Using of Reduced Multidetector Computed Tomography (MDCT) in Evaluation of Urinary Calculi: Is That a Modality of Choice?

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ABSTRACT

Background: MDCT play an important role in evaluation of urinary tract stones. Radiation dose is important as the patient may need to do repeated CT examination.

Patients and methods: The study included 50 patients, they were 29 male patient & 21 female patients with age range in between 20 to 80 years old. All patients are presented clinically by suspected urinary tract stones. Conventional dose & low dose MDCT were done and comparison of their results and reports were done. Results: 114 stones were detected by conventional dose MDCT, they were 62 stones (54.4%) on the right side while there were 45 stones (39.4%) on the left side, 6 vesical stones (5.2%) and 1 stone (0.87%) at posterior urethra out of 50 patients. As comparing Conventional & low dose MDCT regarding Validity and sensitivity the obtained data provide that, a very high sensitivity of 99.98% and positive prognostic value (PPV) of 100% for low dose. There were no significant difference in diagnostic accuracy of both modalities however stone size and density with highly statistically significant reduction of radiation exposure and radiation dose in LDCT technique including tube current (mA)(CDCT 139.2 ± 34.5, and 79.78 ± 22.09 for LDCT p<0.001**, total CT dose index/volume (CTDI) CDCT 12.93 ± 0.02 and 5.098 ± 1.34 for LDCT p<0.001**, effective dose (ED) CDCT 8.68 ± 0.41and 3.48±0.95 for LDCT p<0.001**, and total dose length production (DLP) CDCT579.85 ± 29.5 and 238.86 ± 65.93LDCT p<0.001**, the total effective dose reduction is about 5.2 mSv. Conclusion: low dose MDCT has high diagnostic value for evaluation of urolithiasis with the advantage of reduced radiation dose that the patient exposed to during CT examination.

Keywords: Urolithiasis. Multidetector computed tomography (MDCT) Conventional dose & low dose MDCT

INTRODUCTION

Since introduction of MDCT in 1998, it has become the reference tool for the diagnosis of urolithiasis, through its ability to perform multi-planar reformations three-dimensional (3D) reconstructions and measuring attenuation in Hounsfield Units (HU) that have enhanced the detection, quantification and composition of urinary stones. Besides routine evaluation capabilities of spiral one (1),(2),(3),(4) MDCT helps in decision making of treatment strategies by demonstrating anatomical details of pelvicalyceal system and the relationship of the kidney to various surrounding organs like spleen, liver and colon beside estimation of stone-to-skin distance (SSD) that is an important predictor factor of stone-free survival for patients who are candidates for Extracorporeal shock wave lithotripsy (SWL), (5)

As well as undeniable role of CT, imaging in post-treatment follow-up by detection of any complications related to urological interventions, assessment stone-free status and identify the presence of residual stones especially in the presence of stents or PCN tubes. (6)
Although CT is the reference standard method for diagnosing and follow up urolithiasis, it is also a major source of exposure to radiation during medical imaging especially young patients that may require repeated imaging to assess for recurrent stones or changes in stone burden. (7).

Because of the marked increase in CT use for the evaluation of urolithiasis and the associated increase in ionizing radiation exposure, strategies for reducing the radiation dose have become mandatory. (8)

AIM OF WORK
Detection of validity of low dose multidetector CT as an adequate and safest method in detection of urinary stones

PATIENTS AND METHODS
This study was carried out at Al-Azhar University Hospital (New Damietta) (Radiology and urology Departments) during the period from January 2015 to August 2015. The study protocol was approved by the local ethics and research committee of Al-Azhar Faculty of Medicine (new Damietta), and an informed consent was obtained from each patient guardian for participation in the study.

The study included 50 patients, they were 29 male patient & 21 female patients with age range in between 20 to 80 years old.

All patients were presented clinically by manifestations of urinary tract stones and referred from urology department to radiology department for arrangement to do non contrast CT examination of the urinary tract. MDCT were done using conventional & low dose CT scan.

