e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2024; 16(5); 124-137

Case Series

Non Invasive Diagnosis of Vascular Pathologies by CT Angiography: A Pictoral Presentation

Paresh Bhowmik[1], Susmita Rani Ghosh[2], Jaybrata Ray[3]

[1]Senior Resident Department of Radiodiagnosis AGMC & GBP Hospital
[2]Senior Resident, Department of Radiodiagnosis AGMC & GBP Hospital
[3]Associate Professor, Department of Radiodiagnosis AGMC & GBP Hospital

Received: 01-02-2024 Revised: 15-03-2024 / Accepted: 21-04-2024

Corresponding author: Dr. Susmita Rani Ghosh

Conflict of interest: Nil

Abstract

Spiral CT angiography is a new, minimally invasive technique for vascular imaging that is made possible by combining two recently developed techniques: slip-ring CT scanning and computerized three-dimensional (3D) reconstruction. CT angiography done to diagnose and evaluate blood vessel disease or related conditions, such as aneurysms or blockages, Arteriovenous malformation (AVM), hemangioma, stenosis, AV fistula, aortic dissection, pulmonary embolism, thoracic outlet syndrome etc.

Over the past decade, noninvasive imaging of the arteries has evolved into a highly reliable alternative to invasive digital subtraction angiography. Here we presents few rare cases where diagnosis was made possible by CT Angiography.

(1) Bilateral renal AVM with aneurysmal dilatation of feeding arteries on left side, which was diagnosed by renal CT Angiography.
(2) Cerebral arterio-venous malformation involving left temporo-parietal lobes, diagnose by carotid CT Angiography.
(3) Takayasu arteritis (Type-V), diagnosed by Aortogram.
(4) Arterio-venous malformation involving postero-lateral aspect of middle third of left leg, diagnosed by peripheral CT Angiography.
(5) Non-calcified soft tissue plaque seen at the proximal part of LAD near its origin results in moderate luminal stenosis with negative remodeling, diagnosed by Cardiac CT Angiography.

CT angiography is a type of medical test that combines a CT scan with an injection of a special dye to produce pictures of blood vessels and tissues in a part of our body. The dye is injected through an intravenous (IV) line started in our arm or hand. Before Multi-Detector Computed Tomography (MDCT), the main barriers to the clinical implementation of CT angiography (CTA) were acquisition speed and both spatial and temporal resolution.

Keywords: Computed tomography angiography (CTA), arterial disease, Intermittent claudication, Chronic critical ischemia, Atherosclerosis, Non-atherosclerotic arterial disease.

Introduction

Spiral CT angiography is a new, minimally invasive technique for vascular imaging that is made possible by combining two recently developed techniques: slip-ring CT scanning and computerized three-dimensional (3D) reconstruction[1]. Computed tomography angiography (CTA) uses an injection of contrast material into blood vessels and CT scanning done to diagnose and evaluate blood vessel disease or related conditions, such as aneurysms or blockages, arteriovenous malformation (AVM), hemangioma, stenosis, AV fistula, aortic dissection, pulmonary embolism, thoracic outlet syndrome etc. Over the past decade, noninvasive imaging of the arteries has evolved into a highly reliable alternative to invasive digital subtraction angiography. Computed tomography angiography (CTA) is capable of identifying the location and severity of arterial diseases with high accuracy, and can be used to manage the entire spectrum of patients with suspected or known cases of arterial disease. Although atherosclerosis is the underlying cause of symptoms in the vast majority of patients, noninvasive cross-sectional imaging is also well suited for identification of alternative non-atherosclerotic causes such as vasculitis and other less frequent causes. Here we present few rare cases where diagnosis was made possible by CT Angiography.

Case Series:

Case 1:

A 50 years old female came with the complaint of uncontrolled hypertension & mild flank pain. It is gradual in onset. No past history of similar illness. Four members her family is apparently healthy. She is non- diabetic, non-smoker, non-alcoholic and her bladder, bowel habits normal. She has attained menopause 8 years ago and was on anti-hypertensive medication.

On examination she was found to be hypertensive (160/90mm of Hg). Her built was average with fair nutrition. Other general physical examination findings & routine blood investigations are within normal limits. On CT scan imaging - NCCT KUB: show ill-defined hypodense lesions in both kidneys (Fig 1 A &B). Renal CT angiography of patient show increased vascularity with multiple irregular dilated tortuous vessels of different sizes which include both arterial and venous circulation filling simultaneously in the region of left and right kidneys (Fig 2-coronal CT angiography reconstruction A & B).

Renal angiography 3D reconstructed CT angiography show arteriovenous malformation mid third of right kidney and upper –to mid-third of left Kidney. Dilated feeding arteries in left kidney are seen (Fig 3& 4 – A & B 3D reconstructed CT angiography Images)

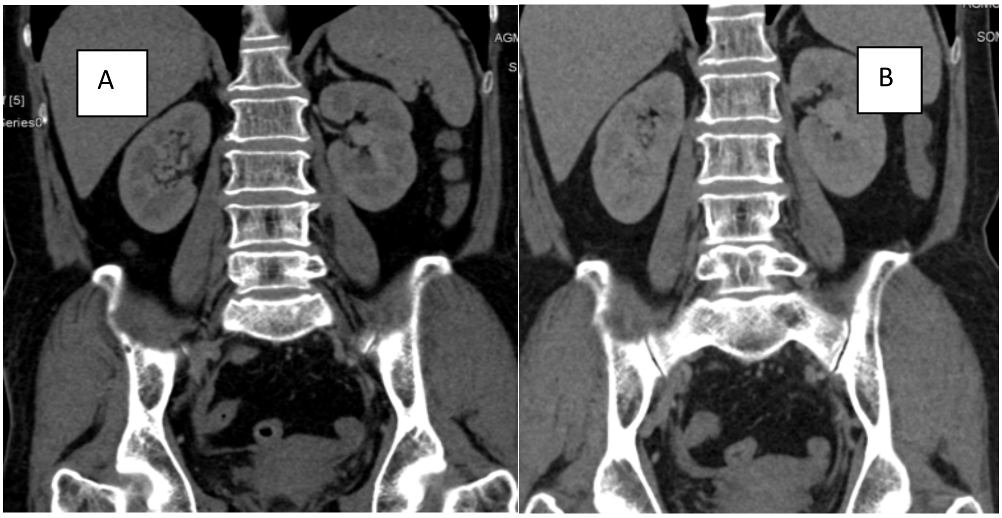


Figure 1: (NCCT KUB) coronal noncontract CT images A & B show ill-defined hypodense lesions in both kidneys

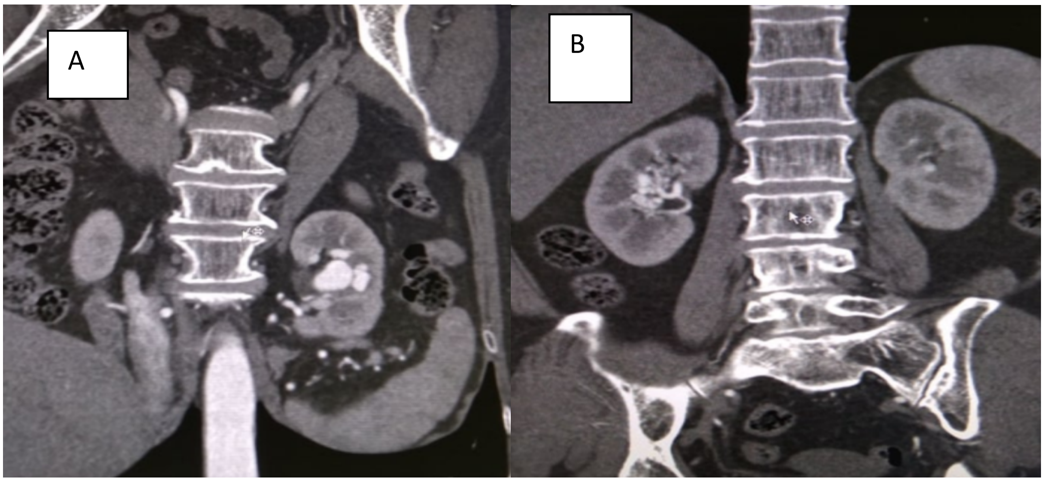


Figure 2: (Renal CT angiography): coronal CT angiography reconstruction A & B images of patient show increased vascularity with multiple irregular dilated tortuous **vessels of different sizes which include both arterial and venous circulation filling simultaneously in the region of left and right kidneys respectively**

