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Jai Singh
Department of Radiodiagnosis, Dr. S. N. Medical College, Jodhpur, Rajasthan, India

Kirti Chaturvedy
Department of Radiodiagnosis, Dr. S. N. Medical College, Jodhpur, Rajasthan, India

Manish Chaturvedy
Department of Urology, Dr. S. N. Medical College, Jodhpur, Rajasthan, India

RN Gehlot
Department of Urology, Dr. S. N. Medical College, Jodhpur, Rajasthan, India

Divyangi Mishra
Dr. S. N. Medical College, Jodhpur, Rajasthan, India

Savitri Nagar
Dr. S. N. Medical College, Jodhpur, Rajasthan, India

Manoj Verma
Dr. S. N. Medical College, Jodhpur, Rajasthan, India

Corresponding Author:
Kirti Chaturvedy
Department of Radiodiagnosis, Dr. S. N. Medical College, Jodhpur, Rajasthan, India

Comparision of low dose computed tomography with standard dose computed tomography for evaluation of urolithiasis

Jai Singh, Kirti Chaturvedy, Manish Chaturvedy, RN Gehlot, Divyangi Mishra, Savitri Nagar and Manoj Verma

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Abstract

Background: Computed tomography (standard and low-dose CT [SDCT, LDCT] scan) has become the reference technique in medical imaging for urinary calculi, to diagnose, plan treatment, and explore differential diagnosis of renal colic.

Objective: This study was done to compare the low-dose non-enhanced CT scan with standard dose CT scan in the evaluation of urolithiasis.

Materials and Methods: Prospective Cross-sectional study on 60 patients undergoing both abdominal low-dose NCCT and standard-dose NCCT. Another optional low dose excretory phase of CT urography was also reserved for suspected patients who had hydronephrosis on NCCT or ureteral calculus on NCCT or whose symptoms could not be explained by finding on NCCT. The patients were scanned by PHILIPS Ingenuity core 64 slice CT scanner with Philips intellispace workstation and software using fixed tube current.

Results: The internal reliability was excellent (cronbach alfa=0.9). There was substantial agreement in both the protocols (Cohens kappa=0.69), even in detecting calculi <5mm (Cohens kappa=0.69). There is no effect of BMI in missing of calculin by LDCT. In LDCT scan the mean tube current was lower (135 mA) as compared to. standard dose CT scan(259 mA) and mean dose < 3 SeV

Conclusion: When compared with standard CT, low dose NCCT KUB scans provide effective methods of identifying, evaluating urinary tract calculi and can provide more comprehensive information for management of urolithiasis in effective dose similar to or less than Intravenous pyelography.

Keywords: Computed tomography, low-dose computed tomography scan, standard dose computed tomography scan, urolithiasis

Introduction

Imaging is intricate part of urolithiasis management. Ultrasound is the first imaging technique performed, detects about 50–60% of ureteral calculi, but Computed tomography (CT) scan provides a higher diagnostic yield [1]. Because of the marked increase in use of CT for the evaluation of urolithiasis and the associated increase in ionizing radiation exposure, strategies for reducing the radiation dose have become necessary [1].

CT is used as the initial diagnostic technique in patients with suspected renal colic because of its high sensitivity and specificity for the detection of calculus. The initial use of CT reveals the presence of a calculus, its size and location, these give us a useful information for selecting the most appropriate therapeutic approach [2]. However, because renal colic frequently affects young adults, with a recurrence rate of about 50%, [2] the increasing trend of use of CT at patient's admission raises concern about the dose of radiation administered [3] The radiation exposure of low-dose CT in renal colic is compared with that of intravenous urography, which used to be the reference modality in the past. Data from the literature reveal that the effective ''low dose'' to detect renal colic to be up to 5 mSv [1] If we consider that the average dose of a standard abdomen and pelvic CT is between 12 and 14 mSv [18, 19], a low-dose scan of less than 5 mSv corresponds to a dose reduction of more than 70%. Despite this significant dose reduction, various studies have shown that the diagnostic performance of low-dose CT remains excellent compared to dose CT for urolithiasis

