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Original Research Paper

Radiology

A STUDY OF RADIATION IN CT UROGRAPHY

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KEYWORDS : CT Urography, Radiation, Split bolus technique, kV, mAs, DLP

INRODUCTION:

Over the past decade, computed tomographic (CT) urography has emerged as the primary imaging modality for evaluating the urinary tract in various clinical settings. It not only allows detailed assessment of the urinary tract but also enables direct visualization of adjacent structures and comprehensive evaluation of the abdomen and pelvis.

CT urography is currently the first-line imaging modality for several indications, including hematuria and flank pain, initial staging of urothelial tumors and follow-up surveillance in patients with prior urothelial tumors.

CT urography has essentially replaced conventional intravenous urography as the first-line imaging modality in most of these settings and has been shown to have increased overall accuracy and sensitivity, particularly for evaluation of hematuria and flank pain. Additional indications for CT urography include evaluation of urinary tract obstruction, depiction of complex congenital urinary tract anomaly, and any clinical scenarios where comprehensive evaluation of the urinary tract is needed.

Various scanning techniques for CT urography have been described, but there is no universally accepted imaging protocol. In the most general sense, complete CT urography is four phase acquisition which includes a non-enhanced/plain phase, an arterial phase/cortico-medullary phase, nephrogenic phase and an excretory phase.

Few imaging protocols are currently used in clinical practice, which allow a decreased radiation dose. Reducing the tube current and the split-bolus technique (combines nephrogenic and an excretory phase into a single phase with a total of two phase acquisition) were used to reduce the radiation dose at our institution.

AIMS AND OBJECTIVES

1. **To reduce the tube current to optimum without compromising the diagnostic efficacy.**
2. **To compare the radiation dose of four phase acquisition protocol with standard & reduced tube current.**
3. **To evaluate the reduction in radiation dose with a two-phase acquisition (combined nephrogenic + excretory phase) split-bolus protocols compared to the standard four phase acquisition protocol.**

With this purpose, we have evaluated and compared the radiation dose of three different CTU protocols:

- **A single-bolus standard tube current four-phase acquisition protocol.**
- **A single-bolus low tube current four-phase acquisition protocol.**
- **A split-bolus two-phase acquisition protocol.**

MATERIALS AND METHODS

- **STUDY POPULATION:**

During the period of July 2014 to December 2016, a prospective study of sixty patients was carried out for evaluation of possible urinary tract abnormalities.

- Each patient was studied with relevant clinical history, examination and laboratory investigations.
- A quick ultrasound examination of abdomen and pelvis was done to look for causative factors of hematuria or flank pain.
- The study population consisted of 60 consecutive patients (26 women, 34 men; mean age 41 years and mean weight 64 kg.)

INCLUSION CRITERIA:

1. All patients with hematuria and flank pain.
2. Cases are included irrespective of age and sex of the patient, A total of 60 exams prospectively recorded,

Single-bolus standard tube current four phase acquisition protocol: 20 patients.

Single-bolus low tube current four phase acquisition protocol: 20 patients.

Split-bolus two-phase acquisition protocol: 20 patients.

EXCLUSION CRITERIA:

1. Patients with Weight below 35 kg and above 85 kg.
2. Patients in whom CT scan study is contraindicated such as renal failure (Creatinine above 1.5 mg/dl), known allergy to iodinated contrast material, pregnant female patients, etc.

The study was conducted in our Radio-diagnosis Department.

CONSENT:

All patients were explained about the possible adverse effects of iodinated contrast and radiation exposure and written consent about agreement of patient to the possible adverse effect are taken.

CT urography was performed on Phillips MX-16 slice MDCT scanner.

- **CT UROGRAPHY SINGLE-BOLUS FOUR PHASE ACQUISITION PROTOCOL:**

Slice thickness: 2mm ; Increment: 1mm ; Pitch: 1 ; Collimation: 16 * 1.5 mm ; FOV(Field Of View): 350mm.