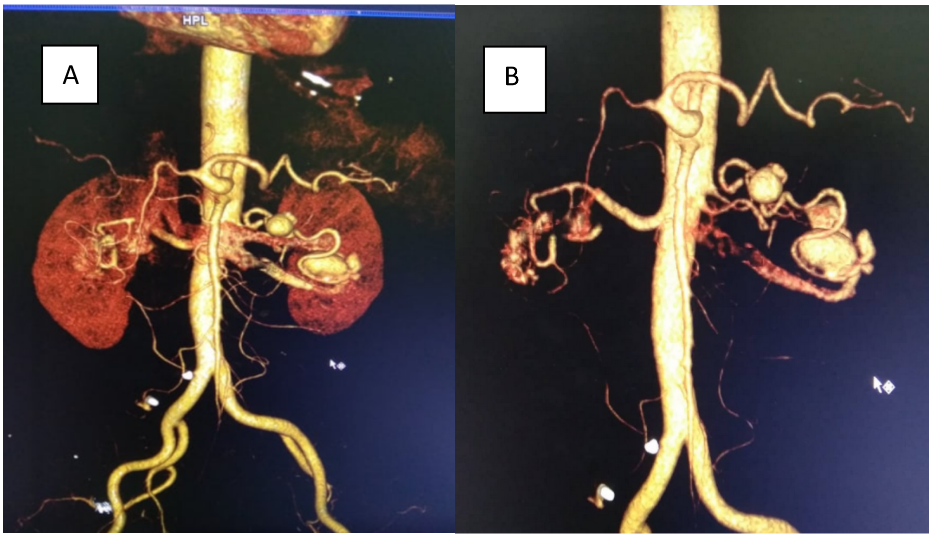


Figure 3: (Renal angiography): A & B 3D reconstructed CT angiography Images Show arteriovenous malformation mid third of right kidney and upper –to mid-third of left Kidney. Dilated feeding arteries in left kidney are seen

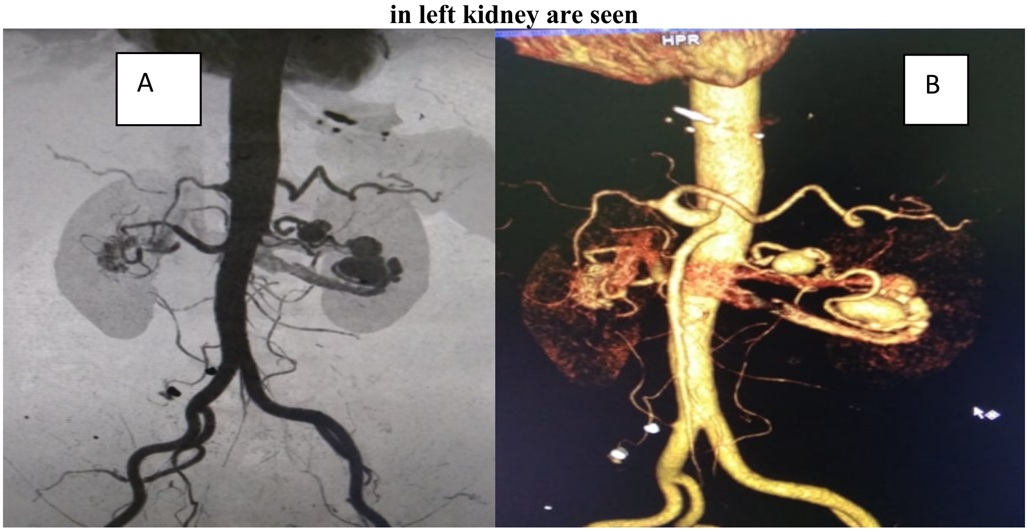


Figure 4: (Renal angiography): A & B 3D reconstructed CT angiography images show arteriovenous malformation mid third of right kidney and upper –to mid-third of left kidney

Diagnos:

Bilateral renal AVM with aneurysmal dilatation of feeding arteries on left side.

D/D:

Renal Arterio-venous fistula: Renal arteriovenous fistulae are usually acquired lesions, unlike renal AVMs which are frequently developmental abnormalities. The majority of cases are iatrogenic and occur as a complication of renal biopsy, nephrostomy, blunt or penetrating trauma, inflammation, malignancy, or renal surgery'

Color Doppler images depict a flash of color, "visible thrill" or "soft tissue bruit" that results from the vibration of the soft tissue surrounding the renal AVF, producing a focal color mosaic overlying the adjacent soft tissue [1]. Adjusting the color Doppler to higher velocities may show the feeding artery and the enlarged draining vein.

Spectral Doppler tracings show a high-velocity, low resistance flow within the artery and turbulent, pulsatile, arterialized flow in the segmental draining vein. If large, the main renal vein may have pulsatile flow

CT angiography may demonstrate the anomalous renal arteriovenous communication with early opacification of the renal vein on the arterial phase.

Saccular aneurysm involving upper left renal artery: -

They are more common in females with a median age of diagnosis of 50 years.

Non-contrast: soft tissue mass lesion in the region or course of renal artery

Post-contrast: contrast-filled out pouching in the course of the renal artery

Angiography (DSA): Aneurysms can be well detected and characterized by angiography, in terms of size, neck diameter and type.

Classification

One classification method proposed by Runback et al is at follows.

Type 1: saccular aneurysms arising from the main renal artery or the large segmental branch: usually amendable to an endovascular approach

Type 2: fusiform aneurysms: may require an open surgical approach

Type 3: intra-lobar aneurysms arising from small segmental arteries or accessory arteries

Case 2:

A 55 years old female came with the complaint of headache & seizure disorders for last one year. It is gradual in onset. All five members of her family are apparently healthy. She is non-diabetic, non-hypertensive, non-alcoholic, non -smoker and her bladder and bowel habits normal. She is post-menopausal and attained menopause 12 years ago. No past history of similar illness is present.

On general physical examination and routine blood investigations are within normal limits.

On CECT brain: Fig 5- A & B Images show serpiginous enhancement with early venous filling involving left temparoparietal lobes**.** Brain angiography: Fig 6- A & B images show increased vascularity with multiple irregular tortuous vessels of different sizes which include both arterial and venous circulation filling simultaneously in the region of left temporo-parietal lobes. Brain angiography: Fig 7 – 3D A & B images show “nidus” left temparoparietal regions having feeding arteries from left middle and anterior cerebral arteries. Draining vein through sagittal sinus

