FROM INTRAVENOUS UROGRAPHY TO CT - INTRAVENOUS UROGRAPHY

Le Trong Khoan[1], Duong Phuoc Hung[2], Le Trong Binh[1]
(1) Department of Radiology, Hue University of Medicine and Pharmacy, Vietnam
(2) Cardiovascular Centre, Hue Central Hospital, Vietnam

Summary

Intravenous Urography (IVU) is a conventional technique to image the upper urinary tract and to evaluate the function of each kidney. Recent development of multidetector computed tomography (MDCT) technology has made CT-Intravenous Urography (CT-IVU) an optimal alternative imaging modality. CT-IVU provides imaging of the entire urinary tract with high-resolution images. Image quality can be also improved by hyperdiuresis and designated phases. Protocols of CT-IVU vary among authors and institutions, however, the ultimate goal is to maximize image quality and minimize acquisition (least radiation exposure). The purposes of this review are to clarify the indications and acquisition techniques of IVU and CT-IVU and to summarize some abnormal findings seen on both modalities. Proper IVU techniques in selected clinical conditions are essential as IVU reserves its specific diagnostic value.

Key words: *Intravenous Urography, CT-IVU.*

1. INTRODUCTION

Computed tomography - Intravenous Urography (CT-IVU) is the imaging of the urinary system in the excretory phase. In the past few decades, advanced technology in the manufacture of contrast media (CM) made this agent safer and improved image quality. The indications of intravenous urography (IVU) therefore broadened to various clinical conditions, including urinary system and retroperitoneal neoplasms, urolithiasis, malformation, infection and trauma… IVU was then undoubtedly recognized as a pillar of uroradiology. However, the era didn't last long since the introduction of sectional imaging modalities such as ultrasonography (US), computed tomography (CT) and magnetic resonance imaging (MRI) which optimized the examination of the urinary system as well as the retroperitoneal cavity. Despite IVU reserved its ability in the imaging of the urinary tract and quantitative evaluation of renal function, the role of this technique significantly decreased [11].

Recent development of imaging technology such as multidetector computed tomography (MDCT), including uroscanner, CT-Urography (CTU), CT-IVU and MRI urography with thin slice or high spatial resolution and 3D reconstruction has made these imaging modalities optimal alternative to IVU in the examination of the urinary system, even in case of urinary tract. MRI urography is radiation-free, however image quality is thought to be inferior to CT-IVU [2]. In addition, MRI urography is not widely available. Indications of MRI urography reserve for children and pregnant women [8]. Reversely, CT-IVU with hyperdiuresis and radiation dose reduction is a substitution for IVU in every clinical conditions, providing detailed information of the urinary tract morphology and renal function.

Then, should we put an end to the role of IVU? The question has existed for over 10 years without answer. In the article, we would like to summarize:

1. Suggested IVU protocol for optimal urinary tract examination
2. Recommended CT-IVU protocol

- Corresponding author: Le Trong Khoan, email: khoan06@yahoo.com.vn
*- Received: 10/06/2015 * Revised: 25/06/2015 * Accepted: 10/07/2015*

3. Pictorial review from IVU to CT-IVU

4. Indications of IVU and CT urography in concordant with the current setting of Vietnam.

2. IVU TECHNIQUES

The overview of IVU technical aspect should be refered as followed:

- IVU can be indicated to those who are not contraindicated for the use of contrast medium (hypersensitivity, asthma, end stage renal disease, heart failure, pheochromcytoma, sickle cell disease, multiple myeloma).

- IVU is a basic work-up prior to examination includes a Kidney-Ureter-Bladder (KUB) plain film, abdominal US, serum creatinine level.

- Bowel preparation is mandatory

- Contrast medium:

+ Hypo or iso-osmolarity (300mOsmol/kg water).

+ High concentrated Iodine 300-370 mg Iode/ml.

+ Bolus intravenous administration, forearm. Injection rate 3-5 ml/s.

- "Functional" image. This image should be acquired 5 minutes after injection, collimated to kidneys to confirm the simultaneous appearance of CM in the calyceal-pelvis bilaterally, and to assess the renal secretory function. (Nephrographic image is not necessary).

- Ureteral compression: acquires immediately after the functional image.

