EXCRETORY PHASE CT UROGRAPHY: MODIFIED TECHNIQUE FOR IMPROVE URINARY COLLECTING SYSTEM DISTENTION AND DECREASE DENSITY OF EXCRETED CONTRAST.

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ABSTRACT

Purpose: To determine if oral water with and without combined intravenous saline infusion and body rotation improved imaging of the urinary collecting system on excretory phase multi-detector CT urography.

Materials and Methods: 42 consecutive renal donors underwent 16-detector CT urography. The excretory phase imaging was performed 400 seconds after intravenous contrast injection either with conventional supine technique (n=17) or modified technique (n=25; after intravenous injection of 250 ml of 0.9% saline and body rotation). Two radiologists retrospectively reviewed blindly and independently scored, 1) degree of distention of collecting system, 2) degree of opacification. Bladder volume was calculated.

Results: The modified cohort had significantly improved distention scores in the intrarenal segments ($p<0.05$) and bladder ($p<0.005$) and larger mean bladder volume ($p<0.001$) as well as significantly higher mean opacification quality scores in the modified cohort ($p<0.005$).

Conclusion: A significantly improved excretory-phase CT urogram was obtained by intravenous saline infusion and body rotation.

INTRODUCTION

A variety of approaches have been advocated for improved distention of the urinary collecting system on multi-detectors CT urography (MDCTU) including scanning in the prone and supine positions,[1] scanning after abdominal compression,[1-6] scanning after supplementaly intravenous infusion of 0.9% saline,[7-8] delayed scanning,[4,8] and scanning after furosimide injection.[9] However, these approaches each have limitations. Imaging in both prone and supine positions increases radiation exposure and imaging time. Use of abdominal compression is cumbersome, may add radiation dose and has shown variable results in achieving distention.[1-6] Use of a 250 ml intravenous saline bolus alone was found to have a non-visualization rate as high as 25% in distal ureteral segments.[8]

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In addition to achieving consistent distention of the urinary collecting system, improving the quality of ureteral opacification (i.e. minimizing beam hardening and achieving homogenous opacification) is important for detecting and characterizing a variety of abnormalities.[10-11] In some studies, use of a saline bolus resulted in diluting excreted contrast and decreasing contrast density with resulting improved excretory image quality.[7-8] In our routine CT urogram protocol, we had patients drink 500 ml of oral water prior to scanning, but anecdotally observed that scans were still degraded by nonvisualized distal ureteral segments, beam hardening and contrast layering artifacts. A simple technique for consistently distending the intra and extra renal collecting system while obtaining a consistent, moderately dense, as well as homogenous opacified urogram was necessary. The purpose of this study was to determine if we could consistently achieve these twin goals, based on a modified MDCTU technique utilizing 500 ml of oral water supplemented by intravenous bolus infusion of 250 ml of 0.9% saline and body rotation prior to obtaining an excretory phase CT urogram in a cohort of potential renal donors who underwent 16-detector CTU.

MATERIAL AND METHODS

Subjects:

This retrospective study was reviewed by our institutional review board (IRB) and was granted an exemption; informed consent was not required. Total 42 consecutive renal donors who underwent donor evaluations between June 2003 and January 2004 were included in the study. All donors were scanned on one of three 16-detector CT scanners (Sensation 16; Siemens Medical system, Erlangen, Germany).

MDCTU = Multi-detectors CT urography

CT Technique:

All examinations were performed on a 16 -detector row CT scanner (Somatom Sensation 16; Siemens Medical system, Erlangen, Germany). Each donor fasted for at least 3 hours prior to the scan and ingested 500 ml of water, within 15-20 min of the scan Unenhanced CT scans were obtained helically using the following parameters: 120 kVp, 200-240 mAs, 12 mm table speed, 0.5 sec rotation speed, 0.75 mm collimation, 5 mm reconstruction. Unenhanced scans were used to ensure the presence of two separate and symmetric kidneys, detect renal calculi and characterize incidental renal, adrenal and liver lesions. Using a power injector, 100-150 ml of nonionic intravenous iohexol (350 mg of iodine/ml) (Omnipaque 350, GE Health, Princeton, NJ) dosed to weight (100ml: less than 100 lbs, 125 ml: 100-200 lbs, 150 ml: greater than 200 lbs) was injected into antecubital vein through 18-gauge peripheral I.V. line at 4.0 ml/ sec. The arterial phase scans were initiated using an automatic bolus-tracking program (Smartprep; Siemens Medical Solution, Erlangen, Germany). A region of interest was placed in the abdominal aorta, just above kidneys. Scanning was triggered at 5 seconds after threshold of 150 HU in the region of interest was reach. Volumetric scans were acquired from the level of the celiac axis to the common iliac artery bifurcation using the following parameters: 120 kVp, 200-240 mAs, 12 mm table speed, 0.5 sec rotation speed, 0.75 mm collimation, and reconstruction with 60% overlap. We reconstructed images at 0.75 mm thickness with 0.6 mm interval for arterial phase. A standard body filter without edge enhancement was used for reconstruction. Nephrographic phase images were acquired 85 seconds following the arterial phase, covering the same area described with similar parameters. Images were reconstructed at 2 mm thickness at 1 mm intervals (50% overlap). Finally, excretory phase images were acquired from the celiac axis to the urinary bladder base approximately 5 minutes after nephrographic phase (approximately 400 seconds after injection) with either the conventional or modified technique. The following parameters were used: 120 kVp, 120 mAs, 15 mm table speed, 0.5 sec rotation speed, 0.75 mm collimation, and 1 mm thickness reconstruction with 0.6 mm interval, extending base.

Conventional technique for excretory phase imaging:

A conventional MDCTU protocol was employed in the first 17 donors (June 2003-August 2003; 11 women, 6 men; mean age: 38 years; age range: 18-58 years). Although these donors ingested 500 ml of oral water within 15-20 minutes of their scan, no other modifications were made. Donors were imaged in the supine position according to the protocol described, approximately 5 minutes after nephrographic phase was acquired (approximately 400 seconds after contrast injection).

Modified technique for excretory phase imaging:

A modified MDCTU excretory phase protocol was used to scan the next 25 consecutive renal donors (13 women, 12 men; mean age: 40 years; age range: 19-54 years). All donors in cohort also drank 500 ml of oral water within 15-20 minutes of their scan and were then imaged with the following modifications: 1) each donor received an intravenous bolus of 250 ml of 0.9% saline supplement after arterial phase scan using a dual headed power injector at a rate of 4 ml/second. 2) After saline infusion and nehprograhpic phase imaging, each donor was asked to rotate in position 3 times on the CT table and imaged in the supine position 300 seconds after the nephrographic phase (400 seconds after contrast injection).

Image analysis:

Excretory phase 16-detector row CT data sets were then loaded on a 3D workstation (Vitrea 2; Vital Images; Plymouth, Mn). Two experienced abdominal radiologists (6 years experience, each) blinded to all donor data retrospectively and independently reviewed the excretory phase data sets from both cohorts in random order on 3D workstations. The reviewers used axial images, supplemented by other 2D reformations (e.g. multiplanar reformation (MPR), maximum intensity projection (MIP)) and 3D reformations (e.g. volume rendering (VR)) according to reader preference.

Each blinded reader was asked to subjectively score the degree of distention and quality of intraluminal contrast density for the entire urinary collecting system and bladder according to the following scoring system: (Figures 1-4)

Fig. 1 Oblique volume-rendered (VR) images obtained with a 16-detector row CT scanner demonstrate degree of distention in intrarenal collecting system and renal pelvis and density of excreted contrast.

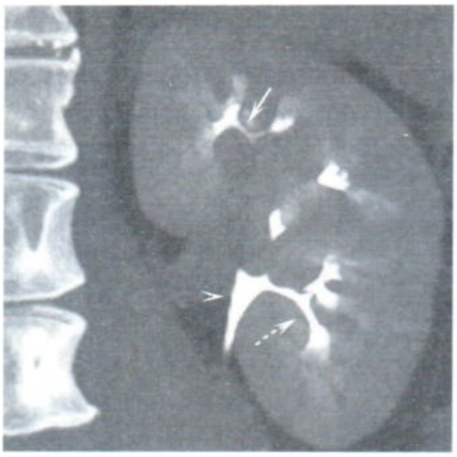

Fig.1A 38 years old female, coronal VR image: arrow = score 1 for upper pole calyx distention, dash arrow = score 2 for lower pole calyx distention, arrow head = score 2 for renal pelvic distention, and score 1 for density of excreted contrast in collecting system.