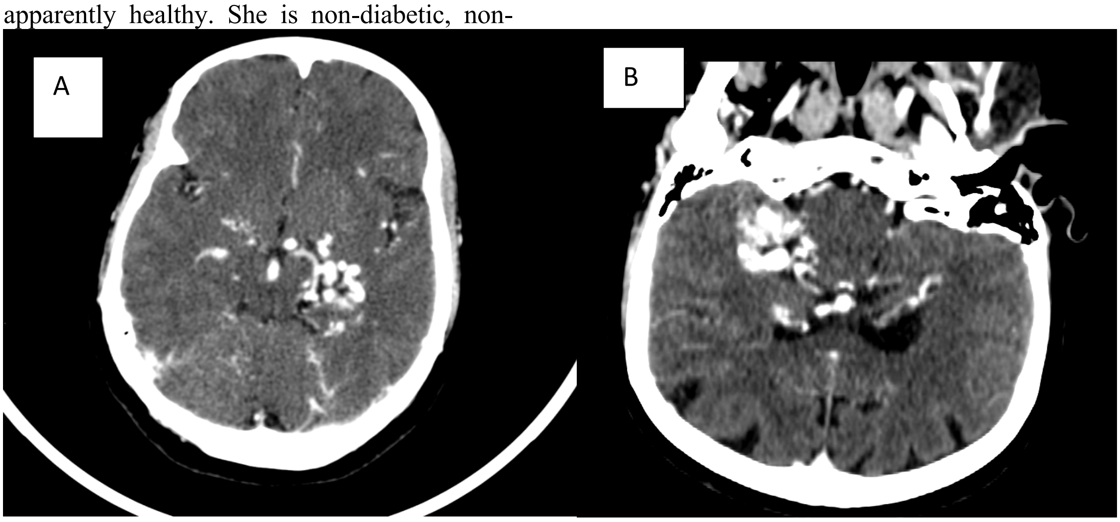


Figure 5: (CECT brain): A & B Images show serpiginous enhancement with early venous filling involving left temparoparietal lobes

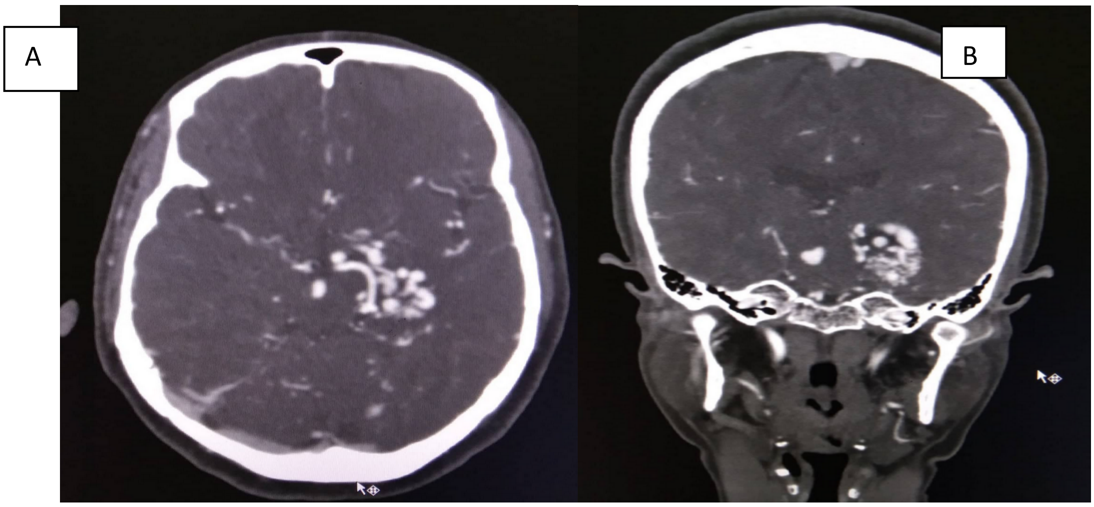


Figure 6: (Brain Angiography): A & B images show increased vascularity with multiple irregular tortuous vessels of different sizes which include both arterial and venous circulation filling simultaneously in the region of left temporo-parietal lobes

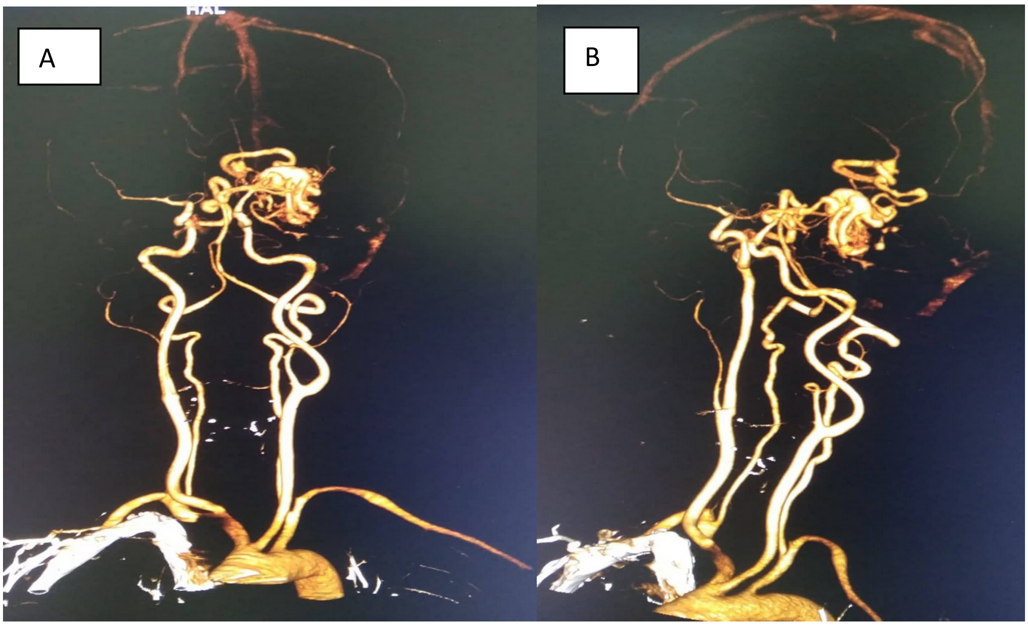


Figure 7: (Brain Angiography): (3D)A & B images show "nidus" left temparoparietal regions having feeding arteries from left middle and anterior cerebral arteries. Draining vein through sagittal sinus

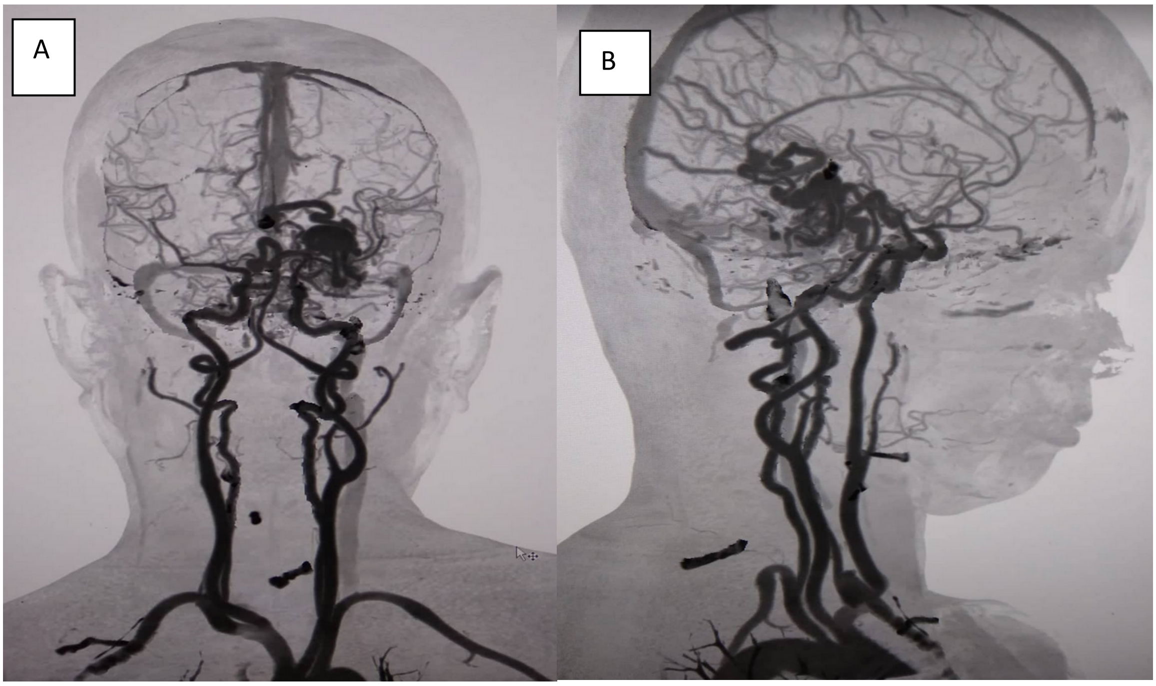


Figure 8: (Brain Angiography): DSA A & B images show "nidus" left temparoparietal regions having feeding arteries from left middle and anterior cerebral arteries. Draining vein through sagittal sinus

Diagnosis: The diagnosis was cerebral arterio-venous malformation involving left temporo-parietal lobes.