- Uretero-pyelographic image: Obtain 10-15 minutes after injection to examine the urinary tract morphology (in case of normal renal function). Distal ureteral spot image, if needed, can be obtained under fluoroscopic control after compression release.

- Bladder images: obtain before and after voiding in male patients.

- Aditional images are recommended in case of impaired renal function by doubling time interval to previous images until the urinary tract is visualized.

- Conclusion of renal dysfunction:

+ Radiologically: after **3** hours without CM excretion.

+ Clinically: after **24** hours without CM excretion.

How to optimize image quality

- Hyper-osmolar CM is not recommended

- Supine position with elevated legs

- Ureter compression (if no contraindication)

- Prone position (for better ureter imaging if pyelogram is opacified)

- Additional projection (oblique, upright)

- KUB collimated to pelvis, tilts cranially or caudally

In case of suspected Ureteropelvic junction (UPJ) malformation, 0.5mg/kg (≤ 40 mg) of Lasix should be administered 15 minutes after the injection of CM, then acquire images every 5 minutes later. UPJ malformation can be ruled out if hydronephrosis is not evident after 10 minutes [8].

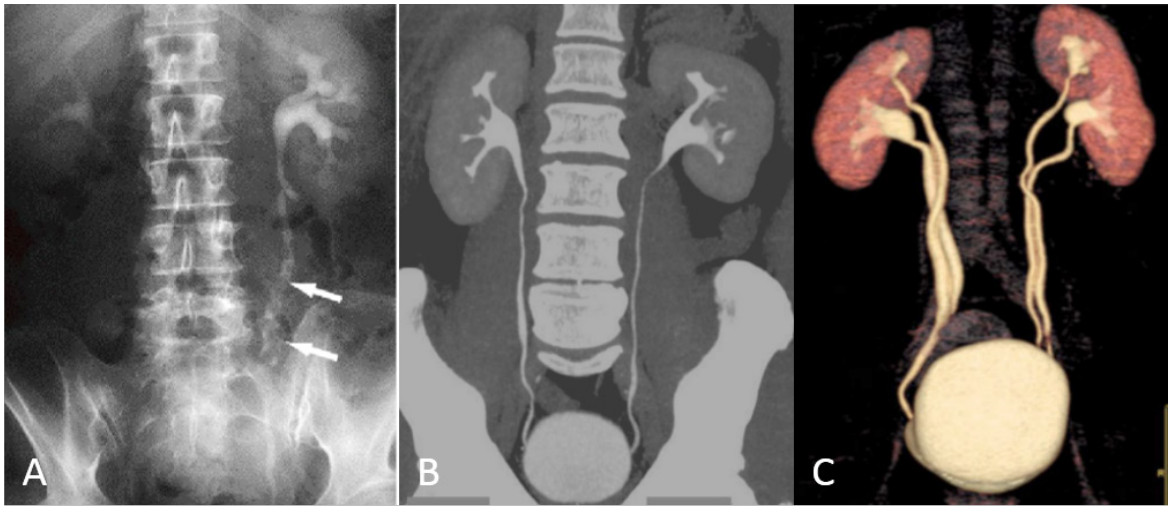

Figure 1. IVU: multiple filling defects in left ureter (A). CT-IVU with Maximum Intensity Projection (B) and 3D image reconstruction (C).

3. CT-IVU

CT-IVU is a diagnostic examination optimized for imaging the kidneys, ureter and bladder. The examimination involves the use of multidetector CT with thin-slice imaging, intravenous administration of a contrast medium, and imaging in the excretory phase [12]. This definition excludes the characterization of complex renal masses, staging of RCC, acute flank pain, renal infection and evaluation of renal arteries.

In the past, abdominal CT scan was insufficient to study the entire urinary tract as it is thin, long and peristaltic. Since the introduction of MDCT with thin-slice imaging and 3D reconstruction of the urinary tract, indications of IVU have switched to CT-IVU. Hyperdiuresis in CT-IVU remains the significant challenge in technical aspect despite it is always essential to optimize image quality, except for acute obstructive syndrome. Another concern of CT-IVU is lowering radiation exposure to patients and medical staffs. Various designated protocols of CT-IVU with dose reduction and selected phases of acquisition have been released so far.