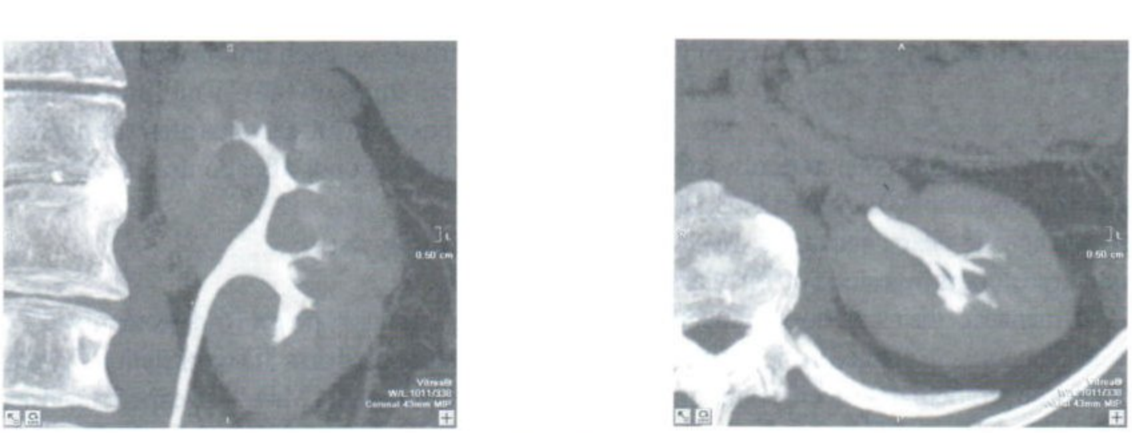

Fig.1B and 1C, 40 years old man, coronal and axial VR images demonstrate score 3 for intrarenal collecting system and renal pelvis distention, and score 2 for density of excreted contrast in collecting system

Fig. 2 40 years old man, selected axial CT urographic images demonstrate distention score for the ureter.

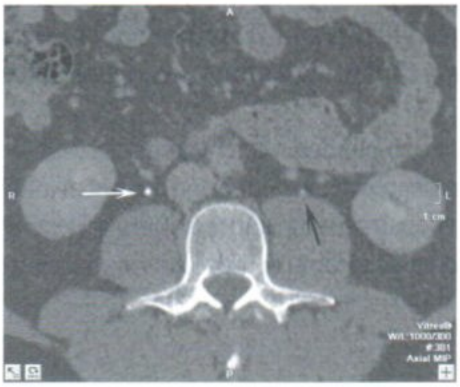

Fig.2A black arrow = score 1 for left proximal ureter distention, white arrow = score 2 for right proximal ureter distention.

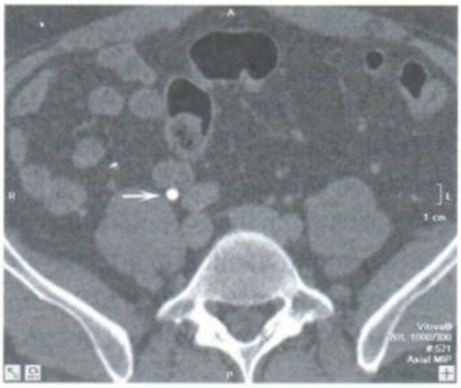

Fig.2B white arrow = score 3 for right mid ureter distention.

Fig. 3 Axial CT urographic images demonstrate different scores for distention and density of excreted contrast for bladder in different consecutive donors.

