ISSN- O: 2458 - 868X, ISSN–P: 2458 – 8687
Index Copernicus Value: 49. 23
PubMed - National Library of Medicine - ID: 101731606

International Journal of Medical Science and Innovative Research (IJMSIR)
IJMSIR : A Medical Publication Hub
Available Online at: www.ijmsir.com
Volume – 3, Issue – 5, October - 2018, Page No. :12 - 21

Axial Multiplanar Reconstruction Contrast-Enhanced Magnetic Resonance Angiography of Supra-aortic Vessels in Predicting Degree of Stenosis: Comparison with Digital Subtraction Angiography

Hale AYDIN[1], Mehmet TEKSAM[2]

[1]Dr AY Ankara Oncology Research and Training Hospital, Radiology Department

[2]Private Practice, Radiology

Corresponding Author: Hale AYDIN, MD, Dr AY Ankara Oncology Research and Training Hospital, Radiology Department, Mehmet Akif Ersoy Mah 13. Cad No: 56 Yenimahalle, Ankara-TURKEY

Type of Publication: Original Research Paper

Conflicts of Interest: Nil

Abstract

Purpose: Contrast-enhanced MR angiography (CE MRA) is a noninvasive, screening and preoperative imaging method used for the evaluation of supraaortic vessels. There might be difficulty during the evaluation of CE MRA from MIP or coronal source images if there is jugular vein enhancement or marked tortuosity of the supraaortic vessels. In this study we evaluated the specificity, sensitivity, and accuracy of axial multiplanar reconstruction (MPR) images of CE MRA and compared the results with digital subtraction angiography (DSA).

Materials And Methods: Two radiologists evaluated supraaortic vessels in a consensual manner blinded to clinical symptoms and DSA results on axial MPR CE MRA images in 168 vessels of 21 symptomatic patients. The severity of stenosis was defined as normal (0%), mild stenosis (1-29%), moderate stenosis (30-69%), severe stenosis (70-99%), and occluded (100%). Axial MPR CE MRA results and corresponding DSA results were compared.

Results: In the detection of stenosis, axial MPR CE MRA sensitivities were 78%, 75%, 62%, and 50% for common carotid artery (CCA), subclavian artery (SA), internal carotid artery (ICA), and vertebral artery (VA), respectively. Axial MPR CE MRA had specificity of 70%, 100%, 50%, and 60% for CCA, SA, ICA and VA, respectively.

Conclusion: Although axial MPR CE MRA imaging provides relatively high sensitivity and specificity for the detection of especially CCA and SA stenoses, axial MPR images alone may not be sufficient. Furthermore, if jugular vein enhancement occurs or marked tortuosity of the arteries is present, evaluation of CE MRA may be difficult. In such a situation, axial MPR images may be used as an adjunctive to MIP and coronal source images.

Keywords: Supraaortic vessels, contrast enhanced MRA, axial multiplanar reconstruction

Introduction

Stroke development has been shown to be associated with the presence of high grade carotid stenosis (1). The North American Symptomatic Carotid Endarterectomy Trial (NASCET) reported that, symptomatic patients who had >70% carotid stenosis would benefit from carotid endarterectomy and their risk of stroke would be reduced (2). In a later study, they also found that stroke risk was moderately reduced when carotid endarterectomy was performed in symptomatic patients with stenosis between 50-69% (3). Furthermore, when asymptomatic patients were evaluated in the Asymptomatic Carotid Atherosclerosis Study, even patients who had 60% stenosis were found to benefit from carotid endarterectomy (4). These data show that the benefit of carotid endarterectomy may be mostly determined by the level of stenosis. Thus, in order to determine if a patient will benefit from intervention we have to accurately grade the level of stenosis.

Currently, carotid artery disease is evaluated with the digital subtraction angiography (DSA) method. However, DSA is an expensive and invasive method with a complication rate between 0.7-1% (6). In order to find a suitable, non-invasive alternative method, techniques such as computed tomographic angiography (CTA) and contrast-enhanced magnetic resonance angiography (CE MRA) have been developed.

