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ORIGINAL ARTICLE

Effects of Saline Administration, Abdominal Compression, and Prolongation of Acquisition Delay on Image Quality Improvement of CT Urography

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Key words: computed tomographic urography; image quality

Objective To retrospectively evaluate the effects of saline administration following contrast material injection, abdominal compression and two delay phase acquisition on image quality improvement of computed tomographic urography (CTU).

Methods Medical records and informed consents of patients were obtained. In totally 122 patients (50 men, 72 women), two delay phase images with CTU were performed. Scans began simultaneously with a contrast bolus injection of 100 mL (300 mgI/mL) followed by a saline bolus injection of 100 mL at a rate of 5 mL/s. Two delay phase images were taken at 400 and 550 seconds for each patient. Examinations were taken by using abdominal compression or not. The distention and opacification of the urinary tract were evaluated by two interpreters together on transverse images and post-processing images. Effects of four techniques (saline administration and abdominal compression, saline administration only, compression only, and neither saline administration nor compression) and two delay phase acquisition on image quality improvement were analysed by using *ANOVA* and *Chi-square* test.

Results Saline administration improved opacification ($P<0.05$) and increased overall image quality ($P<0.01$) of the intrarenal collecting system and proximal ureter. Abdominal compression ($P<0.05$) and delayed phase image acquisition of 550 seconds ($P<0.01$) all improved distention of the intrarenal collecting system and proximal ureter but did not improve opacification. No statistically significant effects on the distal ureter were found. However, there were more visualized distal ureteral segments with the longer imaging delay.

Conclusion Saline administration, abdominal compression and longer imaging delays are all effective in improving image quality of 64-detector row CTU.

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MULTI-detector row computed tomographic urography (CTU) has been the first-line imaging modality for identifying urinary tract abnormalities once believed to be detectable only with excretory urography or retrograde pyelography.^{1,2} As with excretory urography, both adequate distention and opacification of excretory phase images during CTU exam are important for visualization of the contour of urinary tract and detection of intra-luminal lesions. The most common intra-luminal lesion of urinary tract is transitional cell carcinoma, and accurate diagnosis of this kind of malignancy is crucial for patient's treatment.

To date, a few investigators have suggested that abdominal compression during CTU results in improved opacification of the intrarenal collecting system and ureter, which is similar to the excretory urography.³⁻⁵ Others have noted that the use of intravenous saline hydration yields opacification of the urinary tract in comparison with that obtained with excretory urography.⁶ Several studies have described CTU scanning protocols in western population, using different scanning-phase and contrast media injection protocols.⁶⁻¹⁴ According to the newest guidelines,^{2, 15} there is no CTU scanning protocol widely accepted by clinical radiologists. The aim of this study was to retrospectively evaluate the effects of saline administration (SA) following contrast material injection, abdominal compression (AC) and two delay phase acquisition on image quality improvement of CTU in Chinese people.

PATIENTS AND METHODS

Patient enrollment

The study was composed of 122 patients (50 men, 72 women, age range: 18-90 years, mean age: 52 years) who underwent CTU examination in our department from March 2012 to April 2012. Medical records and written informed consent were obtained from each patient. The indications for CTU includes hematuria (60 patients), suspected renal mass (20 patients), suspected urinary calculus (32 patients) and suspected hydronephrosis (10 patients). The criteria for exclusion includes holding breath <10 seconds, allergy to iodine contrast media, uncorrectable coagulopathy, and severe hepatic and/or renal insufficiency.

CT technique

All patients were asked to ingest 1000 mL of water 20-30 minutes before scanning. We used Siemens Somatom Sensation 64 (Forchheim, Germany) as CT scanner. All scans were performed in 4 phases including an unenhanced, nephrographic, delay 1 and delay 2 phase covering the

whole abdomen and pelvis. Delay 1 and delay 2 phases mean early and delayed excretory phases, respectively. After unenhanced CT scanning, all patients had an 18-gauge angiocatheter placed in an antecubital vein. Totally, 100 mL of 300 mgI/mL iohexol iodinated contrast media followed by a saline bolus injection of 100 mL was administered intravenously at a rate of 4 mL per second by an automated power injector. Nephrographic, delay 1 and delay 2 phase images were obtained at 75-, 400- and 550-second delays, respectively. The nephrographic, delay 1 and delay 2 phase acquisition parameters were set as follows: tube voltage 120 kVp, tube current 130-150 mAs, detector collimation 64×0.6 mm, pitch 1.0, reconstructed section thickness and increment 1 mm. Automatic exposure control (CARE Dose 4D; Siemens Medical Solutions; Forchheim, Germany) was routinely applied to decrease the patient's radiation dose.

