Multidetector CT Evaluation in Arterial Stenting

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Abstract

Background : Multidetector CT (MDCT) represents breakthrough in CT technology, significantly improving CT Angiography applications.

Methods : Twenty one patients with aortoiliac & branch aneurysms or stenosis were evaluated by Digital Subtraction Angiography (DSA) and Multidetector CT (MDCT) before and after endovascular repair.

Results : There were eight cases of aortic & branch aneurysms and 13 with stenosis. Four cases had aortic aneurysms, while one case had left subclavian artery aneurysm, thoracic aneurysm, femoral and popliteal artery pseudoaneurysms. Of the 13 cases with stenotic lesions, iliac stenosis was seen in eight patients. The others included carotid, vertebral, aortic, renal and aortic bifurcation stenotic. MDCT offered accurate information on shape and size of aneurysm, shape and patency of graft, the presence or absence of perigraft thrombosis or endoleaks, while in stenotic lesions it provided useful information on shape of graft, its location, its patency and the presence and quantity of distal flow.

Conclusion : MDCT was found to be a potentially useful modality during initial evaluation and follow up of patient undergoing endovascular repair.

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Key Words : Multidetector Computed Tomography; Endovascular stents; Arterial disease

Introduction

Arterial diseases comprise a spectrum of distinctive clinical entities ranging from aneurysms to occlusive disease that affect large and medium sized arteries. In this study, Multidetector Computed Tomography (MDCT), was used for evaluation of aneurysms or stenosis treated with stents. MDCT augments CT angiography by allowing multiphasic studies of vascular system due to faster scan times and optimal use of contrast, accurate delineation of narrow vessels due to the improved z-axis (in-plane) resolution, peripheral runoff angiography due to longer scan and volume coverage and significant reduction in scan time. It improves CT angiography applications further by enabling isotropic imaging (high resolution in any plane) and 3D volumetric analysis of arterial morphology in pre and post stent cases.

Material and Method

Twenty one patients with aortoiliac and branch aneurysms or stenosis were evaluated by Digital Subtraction Angiography (DSA) and Multidetector CT (MDCT) before and after endovascular repair between Feb 2003 and Jan 2005. For aortic aneurysms, the inclusion criteria included those measuring > 30 mm in diameter, infrarenal neck length > 15 mm and diameter < 25 mm, iliac artery angulation < 90°, common iliac artery < 12 mm in diameter and nonstenotic. The exclusion

criteria comprised of ruptured or symptomatic abdominal aortic aneurysms (AAA), juxta or suprarenal extension, occluded superior mesenteric artery or an open Rioloan arch necessitating retained patency of the inferior mesenteric artery, patient age < 21 years, connective tissue diseases and acute infection. Two patients with abdominal aortic aneurysm were excluded due to excessive angulation of the abdominal aorta. For aortoiliac occlusive disease the inclusion criteria were life style altering claudication (Rutherford Becker category 1-3), chronic critical lower limb ischemia (Rutherford Becker category 4-5), lesions in either an iliac and/or a femoral artery, and a lesion length of 1-6 cm. Two patients were excluded due to renal failure and severe sustained hypertension. The patient particulars and the stent devices used are displayed in Table 1.

Endovascular stentgraft technique was performed in a DSA suite using Polystar Top or at operation theatre, under digital fluoroscopy. Under fluoroscopy, the deployment of stent commenced by gradual, deliberate retraction of the graft covers using the deployment handle. The partially deployed stent graft was moved in millimetre increments until it was precisely positioned and the deployment completed. Thereafter, in select cases, touch up balloon dilatation of ends of graft was performed to prevent endoleaks. After removal of delivery sheaths, the femoral arteriotomies were repaired primarily. CT angiography (CTA) studies were performed using a multislice technique with a Somatom Sensation 4 Multidetector scanner (Siemens, Erlangen),

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Table 1**Patient data : Multidetector CT evaluation in arterial stenting**