The differential diagnosis:

Cerebral proliferative angiopathy: "cerebral proliferative angiopathy" (CPA) is a clinical entity, which may be regarded as separate from "classical" brain AVMs in angioarchitecture, natural history, clinical presentation [2].

It is a cerebral vascular malformation separated from classic brain arteriovenous malformation (AVM) and characterized by the presence of normal brain parenchyma interspersed throughout the tangle of vessels that corresponds to the nidus.

The characteristic features of cerebral proliferative angiopathy are:

- Absence of early venous drainage, which helps to differentiate CPA from a classical cerebral AVM

- Large areas of parenchymal involvement, often an entire lobe or even a hemisphere is affected
- The nidus is fed by multiple arteries (absence of a dominant feeder)
- Feeder arteries tend to be of normal size or moderately enlarged
- Associated stenosis of feeder arteries is often present
- Classical nidus appearance with scattered "puddling" of contrast which persists into the late arterial and early venous phases
- The nidus usually has a fuzzy appearance, it is not well-circumscribed

Cerebral proliferative angiopathy:

Developmental venous anomaly:

Dural AVF: Dural arteriovenous fi stulas (AVFs) occur at dural sinuses, which are proximate to or inside the skull bones [3]. Dural arteriovenous fistulas (dAVF) are a heterogeneous collection of conditions that share arteriovenous shunts from dural vessels. They present variably with hemorrhage or venous hypertension and can be challenging to treat.

With CT angiography findings that may be evident:

- Abnormally enlarged and tortuous vessels in the subarachnoid space, corresponding to dilated cortical vein
- An enlarged external carotid artery or enlarged transosseous vessels
- Abnormal dural venous sinuses including arterialization of contrast phase in the affected sinus due to arteriovenous shunting

Case 3:

A 22 years old female came with the history of hypertension and claudication of extremities for last two years. It was gradual in onset. She also gives history of arthralgia and off and on, fever for the same duration.

There are six members in her family and all are apparently healthy. Her bladder and bowel habits are normal. She is non-diabetic, nonsmoker and non-alcoholic. Her menstrual cycle is regular. She is not having past history of similar illness.

On examination – she is well oriented with time, place and person. Not having any focal neurological deficit. Her blood pressure is 116/70 mmHg in left brachial artery. 132/88 mmHg in right brachial artery. Her pulse rate is80/min. Peripheral pulses are decreased. Mild pillories resent. No edema is present.

On systemic examination –cardiovascular system - S1, S2 heard normally, no murmur is found. Respiratory system reveals – normal breath sounds. On examination of abdomen shows, it is soft in consistency and no palpable mass.

Bruits heard over the abdominal aorta. Normal bowel sounds are heard. Routine blood investigations are within normal limits except decreased hemoglobin level.

On CT angiography: show narrowing of ascending aorta, arch of aorta, descending thoracic aorta, abdominal aorta, renal arteries, right common carotid artery and left subclavian artery with circumferential wall thickening.

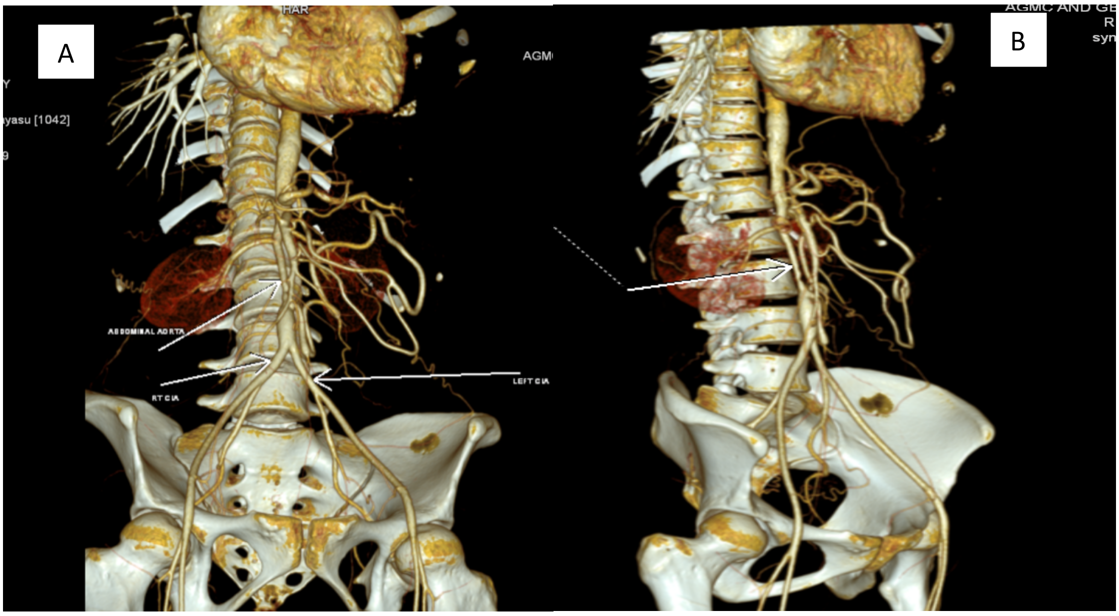


Figure 9: (Abdominal Angiography): 3D CT angiography A & B show– narrowing of abdominal aorta and renal arteries

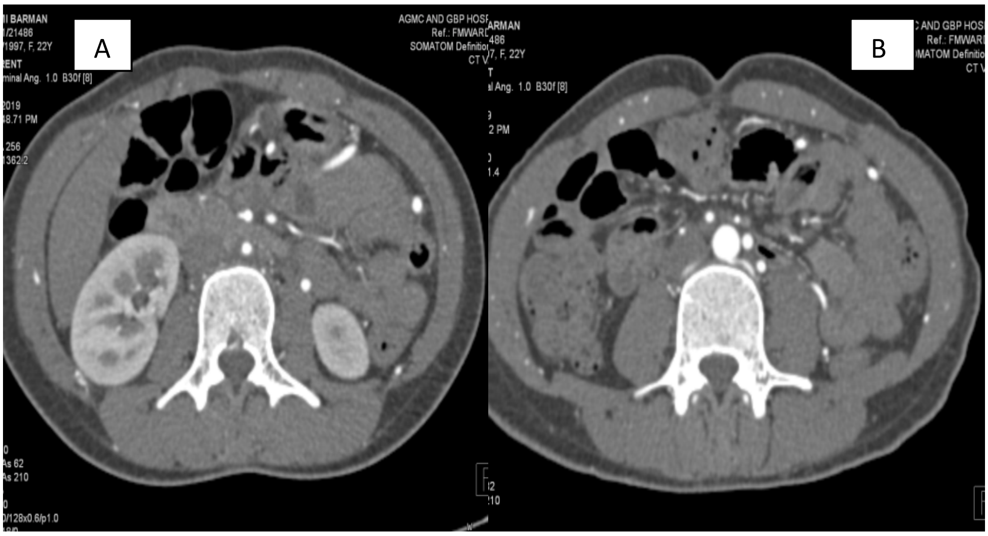


Figure 10: (Abdominal Angiography): CT angiography A & B show– narrowing of abdominal aorta with circumferential wall thickening

