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" Diagnostic capability and radiation safety of low dose CT cystography in acute post-traumatic urinary bladder injuries "

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Abstract:

Background: Genitourinary tract injuries occur in up to 5% of all traumas and at least 10% of abdominal traumas. Pelvic fractures are commonly found in patients with blunt trauma, and up to 40% of patients with bladder injuries are associated with at least one other intra-abdominal organ injury. Conventional cystography was the diagnostic modality for suspected bladder injury. Recently CT cystography is commonly used for evaluating bladder injury. For the risk of possible effects of radiation exposure associated with medical imaging procedures, the imaging centers apply the principles of ALARA.

Aim of work: We aim to assess the diagnostic capability of low-dose CT cystography in the diagnosis and classification of acute post-traumatic bladder injury.

Patients and methods: 44 patients with suspected post-traumatic UB injury were enrolled in this study. Non- and post-contrast CT scan was done using "160" MDCT scanner. Low and standard-dose techniques were applied, and the images were analyzed by two radiologists with at least 15 years of experience.

Results: The study involved 44 patients. 20 patients scanned with low-dose CT while 24 patients scanned with the standard technique. Statistically, there was a significant difference between low and standard-dose groups regarding CTDI volume and radiation exposure (p=0.001) with a good diagnostic capability of low-dose CT.

Conclusion: Low-dose CT cystography offers a good diagnostic capability of bladder injuries comparable to standard dose CT and may be recommended for the assessment of acute UB injuries.

Keywords: CT cystography, low dose CT, bladder injury.

Introduction

Urinary bladder injuries can occur in up to 10 percent of abdominal traumas and can be related to substantial morbidity and mortality, it can result from blunt, penetrating, or iatrogenic trauma (1).

As the bladder is an extraperitoneal organ, bladder injuries can be divided into extra-peritoneal (most common), intra-peritoneal, or combined (2).

The percentages of extra and intra-peritoneal injuries can differ according to topography and mode of injury (3).

Bladder injuries are frequently associated with concomitant pelvic fractures in up to 85% of cases and may cause an extraperitoneal rupture, where urine leaks into the peri-vesicular space but does not extend to the intraperitoneal cavity (4).

Other intraabdominal injuries may be associated with bladder trauma. The mortalities are seen with bladder injuries mostly result from other associated organ injuries, not the bladder injury itself (5).

Isolated bladder injuries are mostly seen secondary to iatrogenic causes, with the incidence being highest in gynecologic and urologic surgeries rather than with general surgeries for GIT (6).

Conventional cystography had been classically used for evaluation of suspected bladder injury, then most centers were directed to use CT cystography due to increased conductibility and rapid turnover time. The European Association of Urology (EAU) advised CT cystography as part of the examination for other possible abdominal injuries, the American Urological Association (AUA) guidelines did not recommend the use of CT versus X-ray (7), however later 2014, AUA permitted the use of CT cystography (CTC), as it has similar specificity to conventional cystography, but with more sensitivity with the use of thinner axial images and multiplanar reformats (8).

Also, CT cystography can be performed without any additional transfer of the patient from the CT scanner to a fluoroscopy machine or changing patient's position during the examination, and so no additional technicians required to perform the examination, which saves time for patient, technician, and radiologists (9).

Although post voiding image is essential in conventional cystography, it is unnecessary in CTC and should be circumvented to avoid extra radiation to the pelvis (10).

Delayed images with the antegrade bladder filling with excreted contrast by the kidneys sometimes may not be acceptable to exclude bladder injury and should be preserved for cases associated with urethral injury. These images may demonstrate injuries if contrast manages to leak out through the defect. Retrograde filling allows adequate distension and stressing of the bladder can be ensured, and injuries will not be missed (11).

The annual per caput effective dose had risen from 0.89 mSv in 2006 to 1.54 mSv in 2013, with a considerable increase of 73.9%, which increased the caution about radiation exposure. (12)

Radiation exposure is one of the risk factors for malignancy, including leukemia and multiple myeloma (13).

The National Council on Radiation Protection and Measurements (NCPR) has recommended an annual occupational exposure limit not to exceed 50 mSv (14)

In low-dose CT scans the image quality has been modified to reduce the exposure dose while maintaining the diagnostic capability. The effective “low dose” to detect nephrolithiasis, is between 1 and 3 mSv. The threshold of 3 mSv is subjective but became the standard threshold for low-dose CT of urinary tract injuries as it corresponds to the average radiation of classic intravenous urography. Standard CT scan for abdomen and pelvis has an average dose between 10 - 12 mSv, while low dose scan has ≤ 3 mSv with about 75% of dose reduction (15).

