Urol Res (2010) 38:127–133
DOI 10.1007/s00240-009-0237-x

ORIGINAL PAPER

Unenhanced helical CT following excretory urography in the diagnosis of upper urinary tract disease: a little more cost, a lot more value

Hong Hu · Xiao-Yun Hu · Xiang-Ming Fang · Hong-Wei Chen · Xia-Juan Yao

Received: 20 March 2009 / Accepted: 4 November 2009 / Published online: 27 November 2009

Abstract The objective of the study is to evaluate unenhanced CT following intravenous urography (IVU) for the detection of upper urinary tract (UUT) abnormalities, when IVU fails to provide the qualitative diagnosis. Helical CT scan was performed on patients with suspected disorders of UUT, after the completion of IVU for further diagnoses. In total, 124 cases of definite diagnosis and 71 cases of uncertain diagnosis via IVU were collected from 195 patients with suspected UUT disorders. Among the 71 uncertain cases, 65 patients were consent to undergo immediate or delayed CT scan. CT data were transferred to the workstation for post-processing. Of all the 65 cases, the major CT diagnoses were the following: stone disease ($n = 41$), urinary tract infections ($n = 4$), UUT tumors ($n = 7$), neighboring invasion or metastasis ($n = 2$), congenital anomalies ($n = 2$), and compressed stenosis ($n = 6$). Among all the results, 62 cases were confirmed by surgery, pathology or clinical follow-up, while three cases (4.6%) left were still uncertain. The diagnose accordance rate of IVU + CT achieved to 95.4%. There was significant difference between IVU and IVU + CT in the determinate diagnosis of UUT diseases ($\chi^2 = 30.4$, $P < 0.05$). In conclusion, IVU + CT provides more valuable information for the localization and qualitative diagnosis of UUT abnormalities. It is recommended as a cost-effective and time-saving complemental means for IVU.

H. Hu · X.-J. Yao
Department of Nephrology,
The Affiliated Jiangyin Hospital of Southeast
University Medical College, 214400 Wuxi, Jiangsu, China

X.-Y. Hu (✉) · X.-M. Fang · H.-W. Chen
Medical Imaging Center,
The Affiliated Wuxi People's Hospital of Nanjing
Medical University, 214023 Wuxi, Jiangsu, China
e-mail: wpdrhxy@hotmail.com

Keywords Tomography · Upper urinary tract · Urography · Diagnosis

Introduction

Plain abdominal radiograph (KUB), intravenous urography (IVU) and ultrasonography (US) until now have been used as the first step in evaluating urinary tract for many decision makers [1], thus IVU remains the standard imaging procedure in the workup of patients with hematuria, to our knowledge, especially in many developing countries. KUB is the simplest tool to detect radiopaque calculus of urinary system, but limited in small or radioparent stones. US has been playing a unique role in the evaluation of both kidney and bladder, but less useful in detecting ureteral disorders due to varied factors. IVU is limited in the evaluation of renal masses, and can also be technically limited in patients who are obese or have excessive bowel gas. Frequently, portions of the collecting system and ureter remain unopacified even when obtaining multiple views in different positions during urography [2]. Recently, spiral computed tomography (CT) has become the imaging modality of choice for evaluation of the whole urinary system, especially in most of developed countries. Several reports have indicated that CT is more accurate than IVU for the examination of patients with renal colic [3–5]. Nevertheless, the technique, especially contrasted CT urography (CTU), is not universally accepted yet by many clinicians in many sub-developed regions due to several factors, such as higher radiation dose, more complex techniques, more pecuniary cost, sophisticated equipment support, and relative high workload [3, 6–8]. In fact, IVU is still the radiographic standard for the evaluation of the renal calyces, infundibula, pelves, and ureters, particularly in many developing

countries despite some disadvantages [5]. Considering the above, we were interested to find out the results if the advantages between IVU and CT were combined. What benefits can we obtain from the combination? To date, few reports on the method of IVU followed by CT scan (defined as IVU + CT) were found in literature [9]. The purpose of this study was prospectively combine the advantages of both CT and IVU to ameliorate the diagnostic efficacy in a population with high pre-test suspected abnormalities of upper urinary tract (UUT).

Materials and methods

Study method and patient group

A senior diagnostic radiologist was prospectively assigned to help radiographers completing IVU, so those patients with uncertain diagnosis via IVU can be selected in time to undergo an add-on CT scan immediately or lingeringly without using additional contrast medium (CM). We defined it as "IVU followed by plain CT", i.e. "IVU + CT".