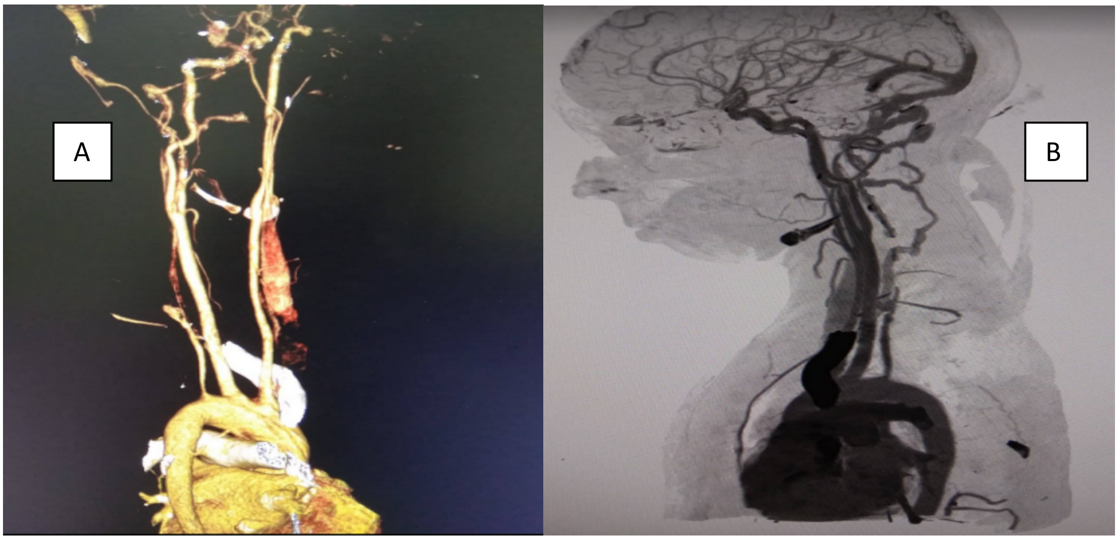


Figure 11: (Aortic arch & neck vessels Angiography): narrowing of thoracic aorta, right common carotid artery, arch of aorta, left subclavian artery and descending thoracic aorta

Diagnosis

Takayasu arteritis (Type-V).

The differential diagnosis:

Giant cell arteritis: Giant cell arteritis (GCA) (plural: arteritides) is a common granulomatous vasculitis affecting medium- to large-sized arteries. It is also known as temporal arteritis or cranial arteritis, given its propensity to involve the extra cranial external carotid artery branches such as the superficial temporal artery.

CT angiography is useful for revealing luminal changes, such as stenosis, occlusion, dilation, and aneurysm. It is also useful for showing mural changes to include wall thickening, which correlate well with the inflammatory changes seen histologically, as was the case in this patient. CT may also show calcification and mural thrombi, which may not be adequately visualized on conventional angiography [4].

Atherosclerosis: Atherosclerotic lesions in the abdominal aorta or its major branches are often incidentally detected on abdominal CT. Atherosclerotic plaques have a non-uniform distribution throughout the aorta.

Polyarteritis Nodosa: Polyarthritis nodosa (PAN) is one of a spectrum of diseases that belongs to the pathologic category of necrotizing vasculitis involves small to medium-sized arteries (larger than arterioles) [5]. A good quality CTA can also demonstrate changes. Findings include: multiple micro aneurysms

- Characteristic but not pathognomonic

- Typically 2-3 mm in size but can be up to 1 cm

-In the kidneys, the microaneurysms typically involve the interlobar and arcuate arteries

Hemorrhage may be present due to focal rupture occlusion may be present

Case- 4:

A 18 years old female came with the history of a swelling in left leg for two years. The swelling is gradually increasing in size. No history of any pain in the swelling. There is no history of trauma. She is non-diabetic, non-hypertensive, nonsmoker, nonalcoholic, bladder and bowel habits are normal. Her menstrual cycles-regular with 3-4days bleeding. No significant past medical /surgical history was there. Her general physical examination & routine blood investigations are within normal limits. Doppler ultrasonography examination of the swelling done which shows--a vascular mass composed of multiple small dilated tortious vessels in the post-riot-lateral aspect of left leg. On spectral Doppler mixed arterial & venous flow noted within the lesion.

On CT angiography of left lower limb show increased vascularity with multiple irregular tortuous vessels of different sizes which include both arterial and venous circulation filling simultaneously with soft tissue swelling postero-lateral aspect of mid third of left leg (Fig -12 A & B images). Fig 13A & B images 3D show “nidus” postero -lateral aspect of mid third of left leg having feeding arteries from posterior tibial artery and draining vein through left posterior tibial vein.

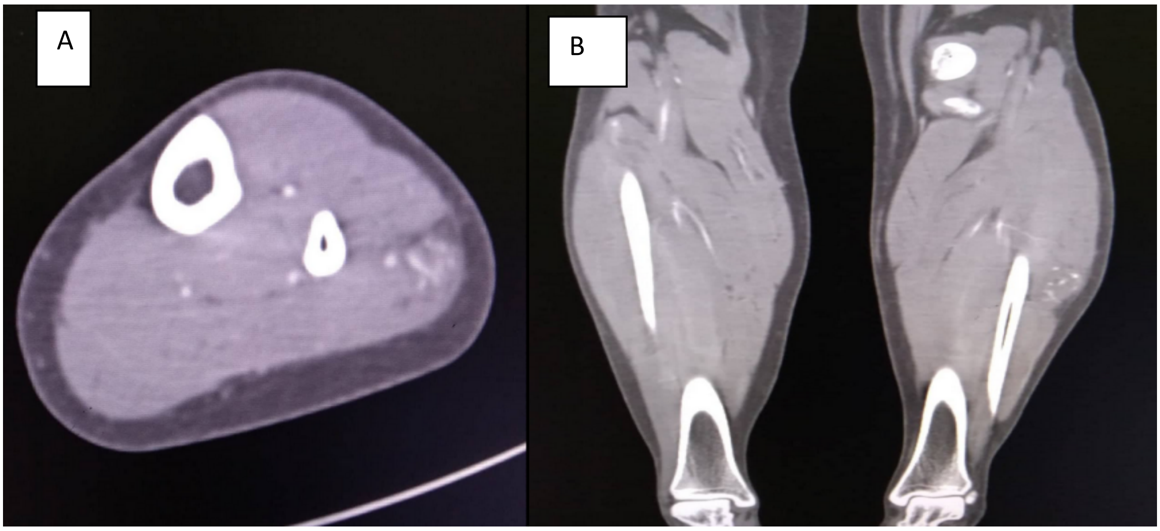


Figure 12: (CT angiography of left lower limb): A & B images show increased vascularity with multiple irregular tortuous vessels of different sizes which include both arterial and venous circulation filling simultaneously with soft tissue swelling postero-lateral aspect of mid third of left leg

Figure 13: (CT angiography of left lower limb): A & B images show “nidus” postero -lateral aspect of mid third of left leg having feeding arteries from posterior tibial artery and draining vein through left posterior tibial vein

Diagnosis:

Arterio-venous malformation involving postero-lateral aspect of middle third of left leg.

The differential diagnosis:

Hemangioma: Intramuscular angiomas or intramuscular hemangiomas are benign vascular soft tissue tumors consisting of benign vascular channels within the skeletal muscle

Ultrasound

On ultrasound intramuscular angiomas/ hem angioma are described as hypoechoic lesions sometimes with calcifications and abnormal resistance on color Doppler imaging.

CT

CT angiography might show curvilinear contrast pooling in the dilated vascular spaces.