Age	Sex	Type of lesions	Prinicipal symptom	Stent	Stent size
Aneurysm (n=8)					
34	F	Left subclavian artery aneurysm	Arm pain, cervical rib	Hemobahn	8 x 60 mm
48	M	Thoracic aortic aneurysm	Hypertension	Medtronic stent graft	38 x 120 mm
60	M	Abdominal aortic aneurysm	Hypertension	Excluder	23 x 160 mm 12 x 80 mm
50	M	Abdominal aortic aneurysm	Hypertension	Excluder stent graft prosthesis	23 x 140 mm 12 x 100 mm
45	M	Abdominal aortic aneurysm	Pain abdomen	Talent	26 x 40 mm 12 x 10 mm
45	M	Abdominal aortic aneurysm	Hypertension	Excluder	23 x 160 mm 12 x 80 mm
61	F	Femoral artery pseudoaneurysm	Post femoral puncture	Viabahn	6 x 40 mm
34	M	Popliteal artery pseudoaneurysm	Post Nail fixation	Viabahn	6 x 40 mm
Stenosis (n=13)					
50	M	Internal carotid artery stenosis	TIA	Smart Nitinol	9 x 30 mm
60	F	Left subclavian artery stenosis	Vertebral steal	Smart Nitinol	8 x 30 mm
60	M	Left renal artery stenosis	Uncontrolled hypertension	Jos (two)	4 x 18 mm 4 x 14 mm
45	M	Aortic stenosis	Ulcer	Wall (two)	12 x 40 mm
58	F	Aortic bifurcation stenosis	Gangrene	Wall (two)	8 x 40 mm 8 x 40 mm
59	M	Iliac stenosis right	Claudication	Hemobahn	8 x 40 mm
64	M	Iliac stenosis right	Rest pain	Hemobahn	8 x 40 mm
47	M	Iliac stenosis right	Rest pain	Smart	8 x 40 mm
49	M	Iliac stenosis right	Claudication	Hemobahn	8 x 40 mm
50	M	Iliac stenosis left	Claudication	Luminex	8 x 60 mm
59	M	Iliac stenosis left	Rest pain	Luminex	8 x 60 mm
51	M	Iliac stenosis left	Claudication	Wall	8 x 40 mm
52	M	Iliac stenosis left	Rest pain	Hemobahn	8 x 40 mm

equipped with an adaptive array matrix, a gantry rotation time of 0.5 sec, Medrad Vistron Pressure injector and CARE Bolus (automated triggering) software. The protocols used in this study are given in Table 2. Patients received 750 ml of water, an hour before the study, in order to produce negative contrast in bowel. Patients were positioned supine, and head immobilization achieved using adhesive tape. After selection of the regions (aorta, aortoiliac, aortoiliacofemoral etc), the angiography mode was activated. A combination of 2.5 mm detectors (4x2.5) was used. An automated triggering technique using Care Bolus was utilised in all cases, with monitoring performed at aorta at the level of the diaphragm, after selection of a threshold attenuation of 100 HU. 100 ml of 300 mg I/mL solution Omnipaque (Nycomed) of contrast material was injected through a 18 gauge antecubital venflow using a power injector at a rate of 3 cc/s. Saline Bolus chase of 30 ml was used in all cases. The breath-hold time ranged between 20 and 35 sec. The axial images were reconstructed with a high-resolution algorithm in steps of 0.5 mm and the same protocol was used to evaluate the patient before and after stent graft placement. Image reconstruction was accomplished with 50% overlap, resulting in an average of 900 images per study, which were used for 3D analysis on a workstation. Follow up CT angiography was performed by a timely schedule within 1 week, 6, 12 and 24 months, following endovascular repair.