Methods

This was cross-sectional observation study carried out on 60 subjects of nephrolithiasis presenting with renal colic or hematuria and requiring CT scan for evaluation. All participants underwent LDCT, followed by standard CT and excretaory phase (optional) as per protocol described Two radiologists(KC and JK) were blinded to any imaging prior to CT scans, examined the CT scans for number (<1 or >1), size (2,2-3,>3) and location (upper, middle ,lower 1/3rd) of calculi and three signs of urolithiasis (pyeloureteral dilatation, renal enlargement, perirenal or periureteral stranding) and disgnosis was based on consensus. LDCT images were interpreted prior to LDCT. The effective dose (ED) in mSv was calculated for each scan by multiplying the Dose Length Product (DLP) of each scan with a constant (.018 mSv/mGy * cm). Noise reducing methods like higher scale of IR and wider window setting was used for LDCT. All participants gave written consent. The study was approved by IEC.

Exclusion criteria: Patients refusing for study, pregnant women, children below 18 years and all patients who had deranged renal function test & had contraindication to iodinated contrast were excluded from study. Following protocol and parameters were used for low dose NCCT, standard dose NCCT and excretory phase (whenever indicated).

Table 1: Parameters of NCCT including low &standard dose and excretory phases of CT Scan. Auto mAs was switched off in all patients.

Parameters	NCCT low dose	NCCT standard dose	Excretory Phase (optional) if indicated as mentioned above
Kilovolt peak (kVp) according body weight	80 /100 a. 80kVp □ 90kg b. 100kVp >90kg	120 kVp	80 /100 a. 80kVp □ 90kg b. 100kVp >90kg
Rotation time (m sec)	420	420	420
Tube current (mAs) according to body weight	a. 2mAs/kg upto 90kg. b. Fixed 200mAs >90 kg.	200-300 4mAs/kg upto max of 300mAs and minimum of 200 mAs	a. 2mAs/kg upto 90kg. b. Fixed 200mAs >90 kg.
Length of scan (cm)	40-45	40-45	40-45

CT scan protocol (Phillips Ingenuity core 64 slice CT scanner with Phillips intellispace workstation and software). Low dose was give (80-100 kVp) over ( ) followed by imaging. Axial reconstructions were done at 1 mm on The 1mm axial reconstruction was viewed in average mode by increasing thickness to 2-5 mm as required to reduce the noise, similarly coronal & sagittal reformation were made after increasing the thickness of 1mm reconstruction in average mode to 2-5mm and then making reformation.

Statistics: Cronbach alfa was used to check reliability of data. Cohens'kappa was used to assss likelihood of low dose CT in detecting calculi as compared to standard CT scan. Since a size of 5mm markedly differs calculi management, Cohens'kappa was also used to assess likelihood of low dose CT in detecting calculi < 5 mm in size as compared to standard CT scan.Pearson correlation was used to analyse whether BMI had any influence on missing of calculi. Paired t-test was used to compare radiation exposure between standard CT and low dose CT. SPSS version 19 was used for analysis.

Results

138 calculi were detected by SDCT scan and 123 calculi were detected by LDCT scan, mean age of patients 39.9 ± 15.8 and mean of body mass index 24.2 ± 4.1, distribution of calculus was males constitute 68% (41) and females 32% (19). 48.2% of patients had stone on the left side and 51.8% had stone on right side, most of patients (42%) presented with solitary stone, 22% of patients had double stone, 15% had triple stone, 5% had four stones, and 16% had 5 or more stone at investigation, 62% of stones were located in ureter, 38% of calculi in kidneys, as per size of calculi 22% of calculi had size <3 mm, 31% of calculi ranged 3–5 mm and 47% of calculi had size □5mm 56 subjects were found to have urolithiasis. 26 subjects underwent excretory phase. Radiating flank pain (60%), and non-radiating flank pain with frequency of micturation (35%) were commonest clinical symptoms. Hydronephrosis was commonest indirect sign of urolithiasis. 21.7% of calculi had size □3 mm, 31% of calculi range 3–5 mm and only 47% of calculi had size □5 mm.