MRI

MRI is considered the most suitable imaging modality for the diagnosis. Hemangiomas usually have a lobulated form. Dilated tubular vascular channels showing flow voids intermixed with fatty tissue in a lace-like pattern next to low signal areas representing thrombi, calcified phleboliths or fibrous tissue are other characteristic features [2,5-7]. This is also known as "bag of worms appearance" [2].

Signal characteristics

- T1: high signal intensity with hypointense foci and flow voids
- T2: high signal intensity with central low signal dots and flow voids
- STIR/PDFS: hyperintense vascular spaces with intermixed fatty tissue
- T1C+ (Gd): marked enhancement of the vascular spaces

Case-5:

A 43 years old male came with the history of chest pain and exertional dyspnea for last six months. It was gradual in onset. His bladder and bowel habits are normal. He is a smoker, on-diabetic, non – alcoholic and hypertensive on irregular medication. There are five members in his family and all are apparently healthy. He has history of myocardial infarction one month back. His general physical examination and routine blood investigations are within normal limits.

On coronary CT angiography - Calcium scoring reveals total calcium score is 0.0(Fig 14). Cardiac function evaluation shows gross reduction in ejection fraction, stroke volume & myocardial mass with increased end systolic volume (Fig 15).

Cardiac CT angiography show no apparent pathology in right coronary artery (Fig 18 A & B) and severe obstructive eccentric luminal narrowing in distal part of proximal segment of left anterior descending (LAD) artery due to non-calcified soft atheromatous plaque with negative remodeling (Fig-19 A & B images).

Fig-16 –A & B - 3D images left coronary artery and its branches show severe narrowing in distal part of proximal segment of left anterior descending (LAD) artery. Fig-17 –A & B show 3D images right coronary artery and its branches.

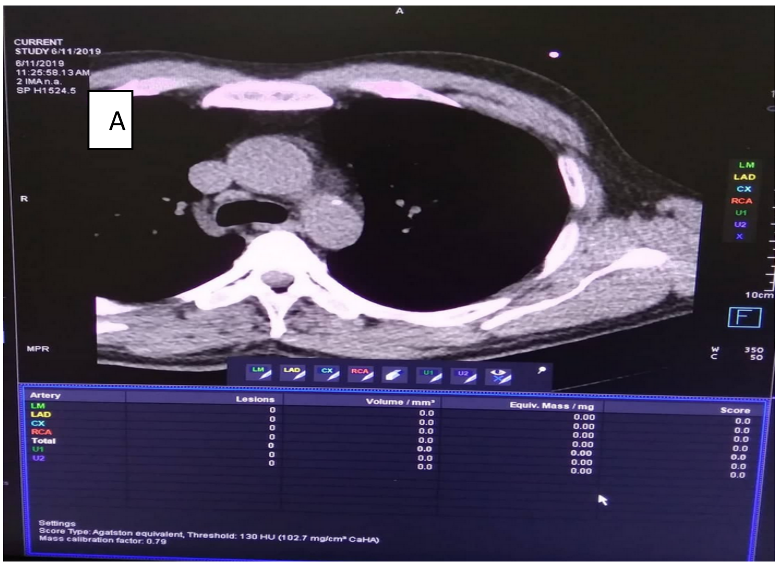
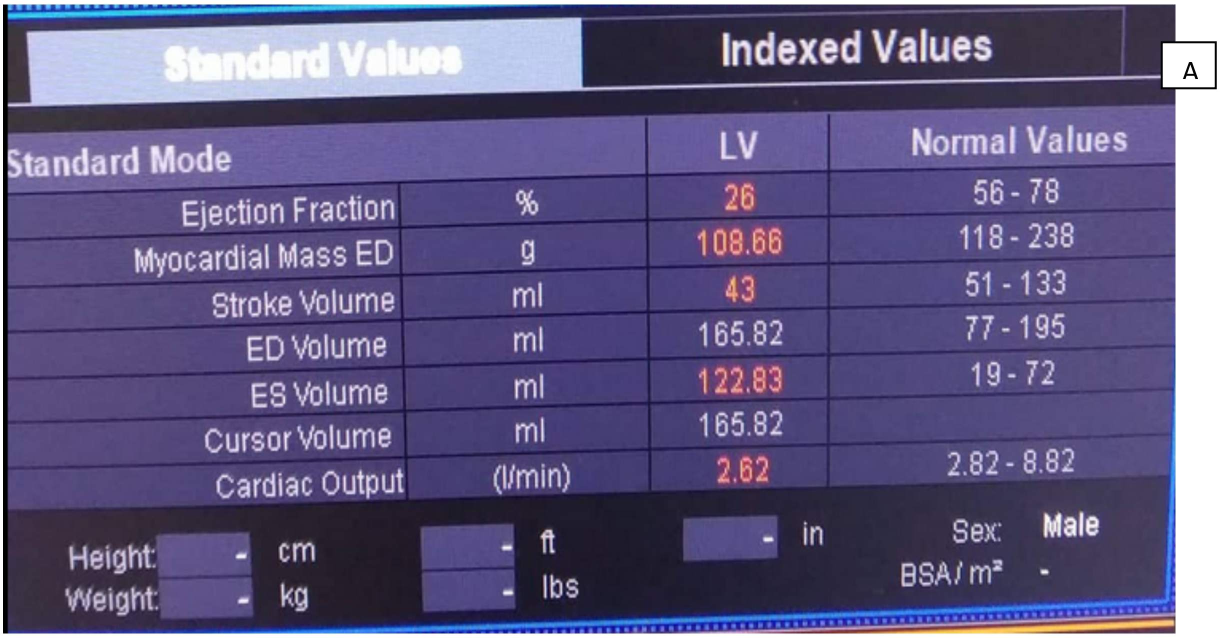


Figure 14: (Calcium scoring): above figure shows total calcium score is 0.0. Cardiac function: Fig 2- Figure shows -gross reduction in ejection fraction, stroke volume & myocardial mass with increased end systolic volume



Standard Mode		LV	Normal Values
Ejection Fraction	%	26	56 - 78
Myocardial Mass ED	g	108.66	118 - 238
Stroke Volume	ml	43	51 - 133
ED Volume	ml	165.82	77 - 195
ES Volume	ml	122.83	19 - 72
Cursor Volume	ml	165.82	
Cardiac Output	(l/min)	2.62	2.82 - 8.82

Figure 15: (Cardiac function): Figure shows -gross reduction in ejection fraction, stroke volume & myocardial mass with increased end systolic volume

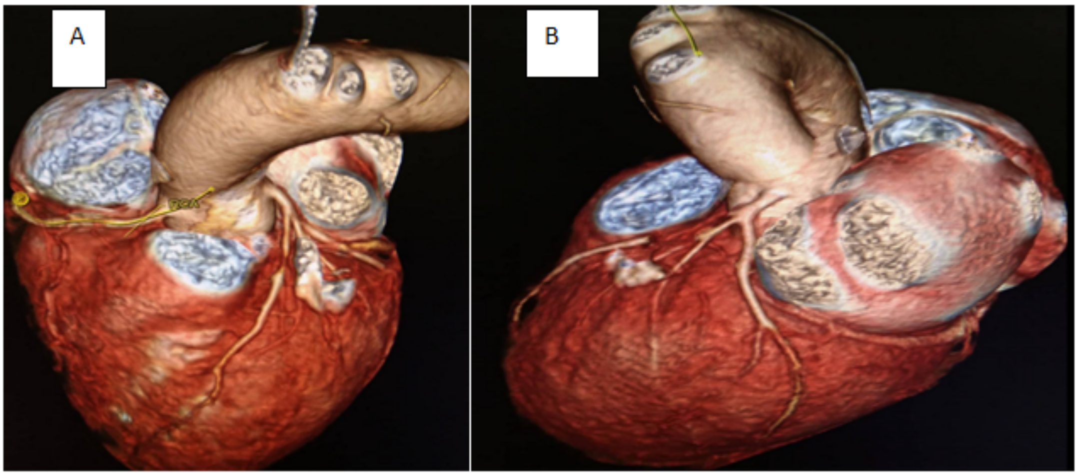


Figure 16: (Cardiac angiography): 3D A & B images show left coronary artery and its branches

