Experiences of using a single post-contrast CT scan of the urinary tract after triphasic contrast injection

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Introduction

I was alerted to an article in *Radiology* Vol. 255 No. 2 (May 2010)[1] by a colleague. The article, entitled 'Kidney and urinary tract imaging: Triple-bolus multidetector CT urography as a one-stop shop – Protocol design, opacification, and image quality analysis', clearly describes the technique, while the quotation below, from the article, summarises the findings:

'We have shown that triple-bolus multidetector CT urography allowed visualization of renal parenchymal, excretory, and vascular contrast-enhancement phases in a single dose-efficient acquisition and provided sufficient opacification of the UUT, with simultaneous and adequate image quality of renal parenchyma and vascular anatomy.'

The main emphasis on this technique is to reduce the number of unnecessary CT scans when assessing the urinary tract. Our previous protocol for scanning the urinary tract for pathology included four phases: a pre-contrast, corticomedullary, nephrographic and delay excretory phase.

This new split-bolus technique, with one 'post-contrast' scan, including all three of the above post-contrast phases, was preferentially initiated in our radiology practice to scan the urinary tracts of patients from our referring urologists (this technique was not used for dedicated renal artery scans or for uncontrasted surveys for renal colic).

This technique was tested on a few cases and we then consulted with our referring urologists. We pointed out the benefits and they were happy for us to scan their patients in this way – in fact, some of them were enthusiastic!

We have now scanned over 100 cases in this manner throughout our practice. It requires the radiologist to shift his/her comfort zone, to rely on a single post-contrast scan replacing the traditional three-phase post-contrast scan. I have included a pictorial representation of numerous different pathologies that we picked up while using the newer technique, to share our experiences over a wide range of pathologies, to assist our colleagues in making this shift of technique with more confidence, and to attempt to address some of the queries that could be raised.

Injection plan

We modified the original recommended protocol. Fig. 1 is a summary of our technique, which is as follows:

1. The patient is hydrated with 3 glasses of oral water 30 minutes prior to examination. This was not always possible as many of the patients were booked for retrograde studies in theatre, by the urologists, on the same day after the CT scan was performed. Many of the scans were performed without this pre-hydration.
2. The patient is positioned on the CT table, an IV canula inserted, and a pre-contrast scan from above the diaphragm to below the symphysis is made. We were not meticulous about doing 'low radiation' precontrast scans as suggested in the article.
3. 30 ml of IV contrast is then injected through the canula, usually by hand injection. No scan is made at this time. The contrast is excreted and will contribute to the 'delayed excretory phase' on the later scan.
4. The contrast pump's 2 syringes are then set up with loaded doses of 120 ml contrast and 50 ml saline separately.
5. After about 10 minutes, the patient is rolled once or twice to mix the contrast in the bladder (this normally layers in the dependent portion after lying flat for prolonged periods).
6. A repeat scoutview is taken, a new scan planned, and the next 2 phases

