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ORIGINAL ARTICLE

Single-bolus Versus Split-bolus Protocol in Multidetector Computed Tomography Urography

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ABSTRACT

Objectives: *To compare the single-bolus protocol with the split-bolus protocol in multidetector computed tomography urography in terms of image quality (opacification), radiation dose, and scan time.*

Methods: *Consecutive patients who received the single-bolus protocol between February and May 2014 were compared with consecutive patients who received the split-bolus protocol between May and August 2014 for elective multidetector computed tomography urography in a regional hospital in Hong Kong. The dose-length product (DLP) and scan time were recorded. The degree of opacification of the urinary tract at the renal calyces, renal pelvis, upper ureter proximal to the iliac crest, and the distal ureter was assessed. The two protocols were compared in terms of the DLP, scan time, and degree of opacification of each urinary tract segment.*

Results: *105 patients aged 19 to 90 years who received the single-bolus protocol and 123 patients aged 22 to 89 years who received the split-bolus protocol were reviewed. Compared with the single-bolus protocol, the split-bolus protocol resulted in lower mean DLP (2610.4 vs. 2209.0 mGy·cm, 15.4% difference, $p < 0.0001$), lower estimated mean effective dose (39.2 vs. 33.1 mGy, 15.4% difference, $p < 0.0001$), and lower mean scan time (46.9 vs. 40.8 s, 12.9% difference, $p < 0.0001$). The two protocols were comparable in terms of the opacification rate at the calyces (100% vs. 98.7%, $p = 0.251$), renal pelvis (99.0% vs. 98.3%, $p = 0.689$), upper ureter (91.6% vs. 86.5%, $p = 0.088$), and lower ureter (83.7% vs. 85.6%, $p = 0.595$).*

Conclusion: *Compared with the single-bolus protocol, the split-bolus protocol resulted in significantly reduced radiation dose and scan time, with comparable image quality.*

Key Words: *Contrast media; Multidetector computed tomography; Urography; Urologic diseases*

中文摘要

比較多檢測電腦斷層掃描尿路造影的單次與分次推注方案

黎爾德、賴銘曦、錢凱、馮啓邦、岑承輝、簡偉權、邱麗珊

目的：比較多檢測電腦斷層掃描尿路造影的單次與分次推注方案對於圖像質量（不透明度）、輻射劑量和掃描時間的影響。

方法：比較在香港一所分區醫院於2014年2月至5月間接受單次推注方案的患者與於2014年5月至8月

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This study has been presented at the 5th Asian Congress of Abdominal Radiology.

間接受分次推注方案的患者的劑量長度產品（DLP）、掃描時間和尿道的不透明度。

結果：回顧105例19至90歲接受單次推注方案的患者及123例22至89歲接受分次推注方案的患者。與單次推注方案相比，分次推注方案導致較低平均DLP（2610.4對2209.0 mGy·cm，15.4%差異，p < 0.0001）、較低估計平均有效劑量（39.2對33.1 mGy，15.4%差異，p < 0.0001）及較低平均掃描時間（46.9對40.8秒，12.9%差異，p < 0.0001）。兩個方案的尿道的不透明度相等，包括腎盞（100%對98.7%，p = 0.251）、腎盂（99.0%對98.3%，p = 0.689）、上輸尿管（91.6%對86.5%，p = 0.088）和下輸尿管（83.7%對85.6%，p = 0.595）。

結論：與單次推注方案相比，分次推注方案的輻射劑量和掃描時間顯著降低，並具相等圖像質量。

INTRODUCTION

The radiation dose of a traditional single-bolus, multiphase contrast-enhanced computed tomography (CT) urography is relatively high due to the high number of phases and images acquired. Split-bolus CT urography yields synchronous nephrographic- and excretory-phase enhancement, resulting in one fewer phase of image acquisition and thus reduced radiation dose and scan time (Figure 1).

