Can Intravenous Urography be Replaced by CT Urography? Our Experience in the Evaluation for Hematuria

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This study was conducted for comparing the diagnostic rate of CT and IVU for hematuria and establishing a proper diagnostic protocol.

During the year of 2004, total 32 patients presented with hematuria received both IVU and CT examination. The CT examination included three phase axial scan: noncontrast (phase I), 90 seconds (phase II) and 180 seconds (phase III) after contrast administration and coronal reconstruction for phase I and III images. The diagnosis of both imaging studies were compared with the final diagnosis. The two examinations were compared by the results of diagnostic accuracy for different diseases.

The most common cause of hematuria is stone, while malignancy is the most common cause in patients more than 50 years old, especially urothelial cell carcinoma (UCC). The diagnostic accuracy for hematuria is 84.3% in CT and 31.3% in IVU. Although suspicious abnormal findings in IVU were recognized in most patients (25/28, 89.3%), they were usually inadequate for making accurate diagnosis and further examinations were thus acquired. The diagnostic rate of CT for stone, renal parenchymal lesion and other intraabdominal pathology is higher than IVU. For the diagnosis of UCC, CT could yield better diagnostic rate as compared with IVU because of its ability to detect wall thickness, adjacent fat infiltration, and contrast enhancement, although IVU yielded better imaging resolution. In the protocol for CT, we found that diagnosis could be obtained in phase I and phase II imaging in most cases.

CT has higher diagnostic rate for hematuria as compared with IVU and could be the one-stop examination for patient with hematuria. CTU should be under consideration to have CTU as the first line diagnostic tool, although more delicate cost-effectiveness evaluation is needed for the conclusion.

Key words: Computed tomography (CT); Hematuria; Intravenous urography (IVU); Ureteral stone; Urothelial cell carcinoma

Hematuria is a common health problem with prevalence rate about 9 to 18 percent among adults [1]. Further assessment and treatment are often not necessary, while hematuria could be a sign of certain serious diseases which include urolithiasis, urinary tract infection, renal vascular disease, malignancy, and other retroperitoneal disorder. The purpose of radiographic examination is to detect those diseases. Intravenous urography (IVU) has long been the first line diagnostic tool for the evaluation of hematuria. It has been standardized and familiar to urologist, but its diagnostic rate is not high and thus other examination is usually needed [2-4].

In recent years, spiral computed tomography (CT) has been a powerful tool for diagnosing renal disease. As compared with IVU, CT has been documented to have much higher accuracy especially in the diagnosis in renal parenchymal disease and urolithiasis [5,6]. With much improved scanning speed and resolution, the collecting system could also be demonstrated with the coronal plane imaging.

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by reconstructing secretory phase image by MPR technique. The diagnostic accuracy of CTU for hematuria has been reported to be 95~100%, which is much higher than the 60~90% of IVU [5, 7-10]. However, the result varies with different studying object and scanning protocol. In addition, the resolution of reconstructed imaging of CT is still not comparable to IVU. Concerning also the higher price and larger radiation exposure, it is still under debating if IVU should be replaced by CTU.

The object of this study is to compare the accuracy of IVU and CTU in the diagnosis for hematuria, and to design the most proper scanning protocol for CTU.

**MATERIAL AND METHODS**

During the year of 2004, patients who were older than 20 years old and presented as hematuria were referred from urological clinic and recruited into our study. They had been evaluated by urologist and further imaging study was considered necessary. Hematuria was defined as RBC more than 3/HPF in urine sediment examination for two subsequent times, and was divided into either micro- or macro-hematuria. Patients with trauma history, nephropathy, or known urological disorder were excluded from the study. Those who were not suitable for intravenous administration of iodine containing contrast medium because of pregnancy, impaired renal function (serum Creatinine > 2 ng/dL), or allergic history were also not recruited in our study. Each patient received IVU and then CTU with the interval between the two examinations more than three days, concerning the renal toxicity of contrast medium.