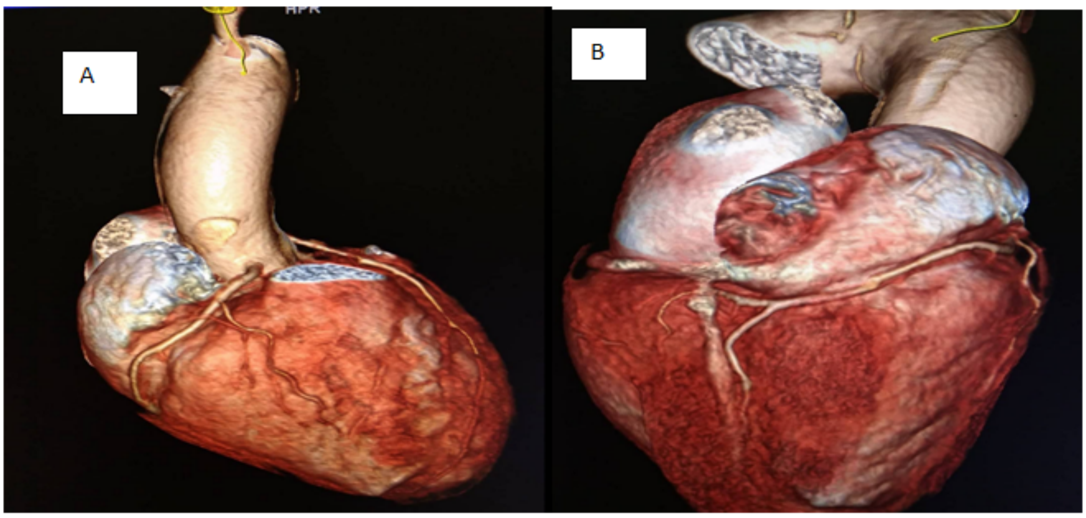


Figure 17: (Cardiac angiography): fig-17 A & B show right coronary artery and its branches

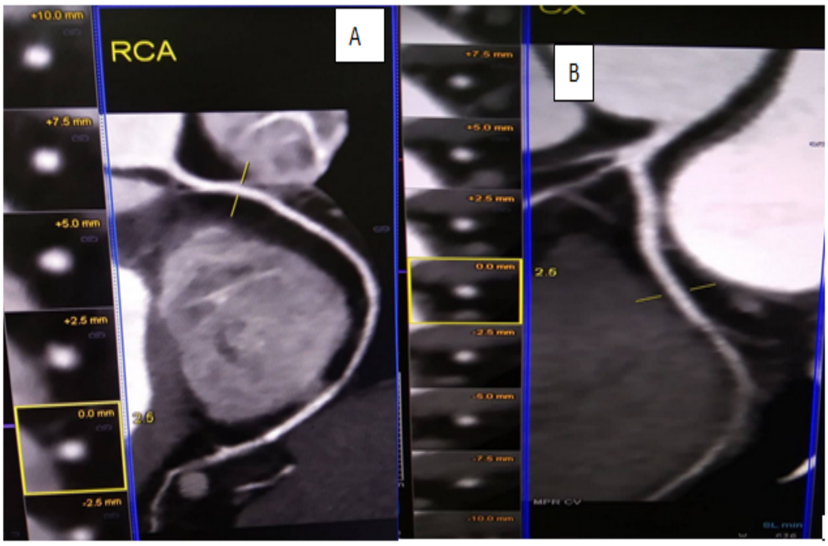


Figure 18: (Cardiac CT angiography): A & B show no apparent pathology in right coronary artery

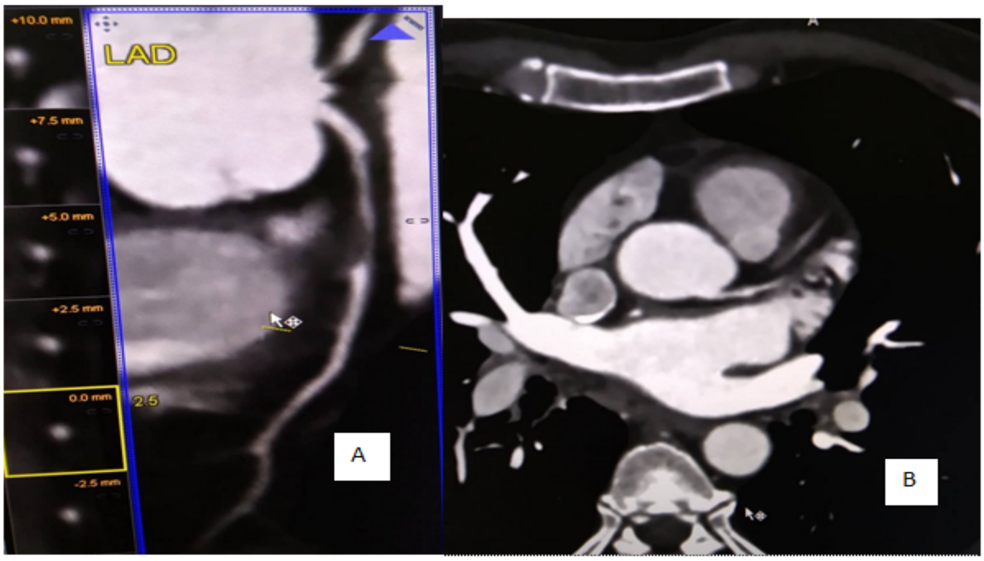


Figure 19: (Cardiac CT angiography): A & B images in the right shows- severe obstructive eccentric luminal narrowing in distal part of proximal segment of left anterior descending (LAD) artery due to non-calcified soft atheromatous plaque with negative remodeling

Diagnosis: Total calcium score is 0.0.

- Severe obstructive eccentric luminal narrowing in distal part of proximal segment of LAD due to non-calcified soft atheromatous plaque with negative remodeling.
- Non-calcified soft tissue plaque seen at the proximal part of LAD near its origin results in moderate luminal stenosis with negative remodeling.
- Gross reduction in ejection fraction, stroke volume &myocardial mass with increased end systolic volume.

Discussion: CT angiography is a type of medical test that combines a CT scan with an injection of a special dye to produce pictures of blood vessels and tissues in a part of our body. The dye is injected through an intravenous (IV) line started in our arm or hand. Before Multi-Detector Computed Tomography (MDCT), the main barriers to the clinical implementation of CT angiography (CTA) were acquisition speed and both spatial and temporal resolution. Imaging of any vascular bed requires rapid volume coverage coupled with the ability to resolve disease in small diameter contrast opacified vessels.

One extreme for volume coverage is CTA for peripheral artery disease (PAD); imaging speed is mandated by blood velocity, on the order of 30-180 mm/sec 6 from the abdominal aorta to the feet. The CT acquisition must be synchronized with the contrast bolus throughout a large craniocaudal, or z-axis, field of view (FOV). This proves challenging in the presence of severe PAD; scans too fast will outrun the bolus. Scans too slow, that is imaging after peak arterial enhancement, result in venous contamination. Another extreme in CTA is coronary angiography where superior temporal resolution is essential to decrease motion related artifacts. Faster gantry rotations, dual source CT, and multi-segment reconstruction have improved temporal resolution so that high quality cardiac imaging is now routine. Egas Moniz developed cerebral angiography in 1927, using x-rays and iodinated contrast material to allow him to diagnose brain disorders such as tumors, strokes, and injuries [7]. The first diagnostic coronary angiography was performed in 1958 [8]. Since then, catheter angiography has assumed the role of gold standard for vascular imaging, despite the invasive nature of the procedure, with 1.5-2% risk of significant morbidity and mortality, and high cost [9]. Less invasive techniques for vascular imaging have been developed, such as sonography with Doppler imaging [10,11] magnetic resonance imaging (MRI) 12 and CTA [13,14] and have matured in conjunction with developments in catheter arteriography. In many cases noninvasive imaging has become complementary to catheter angiography, such as Doppler imaging for the evaluation of patients with recurrent symptoms after angioplasty [15]. In many cases CT has been used in conjunction with catheter angiography, and in a few cases such as imaging the aorta and the pulmonary arteries, CTA has supplanted catheter angiography as the gold standard. The expanding role of CTA emphasizes the need for deep, broad based understanding of physical principles.