Urinary-tract opacification affects image quality and lesion detection. Small lesions are easily missed when the urinary tract is suboptimally opacified. The split-bolus protocol may decrease urinary-tract opacification, because only a fraction of the total injected contrast volume contributes to the excreted contrast, and due to a shortened delayed-phase scan time. Nonetheless, the split-bolus protocol has advantages of reduced radiation dose, scan time, and the number of images acquired and stored.

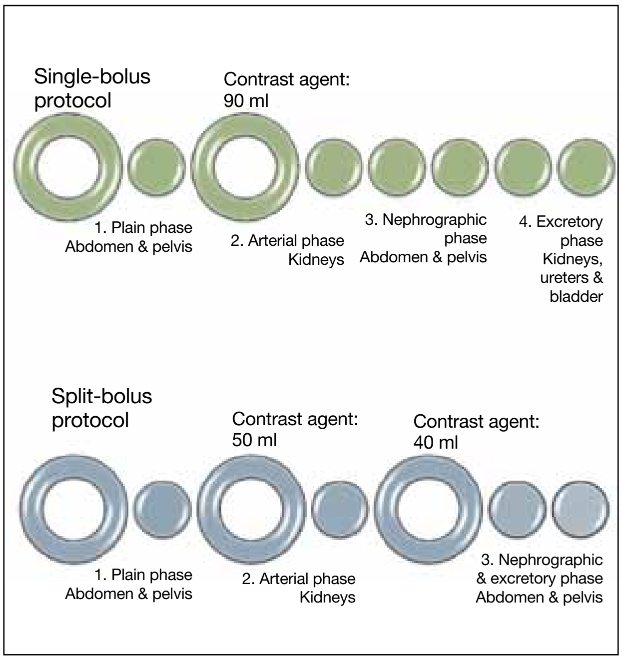

Figure 1. Comparison of single-bolus protocol and split-bolus protocol.

This study compared the single-bolus protocol with the split-bolus protocol in terms of image quality (urinary tract opacification), radiation dose, and scan time.

METHODS

The research protocol was conducted in compliance with Declaration of Helsinki. Consecutive patients who received the single-bolus protocol between February 2014 and May 2014 were compared with consecutive patients who received the split-bolus protocol between May 2014 and August 2014 for elective multidetector CT urography (Toshiba Aquilion 64, 1-mm thickness, 120 kV, and auto-mA) at the Pamela Youde Nethersole Eastern Hospital. Patients who had an extra region of interest (such as the thorax) scanned were excluded. Patients with additional excretory-phase scans were included in order to reflect the actual radiation dose and scan time required for a satisfactory examination.

The intravenous contrast agent used was Omnipaque 350 mg/ml. In the single-bolus protocol, 90 ml of contrast agent was injected and arterial-phase images were acquired immediately. Nephrographic-phase images were acquired after a 75-second delay, followed by excretory-phase images after a 7-minute delay (Figure 2). In the split-bolus protocol, 50 ml of contrast agent was injected, and arterial-phase images were acquired immediately. After 3 minutes and 40 seconds, a second 40 ml of contrast agent was injected. Following a 5-minute delay after the first injection, combined nephrographic- and excretory-phase images were acquired.

The dose-length product (DLP) and scan time were recorded. The effective dose was estimated using a conversion factor of 0.015 mSv/(mGy·cm).[1] The degree of opacification of the urinary tract at the renal calyces, renal pelvis, upper ureter proximal to the iliac crest, and the distal ureter was assessed.[2] The two protocols were compared in terms of the DLP, scan time, and degree of opacification at each urinary tract segment, using the Mann-Whitney *U* test, Chi-square test, or Fisher's exact test. A p value of <0.05 was considered statistically significant.