From March 2006 to June 2008, 426 patients with suspected disorders of genitourinary system were admitted to our hospital. After primary examinations, a population of 195 patients with high pre-test suspected abnormalities of UUT was selected to undergo IVU for further checkup. Among them, 106 males and 89 females (age range 11–75 years; mean 39 years) were included. Clinical symptoms and case history were as follows: hematuria, flank pain, colicky pain, oliguria, recurrent urinary system infection, pelvic tumorectomy, abdomen mass, and so on. During IVU, definite diagnoses in 71 patients were unable to be made by the senior radiologist; they were informed of further examination for possible etiological diagnosis. As a result, a total of 65 patients agreed to undergo IVU + CT; the others declined the suggestion.

This study was approved by the ethics committee of our institute, and written informed consent was obtained from all patients.

Imaging method

For IVU, patients received oral purgative (senna leaf, 20 g) the night before examination. After a film of KUB was obtained with a computerized radiography, ionic CM (angiografin, 50 ml) was injected intravenously, and films were taken at 5th, 10th, 15th minute after the start of injection. When a delay in calyceal or ureteral opacification was present, late films up to 1.5 h were also obtained. Diagnosis of ureteral obstruction was made when we saw unilateral dilatation of the ureter to a specific level or a unilateral delay in the time of appearance of excreted CM into the renal collecting system when compared with the opposite site. IVU images were interpreted by one of two experienced radiologists.

CT examinations were performed with a 64-slice scanner (SIEMENS SOMATOM SENSATION). Images were obtained from the top of the kidneys to the bladder base, using 1.0 pitch at 90–120 kV and 150–250 mAs (adjusted automatically). Images were reconstructed at a thickness of 1.0 mm. Forty-eight patients underwent CT scanning immediately following IVU, while the remaining 17 patients were examined with delayed CT 1.5–2.0 h after CM injection.

Image postprocessing

Raw images reconstructed at a thickness of 1 mm were transferred to an independent workstation (Syngo, Siemens Medical Solutions). Multiplanar reconstruction, curved planar reconstruction (CPR), maximum intensity projection (MIP) and volume rendering (VR) were obtained when needed, so as to demonstrate lesions or regions of interest as clearly as possible. All spiral CT images were interpreted by two senior diagnostic radiologists. Patients diagnosed by consensus were defined as "definite cases", otherwise patients with unclear diagnosis were defined as "uncertain cases". All cases were confirmed by the standard of reference, including clinical and imaging follow-up, cystoscopic, surgical and histological findings.

Statistical analysis

Statistical analysis was performed with the software of SAS (Statistical Analysis System, version 8.1). A $P < 0.05$ was considered significant for all statistical evaluations.

Results

Of all the 65 cases with suspected ureteral diseases, 62 cases (62/65) were conclusively diagnosed with IVU + CT, while the remaining three cases(3/65) were unclearly diagnosed (Table 1). All lesions were better shown on MPR or CPR images.

Table 1 Frequencies of definite or uncertain diagnosis by IVU and IVU + CT

	Definite D		Uncertain D
	Positive	Negative	
IVU ($n = 195$)	114	10	71
IVU + CT ($n = 65$)	62	0	3

Wilcoxon test, $\chi^2 = 30.47$, $P < 0.01$, *D* diagnosis

Small calculi of UUT were found in 41 patients (diameter range 2–12 mm; the average diameter 5.7 ± 3.9 mm) and all these calculi were moderately or strikingly higher density than the CM located in ureteral lumina or urinary tract. However, one patient with mild ureteral dilatation caused by a small stone located at the right ureterovesical junction was indefinitely diagnosed because of the isodensity (compared with soft tissue of bladder wall).

In addition, four cases of inflammatory constriction, seven cases of tumor, two cases of metastasis (neighboring invasion), two cases of congenital disorders, and six cases of compressed stenosis were definitely diagnosed by the method of IVU + CT (Figs. 1, 2, 3). Among all the results, 62 cases were confirmed by surgery, pathology, ureteroscopy or clinical follow-up, but three cases left were still unclearly diagnosed, occupying 4.6%. The diagnose accordance rate of IVU + CT achieved to 95.4%. There was significant difference between IVU and IVU + CT in the qualitative diagnosis of UUT diseases ($\chi^2 = 30.4$, $P < 0.05$). According to Table 2, IVU + CT was found to be the best method in depicting ureteral stones with 97.6% sensitivity, 91.3% specificity, and in conclusive diagnosis with 95.2% sensitivity, 100% specificity; for IVU, these figures were 59.0, 89.7, 70.8, and 43.1%, respectively.