AC was applied prior to contrast media injection following the unenhanced phase. We used a 5 kg sand bag positioned over the anterior abdominal wall and directly below the iliac crest. Compression was maintained during nephrographic phase acquisition and then was released 10 seconds prior to the two delay phases acquisition. So four imaging procedures were used during the study: both SA and AC, neither SA nor AC, without SA or AC, respectively.

Image interpretation

Two abdominal radiologists who were blinded to patient's information except for indications for CTU, reviewed the transverse and reconstructed CT images including maximum intensity projection (MIP) and volume rendering technique (VRT) of delay 1 and delay 2 phase scans prospectively on a workstation together. The urinary tract was evaluated at three segments: the intrarenal collecting system, the proximal ureter which is above the iliac crest and the distal ureter which is below the iliac crest.

The maximal short-axis diameter of the renal collecting system infundibulum or ureter was measured on transverse images of two delay phases in workstation (Fig. 1). The renal pelvis was not evaluated because of the natural variation in renal pelvic caliber.

For each segment, the reviewers assigned an opacification score from 0 to 3 by using VRT images based on the percentage of opacification of each given segment as determined by the length of the segment opacified. A score of 0 indicated no opacification of the segment; a score of 1, less than 50% opacification; a score of 2, 51%-75% opacification; a score of 3, more than 75% opacification (Fig. 2).

The reviewers gave a subjective impression of image quality which was graded on a scale 1-3. A grade of 1 in-

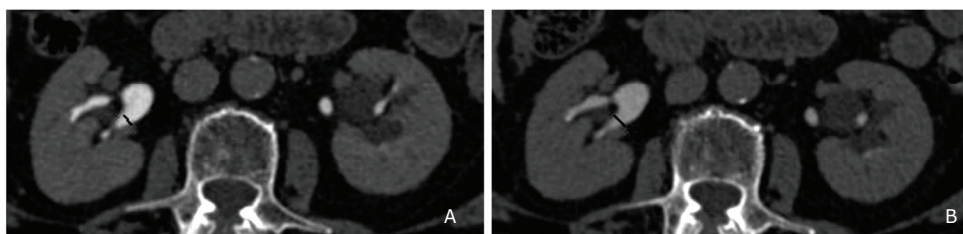


Figure 1. Distention measurement of the renal collecting system infundibulum.
A. delay 1 phase; B. delay 2 phase.

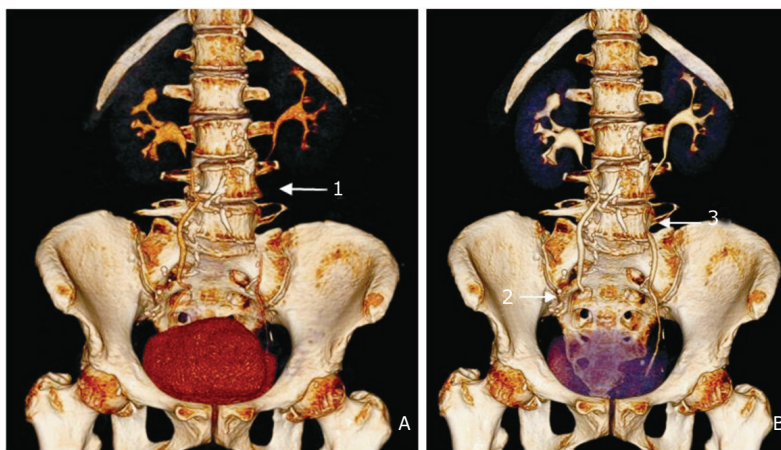


Figure 2. Opacification evaluation of the ureter.
A. delay 1 phase; B. delay 2 phase.
1: $\leq 50\%$ opacification; 2: 51%-75% opacification; 3: $>75\%$ opacification.

dicated poor quality; a grade of 2, adequate quality; and a grade of 3, excellent quality. Visualization may be affected by overlying structures such as vessel calcification, or motion artifact.

Statistical analysis

Statistical analysis was performed using SAS software version 8.1 (SAS Institute, Cary NC, USA). The baseline characteristics of patients [age, gender, body mass index (BMI), hydronephrosis or not, number of urinary tract] were compared to assess the heterogeneity among each imaging group using ANOVA or χ^2 test. We used repeated-measures ANOVA to further adjust statistical models.

