Original Investigation

Dynamic CTA in Native Kidneys Using a Multiphase CT Protocol—Potential of Significant Reduction of Contrast Medium

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Rationale and Objective: The objective of this study was to assess an optimized renal multiphase computed tomography angiography (MP-CTA) protocol regarding reduction of contrast volume.

Materials and Methods: Thirty patients underwent MP-CTA (12 phases, every 3.5 seconds, 80 kV/120 mAs) using 30 mL of contrast medium. The quality of MP-CTA was assessed quantitatively measuring vessel attenuation, image noise, and contrast-to-noise ratio. MP-CTA was evaluated qualitatively regarding depiction of vessels, cortex differentiation, and motion artifacts (grades 1–4, 1 = best). Mean effective radiation dose was registered. Results were compared to standard renal computed tomography angiography (CTA) (80 mL). Student *t* test was applied, if variables followed normal distribution. For other variables, nonparametric Mann-Whitney *U* test was used.

Results: All acquisitions were successfully performed, and no patient had to be excluded from the study. MP-CTA enabled high attenuation (aorta: 503 ± 91 HU, renal arteries: 450 ± 73 HU/456 ± 72 HU) at adequate image noise (13.7 ± 1.5) and good contrast-to-noise ratio (34.2 ± 10.2). Good attenuation of renal veins was observed (286 ± 43 HU/282 ± 42 HU). Arterial enhancement was significantly higher compared to renal CTA (aorta: 396 ± 90 HU, renal arteries: 331 ± 74 HU/333 ± 80 HU; $P < .001$). MP-CTA protocol enabled good image quality of renal arteries (1.5 ± 0.6) and veins (1.7 ± 0.6). Cortex differentiation and motion artifacts were ranked 1.8 ± 0.8 and 1.6 ± 0.8. The mean effective radiation dose was 9 mSv (MP-CTA).

Conclusions: Compared to standard renal CTA, the renal MP-CTA enabled the significant reduction of contrast volume and simultaneously provided a significantly higher arterial attenuation.

Key Words: Renal CTA; Multiphase CTA; Reduction of contrast volume; Contrast induced nephropathy; CT perfusion.

INTRODUCTION

One of the main indications for renal computed tomography angiography (CTA) is the assessment of secondary hypertension, because a common cause of renovascular hypertension is renal artery stenosis (RAS). RAS is defined as a narrowing of the renal artery or of their branches and most often is caused by atherosclerosis (90%) (1). Usually, the plaque formation is located within 1 cm to the ostium and often begins in the aortic wall with progression into the renal artery lumen (2). Less frequently, RAS is related to fibromuscular dysplasia, which is a vascular disease of medium-sized arteries and most commonly affects renal arteries (1). During the clinical course, typical signs of renal, rather than essential, hypertension include an acute increase in hypertension, severe hypertension, or a refractory hypertension (1). Moreover, age, female gender, reduced renal function, increased systolic blood pressure, and peripheral arterial disease are associated with RAS (3). In a patient collective with the findings mentioned previously, a noninvasive screening is indicated. CTA represents a highly reliable technique for detection of RAS that can be used as a screening test and for interventional treatment planning like percutaneous transluminal angioplasty (4,5). Because of its advantages, such as noninvasiveness and high spatial resolution, CTA has also demonstrated strength in the evaluation of other vascular complications such as renal artery embolisms, renal arterial aneurysms, and renal arterial dissections (4,6). Regarding the assessment of living renal transplant donors, CTA enables a highly accurate evaluation of the vascular anatomy (7). Although CTA

Acad Radiol 2018; ■:■■–■■

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https://doi.org/10.1016/j.acra.2017.11.012

is a reliable and noninvasive diagnostic tool, application of contrast medium is necessary and, with respect to contrast-induced acute kidney injury (CI-AKI), can be problematic in case of renal impairment (8). The incidence of CI-AKI varies, depending on the definition of CI-AKI and contrast agents used, and is associated with significantly higher morbidity and mortality, as well as an increased length of hospital stay and costs (9). Most patients sent for evaluation of renal disease have impaired renal function and also have, on average, become older and therefore have increased risk factors for CI-AKI. Thus, the constant risk of CI-AKI represents a significant problem in contemporary medical care and especially in radiological diagnostics of the kidneys. However, CI-AKI is dose dependent and can be reduced by decreasing the volume of contrast medium applied (10,11). Therefore, a CTA protocol that allows for substantial dose reduction would be desirable. The aim of the present study was to compare a new renal multiphase computed tomography angiography (MP-CTA) protocol with significantly reduced contrast volume with a standard renal CTA protocol.