Discussion

As a traditional and conventional method, IVU has been widely used and plays an important role in evaluation of urinary tract diseases. But at the same time, IVU has limitations. Radiolucent calculi may be easily missed, and the exact location and size of small radiopaque calculi or non-calculus lesions may be difficult to determine. In fact,

Fig. 1 A 26-year-old man with a radioparent calculus presenting with left-sided renal colic for 1 week. **a** Digital KUB radiograph obtained with patient in supine position revealed negative. **b** IVU film 15 min, showed no signs of obstruction despite mild dilatation of left ureter. No calculus is visible. **c**, **d** CPR and MIP were obtained respectively, from the data of IVU + CT. A 4-mm diameter calculus at the mid/upper third of the left ureter was found with incompleted obstruction (*arrows*); and the adjacent ureteral wall was thickening

Fig. 2 A 68-year-old woman with inflammatory construction who presented with right flank pain for 5 weeks. **a** IVU film at 20 min showed obstruction at the level of lower right ureter with moderate dilatation, but failed to provide etiological diagnosis. **b** Luminal narrowing and wall thickening of the lower portion of right ureter was clearly demonstrated on axial CT image (*short arrow*), and stranding of surrounding fat tissue denoted pelvic inflammation (*long arrows*). MIP and VR (**c**, **d**, respectively) images intuitively revealed the segmental stenosis and the dilatated ureter (*arrows*)

nearly 40% cases need further examination to determine the causes of UUT disorders [3, 5]. Under this condition, another more effective tool is needed to overcome the pitfalls.

"IVU followed by CT" was defined as "IVU + CT" in our study, that is, at the nearly end of IVU, patients with suspected ureteral obstruction or UUT disease, who were unable to have a conclusive diagnosis, are selected in time to perform CT scan immediately or lingeringly via their consent. Our study confirms that IVU + CT is a powerful method in the evaluation of UUT abnormalities. In most cases, the results of our preliminary study demonstrate that a wide variety of UUT abnormalities can be accurately detected by IVU + CT. Consequently, the conclusive diagnosis can be obtained to a great extent, such as inflammatory constriction, tumor, congenital disorder, compressed stenosis, radiolucent calculi, tiny calculus, etc.. More importantly, through the method we introduced, contrasted CT scanning can be performed without extra CM, but we can ultimately obtain the images of CTU via thin-slice or 3D reconstruction. In our group of 65 patients, the sensitivity and specificity were 97.6% and 91.3% for detecting

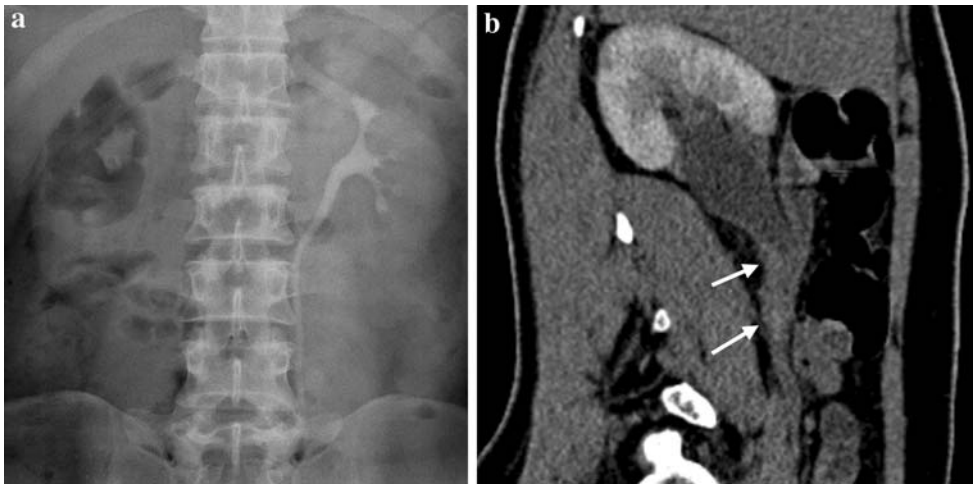

Fig. 3 A 52-year-old woman with upper ureteral carcinoma, presented with hematuria and right flank pain for about 3 weeks, and deteriorated for 3 days. **a** IVU film at 15 min showed delayed opacification of right kidney. **b** CPR image demonstrated that an irregular thickened wall (*arrows*) with mild hydronephrosis was noted at upper portion of right ureter