Study protocol: examination was carried out with (TOSHIBA, Aquilion prime, 80 dual MDCT system, Japan).

Scanning parameters for both conventional dose and low dose CT scans were the same regarding the tube volt (120 kV for all patients). However the tube current was manually reduced in low dose scans to be equal to the patient's body weight, the slice thickness was 5 mm with a 2 mm overlap.

Statistical analysis: the collected data analyzed by statistical package for social science (SPSS) version 21 (IBM®SPSS® Inc., Chicago, USA). Numerical variables expressed as mean and standard deviation (SD); while qualitative data were expressed as relative frequency (number) and percent distribution. Independent samples student (t) test and Chi square tests were used for comparison between groups. P value < 0.05 was considered significant.

RESULTS
Patients' ages in our study ranged from 20-80 years (mean ± SD is 45.08 ± 15.3 years) This study includes 29 males (58%) and 21 females (42%) Their mean weight was 83.2 kg and ranged from 50 t0 150 kg.

In our study, 114 stones were detected by conventional dose MDCT, they were 62 stones (54.4%) on the right side (57 kidney stones {91.9%} & 5 ureteric stones {8.1%}) while there were 45 stones (39.4%) on the left side (37 kidney stones {82.2%} & 8 ureteric stones {17.8%}), 6 vesical stones (5.2%) and 1 stone (0.87%) at posterior urethra.

Regarding the anatomic location of the detected stones, the right kidney stones were 13 stones at upper calyx (22.8%), 19
stones at middle calyx (33.3%), 18 stones at the lower calyx (31.5%) and 7 stones at renal pelvis (12.4%). The right ureteric stones were 1 stones (20%) at lumbar ureter, one stone (20%) at iliac ureter and 3 stones (60%) at pelvic ureter. The left kidney stones were 9 stones at upper calyx (24.3%), 7 stones at middle calyx (18.9%), 16 stones at lower calyx (43.2%) and 5 stones at renal pelvis (13.6%). The left ureteric stones were 1 stone at lumbar ureter (12.5%), 2 stones at iliac ureter (25%) and 5 stones at pelvic ureter (62.5%) Table 1.

Regarding the validity of low dose spiral CT in detection of urinary stones in our study in comparison to the conventional dose spiral CT, only 2 stones (0.02%) out of 114 stones was not detected by low dose spiral CT, the sizes of these stones by conventional dose spiral CT were less than 2 mm. this provide that, a very high sensitivity of 99.98% and positive prognostic value (PPV) of 100% for low dose spiral CT for detection of urinary stones Table 2.

The difference of size and density of the detected urinary stones between conventional dose and low dose spiral CT in our study was statistically insignificant. Thus, measurement of the size and density of the urinary stones by low dose spiral CT will not change the treatment plan or patient management, Table 3

The CT radiation exposure and radiation dose were significantly lower with low dose spiral CT in comparison to conventional dose spiral CT. The difference between tube current (mA), total CT dose index/volume (CTDI), effective dose (ED) and total dose length production (DLP) between conventional dose and low dose spiral CT was highly statistically significant, the total effective dose reduction is about 5.2 mSv. Table 4
Table 4: Radiation dose difference between conventional and low dose CT.

<table>
<thead>
<tr>
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<th>Conventional Dose (Mean ± SD)</th>
<th>Low dose Dose (Mean ± SD)</th>
<th>Test of Significance</th>
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<tbody>
<tr>
<td>Density (Hu)</td>
<td>568.0 (102.0-1433.0)</td>
<td>574.0 (103.0-1403.0)</td>
<td>z=0.38 p=0.7</td>
</tr>
<tr>
<td>Tube current (mA)</td>
<td>139.2 ± 34.5</td>
<td>79.78 ± 22.09</td>
<td>t=10.25 p&lt;0.001**</td>
</tr>
<tr>
<td>CT dose index/volume (CTDI) (mGy)</td>
<td>12.93 ± 0.02</td>
<td>5.098 ± 1.34</td>
<td>t=41.8 p&lt;0.001**</td>
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<tr>
<td>effective dose (ED) (mSv)</td>
<td>8.68 ± 0.41</td>
<td>3.48±0.9</td>
<td>t=43.45 p&lt;0.001**</td>
</tr>
<tr>
<td>Dose length production (M. Gy*cm)</td>
<td>579.85 ± 29.5</td>
<td>238.86 ± 65.93</td>
<td>t=33.37 p&lt;0.001**</td>
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z=Mann Whitney U test  
t: Student t test  
** high statistically significant