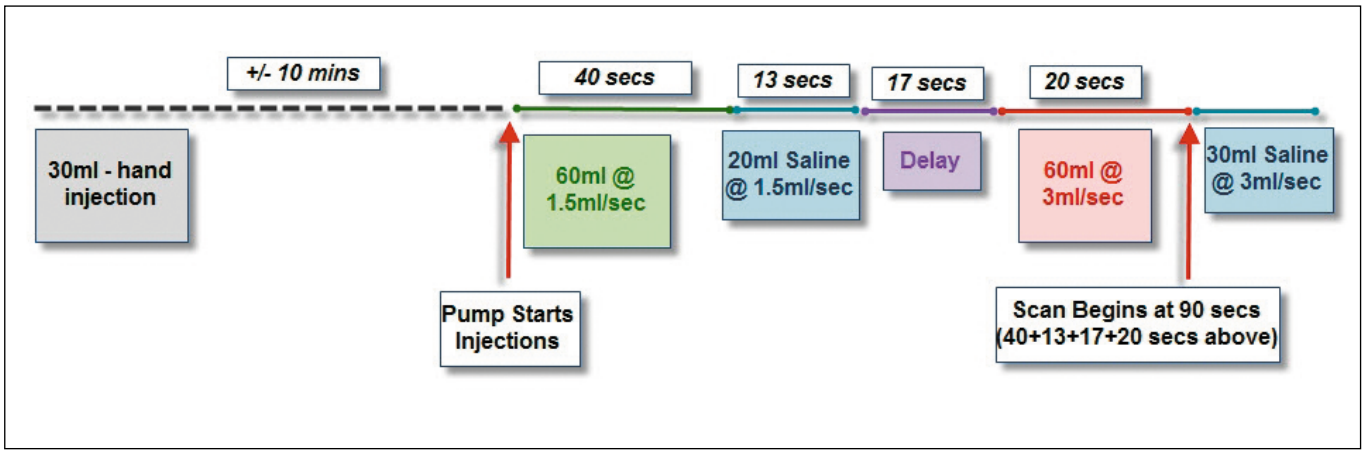


Fig. 1. Injection and scan technique.

of contrast are set up to inject via the automated pump, and injected as follows:

6.1 60 ml contrast at 1.5 ml/sec (40 sec) (contributes to nephrographic phase of the scan), followed by:
6.2 20 ml saline at 1.5 ml/sec (13 sec), followed by:
6.3 a delay after the saline injection (17 sec), followed by:
6.4 60 ml contrast at 3.0 ml/sec (20 sec) (contributes to the corticomedullary phase of the scan), followed by:
6.5 start the scan at this point, followed by:
6.7 30 ml saline at 3.0 ml/sec (chases the last dose of contrast)
7. The scan time on our 64-slice MDCT was 10 - 12 sec, and on the 16-slice MDCT scanners 16 - 20 sec.

Note that, on some of our scanners, the IV pump could not deliver saline injection as well as contrast, and therefore the single saline injection was only delivered after the late corticomedullary-arterial phase injection.

In summary, then, the timing of starting the single post-contrast scan incorporates the following stages:

- excretory phase – about 10 min after the first 30 ml injection
- nephrographic phase – 90 sec after start of the second injection
- corticomedullary/arterial phase – 20 sec after start of third injection.

Will a renal carcinoma be hidden?

The following points are noted from comparing these two cases:

- Renal carcinoma surgery is often done through keyhole surgery. The renal anatomy and the mass relative to the renal artery and vein and the collecting system are all shown on one scan. This allows the urologist to plan surgery and review anatomy more easily, without having to scroll back and forwards between different series.
- Careful evaluation of arterial and vein anatomy is required as there is overlap of these structures. When reviewing the classic 4-phase study above (Fig. 2), one will note that this is a problem with that method as well.

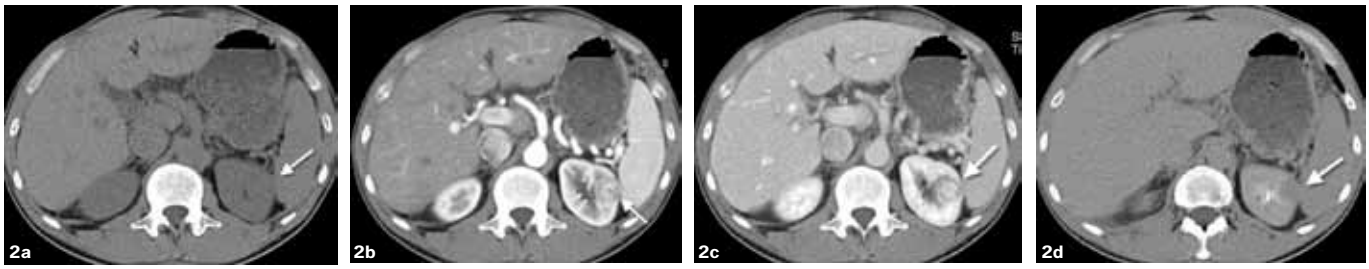
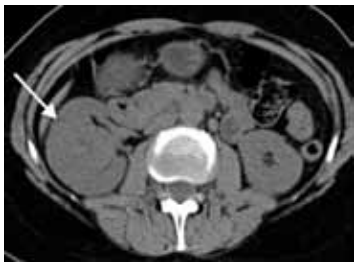
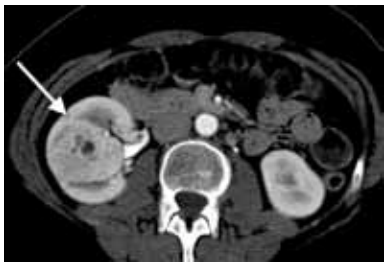


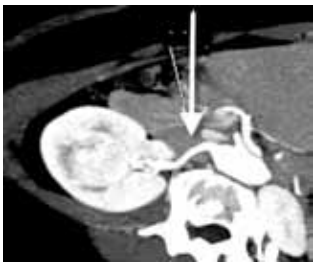
Fig. 2. A traditional renal cell carcinoma scan series with 4 separate post-contrast scans: 2a – pre contrast, 2b – corticomedullary phase, 2c – nephrographic phase, 2d – delay excretory phase.