The aneurysmal data analysed by MDCT comprised of length, diameter, area, volume, and angles. While luminal diameter, detection of calcification and dissection was identified from axial source images, lengths, angles, areas and volumes were calculated from MIP and Volume rendered images using 3D Leonardo and Vessel View software. Aneurysmal size was expressed as maximum diameter and volume. Maximum aneurysm diameter was measured perpendicular to flow line of the vessel. The total aneurysmal volume (volume within native arterial wall), luminal aneurysmal volume (volume circumscribed by native lumen or endograft), and non-luminal aneurysmal volume (volume of thrombus and/or endoleak) was calculated. Furthermore, important measurements in abdominal aortic aneurysms were proximal and distal aneurysmal neck diameter, maximal width of aneurysm, length and width of left and right common iliac arteries, proximity of aneurysm to renal arteries, length of aneurysm, mean luminal centre line, shortest path and total aneurysmal volume and iliac angle [1]. For aortoiliac occlusive disease, MDCT analysis was performed after dividing the vascular tree into seven standard segments i.e lower abdominal aorta, left and right common iliac arteries, left and right external iliac and common femoral arteries and left and right superficial femoral arteries [2]. Each segment was evaluated for number of lesions, presence of stenosis, percentage of stenosis, eccentricity of lesions, presence or

Table 2**Multidetector CT technique in arterial stent evaluation**

Scan parameter	Aortic and branch aneurysm (thoracic)	Aortic and branch aneurysm (abdominal)	Occulsive aortic and branch disease	Occulsive iliac disease
Coverage (mm)	80	150	150	130
Coverage direction	Craniocaudal	Craniocaudal	Craniocaudal	Craniocaudal
mA	130	130	130	130
kVP	120	120	120	120
Scan time (s)	20	27	25	29
Scan thickness	3 mm	3 mm	3 mm	3 mm
Reconstruction	1.5 mm	1.5 mm	1.5 mm	1.5 mm
Total contrast (ml)	100	150	150	150
Saline volume (ml)				
Phase 1				
Contrast Vol (ml)	50	75	75	75
Rate (ml/sec)	5	5	5	5
Phase 2				
Contrast Vol (ml)	50	75	75	75
Rate (ml/sec)	3	3	3	3
Delay (s)	8-12 s	10-14 s	10-14 s	10-14 s

absence of thrombus, calcification and the distal run off. Findings were graded according to six categories: Grade 1 normal (0% stenosis), 2 mild (1-49% stenosis), 3 moderate (50-74% stenosis), 4 severe (75-99% stenosis), 5 occluded, and 6 nondiagnostic. All stented patients in this study with aortoiliac occlusive disease were Grade 4.

Discussion

Broadly in MDCT, there are four significant post-processing techniques, used for 3D imaging evaluation of aortic disease and stents : multiplanar reconstruction (MPR), maximum intensity projection (MIP), volume rendering (VR) and virtual scopy (VS) (Fig. 1). In cases of aneurysms, 3D analysis of multidetector CT data offered information on shape and size of aneurysm, shape and patency of graft, the presence or absence of perigraft thrombosis or endoleaks (Fig. 2). In cases of stenosis, MDCT provided useful information on shape of graft, its location, its patency and the presence and quantity of distal flow (Fig. 3).

The strategy of percutaneous placement of an endovascular graft is credited to Dotter [3]. Stent grafts were initially placed in aortic aneurysms by Volodos et al and Parodi et al [4,5]. They were later used in occlusive vascular disease with successful outcomes. A stent graft is an intraluminal device that consists of a supporting framework made of metal like stainless steel or nitinol and a synthetic graft material. The stent may be located inside, outside or within the graft material and it may be along the entire length of the graft or limited almost to its ends [6]. The evaluation of stents on MDCT depends on the type of stent. While the wire frames of the stent are identified readily on MDCT, the fabric is seen only if they are covered by contrast material on both sides, making it appear as a thin black

wall [7, 8].

In treating aneurysms, optimal selection of a stent is based on preprocedure 3D CT and DSA measurements, which minimizes endoleak, branch occlusion, thrombosis and migration. It is therefore mandatory to qualify and quantify accurately the aneurysm before the stent graft procedure (Fig. 4) [9].

In aortic aneurysms (AA), an incorrectly sized stent might dislodge and drift downstream while endograft diameter smaller by 1 mm or inadequate length of “seal zone” may result in endoleak and graft migration. Conversely, an overly large endograft diameter leads to crimping, endoleak and aortic enlargement [7]. The length of AA, ideally along the bloodflow centerline, needs to be known to determine proper stent length. A stent that is too short may result in subsequent aneurysmal development in unprotected segment of aorta, while a stent that is too long may result in the stent kinking.