MATERIALS AND METHODS

The present study was designed as a nonrandomized, retrospective, clinical cohort study. The study was authorized by the local ethics committee and all patients provided written informed consent. The control group consisted of subjects from the clinical database that underwent a standard renal CTA protocol. To guarantee comparability, the gender ratio of the control group was the same as in the study group. Furhtermore, the cutoffs regarding age, weight, and body mass index (BMI) were set below the maximum values of the study group.

Computed Tomography (CT) Data Acquisition and Reconstruction

Regarding the acquisition of the multiphase CTA protocol, we basically followed previously published methods (12). The study group was investigated using a renal MPCTA protocol consisting of 12 sequential scans. The patients were examined using either a dual-source multidetector computed tomography (MDCT) scanner or a 128-slice MDCT system (Somatom Definition Flash and Somatom Definition AS+, respectively; Siemens Healthcare, Erlangen, Germany). The scans were acquired with an "adaptive four-dimensional (4D) spiral mode" that allows continuous periodic helical imaging. This mode works with smooth acceleration and deceleration of the table (shuttling the table back and forth), without abrupt starts and stops, to reduce motion artifacts. For the same reason, the patients were instructed to breathe shallowly. The scan range was 18 cm, which were scanned in 1.75 seconds. The radiation was activated only during the craniocaudal movement, resulting in a temporal resolution of 3.5 seconds per phase and a total acquisition time of nearly 40 seconds.

For all subjects, a tube voltage of 80 kV and a tube current-time product of 120 mAs were applied. The total injected amount of high-concentration contrast medium was 30 mL (400 mg iodine/mL, Imeron400; Bracco Imaging GmbH, Konstanz, Germany). The contrast medium was administered using a dual-head CT pressure injector (Medrad; Medizinische Systeme GmbH, Volkach, Germany) via an 18-gauge cannula placed in a cubital vein with flow rate of 5 mL/s. Subsequently, 100 mL sodium chloride solution (B. Braun Melsungen AG, Melsungen, Germany) followed by a flow rate of 3 mL/s. The delay between injection and the first scan was 4 seconds. Acquisitions were performed using a collimation of 128×0.6 mm, and the raw data were reconstructed to 3-mm sections (increment of 1.5 mm).

The data of the standard CTA were acquired during clinical routine and followed the common procedure at our institution (13). The control group was examined either with a second-generation dual-source MDCT scanner (Somatom Definition Flash, Siemens Healthcare), a 64-multislice CT scanner (Somatom Sensation64, Siemens Healthcare), or a 128-slice MDCT system (Somatom Definition AS+, Siemens Healthcare). All acquisitions were generated with a tube voltage of 120 kV. All systems provided automated exposure control. This enabled an automated tube current-time product adjustment (Care-Dose-4D, Siemens Healthcare, Erlangen, Germany) based on the scout topogram. Reference values for tube current-time product were adjustable and set to 160, 180, 200, or 220 mAs, depending on patients' anatomy.

A contrast volume of 80 mL (400 mg iodine/mL, Imeron400; Bracco Imaging GmbH) was injected using a dual-head CT pressure injector (Medrad, Medizinische Systeme GmbH) at a flow rate of 4 mL/s, followed by 100 mL of sodium chloride chaser (B. Braun Melsungen AG) at the same rate. Injections were applied through a central venous catheter or through a peripheral intravenous cannula with a minimum size of 20 gauge. Scan timing was optimized using bolus-tracking technique.

The scans were achieved with slice collimation of $2 \times 64 \times 0.6$ mm for dual-source CT and with 64×0.6 mm for multislice CT. Reconstructions with a slice thickness of 3.0 mm and a reconstruction increment of 1.5 mm were generated.

Image Analysis

Regarding the evaluation of the MP-CTA, we followed previously published methods (12). For postprocessing and analysis, a particular workstation running 3D-software (MMWP, Siemens Healthcare), which displays the dynamic phases either in cine mode or independently, phase-by-phase was used. For postprocessing and analysis, a workstation with a dedicated 3D-software (MMWP, Siemens Healthcare) was used. This workstation allowed to display the dynamic phases either in cine mode or independently, phase-by-phase. For density measurements, three size adapted regions of interest (ROIs) were placed manually in the aorta at the outlet of the superior mesenteric artery and in the proximal third of each renal artery, and mean values were calculated. The size of the ROIs located