Review Article

NONINVASIVE 3-DIMENSIONAL ELECTRON BEAM COMPUTED TOMOGRAPHY ANGIOGRAPHY

RENAL ARTERIES

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ABSTRACT

Three dimensional electron beam computed tomography (EBCT) angiography is a useful technique for the depiction of renal artery lesions and for vascular variants. Generic advantages of ultrafast tomography and thin slice imaging, are registered volume data set with overlapping reconstructions to reduce partial volume effect and effective contrast medium utilization. Ultrafast EBCT with its axial images and several three dimensional techniques, is easy to apply, functional and accurate for renal vascular anatomy and renal artery stenosis (RAS) and useful for detection of extension of the trauma and intravascular tumor in partial nephrectomy.

Key Words: EBCT, Three dimension, Angiography, UPJ (ureteropelvic junction) stenoses, Trauma.

INTRODUCTION

In the mid 1970s, a number of investigators began studying the possibility of developing a CT scanner in which mechanical motion during the data acquisition was eliminated, thereby permitting CT images to be obtained in time frames comparable to those in plain film radiography (i.e., sub-second imaging). The requirement to move the x-ray source around the patient has been a limitation in CT imaging because of the time it takes to physically move a heavy x-ray tube through such a distance, and scan time remains a significant limitation in CT. Moving objects and flow in a vessel can degrade the image quality. The use of scanning electron beam technology to move the point of x-ray origination around the body while intense electron beam sweeps along a curved tungsten target that surrounds the patient explores this problem (1).

The design goals for ultrafast CT were to develop a machine having a scan time sufficiently short to freeze cardiac motion while at the same time achieving competitive spatial resolution. To achieve short scan times, not only must mechanical movement of the source be eliminated, but also movement of the detectors. Consequently, EBT (GE-Imatron, C 150 ultrafast

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CT scanner) uses a fixed detector array. Detectors and x-ray target rings are put in different planes for eliminating overlapping. EBT has four target rings and to further increase its multilevel scanning capability, two parallel detector rings (1-4). The radiation dose to the patient and image blurring are much lower with EBT than conventional and multi detector CT because of the short scanning time (50 msec/per image versus 250 msec with multislice CT and longer with conventional CTs) (1, 5). EBT generally operates with a tube current of about 630 mA and 130 kV.

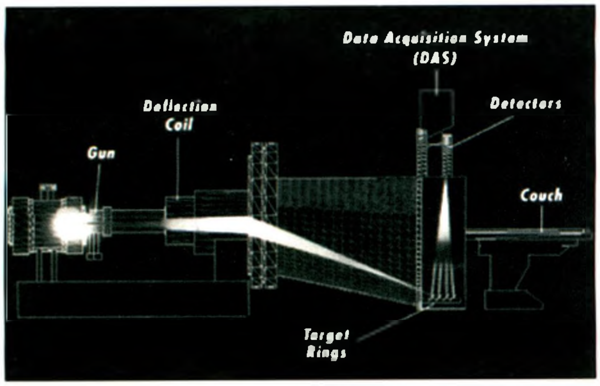

Fig.1: EBT configuration. The electron beam originates at the gun and is accelerated towards the target end, expanding radially due to space charge repulsion of the electrons within the beam. It passes through an electromagnetic coil and is focused to a small spot on a target ring and through an electromagnetic deflection coil that steers it along any one of the target rings. The total path length of the electron beam between the gun and a target is about 3 meters.

METHODS OF EBT RENAL ANGIOGRAPHY

Detailed knowledge of the renal anatomy and variants of the renal arteries is very important. Normal results from computerized tomography angiography virtually rule out renal artery stenosis (6). Different 3-D techniques help to demonstrate vascular anatomy, vascular calcifications, and surrounding tissues with CT examinations (6-17). Overlapping vessels can be evaluated easily (6). Vascular relationships are maintained and calcifications are displayed as distinct from vascular enhancement (18,19). Vessels can be viewed from any orientation.

Typically, arterial branches can be identified at least at the segmental level. The sensitivity of 3-D CTA for the demonstration and location of main renal arteries, when using accurate techniques, approaches 100% (8,9).

It is essential to review the axial images for all necessary information before 3D applications (NIT Insight diagnostic workstation, City of Industry, CA) are performed. This helps to avoid errors because small vessels are easily overlooked on the 3D image if they are not first identified on the axial images (15).