Axial source images and 2D MPR reconstructions were used for analysis in all cases, depicting surrounding tissues with high signal density as well as complex anatomical structures. The luminal diameter and length of aneurysm was determined correctly using 2D MPR reconstructions. MIP reconstructions was found suitable for vessel take off and analysis of angulated segments, while VR reconstructions was suitable for assessing the complete CTA data set, simultaneously depicting thrombus, calcifications, vessels, bone and stents [10]. For 3D visualisation of large volumes, MIP and VR reconstructions are the method of choice. SSD's contributed negligibly amongst all rendering techniques.

Beebe HG et al [11], in a study of fifty patients with

Fig. 1 : Post-processed Multidetector CT images of stent graft evaluation: Counterclockwise from top left: Axial MPR slice shows contrast within aortic stent graft, with no evidence of endoleak; Coronal MIP shows extent of graft and relationship to the aneurysm; VR images depicts the entire CT data, including thrombus, calcifications, vessels, bone and in-situ stent

Fig. 2 : MDCT evaluation of infrarenal aortic aneurysm: Pre stent-graft VR images show shape and size of aneurysm, relationship of aneurysmal neck to renal artery origin and status of iliac arteries, while post stent-graft VR images shows patency of graft with no migration, perigraft hemorrhage or endoleaks.

AAA for endovascular repair using Spiral CT scan showed that CT was unable to evaluate proximal neck length in 5 patients while aortography over estimated neck length in 11 patients. Significantly thirteen patients having one or more iliac aneurysms (> 2 cm) was seen on CT but not in aortography. In our study, using 3D imaging, the proximal neck length was identified in all cases. Wolf YG et al [12], in a recent study using aneurysm volume, orthogonal maximal and maximal transverse diameters from axial CT images, showed that aneurysmal volume increased immediately after endovascular repair, and thereafter gradually decreased. While changes in volume paralleled changes in maximal

Fig. 3 : MDCT evaluation in a case of isolated, short segment, right iliac stenosis: Pre stent-graft VR images show location, extent and degree of stenosis, status of iliac arteries, while Post stent-graft VR images shows location and patency of graft with presence of optimal distal flow

Fig. 4 : MDCT Imaging evaluation in a 58 year old hypertensive man with arch aneurysm treated with stent graft: Counterclockwise from top left: Chest radiograph demonstrates mediastinal widening with aneurysmal dilatation of aortic arch; DSA shows deployment of stent graft at aorta; Oblique coronal VR image shows optimal position of stent-graft in situ isolating the aneurysm with no endoleak. Note the left subclavian artery coursing through the uncovered portion of stent.

aneurysm diameter, no significant changes in orthogonal and transverse diameter and straight-line and centerline aortoiliac length was observed. This observation was present in one case in this study.

Tillich M et al [13], used a novel method to predict aortoiliac stent-graft length by comparing aortoiliac length measured by a median luminal centerline (MLC) and a shortest path (SP) of at least one common iliac arterial radius away from the vessel wall. The shortest aortoiliac path length maintaining at least one radius distance from the vessel wall most accurately enabled stent-graft length prediction.

Endoleaks denote persistent or recurrent flow into the aneurysm which occurs in 6 to 44 % cases [6].

They can persist causing loosening of the stent and progressive enlargement of the aneurysms and are treated by embolization and arterial stenting. Endotension is another emerging entity defined as persistent or recurrent pressurisation of the aneurysm sac after endoaneurysmal repair, in the absence of blood flow. Only one patient with aneurysm had endoleak (Type 1), which was detected during the procedure and was treated with touch up balloon technique successfully.

In cases of occlusive arterial disease causing chronic lower-extremity ischemia, aortoiliac stent placement is a durable, low-risk revascularisation option, improving intermittent claudication, resolving ischemic rest pain, and healing ischemic ulceration. Isolated lesions of the aortoiliac segment cause intermittent claudication of the calf, thigh, and buttock regions, and can cause impotence in men. The lesions occur typically at the aortic bifurcation, with disease extending into the origin of each common iliac artery. Stenoses are more common than occlusions by a 4:1 ratio [14].