Cronbach alfa was 0.9 suggesting good internal reliability. The likelihood of detecting calculi was excellent as suggested by Cohens kappa of 0.69. The likelihood of detecting calculi <5 mm in size was also similar (Cohens kappa=0.69)

The mean effective dose in patients of <70kg was 1.7mSv in LDCT compared to 11.6mSv in standard dose NCCT. Mean effective dose in patients of >70kg in low dose was 3.7mSv compared to 15.38mSv in standard dose NCCT. This showed that our low dose CT was equally effective in significantly reducing radiation exposure in both <70kg and □70kg category of patients. The mean effective dose of 2.1mSv in our low dose protocol is just 3times the effective dose delivered by X-ray KUB (0.7mSv) and is similar or less than IVP (2-4mSv).

Excretory phase urography done with low dose CT parameters in 27 out of 60 patients were able to depict pelvi-calyceal anatomy and holdup of contrast in all patients with ureteric calculus as well as in patients with ureteric strictures. This is most likely because 97% of our patients were done with 80kVp(weight <90 kg) which approaches the K-edge of iodine and hence depicts the high density iodine containing pelvi-calyceal system excellently even at very low mean effective dose (effective dose <3mSv in 98% of patients in excretory phase scan).

Discussion

CT is important imaging modality to detect accurate number, size & location of urinary calculus and find out cause of hydroureteronephrosis. It can be due to due to ureteral calculi or ureteral stricture. Many authors have reported the use of low dose CT (LDCT) for urolithiasis.

The methods to minimize dose in CT depend on both behavioral factors (independent of the CT equipment) and technological factors (some of which depend on how recent the CT equipment is). The behavioral factors are the level of awareness of the medical and paramedical teams, the principles of substitution and justification, as well as limiting the scan coverage area. The technological factors include reduction of the tube current and voltage, automatic tube current modulation, and use of iterative reconstructions [4]

Comparison of LDCT with standard CT

The high internal reliability of our findings can be explained by use CT machine with small slice as compared to other studies. Another reason could be evaluating of indirect signs of urolithiasis like hydronephrosis. Presense of hydronephrosis is more likely to enthuse radiologist to look for its cause which includes calculi. Also radiologists routinely working on same machines are likely to not miss a calculi for artifact. Another reason could be setiing of study tertiary centre.No subject underwent CT scan in emergency setting, or during episode of renal calculi. These are the conditions when calculi are more likely to be missed,as per similar studies (5)

Size of calculi

The error in estimating size of calculi has been achillis heel of the LCT protocols. The error could be to the extent of 20% either ways. The calculi of size <5 mm do not require intervention and also passed easily. (6) Hence the effort has been focused on size >5 mm. We did not find that LDCT missed any more of calculi as compared to standard CT. Hence LDCT can be used not only as screening method but also for follow up of calculi <5mm in size. The excelleny lilelihood of picking up calculi on LDCT can be explained on basis of our CT machine as follows: The noise reducing manoeuvres such as use of iterative reconstruction, increasing thickness of scans to 2-5mm on average mode of 1mm axial reconstruction and then forming sagittal and coronal reformation, helped to get good quality images with reduced noise in 100% of our study patients. Also Low dose NCCT scans were viewed in wide window setting.

Effect of BMI

There was no effect of BMI on missing of calcxulus. This is surprising, as most calculi which were missed were less than 5 mm in size and CT scanning is likely to create more artifact as visceral fat increases. Previous studies have found BMI to be important factor in validation of urolithiasis. There can be three possible explainations. One is that calculi being evaluated in our case could have chemical composition denoting higher levels of calcium phosphate. This could lead to higher density on CT scan and hence not missed. Second, it could depend on site of calculi. Most of calculi were located in kidneys where effect of adipose tissue on CT slices are less pronounced. (7) Third the morphology of obesity in our subjects could be different. Indian subjects are more likely to have centripetal obesity and not perirenal adipose tissue deposition. Also, t should be kept in mind that none of our subject was morbidly obese.. A few of morbidly obese subjects could distort the findings. (8).The sensitivity for urinary calculus detection & counting in those with weight <70 kg and those with weight □70kg was not different. This is in contrast to a number of studies showing BMI to have dampening effect on LDCT sensitivity. In some studies sensitivity fell to 50%. (8) We did not find any difference as our average calculi size was bigger.

