Original Article

A comparison of radiation dose in single and split bolus multidetector computed tomography urography

Joshi BR , Jha A

Department of Radiology & Imaging , Institute of Medicine, Kathmandu, Nepal

Coresponding author – Dr. Birendra Raj Joshi

E-Mail: bjoshi01@yahoo.com

Abstract

Introduction: Routine multidetector computed tomography (MDCT) urography protocols include three phase scan with single bolus contrast material injection. To reduce the radiation dose a split bolus MDCT urography technique has been introduced.

Methods: Nephrographic phase in single bolus was obtained by injecting 90 ml of Ioversol (Optiray320mgI/ml) contrast at the rate of 3ml/s during the preset time of 90 second. The excretory phase was taken at the delay of 10 minutes after the contrast injection. For split bolus only two phases (unenhanced and combined) were scanned from the diaphragm to the base of the urinary bladder. The combined phase in split bolus was performed by injecting the contrast in two bolus in which 40 ml at 2ml/s was injected in the first bolus and after a delay of 9 minutes, 60 ml at a rate of 3ml/s was injected, then the scan was obtained 90 second after the second bolus. The volume CT dose index (CTDIvol) and CT dose length product (CTDLP) were assessed in CT work station.

Results: The mean effective radiation dose for single bolus MDCT urography was 40.5% more than the split bolus MDCT urography.

Conclusion: Split bolus MDCT urography protocol was significantly b**etter** in effective radiation dose reduction compared with the single bolus MDCT urography protocol.

Keywords: CTDIvol, DLP, MDCT urography, Radiation dose

Introduction

CT urography is a relatively new diagnostic imaging examination providing comprehensive evaluation of upper and lower urinary tract. Multidetector Computed Tomography [MDCT] enables isotropic or nearly isotropic high quality multiplanar reformation.[1] MDCT has become the method for choice for the diagnosis and staging of renal masses and detection of urolithiasis. A variety of MDCT urography protocols have been studied. A recent CT urographic technique could image the entire urinary tract in one acquisition, providing intravenous urogram like images in reformatted coronal view.[2] However CT urographic technique use a relatively high radiation dose as compared to the standard IVU.

Commonly used three phase CT urographic protocols with single bolus contrast material injection consist of unenhanced, nephrographic, and excretory phases. The corticomedullary phase is optional.[2] Arterial phase has been incorporated into patients who may require surgery.[3] To reduce the radiation dose a split bolus MDCT urographic technique has been introduced in which two separate contrast bolus injection result in a combined nephrographic-excretory acquisition.[4] The main advantage of a two-phase split-bolus technique is that it limits the radiation dose compared with other protocols that include three or four phases of image acquisition.[5] The study was to compare the mean effective radiation dose in single and split bolus MDCT urography.

Methods

This was a prospective cross sectional study carried out in the Department of Radiology and Imaging, Tribhuvan University Teaching Hospital, Kathmandu. The study population consisted of those cases that underwent MDCT urography scans for various clinical indications. The study was purposive sampling with sample size 68 from October 2015 to February 2016. Age greater than 18 years undergoing MDCT urography for various clinical indications were included in the study. The exclusive criteria consists of patient with large anthropometric measurement (BMI > 29), age less than 18 years, suspected pathology who require arterial phase. The study protocol was approved by the ethical committee of Institutional Review Board (IRB) Institute of Medicine(IOM)and written informed consent was taken from patients.