According to the published criteria,¹⁶ the clinically meaningful differences in the distention, the opacification score, and the image quality score were 0.25 mm, 0.25, and 0.25, respectively. Multifactorial repeated-measures ANOVA was used for evaluation of urinary tract distention, opacification and image quality in delay phase, because multiple measurements of each urinary tract segment are not independent variables when obtained in the same patient. $P < 0.05$ was considered to indicate a significant difference.

On the delay phase imaging, *post hoc* analysis was

performed in the urinary tract segments that were neither distended nor opacified. The number of nondistended and nonopacified segments was compared among the four different procedures by using a χ^2 test to determine if any imaging procedure was associated with improved visualization of the urinary tract.

RESULTS

All the 122 patients were taken CTU exams successfully. Both SA and AC were administered to 31 patients. Neither SA nor AC was administered to 31 patients. There are 30 patients underwent CTU without saline administration or abdominal compression, respectively. Patients' characteristics were reasonably homogeneous in the four groups (all $P > 0.05$, Table 1).

Distention

The mean maximal short-axis diameter of the renal collecting systems and the proximal ureters was similar between patients with SA (3.49 ± 0.56 mm) and no SA (3.55 ± 0.64 mm), without statistically significant differences ($P = 0.23$). The mean maximal short-axis diameter of the renal collecting systems and the proximal ureters was greater when AC was applied (3.99 ± 0.87 mm) than when AC was

Table 1. Comparison of patients' baseline characteristics of four groups

Group	n	Age [§] (yrs)	Gender (man/woman, n)	BMI [§] (kg/m ²)	Hydronephrosis (n)		Number of urinary tract (n)	
					Yes	No	2	1*
Both SA and AC	31	57±23.2	14/17	23.8±2.2	9	22	28	3
SA only	30	50±30.9	10/20	22.6±2.8	6	24	29	1
AC only	30	51±25.9	13/17	24.1±2.1	13	17	30	0
Neither SA nor AC	31	50±27.3	13/18	22.4±2.9	10	21	29	2
F or χ^2 value		2.10	4.27	2.00	5.19		3.98	
P value		0.23	0.41	0.18	0.14		0.39	

§: Plus-minus values are means±SD.

SA: saline administration; AC: abdominal compression; BMI: body mass index.

*Six patients underwent unilateral nephrectomy.

not used (3.56 ± 0.66 mm), with statistically significant differences ($P=0.036$). Greater mean measurements of the renal collecting systems and the proximal ureters were also noted when excretory phase imaging was performed with a 550-second delay (4.01 ± 0.79 mm) than with a 400-second delay (3.47 ± 0.82 mm), with statistically significant differences ($P=0.0072$). No statistically significant effects on distention of the distal ureter were found for SA, AC and two delay acquisitions ($P=0.14$ for SA/no SA, $P=0.45$ for AC/no AC and $P=0.098$ for two delay acquisitions).

Opacification

The opacification score of the renal collecting systems and the proximal ureters was greater when SA was applied (2.24 ± 1.04) than when SA was not used (mean score of 1.82 ± 0.98), with statistically significant differences ($P=0.036$). The opacification score of the renal collecting systems and the proximal ureters was similar between patients with AC (2.14 ± 0.92) and no AC (1.79 ± 1.05), without statistically significant differences ($P=0.09$). Greater mean scores of the renal collecting systems and the proximal ureters were also noted when excretory phase imaging was performed with a 550-second delay (2.01 ± 0.98) than with a 400-second delay (1.94 ± 0.87), but without statistically significant differences ($P=0.37$). No statistically significant effects on opacification of the distal ureter were found for SA, AC and two delay acquisitions ($P=0.67$ for SA/no SA, $P=0.59$ for AC/no AC and $P=0.23$ for two delay acquisitions).

Image quality

The subjectively graded image quality of the renal collecting systems and the proximal ureters was greater when SA was applied (2.83 ± 0.75) than when SA was not used (2.42 ± 0.82), with statistically significant differences ($P=0.0045$). The image quality of the renal collecting systems and the proximal ureters was similar between patients with AC (2.49 ± 0.87) and no AC (2.44 ± 0.79), with

a 550-second delay (2.57 ± 0.81) and with a 400-second delay (2.51 ± 0.72), all without statistically significant differences ($P=0.49$, $P=0.52$, respectively). No statistically significant effects on image quality of the distal ureter were found for SA, AC and two delay acquisitions ($P=0.29$ for SA/no SA, $P=0.14$ for AC/no AC and $P=0.53$ for two delay acquisitions).