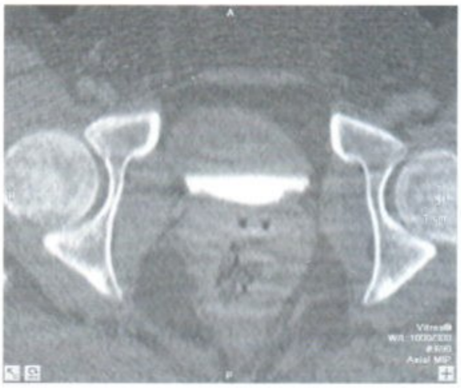

Fig.3A score 0 for distention and density of excreted contrast

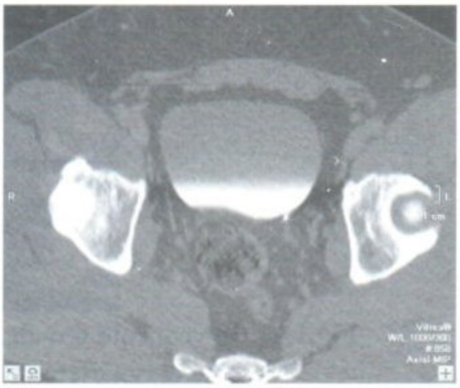

Fig.3B score 1 for distention and density of excreted contrast

Fig. 3C score 2 for distention and density of excreted contrast 3C, score 2 for distention and density of excreted contrast.

Scoring system for distention of upper pole, lower pole intra renal collecting system, renal pelvis, and proximal, mid and distal ureteral segments (6 segments bilaterally)

Score 0: non-visualization
Score 1: less than 50% distention
Score 2: 50-75% distention
Score 3: full distention

Scoring system for urinary bladder distention

Score 0: bladder collapse
Score 1: moderate distention
Score 2: full distention

Scoring system for quality of contrast material in collecting system

Score 0: hyperdense excreted contrast with beam hardening artifact
Score 1: hyperdense excreted contrast without beam hardening artifact
Score 2: homogeneous optimal density of contrast material

Scoring system for quality of contrast material in the urinary bladder

Score 0: hyperdensity of contrast material with beam hardening artifact
Score 1: hyperdensity of contrast material with contrast- urine level
Score 2: Acceptable density of contrast material with minimal contrast-urine level

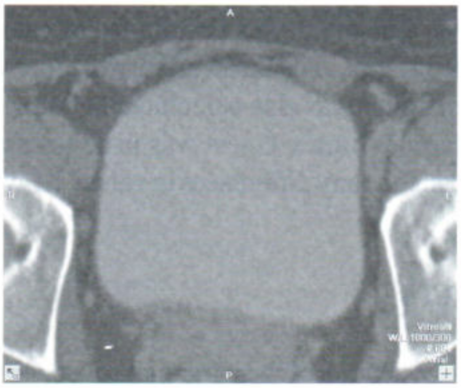

Fig. 4 49 years old woman, axial CT urographic image demonstrates score 2 for bladder distention and score 3 for density of excreted contrast in the bladder.

Score 3: homogeneous, optimal density of contrast material

We divided the intrarenal collecting system (IRC) and extra-renal ureter bilaterally into the following six segments: upper and lower IRC, renal pelvis, proximal (above the iliac crest), mid (between level of iliac crest to sciatic notch) and distal ureter (below the sciatic notch). Two abdominal imagers (6 years experience, each) reviewed the images and assigned the scores for distention of each segment of both kidneys as well as the urinary bladder, and for density of excreted contrast in collecting system and the urinary bladder.

Using volumetric analysis software on the 3D workstation, the excretory phase volume of the urinary bladder in each donor was calculated by manually outlining the bladder with an electronic cursor. The calculated cross sectional area of each section was then summed to give a relative estimate of bladder total volume in milliliters.

Data Analysis:

For each reviewer, the mean scores for bilateral collecting system distention (6 segments per side and bladder) and intraluminal density (collecting system and in the urinary bladder) were calculated separately for both the conventional and modified cohorts. Inter

-observer agreement was determined by calculating weighted Kappa. The mean urinary bladder volume for each donor was also calculated in both cohorts. The Mann-Whitney U test was used to assess the significance of any differences in values between cohorts.

RESULTS

Distention of the intrarenal collecting system and renal pelvis:

Overall, both reviewers scored upper and lower poles intrarenal segments bilaterally were well visualized without any non-visualized segments in either cohort, (Figure 5-6). Both reviewers scored the degree of distention to be significantly better ($p<0.05$) in the modified technique cohort as compared to the conventional cohort. The raw mean scores for renal pelvis distention bilaterally for both reviewers were the best of all six segments analyzed in the modified cohort, and were slightly better than in the conventional cohort with no significantly different.

