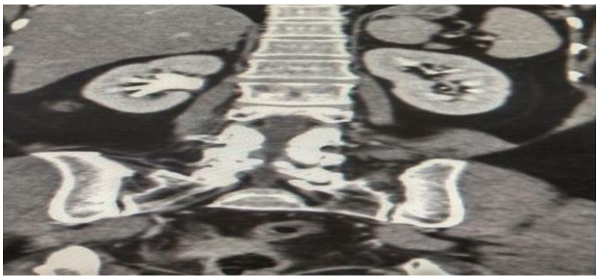

Figure 5: Coronal MIP Post-Contrast CT images showing normal Nephrographic phase and delineation of collecting system in this patient with hematuria by split bolus protocol.

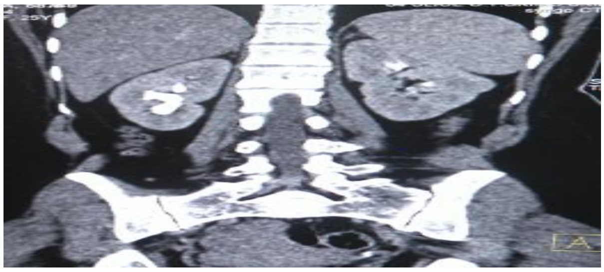

Figure 6: Coronal MIP images in split bolus delayed excretory phase showing the well-delineated pyelocalyceal system, whole ureter and bladder.

Figure 7: Coronal MIP Post-Contrast CT images showing normal PCS in this patient with hematuria by the single-bolus protocol.

DISCUSSION

CT urography provides detailed examination of the whole urinary tract, currently being used for various indications using different technical protocols (Nolte-Ernsting, C., & Cowan, N. 2006; Morcos, S.K. 2007) using pure CT techniques as well as hybrid computed tomography-radiography techniques (Kawashima, A. *et al.*, 2004; Sudakoff, G. S. *et al.*, 2005). The advancement in the imaging modalities used in the evaluation of urinary system using multi-detector CT has led to the accurate depiction of the renal collecting system because of thin sections, increased speed of scanning, enhanced spatial resolution and better reformatted 3-dimensional images. Due to these features, MDCT has succeeded plain radiography in the evaluation of urinary tract pathologies like urolithiasis, renal tumours, and ureteral & bladder abnormalities (Smith, R.C. *et al.*, 1995; NIALL, O. *et al.*, 1999).

Although CTU is now gold standard and first line investigation for the variety of urinary tract disorders but with the use of MDC there is an increased amount of radiation dose delivered to the patient and hence a cause of concern. A number of techniques have been used for the imaging of urinary tract with optimal opacification and reduced radiation exposure (Nawfel, R. D. *et al.*, 2004; Coppenrath, E. *et al.*, 2006). In the multiphase scanning techniques, the radiation dose is usually higher than what a patient gets using single phase protocols. The mean effective dose using 3-phase protocols was 14.8 ± 3.1 mSv which was higher than conventional excretory urography (9.7 ± 3 mSv), as evaluated by Nawfel *et al.*, (2004) MDCT is the investigation of choice for the accurate diagnosis and staging of renal tumors as well as in the diagnosis of renal stones (Wang, L. J. *et al.*, 204; Kalra, M. K. *et al.*, 2005). The coronal reformatted view of a Ct urogram can give the images like intravenous urograms depicting the entire urinary tract in single acquisition (Perlman, E. S. *et al.*, 1996; Kawashima, A. *et al.*, 2004)

CT urography depicts normal ureters with great accuracy along with depiction of urothelial disease (Joffe, S. A. *et al.*, 2003; Akbar, S. A. *et al.*, 2004). However, multiphase CT protocols have higher radiation doses than standard intravenous urography and here comes the role of split-bolus urography which reduces the radiation exposure (Caoili, E. M. *et al.*, 2002; Nawfel, R. D. *et al.*, 2004; McCollough, C. H. *et al.*, 2001).