During CT-IVU, the excretory phase is examined by a single acquisition. Therefore, the urinary tract is required to fill up entirely with CM without any unopacified segment due to hypodiuresis or peristalsis. For conventional abdominal CT scan, visualization of the entire urinary tract can be achieved in only 19% of cases and up to 83% if Furosemide is administered [4].

Intravenous administration of Furosemide (≤ 40 mg) just prior to CM injection improves filling of the urinary tract and CM dilution (0.5mg/kg applied for both adults and children). Hyperdiuresis can be enhanced by oral hydration of 750-1000 ml water or intravenous normal saline infusion (250 ml) [11]. These ancillary manoeuvres help reduce examination time to 5-7 minutes, filling up the tract and lower radiation exposure. Data shown that, without hyperdiuresis, diluted CM (265±90 HU) may prevent artifacts in renal parenchyma (streaking artifact) caused by high CM concentration (1310±398 HU) [4].

CM diluting in distended tract provides proper opacification, optimizes image interpretation (high density urolithiasis, ureteral wall and luminal abnormalities). Dose of CM and Furosemide determines the ideal concentration of CM in the urine. The delayed phase after 1 hour is sometimes necessary to investigate the cause of obstruction [7]. Ancillary manoeuvre such as ureteral compression can be applied to better visualize the urinary tract, a similar fashion as conventional IVU. Then the excretory phase is split into (1) earlier excretory phase of the kidneys and proximal ureters with compression, and (2) later excretory phase of the mid-distal ureters and bladder after compression release [11].

Radiation exposure is associated with ethical issue. Radiation dose of CT-IVU has been proved higher than that of IVU, indicating the relatively delay widespread of this modality [10]. Radiation exposure of biphasic, triphasic and four-phasic CT-IVU are 10 mSv, 20-25mSv và 25-35 mSv, respectively [12]. Single-phasic CT-IVU has an average radiation dose of 8.4 ± 1.5 mSv compared to 3.6 ± 2.9 mSv of IVU [1]. According to ALARA (As Low As Reasonable Achievable) principle, the ideal protocol should maximize image quality while minimize radiation exposure.

Radiation exposure can be reduced by collimation, lowering KV, adjusting mAs [12]. The CT Urography Working Group of the European Society of Urogenital Radiology (ESUR) recommended the application of multiphasic CT-IVU based on specific clinical indications.

1. Single phase: screening situations or depiction of congenital anomalies or trauma of the urinary system.

2. Two phases: a more comprehensive evaluation of other benign or unclear diseases (macrohematuria, mass, tract dilatation, complicated urolithiasis).

Additional delayed phase (1-3 hours) or

a post-scan film to investigate the cause of obstruction [7].

3. Three phases: patients with a high pre-test probability of malignancy or staging.

According to Nolte-Ernsting and Cowan [10], the indication of imaging modalities should be considered in the following circumstances.

- CT-IVU or IVU: over 40 years old, symptomatic, microhematuria, negative finding on US and cystoscopy.

- CT-IVU and cystoscopy: over 40 years old, macrohematuria.

- CT-IVU is not indicated to under 40 year-old patients regardless evident micro or macrohematuria [10].

Protocols of CT-IVU vary globally but they all share the common purpose to maximize image quality (by improving tract filling and spatial resolution) and minimize acquisition [11].

3.1. Protocol of CT-IVU recommended by ESUR 2008 [12]

- Single phasic CT-IVU includes excretory phase plus nephrographic phase if urogenital malformation or trauma is suspected.

- Biphasic plus non enhance CT-IVU: macrohematuria, suspected neoplasms, urinary tract dilatation, complicated urolithiasis imaging work-up.

- Triphasic CT-IVU: neoplasms and staging including imaging of the chest, abdomen and pelvis.

3.2. Protocol of CT-IVU introduced by Deiss et al and endorsed by the French Society of Radiology (SFR) 2011 for the investigation of macrohematuria [6]:

- Non-enhance (dose reduction)

- Arterial phase and

- Nephrographic and excretory phase after bolus CM administration, MIP and 3D reconstruction images are mandatory.