With the new contrast-enhanced MRA techniques; total visualization of the carotid, supraaortic trunk (6-14), and vertebral arteries from the aortic arch up to the circle of Willis is made possible. Furthermore, due to the nature of MRI, images can be manipulated to allow for superior cross-sectional evaluation and measurement of vessel diameter.

The purpose of this study was to assess the accuracy of cross-sectional stenosis measurement of supraaortic vessels on axial multiplanar reconstruction images (MPR) of CE MRA, and to compare findings against the gold-standard DSA.

Materials and Methods

Patients

From January 2002 to September 2002, we retrospectively evaluated 21 consecutive symptomatic patients, which had been referred to our MRI unit by a neurologist or neurosurgeon due to findings of clinical and/or ultrasonographic examination. Patients who had contraindications for DSA or CE MRA (i.e., pacemeker, elevated level of creatinine or renal failure) were excluded from the study. A final total of 21 patients were included. Therefore, in this study, a total of 42 subclavian arteries (SA), 42 vertebral arteries (VA), 42 common carotid arteries (CCA), and 42 internal carotid arteries (ICA) were analyzed. Three of the patients were women, the rest (n=18) were men. The median age of patients was 71 years (range, 48-83 years). CE MRA and DSA were planned for all patients in a randomized manner. Doppler data was not used for this study because all ultrasound examinations did not include information about SA and VA.

Imaging

A 1.5 T unit with neurovascular head and neck and spine coils was used for three-dimensional CE MRA (Magnetom Symphony; Siemens Medical Systems). CE MRA was performed coronally from the aortic arch to the base of the skull. Fast imaging was utilized with the following parameters: relaxation time msec/echo time msec, 4.47/1.54; average, 1; flip angle, 25º; number of sections, 52-56; section thickness, 1.6-1.8 mm; distance, 0.2 mm; FOV, 35 x 35 cm; matrix, 512 x 193; imaging time, 18 sec. Voxel size was 1.6 x 0.7 x 1.7 mm. Breath hold was not implemented.

20 mL's of contrast medium (Gadodiamid, Omniscan; Nycomed, Carrigtohill, Ireland) at a concentration of 0.5 mmol/mL was infused with a power injector (2 mL/sec) (Spectris; Medrad; Pittsburgh, PA) from a 22-gauge venous catheter at the antecubital fossa. 20 mL's of saline was flushed after each bolus. Acquisition was started with the bolus tracking method. Acquisition of images was started when the contrast medium was visualized in the aortic arch with MR fluoroscopy. MPR images with image thickness of 1.6 mm and distance of 0.016 mm on axial

plane were generated from the coronal images. The procedure was finished with the transfer of images to the workstation (Leonardo, Siemens Medical Systems) and evaluation was performed.

For DSA, the digital subtraction technique (Multistar Top, Siemens Medical Systems) was used and catheterization was performed femorally. Arch aortograms were obtained, and the selective catheterization of the common carotid arteries were performed. For each catheterization; anteroposterior, lateral and bilateral oblique projection (+ 45º and - 45º) images were obtained. Eight milliliters of nonionic contrast material (iohexol, Omnipaque 300; Nycomed, Carrigtohill, Ireland) was injected for each injection. DSA was performed with a 33-cm field of view (FOV) and a 1,024 x 1,024 matrix. The spatial resolution was 0.32 x 0.32 mm.

Image Analysis

The degree of stenosis on the SA, VA, CCA, and ICA were separately evaluated by two radiologists (M.T., H.A.) blinded to the results of the DSA and also to the results of the other examinations. The name of the patient was hidden and the order of examination was random. Gold standard was considered as the DSA result. Evaluations were done on the workstation.