One day before IVU examination, laxatives were used. At the beginning of the examination, a KUB was taken. After intravenous administration of 50 mL of non-ionic contrast medium (Iopamiro®, bracco s.p.a.), 5 minutes AP view, 15 minutes AP and bilateral oblique views, 30 minutes AP view and post voiding view were taken respectively. Further delayed images were taken if necessary.

The computed tomography used in this study was SOMATOM SENSATION 16 (Siemens Co.) with the compatible work station of Leonardo VB30B (Siemens Co.). The scanning protocol was as followed: 5 × 1.25 mm collimation/pitch 6, reconstructed axial scan of 5mm thickness with scanning range from kidney to urinary bladder.

- **phase I**: noncontrast administration
- **phase II**: intravenous administration of contrast medium with the rate of 2 mL/sec and total amount 100 mL, delay 60 seconds (nephrographic phase)
- **phase III**: delay 180 seconds (excretory phase)

CTU images were obtained by coronal reconstruction of phase I and III images of 5 mm thickness by the 3D work station.

Both IVU and CTU images were interpreted by two uroradiologists, who were blind to the clinical history, operation findings, pathological findings, final diagnosis and the results of the other imaging examination. The diagnosis of both imaging studies were grouped into (1) accurate diagnosis, (2) suspicious lesion but no definite diagnosis, and (3) no specific finding and the results compared with the final diagnosis. The two examinations were compared by the results of diagnostic accuracy for different diseases. Final diagnosis of the patients were established according operation findings, pathological findings and follow-up clinical course for at least 3 months.

**RESULTS**

During January to December in 2004, a total of 76 patients were referred from urologic clinic for imaging study. After excluding those received only either IVU or CT studies and those with the interval between both examinations more than 7 days, total 32 patients were recruited in our study (23 men and 9 women). The age of patients ranged from 26 to 81 years old with average 61.2 years. Among them, 28 were proved to have urological diseases. They were divided into three age groups and the number of patients in each age group was listed as Table 1. As a whole, the most common cause of hematuria is urolithiasis. Among the nine patients less than 50 years old, six were proved to be urolithiasis and none of them had malignancy. In the group more than 50 years old, the highest percentage was the 47.4% of malignancy (9/19) and the second was the 26.3% (5/19) of urolithiasis. All of the patients with malignancy were proved to be urothelial cell carcinoma, which could be located in upper or lower urinary tract, with single or multiple focuses. Whether the patient presented with gross hematuria or microhematuria had no relationship with the disease.

Among the 28 patients proved to have urological diseases, CT could obtain accurate diagnosis in 23 (82.1%) and IVU in 9 (32.1%) (Table 2). The remaining four had no significant abnormality,
Urolithiasis was failed to be detected most often because of too small size of the stone, radiolucent stone or that the obstruction was too severe that the collecting system could not be opacified. The reasons why urothelial carcinoma could not be diagnosed included too severe obstruction (Fig. 3), suspected to be external compression (Fig. 4), or infiltrative growth pattern of the tumor. In one patient with renal ischemic necrosis, the kidney could not be enhanced in IVU study and therefore diagnosis could not be made. In one case of ureteral stenosis caused by psoas muscle abscess, IVU could demonstrate only ureteral stenosis, while CT could show the retroperitoneal inflammatory process clearly.

CT without contrast enhancement could detect most stones in urinary tract. In one case with ureteral stenosis, both IVU and noncontrast enhanced axial scan of CT misinterpreted the calcification on vascular wall as ureteral stone. In the con-
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Contrast enhanced CTU with coronal reconstruction imaging, urinary tract was separated from vessel and thus accurate diagnosis was obtained (Fig 5). In the cases of urothelial carcinoma, CT could obtain accurate diagnosis in all cases by noncontrast (phase I) and nephrographic phase (phase II) images. The excretory phase (phase III) images could delineate the range of the tumor more clearly, and the relationship of urinary bladder tumor with uretero-vesical junction could be defined. However, phase III image was difficult to be obtained in the cases in which obstruction was too severe.