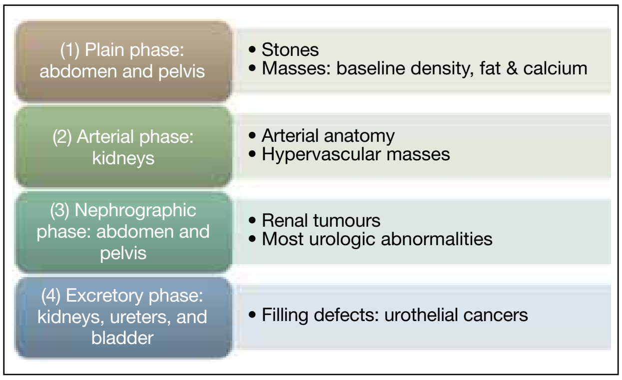

Figure 2. The four phases of the traditional single-bolus protocol.

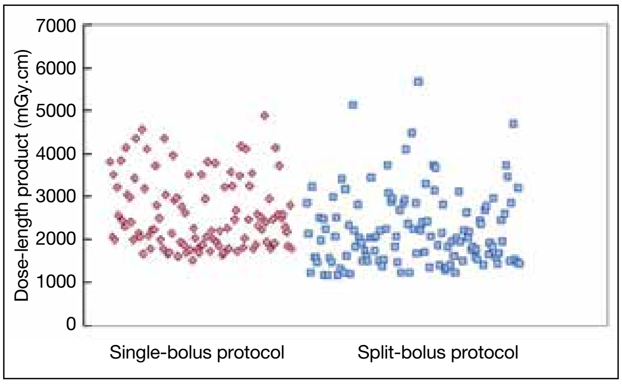

Figure 3. Scatter plot of dose-length product for the single-bolus and split-bolus protocols.

RESULTS

105 patients aged 19 to 90 years who received the single-bolus protocol and 123 patients aged 22 to 89 years who received the split-bolus protocol were reviewed. Compared with the single-bolus protocol, the split-bolus protocol resulted in lower mean DLP (2610.4 vs. 2209.0 mGy·cm, 15.4% difference, $p < 0.0001$, Figure 3), lower estimated mean effective dose (39.2 vs. 33.1 mGy, 15.4% difference, $p < 0.0001$), and lower mean scan time (46.9 vs. 40.8 s, 12.9% difference, $p < 0.0001$). The two protocols were comparable in terms of the opacification rate at the calyces (100% vs. 98.7%, $p = 0.251$), renal pelvis (99.0% vs. 98.3%, $p = 0.689$), upper ureter (91.6% vs. 86.5%, $p = 0.088$), and lower ureter (83.7% vs. 85.6%, $p = 0.595$).

DISCUSSION

Contrast-enhanced CT urography is the investigation of choice for haematuria,[3,4] compared with intravenous urography, retrograde ureterography and pyelography, and ultrasonography. Ureteroscopy can be reserved for patients requiring cytopathological examination or stenting procedures.

Of the 11 most common types of diagnostic CT, multiphasic CT abdomen and pelvis results in the highest effective dose, owing to the high number of phases and images acquired, and the intra-abdominal or intrapelvic location of sensitive organs.[5] Radiologists may prescribe additional excretory-phase images to