There are about 60 % of dose reduction using ultra-low-dose CT in comparison to

use of conventional cystography. yet, the ultra-low dose CT is associated with higher noise, affecting image quality to degree that may affect the diagnostic capability of this technique for lesions detection, so low dose CT is preferred over the ultra-low dose (16).

Despite this considerable dose reduction, many studies have shown that the diagnostic efficacy of low-dose CT is yet excellent compared to standard-dose CT (17).

Materials and methods

Patients: A prospective study was approved by the local ethics committee and informed consent from all participating patients was instantly taken before scanning.

Patients' selection criteria:

Polytraumatized patients and patients with blunt abdominal trauma were clinically assessed and suspected of bladder injury were referred to the radiology department and enrolled in this study after informed consent.

Inclusion criteria

Any age and both genders were included.

Exclusion criteria:

Contraindications for MDCT e.g Pregnancy.

Contraindications for IV contrast injection (use retrograde technique only)

Methods:

All CT examinations were performed at the diagnostic radiology department of our University Hospital using 160 multidetector CT scanner (Toshiba, Aquilion prime).

Scanning:

Before CT cystography:

= Examine patient for urethral injury before Foley's catheter insertion.

Instilling contrast media:

Retrograde bladder filling:

If no apparent urethral injury, place Foley's catheter and drain UB before instilling contrast media.

<u>Instill contrast material into UB by gravity-drip infusion: -</u>

After Foley catheter insertion, sufficient bladder distention is carried out by infusing ≥350 mL of a diluted contrast material (50 ml of iodinated contrast media and 450 ml of 0.9% saline) into the bladder under effect of gravity.

Start scanning when the infusion stops dripping to gravity or patient reports pain or discomfort.

Contrast-enhanced CT with antegrade filing in delayed imaging for cases with suspected associated urethral injury (can't place Foley's catheter).

After modifying the standard CT protocol for abdomen-pelvis trauma, that includes both oral and intravenous administration of contrast media.

Image acquisition and interpretation:

Scan region: from iliac crests to trochanters of femur for pelvis

from lower chest to trochanters of femur for abdomen and pelvis

Low-dose CT scan was obtained at 80 / 100 kVp and 50/60 mAs.

Contiguous 1-2 mm thin-section axial sections were obtained after bladder filling.

Coronal and sagittal images at 2-3 mm thickness are re-constructed.

Post evacuation scans are not required.

In a normal CT cystogram urinary bladder shows uniform hyper attenuation, well-distension thin walled with clear, distinct adjacent fat planes, and no evidence of leaked contrast media.

Images were interpreted by two expert radiologists with at least fifteen years' experience.

Statistical analysis:

An Excel spreadsheet was built up for the entry of data. We used validation checks on numerical variables and option-based data entry approach for categorized variables to lower possible errors. The analyses were carried with SPSS software program (Statistical Package for the Social Sciences, version 24, SSPS Inc, Chicago, IL, USA). The normality of the records was evaluated using Shapiro-Wilk Test. Statistical data had been described as mean ±SD if typically distributed; or median and interquartile vary [IQR] if not typically distributed. Frequency tables with percentages had been used for categorized variables. Independent Student t-test and paired t-test had been used to evaluate parametric quantitative variables, whilst Mann-Whitney assessments and Wilcoxon matched pairs tests had been used to evaluate non-parametric quantitative variables. Chi-square test or Mc Nemar-Bowker tests had been used to analyze categorized variables. A p-value < 0.05 is regarded statistically significant.

RESULTS

44 patients were involved in this study. 20 patients, 14 men (70%) and 6 women (30%), were scanned with low dose CT. Their mean age was 24.7 with ±13.8 SD and mean weight 65.4 ±22.8 SD. 24 patients, 22 men (91.7%) and 2 women (8.3 %), were scanned with standard-dose CT. Their mean age was 33 with ±20.3 SD and mean weight 71.2 ±17.8 SD **(Table 1).**

Table 1: The baseline demographic characteristics of the included patients

Variables	Low dose (N =20)	Standard (N =24)	P-value
Age in years			
- Mean ±SD	24.7 ±13.8	33 ±20.3	0.26
- Median (Range)	24 (8 – 79)	32 (19 – 45)	
Gender			
- Female	6 (30%)	2 (8.3%)	0.19
- Male	14 (70%)	22 (91.7%)	
Weight in Kg			
- Mean ±SD	65.4 ±22.8	71.2 ±17.8	0.095
- Median (Range)	65.5 (22 – 95)	71.5 (65 – 82)	

Data are presented as mean ±SD, median (IQR), or number (%).