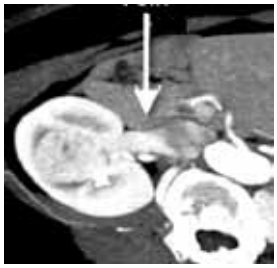
3a. Pre-contrast.



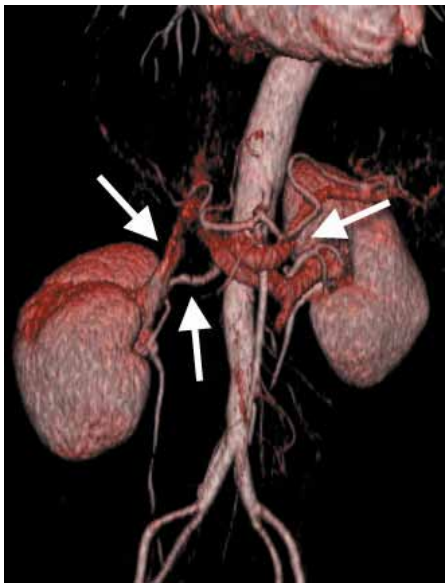
3b. Post triphasic contrast.



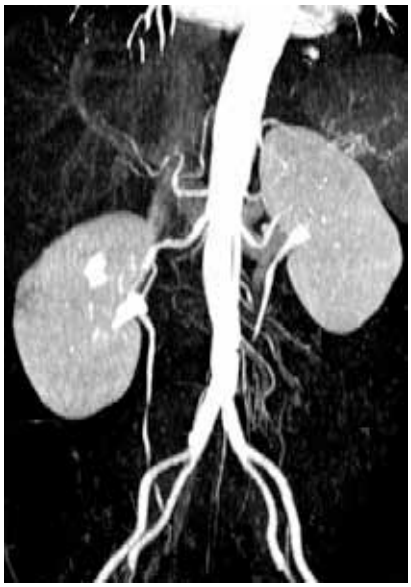
3c. Renal artery.



3d. Renal vein.



3e. 3D reconstruction.



3f. MIP reconstruction.

Fig. 3. Renal cell carcinoma scanned with a single post-contrast series after the triphasic contrast injection. The mass shows up clearly against the background renal tissue. The relation of the mass to the contrast-filled collecting system is shown (b), seen medial to the mass. The renal arteries' (e) and veins' (f) anatomy relative to the kidneys is seen. The lumen of the renal vein is clear and any arterial or venous anomalies are easily seen.

- The contrast concentration in veins and arteries was dense enough to make MIP and 3D reconstructions, for easier interpretation for the referring clinicians.
- The mass was easily seen, and there is no real decrease in clarity of the mass when comparing with the 'classical 4-phase' scan technique above in Fig. 2.
- One is advised to be meticulous about changing window width and levels during the reviewing of the kidneys (and the rest of the urinary tract). This should be standard protocol when reviewing any CT scans, whatever the method of scanning and region of scanning; however, it is unfortunately not always practiced meticulously by radiologists.
- The question about whether hepatic metastases may be missed or hidden by this technique has not been addressed. However, when comparing experiences of radiologists in our large radiological practice, which includes a dedicated oncology practice, most had difficulty in remembering when they last saw renal carcinoma metastases to the liver despite the fact that the 4-phase contrast scan technique has been the standard protocol for many years.

Will neoplasms of the uro-epithelium in the urinary tract be obscured?