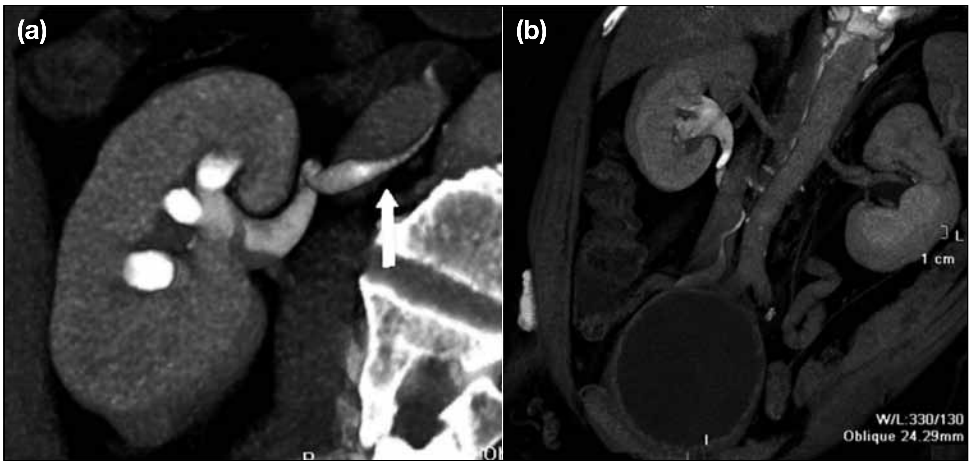

Figure 4. Multidetector computed tomography urography using the split-bolus protocol showing a three-dimensional relationship of the retrocaval ureter (arrow) with the adjacent inferior vena cava on (a) oblique axial and (b) coronal volume-rendered images acquired during the combined nephrographic and excretory phase.