Patients were selected randomly in 1:1 ratio for single and split bolus MDCT urography protocol who met inclusion criteria for the study. The patients were given 1000 ml of water orally starting 60 minutes before scanning and their bladder was almost full before scanning. Their weight were obtained by using weighing machine placed in the scanning room and their height were also taken with the help of wall scale. BMI was calculated and values were recorded. The patients were asked to wear hospital gown and to remove all radiopaque materials from abdominal region. Written informed consent was taken from each patient. The patient was asked to lie down in CT scanning table in supine position, with legs and arms extended. Suitable size cannula (18G/20G) was inserted into vein. The scan was performed in Siemens Somatom Definition AS+128 slice CT scanner (model no. 08098027). The single bolus had three phase acquisition in which the unenhanced scan was obtained from the diaphragm to the base of the urinary bladder. The nephrographic and excretory phase in single bolus were scanned from diaphragm to lower pole of the kidney and the base of the urinary bladder respectively. For split bolus only two phases (unenhanced and combined) were scanned from the diaphragm to the base of the urinary bladder. Volumetric data for unenhanced phase in both the protocol were performed with parameter as follows: kVp-120, mAs-256, pitch-1 acquisition 128×0.6, Gantry rotation 0.5s, FOV 325mm scan circle and matrix size of 512x512. In single bolus protocol a total of 90ml of IV contrast material Ioversol (Optiray) containing 320 mgI/ml was intravenously administered as a bolus via an auto injector with injection rate of 3 ml/s. Nephrographic phase in single bolus protocol were obtained after 90 seconds of contrast injection with following parameter: kVp-120, mAs-256, pitch-1, collimation of 0.625mm, gantry rotation 0.5s, FOV 300mm scan circle and matrix size of 512x512.Excretory phase in single bolus protocol was performed with following parameters : kVp-100, mAs-256, pitch-1, gantry rotation 0.5s, FOV 325mm, with a delay of 10 minutes from the contrast injection. The combined phase in split bolus protocol was performed by injecting the contrast in two bolus: 40 ml at 2ml/s was injected in the first bolus and after a delay of 9 minutes 60 ml of contrast was injected at a rate of 3ml\s and scan was obtained 90 second after the second bolus. All the phases in both the protocols were performed with a single breath hold. After completion of scan, the CTDIvol (Volume CT Dose Index) and CTDLP (Computed Tomography Dose Length Product) automatically calculated by CT scanner were obtained and effective dose of each exam was later calculated by multiplying total DLP (Dose Length Product) by conversion factor for abdomen reported in European guideline on quality criteria for CT.[6] Unenhanced and contrast images were reconstructed at the CT work station and then reformatted in various planes from the volume data.

Analysis of data was performed upon completion of the study using SPSS version 20 and Microsoft Excel 2013 software. Statistical analysis was done along with Wilcoxon's signed rank test and Pearson's correlation coefficient. A 95% confidence interval was taken, and $p<0.05$ were termed as statistically significant.

Results

Total 68 patients were enrolled in which 36 (53%) were male and 32(47%) were female. The age distribution of the patients ranged from 18 to 70 years. Out of the total patients, 25 were between the age group 18-36, 32 were between the age group 36-54, and 11 were between the age group54-72. The 36-54 age group was slightly predominant. The highest BMI was found to be 28.74 kg/m^2 and lowest was 18.90 kg/m^2 and mean BMI was24.55 kg/m^2. The mean BMI for single bolus and split bolus were 24.48 and 24.63kg/m^2 respectively.

The mean effective radiation dose of single and split bolus protocol were found to be 19.17mSv and 13.64mSv respectively. The mean effective dose for single bolus MDCT urography is 40.5% more than the split bolus MDCT urography. The maximum mean effective radiation dose were 28.52mSv and 24.75mSv in single and split bolus protocol respectively. The minimum mean effective radiation dose were 13.75mSv and 9.91mSv in the single and split bolus protocols respectively (Figure. 1).