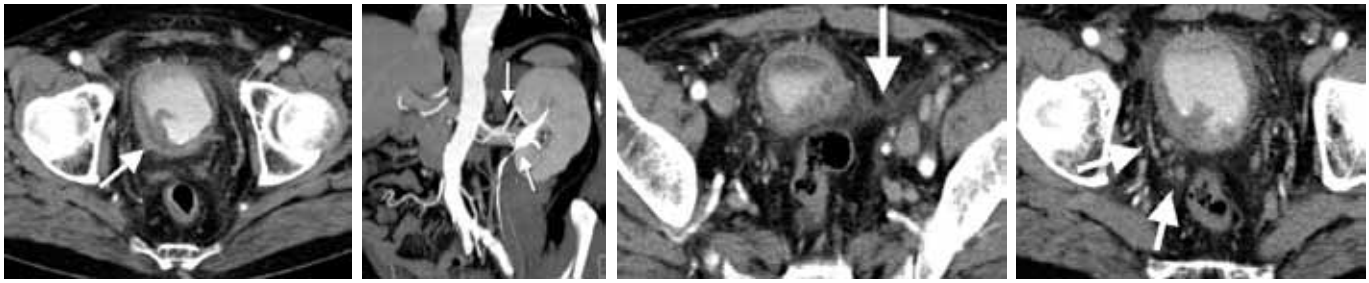
When there is a history of haematuria, it is imperative to not only look for pathology in the kidneys, but also to carefully evaluate the ureters and the bladder. Below are three cases of bladder cancer that highlight different facts (Fig. 4).

A second case of bladder carcinoma is shown below (Fig. 5).

A third case of bladder carcinoma is shown below (Fig. 6).

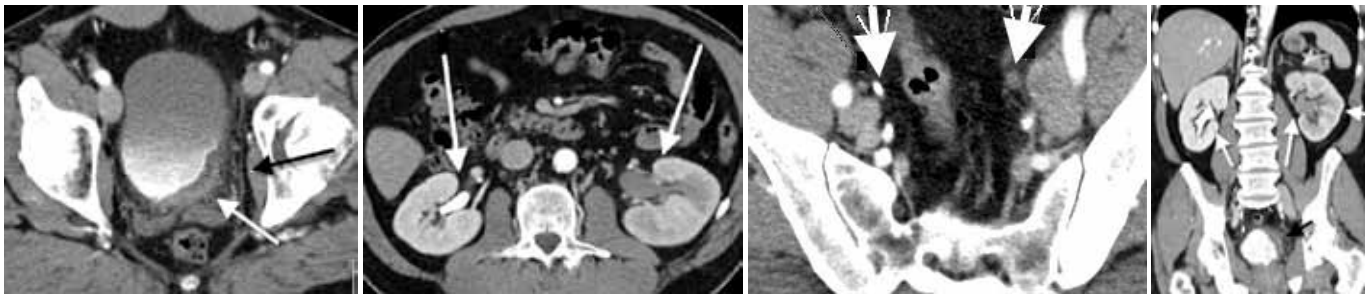
These three cases of bladder carcinoma highlight different points about the bladder and ureters:

- Although the concentration of contrast in the bladder is not dense and there is often layering of contrast (despite rolling the patient),



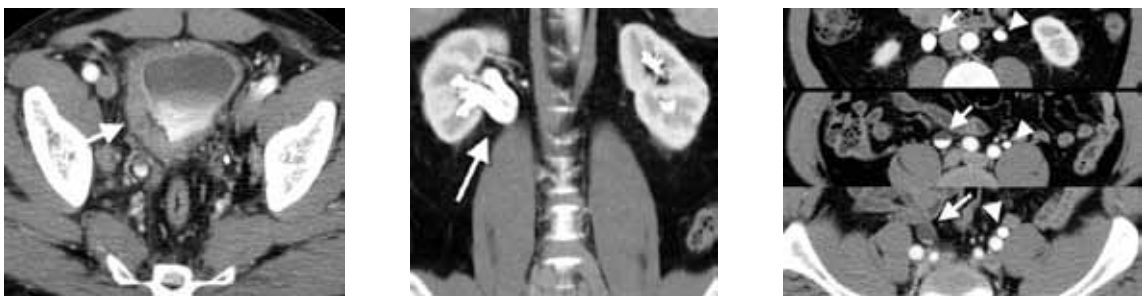
4a. Bladder. 4b. Single kidney. 4c. Perivesical infiltration. 4d. Perivesical lymphadenopathy.