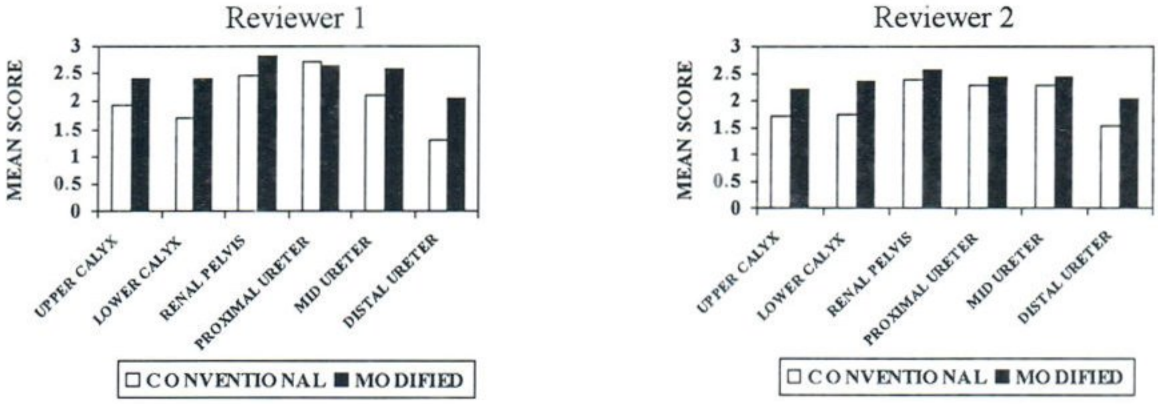

Fig. 5 Vertical bar graphs compare mean score of distention for right collecting system between conventional and modified technique in reviewer 1 (A), and reviewer 2 (B) Statistically difference in mean score for right intrarenal collecting distention between convention technique and modified technique of both reviewers, $p<0.05$

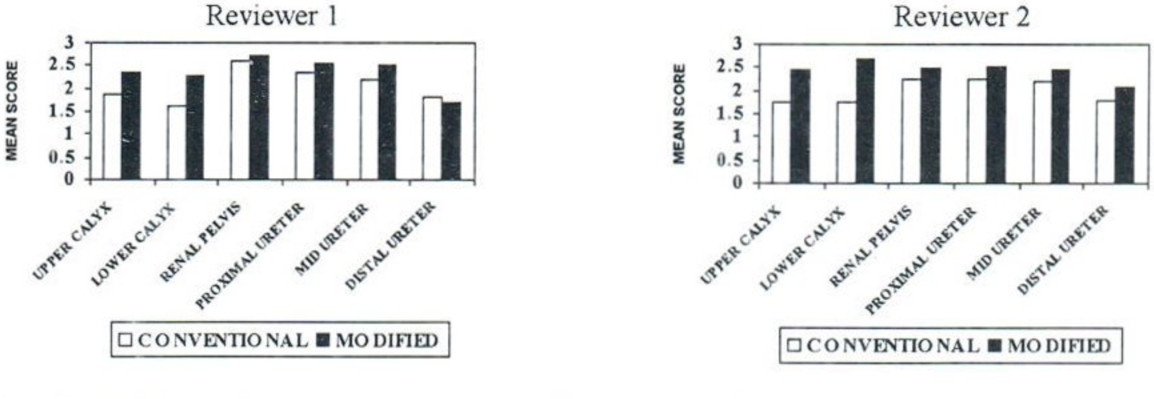

Fig. 6 Vertical bar graphs compare mean score of distention for **left** collecting system between conventional and modified technique in reviewer 1(A), and reviewer 2 (B) Statistically difference in mean score for **left intrarenal collecting distention** of left kidney between convention technique and modified technique of both reviewers, $p<0.05$

Distention of the extrarenal collecting system:

Overall both reviewers scored the degree of distention of the proximal and mid ureteral segments to be well distended in both cohorts, although the scores were generally slightly higher ($p > 0.05$) for the modified cohort. The raw mean distention scores for both cohorts were higher in these two segments compared to all the other segments except the renal pelvis bilaterally. There were no non-visualized segments in either cohort in the proximal ureters. For mid ureter segment, both reviewers scored a non-visualized segment in on the right side in the same single case (4% (1/25 right systems)) in the modified cohort. One reviewer also scored a non-visualized segment in on the right side in a single case in the conventional cohort. Both reviewers scored mean degree of distention of the distal ureteral segments to be slightly lower than other ureteral segments. The mean distal ureteral distention scores were generally slightly better ($p > 0.05$) in the modified cohort. However, there were significantly less non visualized segments overall compared to the conventional cohort, ($p < 0.05$). (Non visualized segments: reviewer 1 conventional: 23.5% (8 of 34 distal ureteral segments) vs modified: 6% (3 of 50 distal ureteral segments); reviewer 2: conventional: 23.5% (8 of 34 distal ureteral segments) vs modified: 4% (2 of 50 distal ureteral segments))