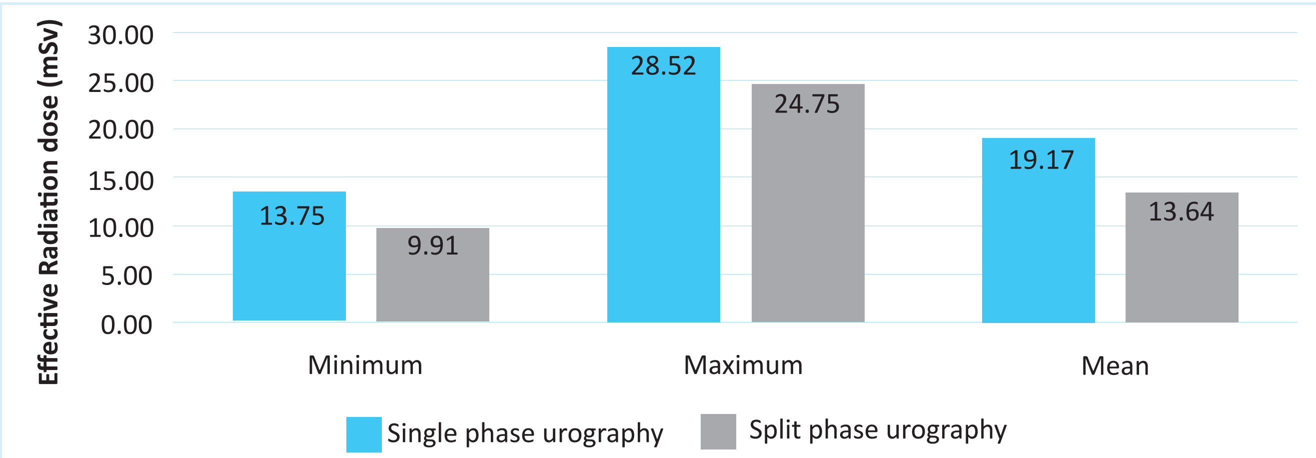

Fig.1 Bar chart showing comparative Effective Radiation Dose between single and split bolus protocols

Table 1 : Comparison of Effective Radiation Dose and mean difference between single and split bolus MDCT urography.

Parameters	Single phase	Split phase	Mean difference	Z-value
Mean	19.17	13.64		
Standard deviation	4.84	3.64	5.53	5.32
Range	14.76	14.84		

Out of 68 cases 34 patients were randomly involved in each protocol. More males were involved in single bolus protocol while more females were involved in split bolus protocol. Mean age for single and split bolus were 52 and 50 respectively (Table 2).

Table 2: Distribution of cases in single bolus and split bolus

	Single Bolus Protocol	Split Bolus Protocol
Number of Cases	34	34
Male	21	15
Female	13	19
Age in Years (range)	52(18-70)	50(20-70)
BMI in Kg/m^2(mean)	24.48(19.16-28.74)	24.63(18.90-28.66)

This study showed that mean CTDIvol in unenhanced phase in single and split bolus protocols were 11.89mGy and 10.79mGy respectively. The mean CTDIvol of nephrogram in single phase protocol was 7.82mGy. The mean CTDIvol in excretory phase of single bolus protocol was 10.55mGyand combined phase of split bolus protocol was 9.63mGy. The mean CTDLP of single bolus unenhanced phase, nephrogram and excretory phase were 509.68 mGy.cm, 317.84mGy.cm and 431.39mGy.cm respectively. The mean CTDLP of split bolus unenhanced phase and combined phase was 486.32mGy.cm and 423.27mGy.cm respectively (Table 3).

Table 3:Radiation Dose Parameters of different acquisition of MDCTU:

		CTDIvol (mGy) Mean	SD	CTDLP (mGy.cm) Mean	SD
Single bolus	Non-contrast (Unenhanced)	11.89	3.10	509.68	180.03
	Nephrogram	7.82	1.79	317.84	84.91
	Excretory Phase	10.55	3.94	431.39	173.46
Split bolus	Non-contrast (Unenhanced)	10.79	2.59	486.32	124.86
	Combined Phase	9.63	2.83	423.27	124.40

Out of the various clinical indications, lithiasis was more frequent indication followed by hematuria. Bladder mass was an indication in one of the cases (Table 4).