Discussion

Noncontrast CT is the imaging study of choice in patients with urinary tract stone disease, replacing traditionally used radiography, ultrasonography, and excretory urography (EU). CT is highly sensitive for stone detection, can be performed rapidly, needs no intravenous contrast media and also identify nonurinary tract pathology (9). Ferrandino et al. (10) reported that the median total effective radiation dose per patient with an acute stone episode during the first year of follow up in a cohort of 108 patients was 29.7 mSv, with 22 (20%) patients receiving more than 50 mSv. One strategy to avoid the repetition of CT is to rely on the visibility of stone on the CT scout film to decide if the surveillance regimen may be based on KUB, or to perform a KUB at the time of CT if the stone is not visible at CT scout to be used as a reference for comparison at KUB follow-up. Similarly, Non-contrast spiral CT is mandatory for the follow-up of radiolucent urinary stones (11).

The concern of a greater radiation dose with helical CT than with conventional IVP was raised. The researchers found that the average effective dose of unenhanced helical CT was more than three times that of three-film IVP. The mean effective dose for an IVU examination is reported as 2.6 mSv, while the estimated effective dose for conventional dose computed tomography (CDCT) is 8–16 mSv (12).

Advances in CT technology tend decrease in mean radiation dose to be 0.7–2.8 mSv to limit the patient's lifetime cumulative radiation exposure with good diagnostic value over IVU examination and near to conventional dose computed tomography (CDCT); currently this dose reduction has been recommended by the American College of Radiology (ACR) (13). Six years since Niemann et al. (16) who reported in their meta-analysis a pooled sensitivity and specificity of reduced-dose CT for urolithiasis of 96.6% and 94.9%, respectively, and two years since the ACR published its appropriateness criteria (13).

In particular, using of low-dose CT for questionable pediatric and pregnant cases after the first trimester solving this situation due to unsatisfactory results of color Doppler US with the evaluation of resistive index as the investigation
technique of choice during pregnancy, followed by MR urography (17), (18), (19). Although this technique did not perform equally well in patients with BMI > 30 kg/m² and in presence of stone < 3 mm; Strategies to minimise the emission of ionising radiation during CT include modification of scan parameters (ie, for instances reducing tube current and slice thickness or increasing pitch), modulation of scan parameters according to patient’s characteristics (weight and cross-sectional abdominal dimensions), and use of automatic dose-modulation software or X-ray filters which adjust the radiation basing on the scout images and according to the thickness and density of various anatomic regions (20).

This study included 50 patients with suspected renal stones by history or clinical examination, they included 50 patients (29 males 58% and 21 females 42%) and their ages ranges from 16-77 with mean age ± SD ratio is 44.23±15.58 years, all patients underwent CDCT and LDCT for detection of renal stones and comparison of the results of both CT protocols., in a study done by Haroun et al., (21) they studied 68 patients (47 males 69.1% and 21 females 30.9%) and their ages ranged from 18 to 69 years with mean age of 46±19 years. So, the two results demonstrated that, there is more incidence of urolithiasis in the males than females. This may be due to the number of males is greater than females in both studies, and males in this age range are more liable to stone kidney disease than females.