This protocol demonstrated its efficacy in the investigation of urolithiasis-induced hematuria, renal vascular malformation, urogenital neoplasms. Arterial phase can be skipped in case of suspected hematuria. Radiation dose reduction should always be considered, particularly when scanning children [6].

Table 1. Recommended scanning parameters (Lille University Hospital - France) [1]

Collimation	40 x 0.625-1.125 mm
Pitch	0.6 - 1
Voltage	120 KV
mAs	≤ 250mAs
Rotation tube time:	0.5 sec
Thickness	1 – 1.5mm/increment 0.75

3.3. Protocol CT-IVU (Medscape 2015) [8]

- Non-contrast axial computed tomographic of the abdomen and pelvis is routinely obtained as part of a CT urogram to look for underlying calculi. The radiation dose is decreased, the trade-off, inevitably, is poorer quality images.

- Injection 120 mL of intravenous contrast (or 85 mL if only one functioning kidney is present) via a peripheral intravenous line at a rate of 2-3 mL/second and image through only the kidneys after a 100-second delay (from the start of the bolus injection) to obtain a nephrographic phase of renal enhancement. No oral contrast is administered.

- After this acquisition, a bolus of 200 mL of saline is administered. The patient is then asked to sit up for approximately 8 minutes (counting from initial bolus injection of contrast) after which they are instructed to lie supine on the CT table with their arms over their head. A second digital scout radiograph spanning the diaphragms through to the pelvis is now obtained. The patient is then scanned from above the kidneys through the pubic symphysis to obtain a 10 minute delayed excretory image to opacity the ureters and bladder. This phase is used to look for filling defects in the urinary collecting system. Sagittal and coronal and 3D volumetric images are obtained from the axial imaging data.

- An alternative technique that is typically used in patients less than 40 years of age is referred to as the "split dose" technique. The initial imaging parameters are the same for both techniques: a scout radiograph and a noncontrast CT scan is obtained (using dose modulation and increasing the noise index at the iliac crests to decrease the dose to

the gonads). Subsequently, 75 mL of intravenous noniodonated contrast is injected via a peripheral line at 2-3 mL/second, which is followed by a 150 mL bolus of saline 8 minutes after the injection of contrast, administer an additional 75 mL of noniodonated contrast at 2-3 mL/second followed by a 50 mL bolus of saline. No oral contrast is administered. After a 100-second delay, a CT scan is obtained from the top of the kidneys through to the pubic symphysis.

Table 2.

Series	kvp	mA	Slice thickness	Reconstruction Algorithm	Noise index
Noncontrast	120	DOSE MODULATION	3.75 mm	Standard	15.7(increased to 25.4 at the iliac crest)
IV contrast 100 seconds delay (from start of bolus injection)	120	DOSE MODULATION	3.75 mm	Standard	15.7
IV contrast 10 minute delay	120	DOSE MODULATION	0.625mm	Standard	30

Table 3. Split-bolus CM injection

Series	Kvp	mA	Slice thickness	Reconstruction algorithm	Noise index
IV contrast combined nephrographic/excretory	120	Dose modulation	0.625mm	Standard	15.7(increased to 25.4 at the iliac crest)

3.4. Image quality from IVU to CT-IVU

Almost all abnormal morphological findings on IVU are depicted on CT-IVU with higher definition.

- Hydronephrosis
- Renal papillary necrosis, calyceal diverticulum
- Filling defects, cut-off sign
- Deformity, shifting, compression of urinary tract can be seen on both IVU and CT-IVU.
- Measurement of HU on nephrographic phase may suggest the nature of lesions. Greater than 10 HU lesion enhancement compared with the findings on unenhanced images indicates the lesion is solid. The lesion is strongly suggested malignant if enhancement is greater than 20 HU [9].
- Radiopaque urolithiasis can be obscured on IVU but well depicted on CT-IVU due to high spatial resolution. CT-IVU also provides detailed information such as density and maximal transverse diameter of the stone.
- CT-IVU provides thin-slice images on different planes axial, coronal and sagittal and 3D reconstruction images (consistent with urologist's preference); well evaluates basal dependent portion of renal calyces owing to collection of diluted CM [1].
- CT-IVU images have higher definition, facilitate the detection of subtle uroepithelial lesions which can be overlooked on IVU. Regarding the investigation of the etiology of microhematuria, CT-IVU is superior to IVU in terms of sensitivity, specificity and diagnostic accuracy [10].
- Adjacent structures of the urinary tract can also be examined on CT-IVU.
- Delayed CM excretion on IVU indicates impaired renal function or the severity of obstruction whereas CT-IVU gives detailed morphological information with high diagnostic value: hydronephrosis, perirenal fat stranding, kidney enlargement, stone-induced ureteral wall

edema (rim sign), perirenal fluid collection, vesicoureteral orfice edema [9].