Distention of the bladder:

Both reviewers scored degree of distention of the urinary bladder ($p < 0.005$), (Figure 7) to be significantly better in the modified technique cohort. The latter assessment was confirmed by the relatively larger calculated mean urinary bladder volume in the modified technique cohort (393.69 ml vs 161.54 ml; $p < 0.001$) compared to the conventional technique cohort.

Assessment of Interobserver agreement:

Both reviewers achieved moderate to good agreement (weighted Kappa statistic = 0.42-0.76) for assessment of the degree of collecting system distention, and moderate agreement for degree of bladder distention (weighted Kappa statistic = 0.46).

Density and homogeneity of excreted contrast in urinary tract system:

Both reviewers scored the overall quality of opacification (contrast density and homogeneity) of intraluminal excreted contrast density to be significantly better for the modified cohort as compared to the conventional cohort, ($p < 0.005$) in the intra and extrarenal collecting system and also in the bladder (Figure 7). There was good agreement between reviewers in assessment of quality of intraluminal excreted contrast ($K = 0.65$-0.72)

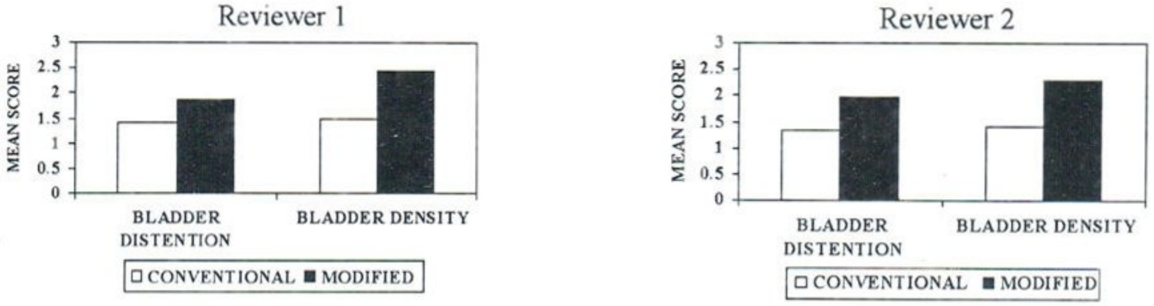

Fig. 7 Vertical bar graph compares mean score of density for urinary bladder distention and density between conventional and modified technique in both reviewers 1(A), and reviewer 2(B). Statistically difference in mean score of urinary bladder distention and density between convention technique and modified technique of both reviewers, $p < 0.005$

DISCUSSION

16-detector CT has enabled acquisition of near-isotropic volumetric data in the renal excretory phase to facilitate high resolution, diagnostic quality CT urograms with IVU like projections familiar to radiologists and urologists. However, the reproducibility and quality of these CT urograms is variable and may be degraded by a variety of factors including lack of distention of the intra-and extra-renal collecting system, as well as inhomogenous opacification of the collecting system and bladder due to layering of excreted contrast and beam hardening artifact caused by high attenuation from concentrated excreted contrast. These problems have been described on both conventional excretory urography and also affected CT urography. Theoretically, improving collecting system distention with a uniform, intermediate density opacification from excreted contrast should enable better evaluation of ureteral lumen and wall.