Table (2) shows the distribution of patients according to the mode of trauma, in low dose CT there were 12 patients (60%) with a road traffic accident, 6 (30%) fall from height while 2 patients (10%) with iatrogenic injury, in standard-dose CT there were 4 patients (16.7%) with a road traffic accident, 14 patients (58%) fall from height and 6 patients (25%) with iatrogenic injury.

Table *2*: Showing type of trauma of the included patients

Variables	Low dose (N =20)	Standard (N =24)	P-value
Type of trauma			
- Road traffic accident	12 (60%)	14 (58.3%)	
- Fall from height.	6 (30%)	4 (16.7%)	0. 25
- Iatrogenic	2 (10%)	6 (25%)	

Data are presented as No. (%).

Table (3) CT parameters among both studied groups. Mean CTDI for low dose CT was 3.157 with ± 1.09 standard deviation, where 14 patients (70%) were examined using the retrograde filling technique and 6 patients (30%)

were examined using the antegrade filling technique, while mean CTDI for standard CT was 11.25 with ± 4.34 SD where 14 patients (58.3%) were examined using the retrograde filling technique and 10 patients (41.7%) were examined using the antegrade filling technique. Statistically significant difference between low and standard-dose techniques groups, were found, regarding CTDI volume and radiation exposure (p = 0.001) with no statistically significant differences between low and standard-dose groups regarding technique (p=0.57).

Table 3: The comparison of CT parameters of the included patients.

Variables	Low dose (N =20)	Standard (N =24)	P-value
CTDI volume			
- Mean ±SD	3.1571 ±1.09102	11.25 ±4.34	0.001
- Median (Range)	3.6 (1.80-3.90)	11.15 (6.9-15.25)	
Technique			
- Ascending	14 (70%)	14 (58.3%)	
- Descending	6 (30%)	10 (41.7%)	0.57

Data are presented as No. (%).

Table (4) shows the spectrum of CT findings of the included patients. For low dose CT, extraperitoneal bladder injuries were found in 14 patients (70%), combined extra and intraperitoneal injuries were found in 2 patients (10%), mural hematoma was found in 2 patients (10%) and 2 patients were normal (10%). As for standard-dose CT, extraperitoneal bladder injuries were found in 18 patients (75%), combined extra and intraperitoneal injuries were found in 2 patients (8.3%), intraperitoneal injuries were found in 2 patients (8.3%) and 2 patients were normal (8.3%), no statistically significant differences between low and standard-dose groups regarding imaging efficacy for detection of urinary bladder injuries(p=0.32).

Table 4: The comparison of CT Findings of the included patients

Variables	Low dose (N =20)	Standard (N =24)	P-value
CT Findings			
- Extra-peritoneal injury	14 (70%)	18 (75%)	
- Extra and intra-peritoneal injury	2 (10%)	2 (8.3%)	0.32
- Hematoma	2 (10%)	0	
- Intra-peritoneal injury	0	2 (8.3%)	
- Normal	2 (10%)	2 (8.3%)	

Data are presented as No. (%).

Table (5) shows the other injuries associated with urinary bladder injury, in low-dose CT 10 patients (50%) had associated with fractured pelvis, 2 patients (10%) had fracture pelvis and rupture hymen, 4 (20%) patients had fracture pelvis and urethral injury, 2 (10%) patients had liver injury white rest of patients had no associated injuries. As for standard-dose CT, 8 patients (33.3%) had pelvic fractures, 2 patients (8.3%) had fracture pelvis and a splenic injury, 2 patients (8.3%) had rectal injuries, 4 patients (16.7%) had splenic injury, 2 patients (8.3%) had vesico-colic fistula while rest of patients had no other associated injuries, no statistically significant differences between low and standard-dose groups regarding imaging efficacy for detection of other associated injuries(p=0.36).

Table 5: The comparison of other injuries associated with urinary bladder injury of the included patients.