The most complex lesions are considered to be occlusions greater than 5 cm in length or lesions adjacent to an aneurysm. Lesions of the iliac arteries are usually amenable to endovascular treatment because they are large in diameter (7 mm to 12 mm) with good shear forces due to high flow. The iliac artery has a large vessel diameter with low risk of acute closure or late restenosis, besides being close to site of access. Factors favouring stents includes stenosis (rather than occlusion), shorter lesion length with good distal runoff, older age, common iliac location and limb-threatening ischemia. When lesions are long, multiple, or diffuse, surgical revascularisation is a better option.

Primary stenting is effective for occlusions, restenosis after percutaneous transluminal angioplasty (PTA) and severe stenosis in the cases with iliac arterial disease. Stenting is less feasible for infra-inguinal arterial lesions, because the long-term results of stenting are not better than those of PTA in spite of its good short-term results [14]. In a recent study that measured long-term outcomes of aortoiliac stent placement in treatment of 365 patients with chronic lower-extremity ischemia, primary patency was 74%, primary assisted patency 81%, and secondary patency 84%, eight years after stent placement [15].

Rieker et al [6], evaluated the accuracy of CT angiography for assessment of stenosis and occlusions of the iliac arteries, in a study of 30 patients. Axial scans recognized 14 of 15 high-grade (> 75%) stenosis, while one case of short stenosis was overlooked. When MIP maximum intensity projections alone were analysed, sensitivity for the diagnosis of 15 high-grade stenosis was only 53%, because of obscuration by calcified

plaques. In our study axial scans recognized all stenosis, including one case of short stenosis. Also, the efficacy of using MIP alone for evaluation of stenosis was limited by the obscuration by calcified plaques. However, when combined with axial slices and VR, the stenosis were accurately identified and quantified.

The number of cases who underwent stents for aneurysm and stenosis in this study is rather small. Furthermore, longer periods of follow-up are needed. The current standard in CT imaging is the 64 slice Multidetector CT, while this study was performed using a 4 slice CT machine, which may have a bearing on accuracy of measurements derived particularly from rendered images. In this study, a variety of stents have been used, which increases the variability in predicting in-stent stenosis.

Conflicts of Interest

None identified

References

1. Filis KA, Arko FR, Rubin GD, et al. Aortoiliac angulation and the need for secondary procedures to secure stent graft fixation: which angle is important? *Int Angiol* 2002; 21: 349-54.
2. Tins B, Oxtoby J, Patel S. Comparison of CT angiography with conventional arterial angiography in aortoiliac occlusive disease. *Br J Radiol* 2001;74 : 219-25.
3. Dotter C. Transluminally placed coil spring endarterial tube grafts: long term patency in a canine popliteal artery. *Invest Radiol* 1969;4:329-32.
4. Valodos NL, Karpovich IP, Troyan VI, et al. Clinical experience of the use of self-fixing synthetic prosthesis for remote endoprosthetics of the thoracic and the abdominal aorta and iliac arteries through the femoral artery and as intraoperative endoprosthesis for aorta reconstruction. *Vasc Suppl* 1991; 33 : 93-5.
5. Parodi JC, Palmaz JC, Barone HD. Transfemoral intraluminal graft implantation for abdominal aortic aneurysms. *Ann Vascular Surg* 1991; 5: 491-99.
6. Kaufman JA, Geller SC, Brewster DC, Fan CM, et al. Endovascular repair of abdominal aortic aneurysms: Current status and future directions. *Am J Roentgenol* 2000;175: 289-302.
7. Rydberg J, Kopecky KK, Johnson MS, Patel NH, et al. Endovascular Repair of Abdominal Aortic Aneurysm: Assessment with Multislice CT. *Am J Roentgenol* 2001; 177 : 607-14.
8. Wever JJ, Blankensteijn JD, van Rijn JC, et al. Inter and intraobserver variability of CT measurements obtained after endovascular repair of abdominal aortic aneurysms. *Am J Roentgenol* 2000;175:1279-82.
9. Broeders IA, Blankensteijn JD, Olree M, Mali W, Eikelboom BC. Preoperative sizing of grafts for transfemoral endovascular aneurysm management: a prospective comparative study of spiral CT angiography, arteriography, and Conventional CT imaging. *J Endovasc Surg*. 1997; 4:252- 61.
10. Huber A, Matzko M, Wintersperger BJ, Reiser M. Reconstruction methods in postprocessing of CT- and MR-

angiography of the aorta. *Radiology* 2001; 41: 689-94.