Fig. 4. There is a carcinoma mass arising from the bladder wall, protruding into the bladder lumen, outlined by the contrast (4a). Perivesical fat infiltration (4c) and adjacent lymphadenopathy (4d) is demonstrated (white arrows). The patient had a unilateral kidney only, with good demonstration of renal anatomy with relevant vessels and collecting system (4b).



5a. Bladder. 5b. Kidneys. 5c. Ureters. 5d. Coronal MPR.

Fig. 5. Bladder carcinoma in left posterior wall of bladder (5a), causing obstruction and hydronephrosis of left kidney (5b and 5d) and left hydro-ureter (5c) with no contrast concentrating in the left collecting system and ureter.



6a. Bladder 6b. Coronal MPR of kidneys. 6c.Ureters at varying levels.

Fig. 6. Bladder carcinoma arising from posterior right bladder wall (6a) causing partial obstruction and dilatation of right collecting system and ureter (6b and 6c). Fig. 6c shows contrast-filled dilated proximal ureters bilaterally, with layering of contrast and urine in dilated, more distal right ureter and no contrast in the dilated right lower ureter.

there is no compromise in identifying the bladder wall mass. In fact, it is probably preferable for contrast not to be less dense than normally seen on the classical 4-phase scans, so not obscuring polypoid masses protruding into the lumen.

- Measurement of enhancement of the bladder mass comparing pre- and post-contrast studies was easy and consistent (examples not included here).
- Enhancement of all the vascular structures, ureters and bladder on one series made identification of lymph nodes and perivesical infiltration easier. One needed to follow contrast-filled tubular structures proximally to differentiate ureters from blood vessels; this was an easy and consistently reproducible task.
- Obstructive hydronephroses and hydro-ureters were also easily identified and the ureters followed to the site of obstruction by the mass.

Will ureteric masses and other pathology be missed?

Numerous instances of ureteric wall thickening associated with inflammatory and obstructive uropathies were demonstrated. It is assumed that ureteric and pyelocalyceal masses will also be easily identified.

What about other renal masses?

Interestingly, the above scan was made using the same technique, but on a single-slice entry-level CT scanner, acquired in 1998 and still in service. This scanner has a limited heat capacity, and scan series have to be spaced to allow tube cooling, with a limited scan time of 40 sec per series. This proved to be the ideal technique to gain a comprehensive study with all contrast phases on 1 series, which demonstrated the robustness of the technique. This technique also allowed us to use a 5 mm-thick spiral cut on a single post-contrast scan – rather than the 8 mm-thick cuts necessary if both a corticomedullary and nephrographic series have to be run back to back (less cuts with less time required and less tube heating from each series). The resolution is thus significantly increased.

We modified the protocol for a single-slice scanner (see addendum at end).

What about renal cyst analysis?

Will the interpretation of subtle changes in renal cyst walls and lumens be compromised?

The calcification within the cyst, the cyst walls and density are clearly seen on both scan series (white arrows), and the contrast within a calyx is seen abutting the cyst margin (black arrowhead in Fig. 9b).

Small and large renal cysts were easily identified and analysed, and their relationship to contrast-filled vessels and pelvicalyceal structures all on one scan made the interpretation easier.

Is this useful in trauma of the urinary tract?

Provided that the patient is clinically stable and can be left in the department for the required time, I believe that this technique can be used. Below is a case of a subcapsular renal haematoma.

I believe that injury to vascular structures as well as the urinary organs will be identifiable. The purist may argue that a dedicated vascular series is required. It may be that this series might only be useful in the more chronic post-injury cases for follow-up, as was this case.

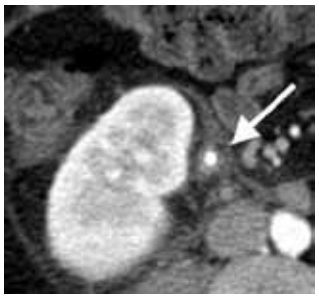


Fig 7. This is an image from the same case as Fig. 13 below – a calculus impacted in the distal right ureter. Note the proximal ureteric wall thickening clearly demonstrated around contrast in the lumen.