Site of calculus

Our results reveal that 60% of calculus located in kidney, 27% of calculus lie at distal ureter and 13% in proximal ureter. This is similar to previous study (9) which reported ureteral calculus to present in 36% of patients. The location of ueteric calculus is important coz, the success of low dose protocol for ueretric stone identification depend on pretest probability calculated on routine clinical and laboratory examination. For example application of STONE essentially allows all patients except high risk to undergo low dose CT. Better sensitivity (89%) found in our study is therefore due to high percentage of ureteric calculus (10)

Number of calculi

Most of the patients (42%) had single urinary calculus and almost 80% patients had less than three urinary calculi and 16% patients had □ 5urinary calculi. The possibility of missing urinary calculus was highest when the number of calculi in each patient was □ 5 in number, possibility due to poor border distinction. The probability of missing calculus in kidneys was more than missing calculus in ureters (sensitivity 84.1% and 96.4% respectively). This was probably because of more frequency of multiplicity of calculi in kidneys due to which multiple adjacent calculi in kidneys may appears as single calculus on low dose NCCT due to noise. However, this finding may not have clinical relevance. It should be noted that we compared CECT. The only true gold standard can be endoscopy. It has been shown that CT may both overestimate and under estimate no of calculi. This error increases when size of calculi decreases. [11]

Effect on radiation exposure

The radiation exposure in standard CT is 5-25 mSv. 57% of our study subjects underwent low dose CT scan with effective dose <2mSv while ~94% patients were scanned with effective dose □3mSv in low dose protocol. There was ~85% reduction in mean effective dose with our low dose protocol as compared to Standard dose NCCT. Considering Urolithiasis is a disease which requires frequent imaging, use of LDCT may in significantly lesser radiation exposure cumulative exposure over a period of time (12). Most studies have focused on sensitivity of LDCT in detecting calculi at particular point of time. More important aspect is reliability lesser sensitivity of LDCT can be overcome by repeated imaging. In fact each renal colic admission requires imaging [13]

Excretory phase urography done in 27 out of 60 patients was able to depict pelvi-calyceal anatomy and holdup of contrast in all patients at low dose NCCT parameters in patients with ureteric calculus as well as in patients with ureteric strictures. This is because we used 80kVp which approaches the K-edge of iodine and hence depicts the high density iodine containing pelvi-calyceal system excellently even at very low mean effective dose (effective dose <3mSv in 98% of patients in excretory phase scan).

Conclusion

Low dose NCCT KUB scans provide effective methods of identifying and evaluating urinary tract calculi. High sensitivity (100% for calculi >3mm) and diagnostic performance are maintained despite significant radiation dose reduction compared to standard dose NCCT KUB.