Variables	Low dose (N =20)	Standard (N =24)	P-value
Associated Injuries (n = 18)			
- Fracture pelvis	10 (50%)	8 (33.3%)	
- Fracture pelvis, rupture hymen	2 (10%)	0	
- Fracture pelvis, urethral injury	4 (20%)	0	0.36
- Fracture pelvis, splenic injury	0	2 (8.3%)	
- Liver injury	2 (10%)	0	
- Rectal injury	0	2 (8.3%)	
- Splenic injury	0	4 (16.7%)	
- Vesic-colic fistula	0	2 (8.3%)	

Data are presented as No. (%).

Table (6) showing diagnostic efficacy of low dose CT, 20 patients were scanned using low dose CT, 18 patients (90%) showed positive findings in form of bladder injury with associated other organ injuries, only two cases showed negative bladder injury, that was confirmed by reviewing surgical results of cases diagnosed by low dose CT, giving 92.86% sensitivity, 100% specificity, and PPV.

Table 6: Shows the diagnostic accuracy of low dose CT. The sensitivity of low dose CT was 92.86% and the specificity was 100%.

Variables	Low-dose CT Findings		Standard CT Findings		Surgery	
	No	%	No	%	No	%
Traumatic Injury						
- Positive	9	90	11	91.7%	22	100
- Negative	1	10	1	8.3%	0	0
- Total	10	100	12	100	22	100
- Sensitivity	92.86%		87.50%			
- Specificity	100%		100%			
- PPV	100%		100%			
- NPV	100%		100%			

Discussion

In the past, suspected bladder injuries were investigated by conventional cystography, a time-consuming and burdensome procedure in traumatized patients that provides very limited information on the anatomical relationships. **(18)**

CT cystography was developed to complement body CT in patients with possible traumatic bladder injuries, a technique nearly as accurate as conventional studies for assessment of bladder integrity, with additional information on other pelvic organs and bones. **(19).**

Acutely traumatized patients due to their urgency, have a possibility to be examined with wide-ranging diagnostic studies, as a result this increases the risk of excess radiation exposures. So, it is highly recommended to lower radiation doses according to the specific indication of the examination using the ALARA principle (**20).**

Thus, we conducted the present study to assess the role of CT cystography in the diagnosis and management of traumatic bladder injury while maintaining patients' safety through exposure to a low dose of radiation.

The present prospective study conducted at the diagnostic radiology department of our university hospital included Forty-four cases with abdominal trauma and suspected urinary bladder injury.

In the present study, the mean age of the included patients was 29.23 ±17.8; while most of them were males (81.8%).

Blunt, penetrating, or iatrogenic traumas can cause bladder injury, the risk of injury varies according to how much bladder is full; a full bladder is more vulnerable to injury than an empty one **(21).**

In the present study, the most common cause of injury was a road traffic accident (59.1%), followed by fall from height (22.7%) and iatrogenic (18.2%).

Urinary bladder injuries are frequently associated with injuries to other organs. Multi-organ involvement occurs in 70% of patients **(22).**

In our cohort, 81.1% of the patients had associated injuries. The most common associated injuries were fractured pelvis (40.9%), followed by fracture pelvis, urethral injury (9.1%), and splenic injury (9.1%).

This agrees with **Deibert and colleagues (2011)** who stated that 60–90% of patients with bladder injuries caused by blunt trauma have associated pelvic fractures, and 44% of patients with bladder injuries have no less than one other associated intraabdominal injury

In terms of CT findings in the present study, we found that the most common finding was extra-peritoneal injury (72.2%), followed by extra & intraperitoneal injury (9.1%), normal findings (9.1%), and intraperitoneal injury (4.5%).

To our knowledge, no previous studies have assessed the role of low-dose CT in acute traumatic bladder injuries. However, other reports utilized conventional MDCT.

Ramadan and colleagues (2017), assessed the role of CT in the diagnosing traumatic urinary bladder injuries, they included 32 patients with possible traumatic urinary bladder injury in their study, all were subjected to post-contrast CT scan using 120kVp and 350mA, they found that the extraperitoneal bladder injury was the most common type (43.7%) of the cases while intraperitoneal urinary bladder injury represented (18.8%) of cases and combined injuries represented (18.8%) of cases, these results were in line with the current study results but with a significant reduction in radiation exposure, where mean CTDI volume was about 3.2 mGy. **[Fig1,2]**