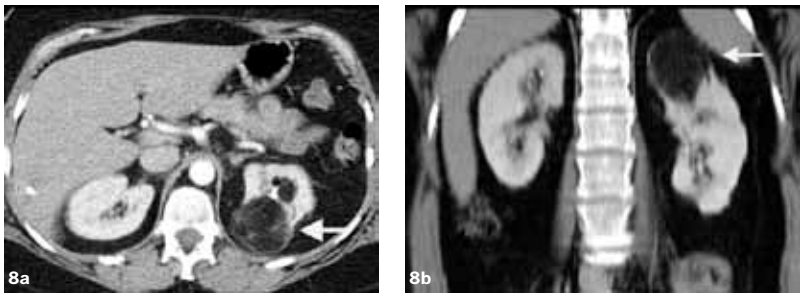


Fig. 8a. Axial post-contrast scan with (8b) coronal MPR showing inhomogenous, predominantly fatty renal mass in left kidney – a known angiomyolipoma for follow-up.

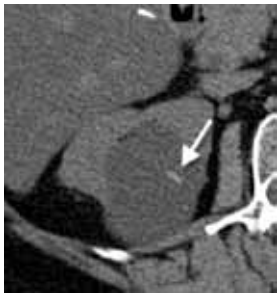


Fig. 9a. Pre-contrast.

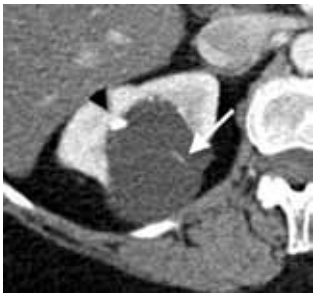


Fig. 9b. Post-contrast.

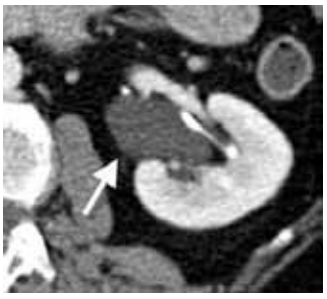


Fig. 10. Parapelvic renal simple cyst showing relationship to adjacent renal vein and adjacent contrast-filled calyx.

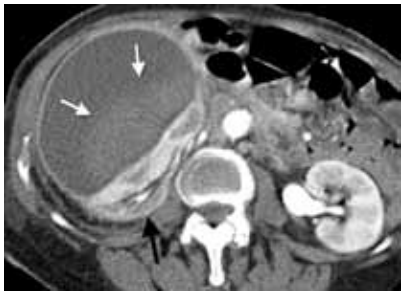


Fig. 11a. Post-contrast axial view.

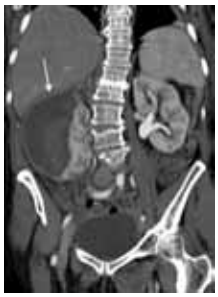


Fig. 11b. Coronal MPR.

Fig. 11. The large subcapsular haematoma is noted compressing and distorting the kidney. The subtle increased density of the retracting clot within the larger seromatous fluid collection can be differentiated; this was also noted on the precontrast series, with no change in density after contrast, confirming this was not contrast leakage.

What about renal calculi and more chronic mechanical obstructions?

The above two cases of a chronic calculus obstruction in a ureter and an acute obstruction are included to highlight the following points of the technique:

- highlights non-functioning hydronephrosis, with its cause: calculus in ureter
- highlights calculus in bladder – seen pre-contrast and not hidden by contrast
- shows calculus within contrast-filled ureter, causing a partial obstruction – need to change windows to view
- see ureteric jets into bladder, confirming obstruction on the right is only partial in Fig. 13.

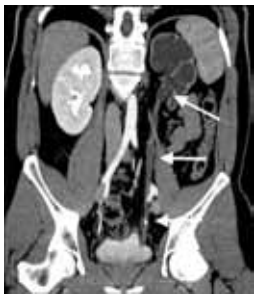


Fig. 12a. Coronal MPR of the urinary tract.

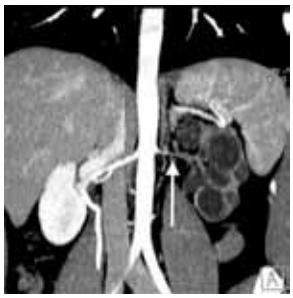


Fig. 12b. Coronal MIP of the renal arteries.