Arteriovenous malformations (AVMs) are characterized by an abnormal leash of vessels allowing for arteriovenous shunting. They can occur anywhere in the body but are most common in the brain. There is direct arteriovenous communication with no intervening capillary bed. They can be congenital or acquired.

Takayasu arteritis (TAK), also known as idiopathic medial aortopathy or pulseless disease, is a granulomatous large vessel vasculitis that predominantly affects the aorta and its major branches. It may also affect the pulmonary arteries. There is a strong female predominance (F: M ~ 9:1), an increased prevalence in Asian populations, and it tends to affect younger patients (<50 years of age). The typical age of onset is at around 15-30 years of age.

Classification:

It has been classified based on location

1. Type I involves only the branches of the aortic arch.
2. Type IIa involves ascending aorta, aortic arch and its branches.
3. Type IIb affects ascending aorta, aortic arch and its branches, and thoracic descending aorta.
4. Type III involves the descending thoracic aorta, the abdominal aorta and/or the renal arteries. The ascending aorta, the aortic arch and its branches are not affected.
5. Type IV involves only the abdominal aorta and/or renal arteries.
6. Type V has combined features of Type IIb and IV.

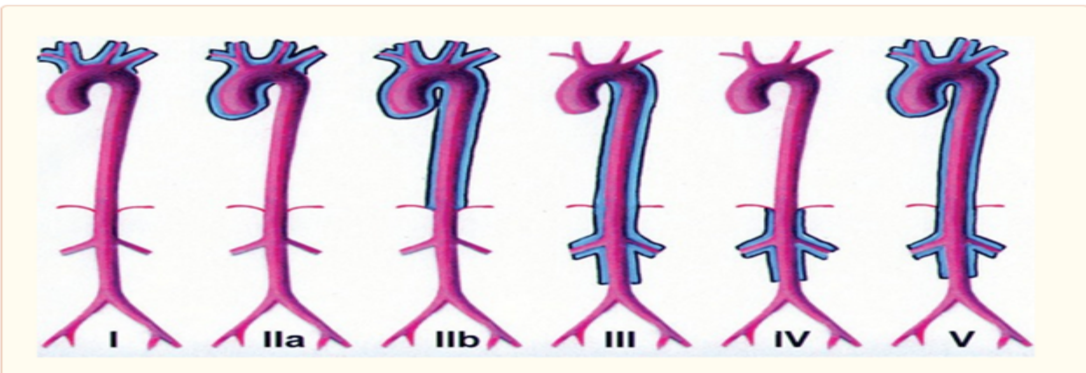


Figure 20: Classification

Sharma criteria for diagnosis of Takayasu arteritis [12]

Major criteria	Left mid-subclavian artery lesion
	Right mid-subclavian artery lesion
	Characteristic signs and symptoms of at least one month duration[a]
Minor criteria	High erythrocyte sedimentation[b]
	Carotid artery tenderness
	Hypertension[c]
	Aortic regurgitation or annuloaortic ectasis
	Pulmonary artery lesion
	Left mid-common carotid lesion
	Distal brachiocephalic trunk lesion
	Descending thoracic aorta lesion
	Abdominal aorta lesion
	Coronary artery lesion

Presence of two major, or one major and two minor criteria, or four minor criteria suggests a high probability of Takayasu arteritis.

[a]Including limb claudication, pulselessness or pulse differences in limbs, an unobtainable or significant blood presence difference, fever, neck pain, transient amaurosis, blurred vision, syncope, dyspnea or palpitations.

[b]Higher than 20 mm h^{-1} (Westergren method).

[c]Higher than 140/90 mmHg brachial or 160/90 mmHg popliteal.

Chart 1: Criteria for diagnosis:

References:

1. Evan H. Dillon, 1 Maarten S. van Leeuwen, M. Arancha Fernandez, and Willem P. T. Spiral CT Angiography. AJR 1993: 160:1273-1278.
2. 2.Pierre Lasjaunias, Pierre Landrieu, Georges Rodesch, PhD, Hortensia Alvarez, Augustin Ozanne, Staffan Holmin, Wenuan Zhao, Sasikhan Geibprasert, Dennis Ducreux, and Timo Krings. Cerebral Proliferative Angiopathy. Stroke 2008:39(3): 878-885.
3. Chung-Wei Lee, Adam Huang, Yao-Hung Wang, Chung-Yi Yang, Ya-Fang Chen, Hon-Man Liu. Intracranial Dural Arteriovenous Fistulas. Radiology 2010: 256(1):219-228.
4. Jennifer L. Bau, Justin Q. Ly, Gregory C. Borstad, Joanna D. Lusk, Thomas M. Seay1, Douglas P. Beall1. Giant Cell Arteritis. AJR 2003: 181:742-743.
5. Anthony W. Stanson, Jeremy L. Friese, C. Michael Johnson, Michael A. McKusick, Jerome F. Breen, Enrique A. Sabater, James C. Andrews. Polyarteritis Nodosa: Spectrum of Angiographic Findings. RadioGraphics 2001: 21:151–159.
6. Fleischmann D, Rubin GD. Quantification of intravenously administered contrast medium transit through the peripheral arteries: implications for CT angiography. Radiology. 2005; 236(3):1076–1082.
7. Ligon BL. Biography: history of developments in imaging techniques: Egas Moniz and angiography. Semin Pediatr Infect Dis. 2003; 14(2):173–181.
8. Mueller RL, Sanborn TA. The history of interventional cardiology: cardiac catheterization, angioplasty, and related interventions. Am Heart J. 1995; 129(1):146–172.
9. Waugh JR, Sacharias N. Arteriographic complications in the DSA era. Radiology. 1992; 182(1):243–246.
10. Scoutt LM, Zawin ML, Taylor KJ. Doppler US. Part II. Clinical applications. Radiology. 1990; 174(2):309–319.
11. Krnic A, Vucic N, Sucic Z. Duplex scanning compared with intra-arterial angiography in diagnosing peripheral arterial disease: three analytical approaches. Vasa. 2006; 35(2):86–91.
12. Wardlaw JM, Chappell FM, Best JJ, Wartolowska K, Berry E. Noninvasive imaging compared with intra-arterial angiography in the diagnosis of symptomatic carotid stenosis: a meta-analysis. Lancet. 2006; 367(9521):1503–1512.

13. Heijenbrok-Kal MH, Kock MC, Hunink MG. Lower extremity arterial disease: multidetector CT angiography meta-analysis. Radiology. 2007; 245(2):433–439.
14. Schoenhagen P, Halliburton SS, Stillman AE, Kuzmiak SA, Nissen SE, Tuzcu EM, White RD. Noninvasive imaging of coronary arteries: current and future role of multi-detector row CT. Radiology. 2004; 232(1):7–17.
15. Rybicki FJ, Nallamshetty L, Yucel EK, Holtzman SR, Baum RA, Foley WD, Ho VB, Mammen L, Narra VR, Stein B, Moneta GL. ACR appropriateness criteria on recurrent symptoms following lower-extremity angioplasty. J Am Coll Radiol. 2008; 5(12): 1176–1180.