Reviewing the surgical results in comparison to our diagnosis by low-dose CT, our study was carried out on acutely traumatized 20 patients with suspected urinary bladder injuries. 18 patients showed positive findings by low-dose CT while 2 patients showed negative findings on low-dose CT studies. Accordingly, the sensitivity of low-dose CT in the diagnosis of urinary bladder injuries was 92.86%. ROC curve analysis of sensitivity and specificity of both low and standard-dose CT for diagnosis of acute urinary bladder injuries shows equal AUC for low dose and standard-dose CT (0.500). Illustrations of the diagnostic sensitivities and specificities of the two techniques are shown in [**Figure 3].**

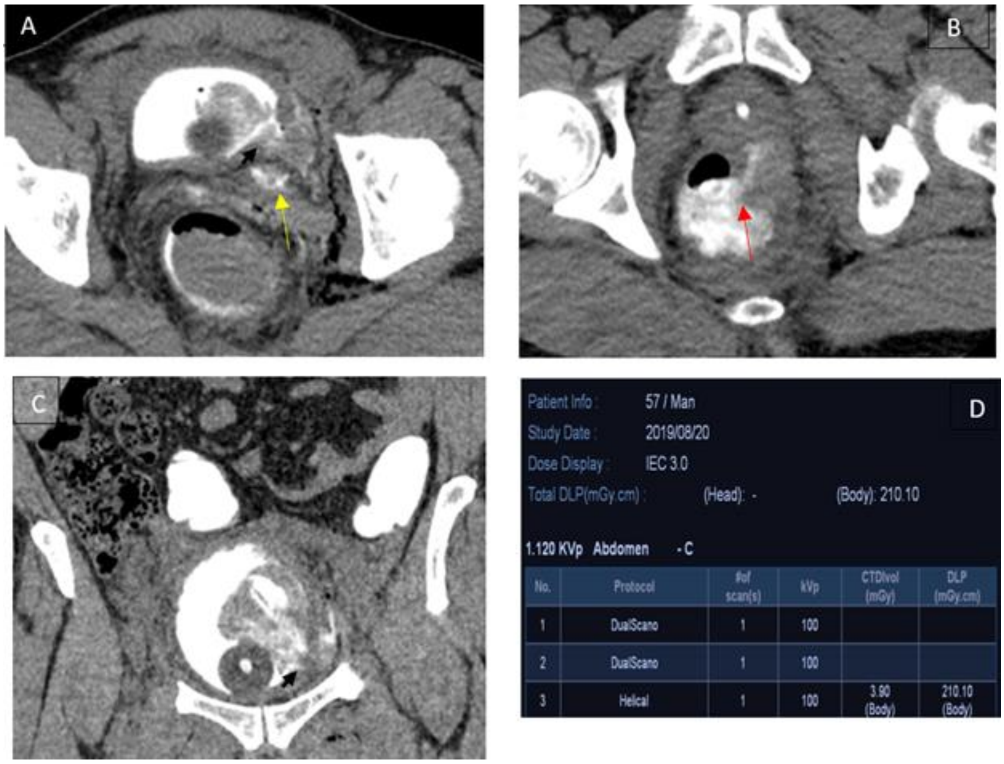

Figure (1): Low dose CT cystography for 57 years old male patient with road traffic accident **(a)** axial image showed extra-peritoneal leakage of contrast to the peri-vesical space (yellow arrow) and the site of wall defect left lateral wall (black arrowhead). **(b)** axial image shows associated rectal wall defect (red arrow) with contrast leakage (**c)** coronal reformat showing bladder wall defect with contrast leak and associated bladder hematoma. **(d)** showing CTDI volume about 3.9 mGy.