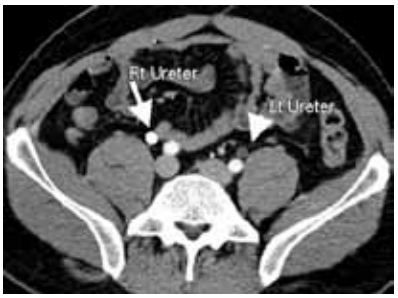


Fig. 12c. Axial view of the ureters.

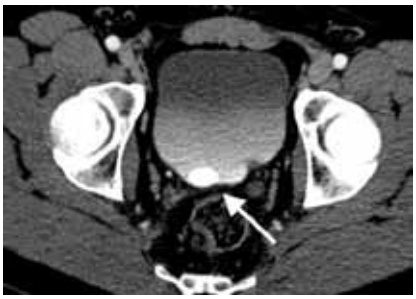


Fig. 12d. Axial view of the bladder.

Fig 12. shows a calculus impacted in the distal left ureter causing chronic obstruction a) with hydronephrotic non functioning left kidney and ureter. Atrophy of the left renal artery b). The non contrast filling of the left ureter (compared with the contrast filled right) is clearly shown on the axial view c). There is also a bladder calculus d) which was not obscured by the contrast (this was also seen on the precontrast series – image not included)

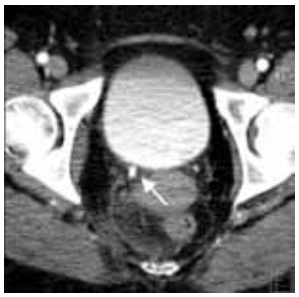
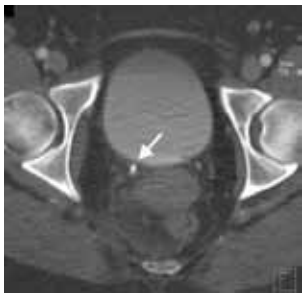
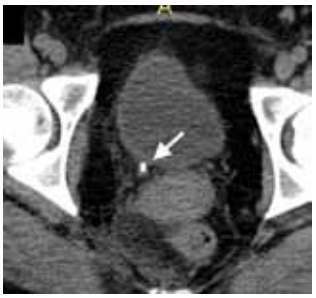


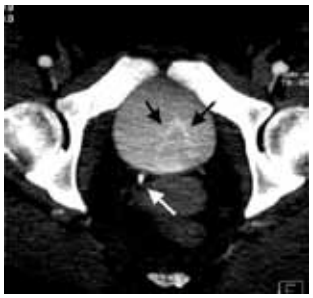
Fig. 13a. Axial post-contrast view.



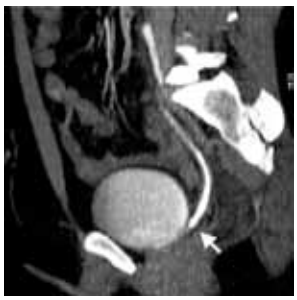
13b. Same as 13a, with wide windows.



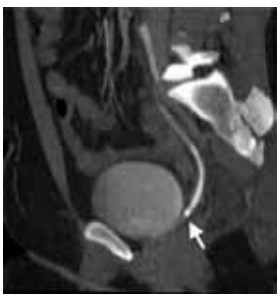
13c. Pre-contrast.



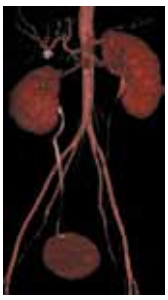
13d. Post-contrast.



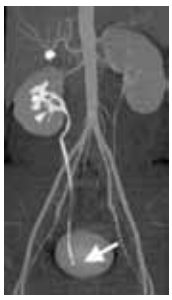
13e. Sagittal MPR of right ureter.



13f. Wide window.

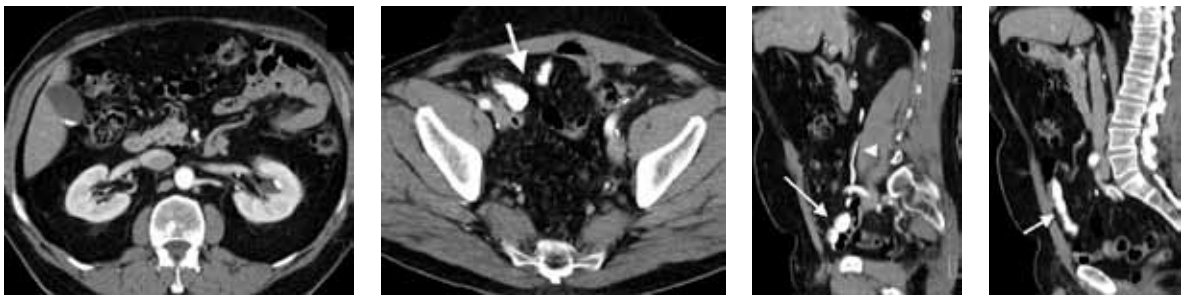


13g. Coronal MIP.