There is no clear consensus among radiologists that methods of achieving these goals and a variety of techniques have been advocated. Various forms of abdominal compression in either one or two acquisions have been advocated to improve distention of the proximal, mid and distal ureters.[1-6] One group[2] uses a split dose technique with post compression imaging of the upper ureters and compression release views of the lower ureters. Others advocate imaging the excretory phase in the after release of compression.[4,8] However, compression is cumbersome, may require multiple acquisitions in some protocols and has limited visualization of the distal ureter. However, a more recent study found that abdominal compression did not significantly improve distention or opacification of the urinary tract.[8] Other techniques advocated to improve distention include use of a 250 ml intravenous 0.9% saline bolus[1,8] or administration of furosimide.[9] Aside from the issue of distention, improving the overall quality of the excreted contrast to achieve a moderate density, homogenous opacified urogram has only been examined in a few studies[1,8,12]

In this study, both control and modified technique cohorts ingested 500 ml of oral water within 20 minutes prior to multidetector CT scan, since this had routinely been part of the protocol for many years. However, since we had anecdotally observed some non-visualized segments and some scans degraded by excretory phase beam hardening, we modified the technique to include a supplemental infusion of 250 ml of intravenous 0.9% saline due to its relative ease of hydration and its proven effect in improved collecting system distention and dilution of excreted contrast described in excretory urography[13-14] and in multi-detector CT urography.[7,8] Body rotation on the CT table just prior to excretory phase imaging was intended to preclude contrast layering and achieve more homogenous contrast opacification in the collecting system and bladder in this population.

In this study, overall distention was generally very good over a range of six intrarenal and extrarenal collecting system segments and bladder in both the control and modified technique cohorts. However, the modifications (intravenous saline bolus and body rotation) in the latter cohort generally resulted in better distention of the entire collecting system and the bladder. Overall distention was scored well in the proximal and mid ureters bilaterally with an incrementally higher mean distention score in the modified technique cohort. A significantly higher mean score for distention was noted in the intrarenal collecting system and bladder with a significant decrease in the percentage of non-visualized distal ureteral segments (23.5% vs 4-6%). Previously, studies assessing the use of an intravenous saline bolus have reported mixed results. McTavish et al.[7] in a comparison different techniques found that a 250 ml saline injection and excretory imaging at 480 to 600 second delay significantly improved "opacification" only in the distal ureter, but not in the intrarenal collecting system or proximal ureters. Caoli et al.[8] in a retrospective study, which compared four techniques in a non-renal donor population, found slight improvement in distention of all portions of the renal collecting system with both saline administration and abdominal compression techniques. Overall distention was significantly better in the intrarenal collecting system and bladder as compared to other segments of the ureters in the saline cohort. Based on our results, we believe that overall distention in the intra renal and extra renal collecting system and bladder is consistently improved by use of both oral water and a supplemental intravenous saline bolus, especially in the difficult to image distal ureters. The use of oral water may be especially helpful to distend the distal ureters. In comparison to the 26% and 27% of non visualization rate reported by Caoli et al.[8] in the control and saline injected cohorts, we found a 23.5% non-opacification rate in controls (oral water only) which significantly decreased to 4-6% in the modified cohort (oral water, intravenous saline and body rotation). Further, there were no significant non-visualized segments in proximal and mid ureters in our series, whereas Caoli et al.[8] found an 8% and 16% non visualized rate in the proximal and mid ureters respectively even in the saline augmented cohort.

Aside from providing consistently good collecting system and bladder distention, the overall quality of excreted contrast was scored significantly higher in the modified technique cohort in both the intra renal and extra renal collecting system and bladder. Specifically there was there was significantly and consistently less subjective beam hardening and contrast layering artifacts. All subjects in the modified cohort were able to perform body rotation on the CT table during the waiting period for the excretory phase scan. The results support those of previous studies demonstrating a decreased density of excreted intraureteral contrast after saline administration. Both McTavish et al.[7] and Caoli et al.[8] found improved mean opacification scores to be improved in patients, who received an intravenous saline bolus compared to controls who did not receive a bolus.

Our study has limitations. We used subjective -criteria for grading of distention and intraluminal contrast density by two readers, with quantification of only bladder size. However, we believe that this is more clinically relevant since judgments related to distention and quality of opacification are usually subjective. Further, our study was performed in presumed healthy potential renal donors Modifications such as oral water ingestion, intravenous saline bolus and body rotation may not be possible patients with cardiac, renal or liver disorders and body rotation may not be successful in disabled, elderly or obese patients. Finally, this utility of these techniques in detecting urothelial pathology was not assessed, since this study was designed to assess technical improvements.

CONCLUSION

Excretory phase 16-detector CTU performed with oral water and supplemental infusion of saline with body rotation enabled consistently good distention and quality of excreted contrast of urinary tract system.

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