First unenhanced CT is performed to identify calcifications, renal calculi, or demonstrate any fat if there is in a lesion. After noncontrast study, the dynamic phase is performed. 1.5 mm.slice thickness, 20 mL bolus injection is administered at a rate of 3 mL/sec. 12 to 16 second delay prior to the acquisition of the first image. Time to maximum aortic enhancement is calculated (time density analysis=TDA). Next 80 to 100 cc. contrast material is injected at a rate of 3 mL sec. for renal arterial anatomy. Scan time is 17-20 seconds and patients suspend their breath during the examination.

For detection of renal lesions, the most sensitive phase is the parenchymal phase which is initiated approximately 160 seconds after contrast material injection. Oral contrast material is not administered because it usually interferes with 3D techniques.

3D CTA examinations are highly accurate and replacing conventional preoperative angiography in many institutions (19-23).

Renal artery stenosis is only one of the causes of hypertension in patients with renovascular hypertension, but its identification is important because it represents a potentially reversible cause of hypertension and there is a corrective interventional treatment in place of life long medical therapy. CTA provides direct visualization of the vasculature during the arterial phase of contrast material infusion. There is a clear advantage of CTA over conventional angiography for the characterization of eccentric stenosis and vascular calcifications (6).

Accessory renal arteries constitute the most common clinically important renal vascular variant and are seen in up to one-third of patients. There could be multiple renal arteries up to 30% unilaterally and 10% bilaterally (24,25). Accessory arteries usually arise from the aorta or iliac arteries anywhere from the level of T 11 to the level of L4.

Spring et al showed 3D CT angiography to be 100% sensitive in the identification of accessory renal arteries (26).

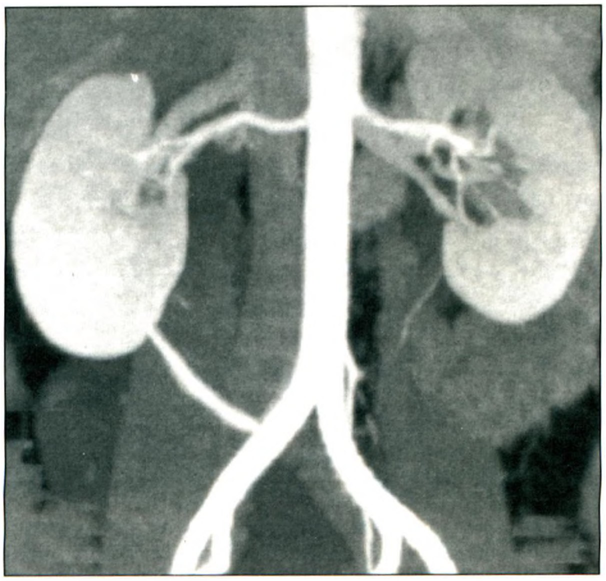

Fig.2: Bilateral normal renal arteries and aberrant renal artery originate from the right iliac artery, feeding the right renal lower lobe.

Renal arteries are categorized as normal; with mild (1%-49%), moderate (50%-69%), or severe (70%-99%) stenosis; or occluded (6). Renal artery stenosis is usually caused by atherosclerosis (27). The stenosis typically occurs in men over 50 year old and results from atherosclerotic plaque and calcification located at the proximal renal artery near the orifice. The disease is bilateral in approximately 30% of the patients (28).

Renovascular hypertension affects 15-30% of the patients who have clinical criteria suggestive of renovascular disease. Noninvasive screening is crucial for patient selection prior to conventional angiography and renal revascularization. Renal scintigraphy has been reported to be sensitive for detection of renovascular hypertension, but some of its limitations in the setting of bilateral renal artery stenosis should be considered. Doppler Ultrasonography allows direct evaluation of the renal arteries as well as transrenal doppler waveform analysis, but it remains operator dependent. Gadolinium enhanced magnetic resonance angiography is also an alternative to conventional angiography. The main limiting factors of this technique are inadequate visualization of segmental and accessory renal arteries as well as a tendency toward overestimation of stenoses (29).

The term renovascular hypertension (RVH) pertains to the causal relationship between a RAS and its clinical consequences, namely, hypertension or renal failure. Among the population of hypertensive patients, approximately 1%-5% have true RVH. (30).

Fibromuscular dysplasia is the second most common cause of renal artery stenosis and accounts for a significant number of patients with renovascular hypertension (31). The majority of these patients are young or middle aged women (32). Lesions typically develop in the distal renal artery and are bilateral in two-thirds of the patients .

CTA is also valuable in assessing abdominal aortic aneurysm, and can accurately depict the extent and location of the aortic abnormality as it relates to the renal arteries.