11. Beebe HG, Jackson T, Pigott JP. Aortic aneurysm morphology for planning endovascular aortic grafts: limitations of conventional imaging methods. *J Endovasc Surg.* 1995; 2: 139-48.
12. Wolf YG, Tillich M, Lee WA, Fogarty TJ. Changes in aneurysm volume after endovascular repair of abdominal aortic aneurysm. *J Vasc Surg.* 2002;36:412-3.
13. Tillich M, Hill BB, Paik DS, Petz K, Napel S, Zarins CK, Rubin GD. Prediction of aortoiliac stent-graft length: comparison of measurement methods. *Radiology* 2001; 220 : 475-83.
14. Schurmann K, Mahnken A, Meyer J, et al. Long-term results 10 years after iliac arterial stent placement. *Radiology* 2002;224:731-8.
15. Murphy TP, Ariaratnam NS, Carney WI Jr, et al. Aortoiliac insufficiency: long-term experience with stent placement for treatment. *Radiology* 2004;231:243-9.
16. Rieker O, Duber C, Neufang A, et al. CT angiography versus intraarterial digital subtraction angiography for assessment of aortoiliac occlusive disease. *Am J Roentgenol* 1997;169:1133-8.

Answer to the Quiz

Avascular necrosis of Lunate: Kienbock's Disease

The radiograph reveals sclerosis and collapse of the lunate with a transverse fracture through it. Kienbock's disease involves avascular necrosis of the lunate following trauma or dislocation of the bone. The development of Kienbock's disease is not solely attributable to extrinsic trauma. Presence of negative ulnar variance, wherein the distal articular surface of the ulna lags behind the radius, predisposes to its development, as the shortness of ulna in these cases causes an irregular articular surface, against which the lunate gets compressed [1]. Once osteonecrosis begins, an established progressive sequence of events is set in motion characterised by flattening and elongation, of lunate proximal migration of capitate, scapho-lunate dissociation and finally osteoarthritis of the radiocarpal joint. These series of changes form the basis of classification into four grades with Grade 1 changes involving marrow oedema usually not seen on radiographs. Magnetic Resonance Imaging (MRI) with its ability to pick up marrow oedema as hyperintensity on T2 weighted images, can pick up Grade 1 changes [2]. Grade 2 changes show sclerosis and flattening of

the bone on the radial side and are seen well on plain radiograph. Grade 3 changes involve marked decrease in the size of the bone with associated proximal migration of capitate, with or without scapho-lunate dissociation. Grade 4 changes are characterised by complete disintegration of the bone with associated radiocarpal osteoarthritic changes. The treatment of this condition depends on the grade and includes revascularisation procedures, radial shortening or ulnar lengthening procedures, silicon replacement arthroplasty and intercarpal arthrodesis for early disease (Grades 1-3). Treatment of Grade 4 disease is similar to treatment of degenerative arthritis of wrist involving salvage procedures like proximal row carpectomy, radiocarpal fusion or total wrist arthroplasty [3].

References

1. Greenspan AS. Trauma Upper Limb. In: Adam S Greenspan, editor. *Orthopedic Radiology, A Practical Approach*. 3rd ed. Lippincott : Williams and Wilkins, 2000;177-80.
2. Bearcroft PWP, Dixon AK. Joint Disease. MRI aspects. In: Grainger, Allison, editors. *Diagnostic Radiology*. 4th ed. Edinburgh : Churchill Livingstone 2003; 2050-1.
3. Delaere O, Dury M. Conservative versus operative treatment for Kienbock's disease. A retrospective study. *J Hand Surg* 1998; 23(1): 33-6.