Phase	Coverage(scan length)	Timing
Plain scan	From diaphragm to symphysis pubis	0 min
A/CM	Renal fossa (approx. from vertebral level T12 – L5)	30 sec
Nephrogenic phase	Renal fossa (approx. from vertebral level T12 – L3)	90 sec
Excretory phase	From diaphragm to symphysis pubis	10 min

Single-bolus four Phase acquisition protocol	Tube voltage (kV)	Tube current (mAs)
Standard tube current	Excretory phase: 90 Other phases: 120	ranges from 107 to 197
Low tube current	Excretory phase: 90 Other phases: 120	ranges from 45 to 101

Automatic tube current modulation was used in both standard and low tube current four phase acquisition protocol. Therefore, the effective tube current–time product varied between phases of one patient and between different patients. The mean value of the effective tube current–time product in each phase was used in the calculations.

- **SCANNING TECHNIQUE- SINGLE-BOLUS FOUR PHASE ACQUISITION PROTOCOL:** All patients were asked to drink approx 1L of water while in the waiting area approximately 20 minutes before scanning. IV contrast material (Omnipaque) was administered: 100 mL was administered through OptiVantage double syringe automatic injector at a rate of 3 mL/s after the unenhanced phase **(0 min).** Breath-hold images were acquired at 20 second for arterial/cortico-medullary phase, at 90 second for nephrogenic phase and at 10 min for excretory phase.

- **CT UROGRAPHY SPLIT BOLUS TWO PHASE ACQUISITION PROTOCOL:**

Slice thickness: 2mm ; Increment: 1mm ; Pitch: 1 ; Collimation: 16 * 1.5 mm ; FOV(Field Of View): 350mm.

	Tube voltage (kV)	Tube current (mAs)	Coverage (scan length)	Timing
Plain phase	90	79	From diaphragm to symphysis pubis	0 min
Combined (nephrogenic and excretory phase)	120	99	From diaphragm to symphysis pubis	10 min

- **SCANNING TECHNIQUE- SPLIT BOLUS TWO PHASE ACQUISITION PROTOCOL:**

All patients were asked to drink approx 1L of water while in the waiting area approximately 20 minutes before scanning. IV contrast material (Omnipaque) was administered as follows: 50 mL (50% of total contrast) was administered through OptiVantage double syringe automatic injector at a rate of 2 mL/s after the unenhanced phase (0 min). After 8.5-minute delay, remaining 50 mL (50% of total contrast) was administered at 3 mL/s rate. The contrast-enhanced, breath-hold images were acquired 90seconds after the second contrast bolus, yielding images in synchronous nephrogenic and excretory phases of enhancement.

IMAGE RECONSTRUCTION: In addition to axial images, coronally and sagitally reformatted maximum-intensity-projection (MIP) and average-intensity-projection images were generated in all cases with iterative reconstruction algorithm. Additional reformatting with volume rendering and curved planar reformation was performed on occasion on an as-needed basis but was not performed routinely.

OBSERVATION:

1. SINGLE BOLUS STANDARD TUBE CURRENT FOUR PHASE ACQUISITION PROTOCOL:

We studied 20 patients (12 males + 8 females) with this protocol.

- 14 patients were diagnosed with urolithiasis (renal calculi/ ureteric calculi/ bladder calculi).
- 2 patients were diagnosed with renal infection (pyelonephritis).
- 2 patients were diagnosed with congenital anomaly (horse-shoe kidney, cross fused ectopic kidney).
- 1 patient was diagnosed with uroepithelial tract malignancy.
- 1 patients was having normal CT urography study.

The mean mAs and DLP (mGy*cm) value of each phases are as follows:

Phase	mAs (mean Value)	DLP (mGy*cm) (mean value)
Plain phase	145	577.95
A/CM phase	143	564.57
Nephrogenic phase	138.5	375.62
Excretory phase	141	290.38

The mean value of TOTAL DLP (mGy*cm) of this protocol: 1845.

2.Single Bolus Low Tube Current Four Phase Acquisition Protocol:

We studied 20 patients (12 males + 8 females) with this protocol.

- 16 patients were diagnosed with urolithiasis (renal calculi/ ureteric calculi/ bladder calculi).
- 1 patient was diagnosed with renal infection (pyelonephritis).
- 1 patient was diagnosed with congenital anomaly (congenital absent kidney).
- 2 patients were diagnosed with uroepithelial tract malignancy.