Table 2 Comparison of diagnostic capability between IVU and IVU + CT

	IVU (n = 195)		IVU + CT (n = 65)	
	Stone versus non-stone	Definite versus uncertain D	Stone versus non-stone	Definite versus uncertain D
TP	98	102	41	59
TN	26	22	21	3
FP	3	29	2	0
FN	68	42	1	3

D diagnosis, *TP* true positive, *TN* true negative, *FP* false positive, *FN* false negative

stones (the figures consist with those in literature [3, 4]), and 95.2 and 100% for conclusive diagnosis, respectively. As a result, uncertain diagnoses raised on IVU related to UUT disorders were readily resolved by the add-on CT, saving the patient another visit, another injection of CM, and a more rigorous and expensive examination. While the IVU portion of the study still remains necessary to provide functional information, and to select patients with uncertain diagnosis for add-on CT. Under this condition, the combination of IVU and CT is more likely to reflect the efficacy of $1 + 1 > 2$.

To date, multi-detector CTU has become a robust imaging modality of choice for evaluation of the kidneys and urinary tract, which was originally described as a triphasic technique utilizing a single bolus of intravenous CM [8, 10, 11]. It usually includes unenhanced, nephrographic and excretory phase. As multi-detector CTU has become more widely available with high diagnostic value for urinary diseases, especially in a lot of developed countries, some experts even thought that CTU has begun to replace other imaging techniques, particularly IVU [12]. However, CTU has several inherent limitations in comparison with IVU, such as higher radiation dosage, more cost, and dependency on sophisticated equipment. If CTU was taken as a first choice for evaluation of urinary system, it may result in medical resource waste, patients' heavy burden (more money and more irradiation), as well as lack of aim. Because a considerable proportional questions of urinary system disorders would have been able to be solved by other imaging modalities, especially IVU; considering our study, for example, in 124 of 195 (63.6%) patients with suspected UUT diseases, conclusive diagnoses could be made via IVU alone. After all, urolithiasis occupies the major portion of urinary system disorders. Accordingly, CTU can be tailed towards the clinical question based on the clinical information if traditional work-up remains negative [12], or when the initial workup is equivocal for both ureteral obstruction and alternative causes or when urologic interventions is believed necessary [13].

As to unenhanced CT scanning, besides the above disadvantages, there are such pitfalls as follows: hardness to distinguish the detailed anatomic structures due to lack of CM; inability to give information on renal function. In addition, plain CT has some limitations in detecting and diagnosing UUT disease unrelated to stones. In contrast, IVU is a simple, classic and traditional tool, used as a universally accepted technique. Therefore, IVU is still the standard and first-choice examination to investigate the abnormalities of urinary system in numerous institutes [5]; then, CT is followed when necessary.

With regard to financial cost, the charge for unenhanced helical CT for whole urinary system is, at least, approximately 1.5 times greater than that of IVU in most of the hospitals of many regions, if using ionic CM. Otherwise, the cost for contrasted CTU is about three times that of IVU if non-ionic CM were used for both. In our institution, the ionic CM is much cheaper and widely used in IVU with a dosage of 50 ml (nearly equals to half dosage of non-ionic CM in CTU). Hence, the charge for IVU equals to 1/5–1/6 of that for CTU, and the cost of IVU + CT is as much as 1/2–1/3 of CTU.

Finally, the radiation dose must be importantly and intensively considered. Nawfel et al. [6] thought that standard protocol for CTU led to higher mean effective dose, approximately 1.5 times the radiation risk for IVU. Using a mathematical computer model, Dillman et al. [8] had calculated that a single-bolus three-phase CTU examination at their institution imparts an estimated effective dose between 20 and 30 mSv which is far more than the ICRP limit for occupational exposure (20 mSv/year). Some scholars also found that, for an average size male, their four-phase CTU protocol resulted in an effective radiation dose of 25–35 mSv which greatly exceeded the 5–10 mSv dose for the 10–12 film IVUs performed at the same institution [5]. More importantly, because many patients with stones experience repeat stone formation, they may undergo CT examinations several times in the course of young adulthood. Consequently, a selective use of CT would reduce overall population exposure dose, particularly beneficial to young patients. In our study, only 4–5 films of IVU were performed, then underwent one CT scan. Therefore, the estimation of IVU + CT for radiation dose was only 1/5–1/3 of CTU. Based on the considerations of exposure, the pros and cons of CTU will alert the physicians not to proceed abusively with contrasted CTU, which also leads ESUR (European Society of Urogenital Radiology) to attempt to reach consensus of guidelines for the clinical application of CTU. As a consequence, true evidence-based guidelines could not be formulated, but most experts were in favor of the indications that CTU may be used as a problem-solving examination except as a first-line test for patients with macroscopic hematuria, at high risk for urothelial cancer [12].