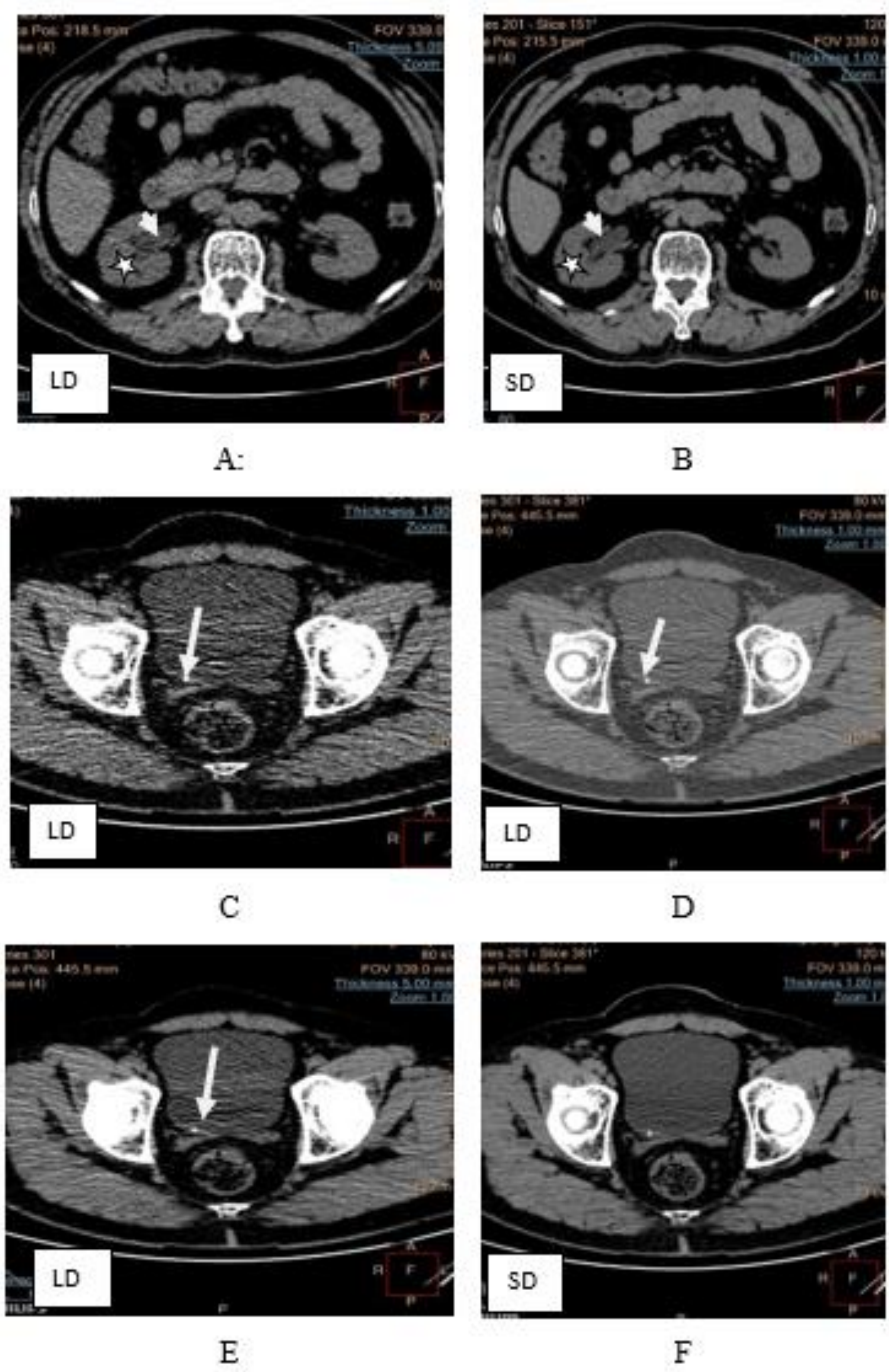

Fig 1: 60-year-old man (weight, 72 kg; BMI, 26kg/m2) with right flank pain. (A) Axial low-dose CT image (80 kVp & 144 mAs, DLP of 146 mGy.cm and 2.6 mSv). (B) Standard dose CT image (120 kV, 288 mAs, DLP of 978 mGy.cm and 17.6 mSv) of upper abdomen shows enlargement of right kidney (asterisk) and dilatation of right pyelocaliceal system (arrowhead). Images at the level of S4-S5 (C,D,E) shows 3.7mm (arrow) urinary calculus wedged in the vesico-ureteral junction. (C) Axial plane 1mm section, (D) increased window width(WW-600) and (E) LDCT-1mm axial reconstruction viewed in average mode by increasing thickness to 5mm (F) Standard-dose CT image at same level as C,D,E shows 3.7mm calculus (arrow) at right vesico-ureteral junction.