Table 4: Number of incidence cases according to Clinical Indication

Clinical Indication	Single Phase Urography	Split Phase Urography
Lithiasis	12	18
Hematuria	8	6
Abdominal pain	1	0
Renal Cyst	8	6
Hydronephrosis	5	3
Bladder mass	0	1

Discussions

Routine single bolus MDCT urography included unenhanced and two contrast enhanced acquisitions which may increase the effective radiation dose to the patient but in case of split bolus technique MDCT urography which included two bolus of contrast media injections caused 40.5% reduction of the effective radiation dose in this study. A similar study performed by Salmeron Belizet et al on "single and split bolus CT urography: radiation dose and image quality comparison" in 20 rows detector with Care Dose 4D concluded that mean effective dose of the split bolus protocol was 35% lower than that of the single bolus protocol but our study showed higher dose reduction due to the efficiency of 128 slice MDCT and body habitus variation. Various studies performed on split bolus technique showed 15-45% reduction of effective radiation dose.[7]

Caoili et al suggested acquiring two excretory phase images (300 and 420 seconds)in single bolus protocol which resulted in better opacification of distal ureters with a longer delay time. However, effective radiation dose exposure was increased to 25–35mSv.[8]

Patient parameters were measured manually and the value may not be consistent because it varied with the equipment, concentration of contrast media and size of the patient. The most important limitation of our study was the dose estimation. We estimated the dose based $CTDI_{vol}$ and CTDLP displayed on the scanner. We did not perform phantom scanning for the dose estimation. However, dose estimation values provided by different studies with phantom studies were concurrent with our data. To estimate the exact dose reduction value, study with phantom scanning is recommended.

Conclusion

Routine single bolus contrast injection MDCT urography protocol with three phase acquisition have higher effective radiation dose. To reduce the radiation dose a split bolus MDCT urography technique has been introduced in which two separate contrast bolus injections result in a combined nephrographic-excretory acquisition.

Split bolus MDCT urography protocol was found significantly beneficial with 40.5% reduction in mean effective radiation dose as compared to single bolus protocol with no much difference in image quality. MDCT urography with split bolus protocol seems to be beneficial for patient in context to radiation dose.

Conflict of interest: None declared

References

1. Aart J. Van Der Molen, Nigel C. Cowan et al, CT urography: definition, indications and techniques. A guideline for clinical practice, ESR Sep 14, 2007
2. Maka Kekelidze, Roy S. Dwarkasing, Marcel L. Dijkshoorn et al, Urinary Tract Imaging: Triple-Bolus Multidetector CT Urography as One-StopShop—Protocol Design, Opacification,and Image Quality Analysis RSNA 2010
3. Lawrence C. Chow, Sharon W. Kwan, Eric W. Olcott, Graham Sommer, Split-Bolus MDCT Urography with Synchronous Nephrographic and Excretory Phase Enhancement, AJR 2007; 189:314-322
4. SalmeronBeliz, I. Cogollos, N. Blazquez, M. Ibanez, et al, Single and split-bolus CT Urography: radiation dose and image quality comparison, ECR 2013
5. EktaMaheshwari et al, Split-Bolus MDCT Urography: Upper Tract Opacification and Performance for Upper tract Tumors in Patients With Hematuria, AJR 2010; 194:453-458
6. Jessen K, Panzer W, Shrimpton P, et al. EUR 16262: European guidelines on quality criteria for computed tomography. Luxembourg: Office for Official Publications of the European Communities, 2000.
7. Portnoy O, Guranda L, Apter S, Eiss D, Michal Amitai M, Konen E. Optimization of 64-MDCT Urography: Effect of Dual-Phase Imaging With Furosemide on Collecting System Opacification and Radiation Dose. AJR 2011; 197:882–886.
8. Caoili EM, Inampudi P, Cohan RH, Ellis JH. Optimization of multi-detector row CT urography: effect of compression, saline administration, and prolongation of acquisition delay. Radiology 2005; 235 (1): 116 – 123.