We admitted the following factors that may limit the application of IVU + CT. The add-on CT may: (1) save patients' time, radiation dose, and cost, but obviously increase radiologists' workload. However, it is worthwhile to accept the increased load as long as IVU + CT provides radiologists with more qualitative diagnoses; (2) need close cooperations from different departments of a hospital. However, in many institutes, there are by no means such questions like the above. Actually, IVU + CT usually decreases much workload as a whole for both clinicians and radiologists because it can be performed quickly, at controlled cost, is highly accurate, and is convenient for patients, referring physicians, and the examining department [9]. At most hospitals in Asia as we know, rooms of both IVU and CT often share the same building, even the same floor. In our institute, rooms for patients' examinations are separated, but doctors share the same room for operation.

In general, based on the factors as convenience, cost, safety, it is practical and feasible to combine the advantages of both IVU and CT. Our initial experience confirmed that the add-on CT is a favorable alternative, effectively strengthening the weakness of IVU because of such factors as accurate stone detection, the ability to detect abnormalities unrelated to calculus disease, short examination time, less radiation dose, and generally more convenience in appropriate situations. This was so-called "a little cost we pay, a lot value we gain". In this situation, we suggest CTU should be reasonably considered as an alternative and question-solving tool in comparison with IVU + CT.

The main pitfall of this study was that there was no direct comparison between IVU + CT and CTU in a large sample of patients. Actually, it is unfeasible to perform the comparison in the same population largely due to the consideration of the irradiation dose. But possibly, an indirect comparison in different samples may be worthy of a further study.

Conclusions

The method of IVU + CT, although a little more cost compared with single IVU, provides much more valuable diagnostic information for precisely determining the localization and nature of UUT abnormalities. In our apprehension, it is recommended as a powerful and cost-effective complemental diagnostic means for IVU or CTU. In the future, it will be worthwhile to continue ongoing IVU + CT research related to maximally detection rate of UUT abnormalities, as well as to develop ways to spread the method.

Conflict of interest statement None declared.

References

1. Kim JK, Cho KS (2003) CT urography and virtual endoscopy: promising imaging modalities for urinary tract evaluation. Br J Radio 76:199–209
2. Heneghan JP, Kim DH, Leder RA, DeLong D, Nelson RC (2001) Compression CT urography: a comparison with IVU in the opacification of the collecting system and ureters. J Comp Assist Tomogr 25:343–347
3. Yilmaz S, Sindel T, Arslan G et al (1998) Renal colic: comparison of spiral CT, US and IVU in the detection of ureteral calculi. Eur Radiol 8:212–217
4. Worster A, Preyra I, Weaver B (2002) The accuracy of noncontrast helical computed tomography versus intravenous pyelography in the diagnosis of suspected acute urolithiasis: a meta-analysis. Ann Emerg Med 40:280–286
5. Caoili EM, Cohan RH, Korobkin M et al (2002) Urinary tract abnormalities: initial experience with multi-detector row CT urography. Radiology 222:353–360
6. Nawfel RD, Judy PF, Schleipman AR, Silverman SG (2004) Patient radiation dose at CT urography and conventional urography. Radiology 232:126–132
7. Nolte-Ernsting C, Cowan N (2006) Understanding multislice CT urography techniques: many roads lead to Rome. Eur Radiol 16:2670–2686
8. Dillman JR, Caoili EM, Cohan RH (2007) Multi-detector CT urography: a one-stop renal and urinary tract imaging modality. Abdom Imaging 32:519–529

9. Perlman ES, Rosenfield AT, Wexler JS, Glickman MG (1996) CT urography in the evaluation of urinary tract disease. J Comput Assist Tomogr 20:620–626
10. McNicholas MM, Raptopoulos VD, Schwartz RK et al (1998) Excretory phase CT urography for opacification of the urinary collecting system. AJR Am J Roentgenol 170:1261–1267
11. Chow LC, Sommer FG (2001) Multidetector CT urography with abdominal compression and three-dimensional reconstruction. AJR Am J Roentgenol 177:849–855
12. Van Der Molen AJ, Cowan NC, Mueller-Lisse UG et al (2008) CT urography: definition, indications and techniques: a guideline for clinical practice. Eur Radiol 18:4–17
13. Catalano O, Nunziata A, Altei F, Siani A (2002) Suspected ureteral colic: primary helical CT versus selective helical CT after unenhanced radiography and sonography. AJR Am J Roentgenol 178:379–387