Although SA, AC and two delay acquisitions all had no effect on distention, opacification and image quality of the distal ureters, there were more distal ureters visualized when images were acquired at 550 seconds than 400 seconds. And 25% of the distal ureteral segments were not opacified at 550 seconds, while 38% of distal ureteral segments were not opacified at 400 seconds.

DISCUSSION

As several studies described before,^{1, 2, 4, 6} incomplete distention and opacification of the intrarenal collecting systems and ureters have been acknowledged as potential limitations of CTU. In this kind of situation, the risk of missing small mural or intra-luminal urinary tract abnormalities is greatest when these are located in urinary tract segments that are either poorly distended or unopacified.¹⁶ So it is very important to achieve optimal distention and opacification of the urinary tract lumen for the aim of maximizing sensitivity in the detection of malignant lesions during CTU.

AC was first described in 1930¹⁷ and gained acceptance by urologists and radiologists during excretory urography. A partial obstruction of the middle ureter produced by AC improved distention and opacification of the proximal and middle segments of the ureter. Currently, there are different viewpoints regarding how to perform CTU when AC is used. One study¹⁶ used AC after nephrographic phase acquisition and performed excretory phase imaging of the whole renal collecting systems and ureters after compression released. Others³⁻⁵ have used a split-imaging

technique that initial excretory phase images of the proximal urinary tract are obtained with compression and a set of images through the lower urinary tract and bladder is acquired subsequently after compression is released. Authors of studies using both techniques have found compression to be effective in improving distention and opacification of the upper urinary tract. McNicholas *et al*⁴ compared opacification of upper urinary tract in 25 patients who underwent supine CTU without compression with that in 10 patients who underwent supine CTU with compression. Additional comparisons were made in 10 other patients who underwent CTU in the prone position and in 25 patients who underwent excretory urography without compression. Prone and CTU with compression improved opacification of the intrarenal collecting system and the upper ureter compared with excretory urography, whereas supine CTU without compression did not. Heneghan *et al*⁵ compared opacification of the upper urinary tract in 50 patients who underwent CTU with compression with that in 50 other patients who underwent excretory urography with compression. They found improved opacification of the intrarenal collecting system and the middle ureter and equivalent opacification of the proximal and distal ureters at CTU compared with that at excretory urography. However, this study did not assess the true effect of compression since there was no control group for comparison. Caoili *et al*^{16, 18} conducted two studies to investigate the effects of AC on the visualization of upper urinary tract. Previous study¹⁸ found compression produced a detectable increase in distention of the upper urinary tract while the newly study demonstrated that AC had no effect on distention and opacification of the upper urinary tract. We believed the different results of these two studies were due to the different BMI of the subjects. The obstruction of the upper urinary tract by AC will decrease in patients with high BMI. In our study, the subjects were Chinese people with BMI being up to upper limit. We found that AC can improve distention of the upper urinary tract. It should be notified that AC can not be applied in patients with a history of newly abdominal surgery, abdominal aneurysm and severe urinary obstruction.

Intravenous SA for hydration either prior to or following contrast material injection can improve image quality in excretory urography.

McTavish *et al*⁶ compared mean opacification scores in patients who underwent prone CTU with a 250-mL infusion of normal saline immediately after the administration of contrast material and in patients without saline hydration. They concluded that saline hydration improved the mean opacification scores in the distal ureter. Raptopoulos and

McNamara⁷ found that 30 mL contrast media followed by a saline bolus injection of 120-150 mL could improve opacification of the upper urinary tract during excretory phase in CTU exam. Our study suggested that SA of 100 mL could improve opacification and increase overall image quality of the intrarenal collecting system and proximal ureter as well as no effects on distal ureteral segments.

There is no consensus regarding CTU and the optimal delay for excretory phase image acquisition. Several studies^{5-7, 9-11, 16} performed excretory phase imaging at a 180-600 seconds delay, and Meindl *et al*⁸ used a 600-960 seconds delay for better visualization of distal segments of the ureter. In this study, we found that delayed phase image acquisition of 550 seconds improved distention of the intrarenal collecting system and proximal ureter but did not improve opacification. However, there were more visualized distal ureteral segments with the longer imaging delay.

In conclusion, our findings suggest that SA, AC and longer imaging delays are all effective in improving image quality of 64-detector row CTU.

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