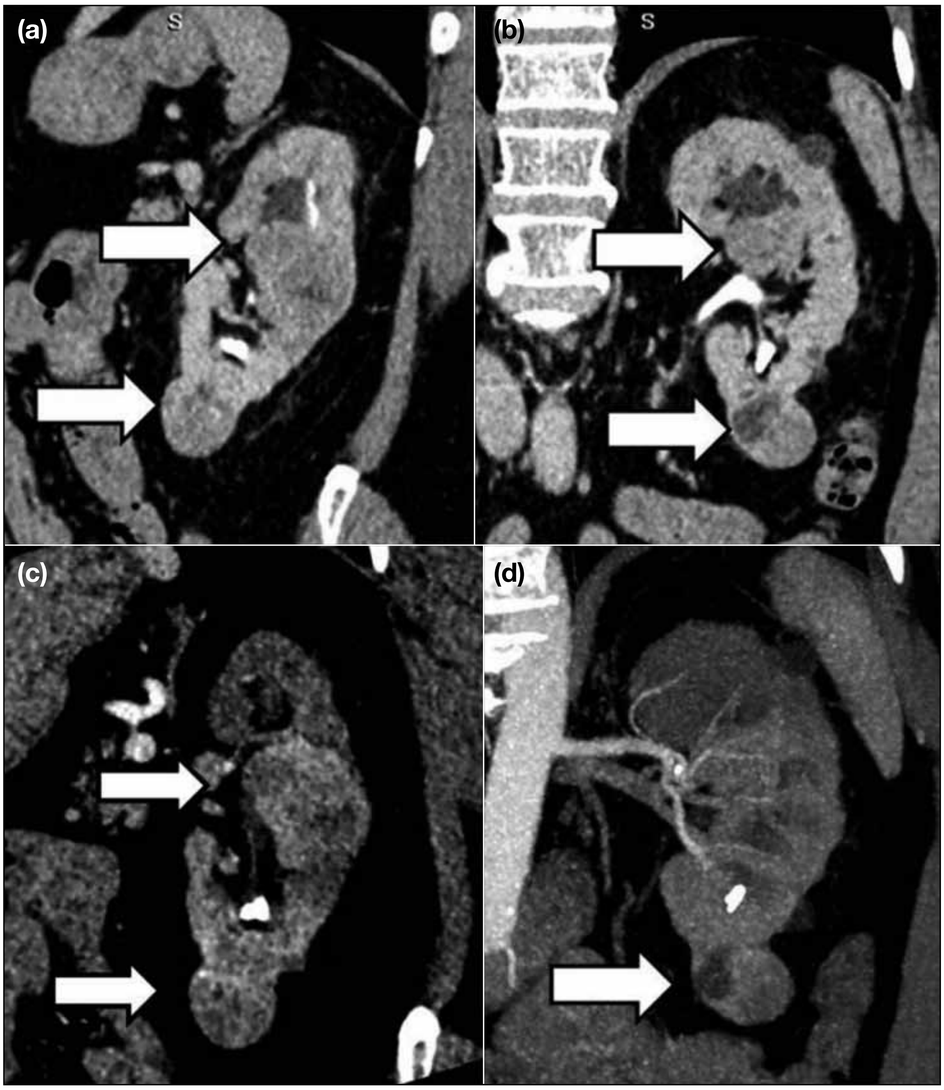

Figure 5. Multidetector computed tomography urography using the split-bolus protocol showing multifocal heterogeneous enhancing tumours (arrows) in the left kidney on (a) sagittal and (b) coronal images acquired during the combined nephrographic and excretory phase. In the arterial phase, (c) lesions are enhanced (arrows) and highly suspicious of multifocal renal cell carcinomas, and (d) maximal intensity projection image showing the arterial anatomy for preoperative planning, with the lesion enhanced (arrow).

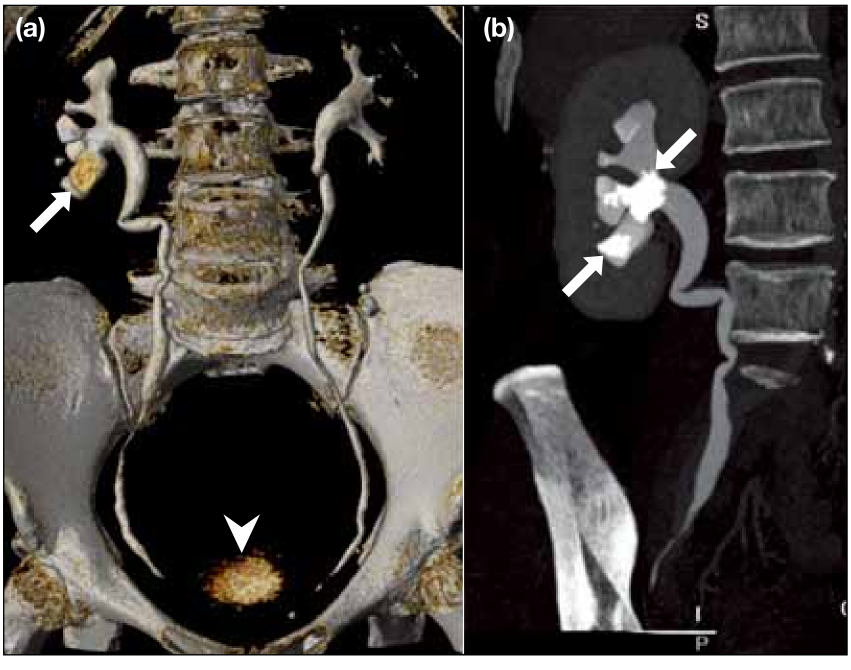

Figure 6. Multidetector computed tomography urography using the split-bolus protocol with (a) coronal volume-rendered and (b) oblique coronal maximum intensity projection images acquired during the combined nephrographic and excretory phase showing staghorn stones in the right renal pelvis and calyces (arrows). Opacification of bilateral upper urinary tracts with small amount of contrast filling the urinary bladder is seen (arrowhead).

reveal more opacified urinary tract segments; this results in more radiation exposure. CT urography using the split-bolus protocol achieves comparable image quality with reduced radiation exposure and scan time.[6] It is useful for evaluation of urinary tract calculi, renal abnormalities, and urothelial lesions (Figures 4 to 6),

Optimum urinary tract opacification is necessary for accurate detection of upper tract urothelial cancer. In the split-bolus protocol, over 85% of our patients achieved over 50% opacification, comparable to that in the single-bolus protocol. The lower ureter was the least well-opacified segment, owing to its smaller calibre.[7,8] Techniques to increase opacification include abdominal compression, scanning in the prone position, and administration of diuretics.[9] Oral or intravenous hydration may prevent contrast-related nephropathy.[9]

CONCLUSION

Compared with the single-bolus protocol, the split-bolus protocol resulted in significantly reduced radiation dose and scan time, with comparable image quality.

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