13h. Coronal 3D.

Fig. 13 shows a case of a small calculus impacted in the distal end of the right ureter, causing partial obstruction in the right ureter.



14a. Axial renal. *14b. Contrast in ileal bladder.* *14c. Sagittal MPR right ureter.* *14d. Sagittal view of bladder.*

Fig 14. Views of an ileal bladder (arrows in 14b, 14c and 14d), with the kidneys and right ureter (arrowhead in 14c).

Ileal bladder

This series shows the function kidneys, ureters and bladder.

This case was included to highlight the use of this scan technique in the unusual situation of assessing the urinary tract after diversion surgery.

Discussion

- In this radiologist's opinion, it was far easier and more efficient to read pathology of the urinary tract with all the relevant information on one series, without having to skip backwards and forwards between three post-contrast series to try to correlate findings, particularly with complex pathology situations.
- Referring clinicians are not usually as skilled as radiologists when viewing CT scans on work stations or their computers. This simplifies the number of series they have to view to gain all the information they require when reviewing the images.
- A range of urinary tract pathologies has been included to highlight the robustness and reliability of this technique. Very few delayed scans were required for better visualisation of the contrast-filled collecting systems and bladder; in my experience, this did not compromise the demonstration of any pathology. There were no cases where I regretted not performing the classic 4-phase series.
- Many of the cases did not get their pre-injection oral water load and, at some of the scanners, the injection pump could not be programmed for dual saline flushes after the two later contrast injections; this did not seem to compromise the quality of resulting images.
- The cases presented above were a fair representation of the quality of scans acquired. These cases were not 'hand-picked' because of quality – they were chosen purely for demonstration of pathology.
- There is a strong drive and emphasis by the radiological fraternity towards reducing radiation doses to patients. This technique effectively halves the radiation dose.
- There is a reduction of wear and tear on expensive CT scanners, by reducing scanning time.
- The number of images requiring either printing on film or taking up storage space on digital archives is halved.
- Medical insurers are reluctant to compensate for the full series of scans required for good diagnostic care in radiology. This technique allows one to gain all the information required within the 'limited fee' that the medical insurers insist on when dictating how many post-contrast series they feel is adequate. If patients foot the bill privately, it also helps to contain costs to them.
- This technique is not recommended for dedicated renal arterial angiography.
- Experience with renal carcinoma, hepatic metastases and pyelonephritis has not yet been gained; however, I am convinced that this technique will be as reliable in visualising the pathology as the classical 4-phase technique.
- There is debate as to whether small renal cell carcinoma masses may be missed, and this aspect may need further studies. However, I feel that meticulous variation in windowing the kidneys during viewing will prevent this potential problem; in fact, it may prove to be even more accurate – as I feel is the case with bladder masses.

Addendum

Single-slice scanner protocol

- 30 ml IV by hand
- 55 ml IV at 1.5 ml/sec (36 sec)
- 37 sec delay
- 70 ml IV at 2.5 ml/sec (28 sec)
- No saline pump to 'chase' the contrast is available at this facility.

The sum of the times during the active phase of the injection are as follows: 36+37+28 sec=101 sec. The scan is started at 90 sec from beginning the nephrographic contributing phase of injection. Therefore it starts 18 sec into the corticomedullary contributing phase of the injection, and a further 11 sec of contrast injection at the arm venous level follows the start of the scan (101 sec minus 90 sec=11sec).

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1. Kekelidze M, Dwarkasing RS, Dijkshoorn ML, Sikorska K, Verhagen PCMS, Krestin GP. Kidney and urinary tract imaging: Triple-bolus multidetector CT urography as a one-stop shop – Protocol design, opacification, and image quality analysis. Radiology 2010;255(2):508-516.