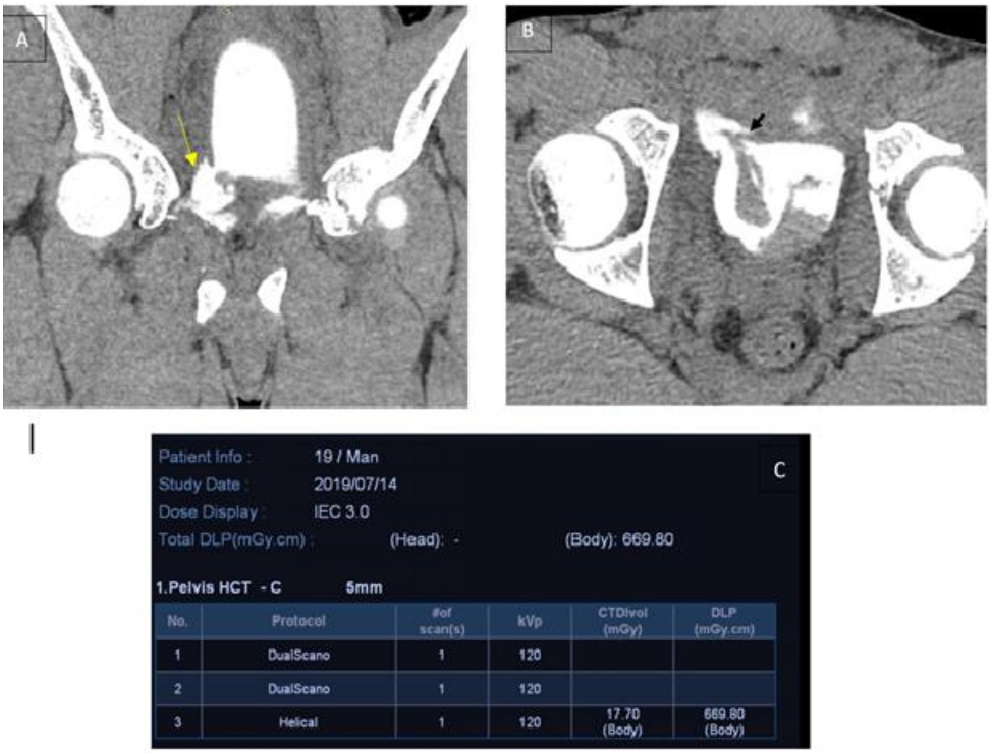

Figure (2): Standard dose CT cystography for 19 years old male patient with road traffic accident (a) coronal reformatted image showed extra-peritoneal leakage of contrast to the peri-vesical space (yellow arrow) and the site of wall defect right anterior lateral aspect. (b) axial image shows urinary bladder wall defect contrast leak (black arrowhead). (c) showing CTDI volume about 17.7 mGy.

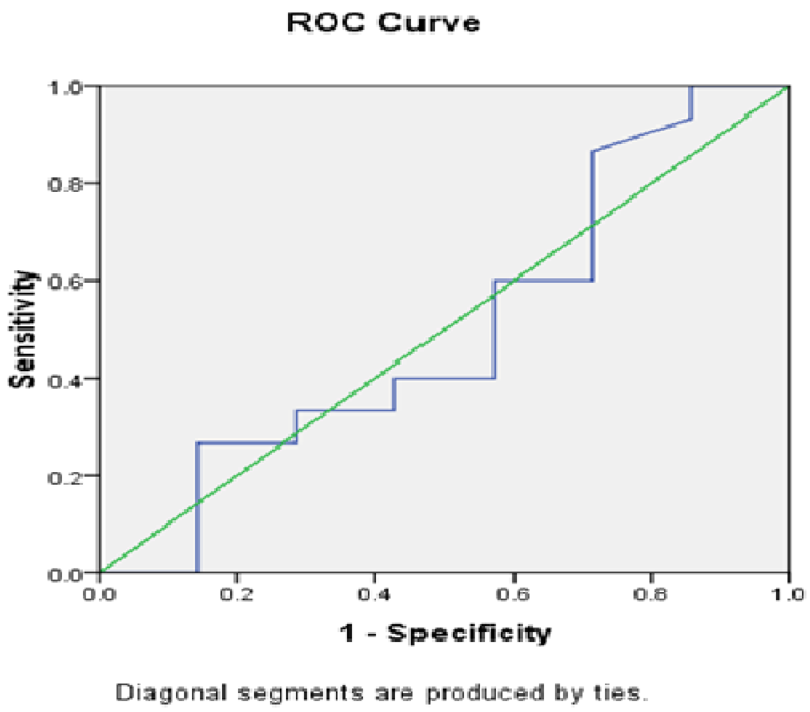

Figure (3): ROC curve for relation between sensitivity and specificity of CTDI volume in diagnosis of urinary bladder injuries

Limitations

Artefacts and lower image quality in overweight patients (>130 Kg)

Single-center study with a relatively small sample size that limits the accreditation of the technique as a standard protocol.

Conclusion

According to our results low-dose CT cystography provided a convenient assessment of urinary bladder integrity, its anatomical relationship with a degree of sensitivity and specificity comparable to that of standard-dose CT and significant reduction of radiation exposure keeping radiation safety help protecting patients from excess radiation hazards.

Recommendation

We recommend for multi-center study with a larger sample size to settle low-dose CT cystography as standard protocol.

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