EBCT with its 3D techniques is a noninvasive test to delineate renal tumors and renal anatomy prior to nephron-sparing surgery because it is known to conserve normal renal parenchyma adjacent to the tumor. It provides all the information required for preoperative and intraoperative planning in nephron-sparing surgery in a single test (19,20,23). Depiction of the relationship of the tumor to adjacent calyces allows the surgeon to anticipate extension into the collecting system and minimizes postoperative complications such as urinary fistula or urinoma. Renal artery stenosis, aneurysms, dissection, venous disorders, thrombosis, intravascular tumor extension can all be evaluated. Renal position, tumor location and depth of tumor extension in to the kidney, relationship of the tumor to the collecting system are easy and accurate to demonstrate (33-36).

CTA demonstrates not only the renal vascular anatomy but also the secondary parenchymal changes, including infarcts and atrophy (33). Renal hematoma, laceration and infarction may result from blunt injury. Infarction may be partial or global and secondary to either thrombosis or avulsion accompanied by central retroperitoneal hematoma. Lacerations may produce peripheral vessel disruption and pelvic calyceal laceration. In cases of suspected renal injuries the CT scan should be performed as a three phase study, an initial non-contrast study to detect intraparenchymal hematoma that may be isoattenuating with normal renal parenchyma on the post contrast exam; a dynamic phase study to detect pelvicalyceal and ureteric disruptions with contrast leakage into the perirenal or pararenal spaces.

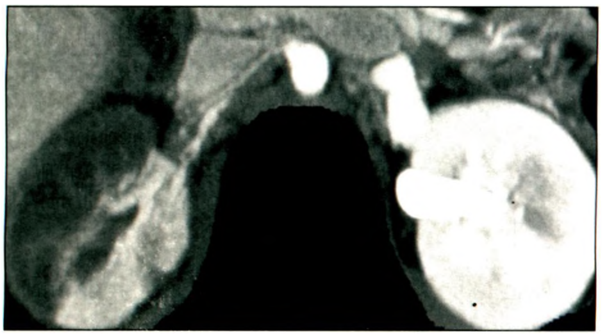

Fig.3: Trauma. Right renal infarct at the lateral part of the upper pole. There is no renal function.

Many vascular, parenchymal and urinary tract anomalies are discovered incidentally during CT studies. These include accessory renal arteries, aberrant renal artery origins, anomalies of renal veins, ptotic malrotated and horseshoe kidney, urinary tract duplication and ectopic ureteroceles. Vascular anomalies are evident on arterial or renal venous-imaging phase studies and urinary tract anomalies on both cross-sectional imaging and CT urography. When an aberrant renal artery causes ureteropelvic junction stenosis, it is easy to detect with ultrafast CT contrast enhanced study.

In summary, CT angiography is useful for many clinical applications, renal artery stenosis, renal artery disease related to aortic diseases, preoperative evaluation of renal donors, preoperative evaluation of renal anatomy before renal or urinary system surgery. CT angiography

Fig.4: A very well-known extrinsic cause of UPJ stenosis. Aberrant renal artery. Left renal accessory artery crosses the UPJ, causing stenosis. Large, dilated anechoic renal pelvis communicating with calices without dilated ureter.

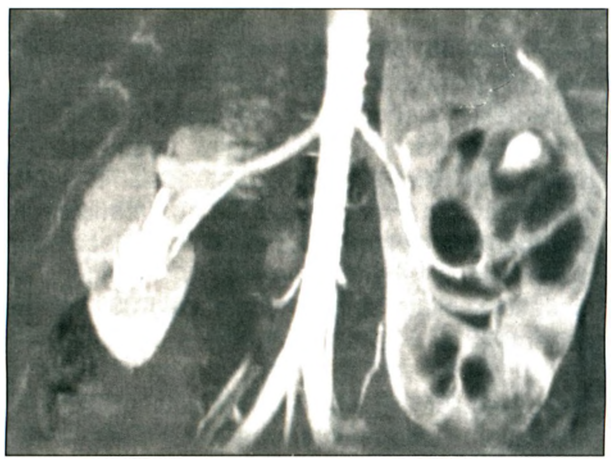

Fig.5: An example of an intrinsic cause of UPJ. In this case no aberrant renal artery detected.

provides an accurate assessment of the renal vasculature in a fast and efficient manner without the risks of more invasive conventional angiography. A diagnosis of renal artery stenosis is important since the condition represents a potentially reversible cause of hypertension (37). Advantages of EBT are the very low exposure time and low radiation dose to the patient. Three dimensional data sets of EBT CTA can be obtained with superior z-axis resolution, spatial resolution is lower than those of helical CT. The signal to noise ratio in EBT slices is reduced. Shorter scan time allows a higher contrast enhancement with lower contrast medium in the vessels of interest (17,38,39).

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