Sensitivity and specificity as well as image quality of this protocol in pathologies like urolithiasis, renal infection, congenital anomaly and uroepithelial track malignancy are comparable to standard tube current four phase acquisition protocol.

The mean mAs and DLP (mGy*cm) value of each phases are as follows:

Phase	mAs (mean value)	DLP (mGy*cm) (mean value)
Plain phase	82	280.26
A/CM phase	81	275.61
Nephrogenic phase	76	179.04
Excretory phase	74	111.04

The mean value of TOTAL DLP (mGy*cm) of this protocol: 917.

3. SPLIT BOLUS TWO PHASE ACQUISITION PROTOCOL:

We studied 20 patients (10 males + 10 females) with this protocol.

- 15 patients were diagnosed with urolithiasis (renal calculi/ ureteric calculi/ bladder calculi).
- 2 patients were diagnosed with renal infection (pyelonephritis).
- 1 patient was diagnosed with congenital anomaly (horse-shoe kidney).
- 2 patients were normal in CT scan study.

Sensitivity and specificity as well as image quality of this protocol in pathologies like urolithiasis, renal infection and congenital anomaly are comparable to four phase acquisition protocol.

The mean DLP (mGy*cm) value of each phases are as follows:

- Plain phase: 112.97 mGy*cm.
- Combined (NP + EP): 385.16 mGy*cm.

The mean value of TOTAL DLP (mGy*cm) of this protocol: 495.

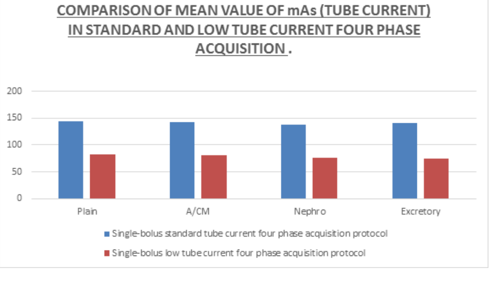
1. Statistical Comparison Of Patients Data:

	Single-bolus standard tube current four phase acquisition	Single-bolus low tube current four phase acquisition	Split bolus two phase acquisition
Number of patients	20	20	20
Male	12	12	10
female	8	8	10
Mean age(yrs)	52	33	37
Mean weight(kg)	67.85	58.95	64.35

2. Comparison Of Mean Value Of Mas (tube Current) In Standard And Low Tube Current Four Phase Acquisition Protocol:

Phase	Standard tube current (mean mAs)	Low tube current (mean mAs)
Plain	145	82
A/CM	143	81
Nephrogenic	138.5	76
Excretory	141	74

- Single-bolus standard tube current four phase acquisition protocol : mean mAs value ranges from 138.5-145.
- Single-bolus low tube current four phase acquisition protocol : mean mAs value ranges from 74-82.

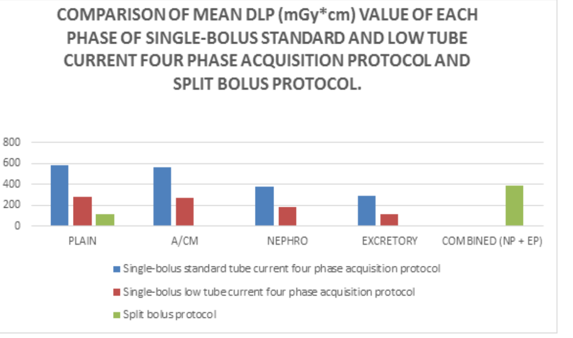


- As compared to Single-bolus standard tube current protocol, in Single-bolus low tube current four phase acquisition protocol there is,

  Reduction of 43.44% mAs value in plain phase
  Reduction of 43.36% mAs value in A/CM phase
  Reduction of 45.13% mAs value in nephrogenic phase
  Reduction of 47.52% mAs value in excretory phase

3. Comparison Of Mean Dlp (mgy*cm) Value Of Each Phase Of Single-bolus Standard And Low Tube Current Four Phase Acquisition Protocol And Split Bolus Protocol:

Phase	Standard tube current four phase acquisition protocol DLP (mGy*cm) (Mean value)	Low tube current four phase acquisition protocol DLP (mGy*cm) (Mean value)	Split bolus protocol DLP (mGy*cm) (Mean value)
Plain	577.95	280.26	112.97
A/CM	564.57	275.61	
Nephrogenic	375.62	179.04	
Excretory	290.38	111.04	
Combined (NP + EP)			385.16

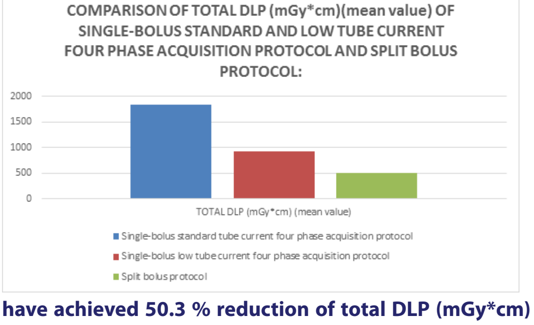


- As compared to single bolus standard tube current four phase acquisition protocol, in low tube current protocol by optimizing mAs value there is :

  Reduction of 51.51% DLP(mGy*cm) value in plain phase
  Reduction of 51.18% DLP(mGy*cm) value in A/CM phase
  Reduction of 52.33% DLP(mGy*cm) value in nephrogenic phase
  Reduction of 61.76% DLP(mGy*cm) value in excretory phase

COMPARISON OF TOTAL DLP (mGy*cm)(mean value) OF SINGLE-BOLUS STANDARD AND LOW TUBE CURRENT FOUR PHASE ACQUISITION PROTOCOL AND SPLIT BOLUS PROTOCOL:

	Single-bolus standard tube current four phase acquisition protocol	Single-bolus low tube current four phase acquisition protocol	Split Bolus protocol
Total DLP (mGy*cm) (mean value)	1845	917	495



We have achieved 50.3 % reduction of total DLP (mGy*cm) in low tube current protocol compared to standard tube current protocol without compromising diagnostic efficacy.

We have achieved 46.02% of reduction of total DLP (mGy*cm) in split bolus protocol compared to low tube current protocol.

We have achieved 73.17% of reduction of total DLP (mGy*cm) in split bolus protocol compared to standard tube current protocol.

DISCUSSION

Reviewing the literature, we have come across two similar studies as ours and we are hereby comparing our results with those two studies.

- Study A: Done by I. Salmerón Béliz, I. Cogollos, N. Blazquez et al
- Study B: Done by T. Auer, T. De Zordo, D. Junker, F.H. Aigner et al.
- We will be comparing these data with our following acquired data sets:
- Single bolus standard tube current four phase acquisition protocol.
- Single bolus low tube current four phase acquisition protocol.

- Split bolus two phase acquisition protocol.

TABLE 1 : Comparison Of Demographic Data Of Our Single Bolus Study With Other Single Bolus Study:

	Single bolus (Low tube current) protocol of our study	Single bolus protocol of Study A	Single bolus protocol of Study B
Total number of patients	20	34	20
Male	12	16	15
Female	8	18	5
Mean age	33	59	68.2

TABLE 2 : Comparison Of Demographic Data Of Our Split Bolus Study With Other Split Bolus Study:

	Split bolus protocol of our study	Split bolus protocol of Study A	Split bolus protocol of Study B
Total number of patients	20	31	20
Male	10	12	16
Female	10	19	4
Mean age	37	50	66.3

TABLE 3: Comparison Of Mas Value Of Our Single Bolus Study With Other Single Bolus Study:

Phase	Single bolus (Low tube current) protocol of our study (mean value)	Single bolus (Standard tube current) protocol of our study (mean value)	Single bolus protocol of Study A
Plain	82	145	70
A/CM	81	143	
Nephrogenic	76	138.5	175
Excretory	74	141	175

TABLE 4: Comparison Of Mas Value Of Our Split Bolus Study With Other Split Bolus Study:

Phase	Split bolus protocol of our study	Split bolus protocol of Study A
Plain	79	70
Combined (NP + EP)	99	175

TABLE 5: Comparison Of Kv Value Of Our Single Bolus Study With Other Single Bolus Study:

Phase	Single bolus protocol of our study	Single bolus protocol of Study A
Plain	120	120
A/CM	120	
Nephrogenic	120	120
Excretory	90	100

TABLE 6: Comparison Of Kv Value Of Our Split Bolus Study With Other Split Bolus Study:

Phase	Split bolus protocol of our study	Split bolus protocol of Study A
Plain	90	120
Combined (NP + EP)	120	120

TABLE 7 : Comparison Of Total Dlp Mean Value Of Our Single Bolus Study With Other Single Bolus Study:

	Single bolus (Standard tube current) protocol of our study	Single bolus (Low tube current) protocol of our study	Single bolus protocol of Study A	Single bolus protocol of Study B
Total DLP (mGy*cm) (Mean value)	1845	917	804	1275

TABLE 8 : Comparison Of Total Dlp Mean Value Of Our Split Bolus Study With Other Split Bolus Study:

	Split bolus protocol of our study	Split bolus protocol of Study A	Split bolus protocol of Study B
Total DLP (mGy*cm) (Mean value)	495	534	959

MERITS AND DEMERITS OF SPLIT BOLUS PROTOCOL:

A. Merits:

1. Image quality and diagnostic efficacy of split bolus protocol with optimized mAs and kV value is comparable to single bolus four phase acquisition study in following conditions:

- Urolithiasis:
  - Renal calculi
  - Pelvic calculi
  - Ureteric calculi
  - Bladder calculi
- Renal infection:
- Congenital anomalies:
  - Horse-shoe kidney
  - Ectopic kidney
  - Circumcaval ureter
  - Ureterocele

2. Significantly reduced effective radiation dose to the patients.

B. Demerits:

1. Arterial anatomy:

In split bolus study arterial anatomy is not depicted / visualized satisfactorily.

The need of arterial anatomy is necessary / essential in following conditions:

- Renal artery stenosis or fibro-muscular dysplasia.
- Atheromatous changes in renal artery in old age patients contributing to renal arterial hypertension.
- Pre-operative evaluation of arterial anatomy in urosurgery & kidney transplant donors.

2. Changes of attenuation & post contrast enhancement characteristics of mass lesions:

In four phase acquisition protocol, it is possible to evaluate the changes of attenuation and dynamic contrast study of lesion like renal cell carcinoma or transitional cell carcinoma following contrast administration. This characterization of lesion is not satisfactory in split bolus technique.

CONCLUSION

The last decade has seen dramatic improvement in CT technology. The introduction of MDCT has resulted in improved spatial resolution, shorter scan times, and increased patient throughput. Thus CT is a key technique in radiology, and CT urography has replaced conventional urography at many centers.

The major disadvantage of CT is the high patient radiation dose compared with that in other imaging modalities. Therefore, it is important to focus research on justification of CT urography and optimizing CT scan protocols and scanning tube load parameters.

In this study, two different approaches were adopted to reduce the patient radiation dose, one in which the tube current was kept as low as possible without compromising image quality and the other in which the number of image acquisitions were reduced to just two phase (unenhanced phase and only one post contrast image by combining the nephrogenic and excretory phases) and this was helped by giving i.v. contrast in split bolus technique. With this, the tube load was lowered considerably, and the total effective dose decreased without loss of clinically important information.

The only disadvantage of our split bolus two phase acquisition protocol is that we get only one post contrast image so the dynamic contrast study and thereby lesion (mass) characterization is not satisfactory as compared to the four phase acquisition protocol. Small urothelial cell carcinoma may be missed in the combined nephrogenic and excretory phases of split bolus protocol because of blooming artifact from concentrated contrast material, especially in the lower urinary tract and the calyces.

In four phase acquisition with low tube current protocol the arterial anatomy and characterization of mass lesion with dynamic contrast study is possible which is not satisfactory in split bolus protocol. Radiation dose to patients is reduced significantly by reduced tube load without affecting diagnostic efficacy of the protocol. So in patients with suspected urolithiasis, congenital anomaly and renal infection split bolus protocol should be used wherein patients with suspected malignancy or in whom visualization of arterial anatomy is essential four phase low tube current protocol should be used. So it should be a radiologist's call to decide the protocol to be used in individual patients.

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