3.5. Limitation of CT-IVU

In enhanced CT, the classic limitations are artifacts or misdiagnosis due to heterogeneous concentration of CM in the urinary tract. High concentration of CM in the dependent portion can be misdiagnosed as urolithiasis while severe tract obstruction and dilatation may mislead to a filling defect.

Limitation of CT-IVU:

- Hyperdiuresis-induced dilatation mimics obstructive hydronephosis.

- In case of impaired secretory function, the insufficient concentration of CM in the tract (<200 HU) may result in poor contrast ability and lesions can be overlooked or underestimated.

- CT-IVU is unable to evaluate urodynamic of CM (secretory and excretory).

- CT-IVU is impossible to determine hypotonic tract dilatation.

- In comparison with IVU, CT-IVU reveals several inherent disadvantages in additional projections such as serial filming, prone or erect position and voiding which may limit its diagnostic role in case of vesicoureteral reflux, UPJ anomaly, megaureter, mild tract dilatation [7].

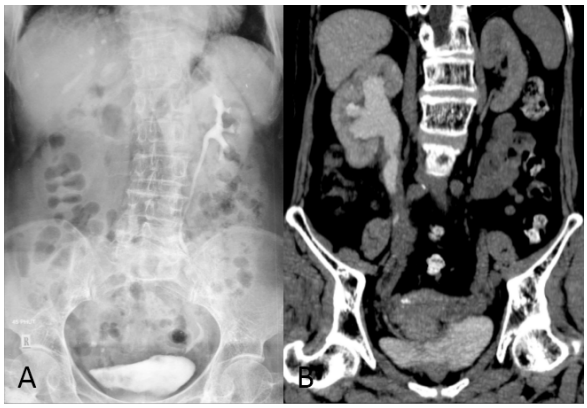

Figure 2. Transitional cell carcinoma with invasion into the right proximal and middle ureter seen on IVU (A) and CT-IVU (B).

3.6. Current indications of IVU and CT-IVU

According to the American College of Radiology practice guideline 2010, update 2015, IVU is indicated to the following: [8]

- To evaluate the presence or continuing presence of suspected or known ureteral obstruction.

- To assess the integrity of the urinary tract status after traumatic condition (including iatrogenic interventions), particularly in situations in which cross-sectional imaging is unavailable or inappropriate.

- To assess the urinary tract for suspected congenital anomalies, particularly in situations in which cross-sectional imaging is unavailable or inappropriate.

- To assess the urinary tract for lesions that may explain hematuria or infection. In particular, excretory urography may be used to evaluate for an underlying parenchymal mass or may be used to evaluate for a lesion of the urothelial tract in settings in which cross-sectional imaging is unavailable or inappropriate.

3.7. Indications of IVU, recommended by Lille University Hospital – France [1]

- Evaluation of peristalsis

- Evaluation of urogenital malformation in pediatric patients

- Evaluation of urethra during voiding

- Evaluation of intermittent obstructive syndrome

- Evaluation of urinary catheters

- Evaluation of vesicoureteral reflux in combining with voiding cystourethrogram (VCUG)

3.8. Indications of CT-IVU [1], [12] (can be substituted to almost all indications of IVU):

1. Hematuria with suspicious malignancy [5], [11]

2. Hydronephrosis

3. Complicated or secondary urolithiasis, imaging work-up prior to percutaneous nephrolithotomy (PCNL)

4. Post-operative injury

5. Complicated urinary tract infection

4. CONCLUSION

- Proper indications and protocol of IVU is important.

- Findings on IVU are also seen on CT-IVU with higher definition.

- Specific protocol of CT-IVU should be considered upon clinical conditions. Indications of CT-IVU should be increased to gain better image quality and diagnostic accurary.

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