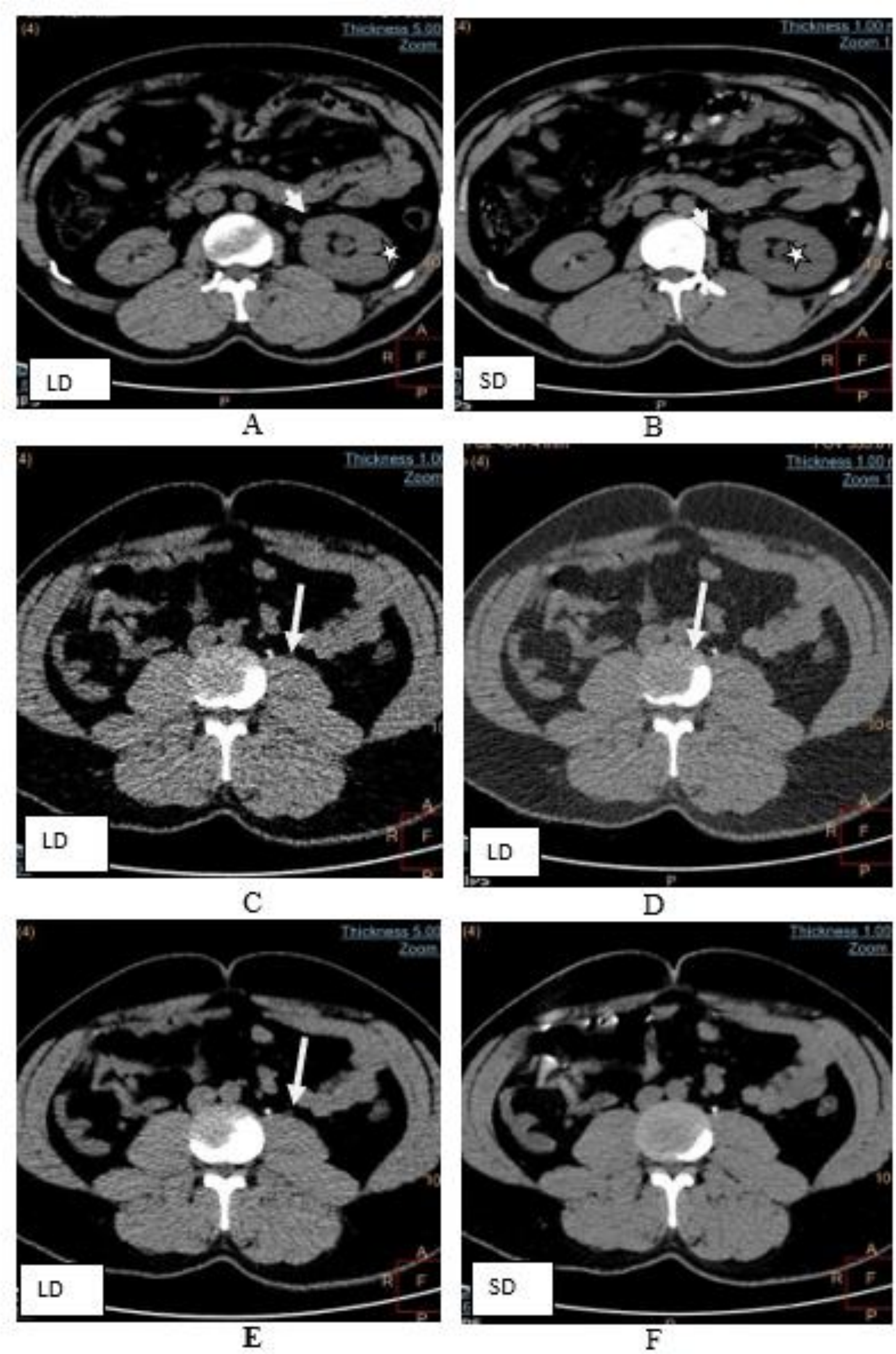

Fig 2: 30-year-old man (weight, 72 kg; BMI, 29kg/m2) with left renal colic. (A) Axial low-dose CT image (80 kV, 144 mAs, DLP of 135 mGy.cm and 2.4 mSv). (B) Standard dose CT image (120 kV, 288 mAs, DLP of 938 mGy.cm and 17 mSv) of upper abdomen shows enlargement of left kidney(asterisk) and dilatation of left pyelocaliceal system & left upper ureter (arrowhead). Images at the level of L3-L4 (C,D,E) shows 2.6 mm calculus in left mid ureter (arrow). (C) Axial plane 1 mm section, (D) increased window width-WW 600. (E) LDCT-1mm axial reconstruction viewed in average mode by increasing thickness to 5mm. (F) Standard-dose CT image at same level as C,D,E shows 2.7 mm calculus (arrow) in left mid ureter

Fig 3: Low-dose multidetector CT urography obtained at 80 kVp, 104 mAs, DLP of 88mGy.cm and 1.6 mSv in 20-year. Maximum intensity projection with reformation (A) Sagittal, (B) Axial and (C) Coronal planes shows excellent depiction of pelvi-calyceal system anatomy and mildy prominent right PCS & right ureter up to right uretero-vesical junction (UVJ) in a patient with <2mm calculus at right UVJ.

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