**Figure 1 a.** IVU, 15 minutes oblique view. A radiolucent band (arrow) was noted at right ureteropelvic junction, and intraluminal filling defect was considered. **b.** The phase III axial CT scan confirmed that the radiolucent band was due to vascular indentation (arrow).

**Figure 2 a.** The coronal reconstruction imaging of phase III CT scan revealed stenosis of left distal ureter (arrow), with cause to be determined. **b.** In IVU at the corresponding location, the irregularity of ureter wall (arrow) could be well appreciated which indicated infiltrative tumor growth.
As a whole, the accuracy, sensitivity and specificity for the diagnosis of hematuria was 84.3% (27/32), 82.1% (23/28) and 100% (4/4) for CT and 31.3% (10/32), 32.1% (9/28) and 25.0% (1/4) for IVU respectively. For urothelial carcinoma, the sensitivity of CT is 66.7% (6/9) and that of IVU is 44.4% (4/9). For urolithiasis, the sensitivity of CT is 100% (11/11) and that of IVU is 36.4% (4/11).

Figure 3  a. IVU, 30 minutes AP view. The left side collecting system could not be demonstrated. b. The coronal reconstruction imaging of phase III CT images (two sequential images) showed left side hydronephrosis and hydroureter with intraluminal tumor growth (arrow).

Figure 4  a. IVU of 15 minutes oblique view showed segmental anterior lateral deviation of the right upper ureter (arrows), and external compression was suspected. b. The coronal reconstruction imaging of phase III CT images (three sequential images) revealed eccentric intraluminal tumor growth (arrow).
DISCUSSION

The cause of hematuria is complicated and the percentage varied in different studies, depends on the criteria for recruit studying objects. Generally speaking, the incidence of malignancy significantly increase after 40 years old and may up to 11–12%. In previous studies, comparing different clinical presentation of macrohematuria and microhematuria, the former has the incidence of malignancy four times higher than the later [1, 4, 11]. In our study, there was no relationship between the diagnosis and the clinical presentation as micro- or macrohematuria. Most patients under 50 years old had urolithiasis, but in those older than 50 years old, more than one third were found to have malignancy (9/23, 39.1%).

With the CT protocol used in our study, the diagnostic accuracy of CTU for hematuria was 84.3%, which was significantly higher than the 31.3% of IVU. Although suspicious abnormal findings in IVU were recognized in most patients (25/28, 89.3%), they were usually inadequate for making accurate diagnosis and further examinations were thus acquired. Although CTU has higher radiation dose and cost, it does provide more information than IVU and could be the one-stop examination for patient with hematuria. Concerning the high percentage of true pathological finding among the patients with hematuria in our study (28/32, 87.5%), it should be under consideration to have CTU as the first diagnostic tool, although more delicate cost-effectiveness evaluation is needed for conclusion.

All of the cases in which accurate diagnoses were failed to be made by CTU were urothelial carcinoma with infiltrative growth pattern. On CT images, only mild wall thickening could be demonstrated and could not be differentiated with inflammation, fibrosis or other process of benign stricture. In one case of infiltrative urothelial carcinoma of urinary bladder, the lesion was difficult to be appreciated because the bladder was collapsed. Therefore, proper distention of urinary bladder could be helpful for tumor demonstration. In another case, only stenosis at lower ureter was found in CTU, while irregularity on ureter wall was well appreciated on IVU, and therefore accurate diagnosis of tumor could be made. By this case, we can say that the resolution of IVU is better than that of CTU. To improve the resolution of CTU, several strategies could be considered: to reduce the thickness of coronal reformation imaging, to demonstrate the whole course of ureter by curved MPR, or add MIP images.