Chai *et al.*, (2001) used split-bolus CT urography technique which reduced the number of scanning phases from three to two thereby reducing the radiation dose. This technique combined two phases, that is, nephrographic phase from the second bolus and excretory phase from the first bolus. The split-bolus technique instead of obtaining two separate scans for nephrographic and excretory phases, gets both these phases in single phase, thereby reducing the scan time as well as radiation dose (Chow, L.C., & Sommer, F.G. 2001; Chow, L.C. *et al.*, 2007).

A modification of split-bolus MDCT was devised by Raptopoulos *et al.*, (2005) in which 30ml contrast material was to be injected initially to obtain arterial & excretory phases and re-injecting 70-100ml contrast agent 2-3 minute later. The scan was obtained 60 seconds after the second contrast injection which depicted the corticomedullary phase.

Many low-dose Ct protocols are being developed to reduce the scan time and radiation doses for the evaluation of urinary tract pathologies (Kemper, J. *et al.*, 2007; Yanaga, Y. *et al.*, 2009). So in order to study the radiation dose with single-bolus and split-bolus CTU, we did a comparative observational study in our department of Radio-diagnosis in a group of 39 patients.

Age and Gender Distribution:

Our study sample consisted of 39 patients. Out of 39, 22(56.4%) were males and 17 (43.6%) were females. The mean age of presentation was 46.54 (SD± 10.03) with a minimum age of 20 years and a maximum age of 60 years.

Out of 39 patients, 19 patients were done by single-bolus protocol and 20 patients were done by the split-bolus protocol. In the study conducted by Salmeron Beliz I *et al.*, (2013), 64 patients were included,34 were done by the single-bolus protocol with 16 male and 18 were female and 31 by the split-bolus protocol with 12 male and 19 female patients. EktaMaheshwari *et al.*, (2010) did a study on 200 patients with 119 males and 81 females, with a median age of 58 (age range of 18-89 years). These findings were consistent with our study. Similar age and gender distribution was reported in the study conducted by Chong M.C. *et al.*,. Thus in our study males formed the predominant group and constituted 56.4% of patients.

Clinical Features:

In our study, Hematuria was the most common symptom present in 17(43.65%) patients followed by renal calculus and cortical cysts present in 5(12.8%) patients. Other symptoms include HDN, Flank pain, Renal Mass and ureteric calculus with 3(7.7%) patients each. In the study conducted by Jeffrey D. McTavish *et al.*, (2002), Hematuria and suspicious renal mass was the commonest symptom. Other symptoms in the study were hydronephrosis, calyceal diverticulum, renal cell carcinoma and renal cysts.

Radiation Dose Parameters:

In our study, the mean of CTDIvol for single bolus CTU was 17.97(S.D ±3.37) with a maximum value of 25.09 and minimum value of 13.75. For split bolus CTU, the mean of CTDIvol was 11.03(S.D±1.52) with a maximum value of 15.49 and a minimum value of 8.91.

The mean value of DLP for single bolus CTU was 739.68 with a maximum value 1124 and minimum value of 570 and for split bolus CTU the mean value was 531.65 with a maximum value of 732 and minimum value of 389.

A study conducted by SalmerónBélizand N. Blazquez (2013), the mean of CTDIvol for single bolus CTU was 17(S.D±3) and for split bolus CTU the mean of CTDIvol was 11(S.D±1)The mean value of DLP for single bolus was 804 and for split bolus CTU,the mean value of DLP was 534.The values of their study were consistent to our study.

In our study, mean value of Time for single bolus was 64.47(S.D±2.97), with a maximum value of 68 and minimum value of 58.The mean value of Time for split bolus CTU was 55.90(S.D±1.71), with a maximum value of 60 and a minimum value of 53.

CONCLUSION

Split-bolus CT urography is a reasonably better alternative to single bolus technique in terms of radiation dose and scan time. No significant effect on image quality is observed with split bolus technique.

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