The difference between median of stone size and density in CDCT and LDCT in our study were statistically insignificant, the median of widest diameter in CDCT was 6.5 and was 7.2 in LDCT with P value = 0.47 and the median of stone density in CDCT was 568 and was 574 in LDCT with P value = 0.7, these results corresponds to the results of the study done by Abo El-ghar et al., (7), who found that the median of stone sizes by CDCT and LDCT were equal (= 6.5) while the difference between the median of stone density in CDCT (= 470) and LDCT (= 512) was statistically insignificant with P value = 0.89.

In this study, we used the conventional parameters of tube volt and current in CDCT which were 120Kv and 200 mAs with no use of automatic tube current modulation; in the LDCT we changed only the tube current to be equal to the patient's weight while the tube volt is fixed to be 120 Kv. In the study done by Karmazyn et al. (22), The tube current in CDCT is adjusted according to their institutional weight-adjusted CT protocols, with tube current ranged from 140 to 260 mA in CDCT while they made a simulated tube current reduction which is a proprietary tool that operates with projectional scan data from diagnostic CT examinations. User controlled random gaussian noise is added to the original scan data to simulate a reduction in tube current. In study done by Abo El-ghar et al., (7), Imaging parameters for both CDCT and LDCT studies were the same (120 kV for all patients) except that the tube current was manually reduced to obtain half the radiation dose. Niemann et al. (16) stated that the current use of automatic tube-current modulation techniques, concepts of absolute effective dose reduction are difficult to apply in all patients because of differences in the body mass index (BMI) of patients. On the other hand, in our series, we found that reduction of the tube current as low as possible to be equal to the patient's body weight is an effective method that significantly reduces the effective dose.
delivered to the patient with high diagnostic accuracy.
In this study, the mean effective radiation dose is reduced by 5.2 mSv, which is higher than in the previously reported reduced-dose protocols. We used variable tube current equal to patient's weight to reduce the radiation dose from the automated dose generated at CDCT but with accepted quality of images produced by LDCT protocol to ensure diagnostic accuracy, while in study done by McLaughlin et al., (23), they used a fixed low tube volt (100 kv) and tube current ranged from 35-40 mA but on the expense of the image quality which need further processing by iterative reconstruction and special software. In our study we modified the dose according to body weight and this yielded an acceptable image quality that allowed a high diagnostic accuracy in our patients.
In this study, the mean ± SD ratio of the effective dose delivered to the patients in LDCT is 3.48 ± 0.95 mSv as compared to 8.68 ± 0.41 mSv in CDCT with effective dose reduction by more than 40%, these results are compatible with previous study done by Poletti et al., (24) who reported that Comparable sensitivity, specificity, and accuracy for diagnosis of urinary tract stones> 2–3mm was demonstrated at a 51% to 81% decreased radiation dose in non obese patients. Low-dose CT was also similar to standard-dose CT in identifying alternative disease, such as appendicitis and diverticulitis ;and defined low dose CT scan for renal colic by effective dose delivered to the patient is less than 4 mSv.
LDCT has some disadvantages in the acute-care setting with stones of <3 mm in diameter, and is less accurate for determining stone size than CDCT especially that impacted at VUJ or stones in obese patients may not be detected with the low-dose technique (22),(24).
In our study, only two stones measures less than 2 mm were not detected with the LDCT technique, when compared with CDCT but these stones were clinically insignificant.In light of these results, we think that careful review of institutional kidney stone protocols is warranted to ensure patient safety from radiation hazards. More direct intervention may be required to see substantial and consistent dose reductions. Collaboration of not only radiology departments but also of emergency medicine and urology departments is needed to instill confidence in proper ordering of these reduced–radiation doses CT examinations.
According to our results, we recommend using unenhanced LDCT with tube current modulation to be equal to patient's weight for all patients with stone disease, especially during the follow-up after treatment, for detecting residual or recurrent stones and in children. This can effectively reduce the effective dose delivered to the patient as low as that of entire IVP study, and with high diagnostic accuracy in comparison to CDCT. Further evaluation is recommended to study the effect of a further dose reduction and the effect of stone composition on stone density at LDCT.

REFERENCES

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