Proper CT protocol is crucial for successfully demonstrating lesions in urological system. For example, urolithiasis is shown clearly only in noncontrast enhanced (phase I) imaging and contrast medium in collecting system might obscure the stone. For those under 50 years old in whom urolithiasis is the most common pathology, phase I
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Images could make definite diagnosis and contrast medium administration and additional radiation could be obviate. On the contrary, lesions in renal parenchyma are demonstrated best in nephrographic phase (phase II), in which the renal parenchyma is homogeneously enhanced. In phase III images, intraluminal lesions such as tumor, blood clot, or other space occupying lesion would be shown clearly as filling defects. According the results of our study, conclusion could be obtained in most cases by phase I and II images only. Phase III images usually add not much information and could be helpful only when the tortuosity of ureter made the course hard to be traced in phase I and II images, which is especially problematic for lower segment of ureter. With the lumen filled with contrast medium, the course would be easily demonstrated and the wall thickness is easier to be evaluated. However, in the phase III images of delay 180 seconds, the collecting system usually could not be fully opacified due to either severe obstruction or impaired renal function, which are not infrequently encountered in patients with hematuria. In those patients with multiple lesions, obstruction caused by upper lesion might also lead to the lower ureter unopacified and collapsed, and thus failed to detect the other lesions. It might be helpful to repeat CTU with longer delay time. However, concerning the large radiation dose, it is not recommended. IVU study could offer information about the proper delay time for CTU. If the kidney and collecting system are completely not opacified in IVU, we recommend performing only phase I and II studies for CTU.

In conclusion, CT has higher diagnostic rate for hematuria as compared with IVU and could be the one-stop examination for patient with hematuria. Concerning the high percentage of true pathological finding among the patients with hematuria in our study, it should be under consideration to have CTU as the first line diagnostic tool, although more delicate cost-effectiveness evaluation is needed for conclusion.

REFERENCES

血尿病患之影像學評估-電腦斷層可以取代靜脈尿路攝影嗎？

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本前瞻性研究之目的為比較電腦斷層與靜脈尿路攝影對於血尿病因之診斷率，並建立適當的診斷流程。

一年期間，共有32名血尿病患接受電腦斷層與靜脈尿路攝影檢查。電腦斷層攝影包括三相軸狀切面影像：不施打顯影劑phase I，延遲90秒（phase II）與延遲180秒（phase III），並以二維影像重組phase I與III之冠狀切面。兩種影像學檢查之結果分別與最終診斷對照，並依據不同病竈比較二者之診斷率。

最常造成血尿之原因為結石；但在超過五十歲之病患中，良性腫瘤為最常見之原因，特別是尿路上皮細胞癌。電腦斷層影像對於血尿病患的確定診斷率為84.3%，靜脈尿路攝影則為31.3%。靜脈尿路攝影雖然在絕大部分的病例都有可疑之影像學表現（25/28，89.3%），但經常無法得到確定診斷而需要進一步之檢查。電腦斷層對於結石，腎實質癌與其他的腹腔內病灶診斷率皆高於靜脈尿路攝影。對於尿路上皮細胞癌，雖然靜脈尿路攝影之影像解析度較佳，但因電腦斷層可清楚顯示壁厚，周圍脂肪浸潤與顯影增強，整體診斷率仍高於靜脈尿路攝影。在電腦斷層攝影的流程方面，phase I與II影像在大部分病例即可得到確定診斷，延遲相影像包括軸狀切面與冠狀重組所得的電腦斷層尿路攝影不一定能提供更多資訊，尤其是在有尿路阻塞的狀況。

電腦斷層攝影對於血尿的診斷率，整體而言高於靜脈尿路攝影，經常一次檢查便足夠得到確定診斷。我們認為，以電腦斷層攝影取代靜脈尿路攝影作為血尿病患之第一線評估工具可能是合理的，不過這仍需要更細緻的投資報酬率（cost-effectiveness）分析才能定論。

關鍵詞：電腦斷層攝影，血尿，靜脈尿路攝影，輸尿管結石，尿路上皮細胞癌