In each patient, the diameter at the most severe stenosis site was divided by the diameter of the artery beyond the stenosis. The resulting value was subtracted from one and then multiplied by 100 to yield the vessel's stenosis percentage. The stenosis was graded as: I, (normal, 0%), II (mild, 1-29%), III (moderate, 30-69%), IV (severe, 70-99%), and V, (occluded, 100%). Total occlusion was identified as the lack of appreciable patent lumen. Negative values were defined as 0% stenosis. Measurements to determine the exact degree of stenosis were done at the site in which stenosis was maximal for each stenotic level through the artery by using high magnification and a computer calibration. The degree of stenosis was measured at the same levels in both DSA and MPR CE MRA images.

Statistical Analysis

Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of axial MPR CE MRA were calculated for each vessel in all patients. Agreement between axial MPR CE MRA and DSA was calculated separately for ICA, CCA, VA and SA using the κ coefficient. The degree of agreement between methods was classified as mild , good , or excellent. The κ values for these groups were (κ > 0.40-0.69), (κ >0.70-0.89), and (κ >0.90-1.00), respectively.

Results

In all 21 patients, the quality of images from both imaging techniques (MRA and DSA) were -at the least- graded as adequate for diagnosis. No motion artifacts that would eliminate the quality of axial MPR MRA images were found.

Comparison between axial MPR CE MRA and DSA results are extensively reported in Tables 1-4. In the total proximal valuable vessels, 26 SA and 43 CCA stenosis, and 2 CCA occlusion were detected with axial MPR CE MRA. The sensitivity and specificity for SA were 75 and 100%, respectively, with PPV 100%, NPV 55%, and accuracy 81%. The CCA sensitivity and specificity were 78 and 70%, respectively, with PPV 93%, NPV 39%, and accuracy 77%. For the ICA, thirty lesions were graded as mild, 13 as moderate, and 3 as severe (Fig. 1a, 1b and 1c). Three ICA were occluded (Fig. 2a, 2b and 2c). The ICA sensitivity and specificity were 62 and 50%, respectively with PPV 95%, NPV 4%, and accuracy 61%.

In vertebral artery evaluations, 8 lesions were graded as mild, 15 as moderate, and 3 as severe. Two vertebral arteries were occluded (Fig. 3a, 3b and 3c). Sensitivity and specificity were 50 and 60%, respectively, with PPV 91%, NPV 12%, and accuracy 51%.

There was mild aggrement between axial MPR CE MRA and DSA in CCA (κ = 0.61) and ICA (κ = 0.44). No agreement was detected in VA (κ = 0.34). Due to the lack of 2-way tables in which the first and second variables should match, κ statistics could not be computed for SA.

Discussion

The NASCET reported that, symptomatic patients who had >70% carotid stenosis would benefit from carotid endarterectomy and their risk of stroke would be reduced (2, 15). Later in the ACAS study in 1995, patients with asymptomatic carotid artery stenosis (≥60%) were found to be indicated for carotid endarterectomy (4). In the final results of the NASCET study (1998), it was found that stroke risk was also moderately reduced when carotid endarterectomy was performed in symptomatic patients with stenosis between 50-69% (3).

DSA is currently the gold-standard for carotid stenosis evaluation, however it has widely established risks and limitations. However, DSA is an expensive and invasive method and its use is accompanied by the risk of major complications. Although mortality is low, there is still the risk for neurological events which are seen in 0.45-2.6% of patients who undergo DSA. The overall benefit of endarterectomy may be reduced by the possibility of thromboembolic events during the use of DSA to determine its requirement. Thus, the evaluation of supraaortic vessels with noninvasive techniques will prevent the inherent risks brought by DSA. Thus, there currently is a need for identifying noninvasive alternatives to DSA.

The standard for the evaluation of cervical occlusive disease is Doppler sonography imaging. Ultrasound is a widely available, cheap, and noninvasive method which presents no risks for the patient. Borisch et al. recently demonstrated that duplex sonography has a sensitivity of 92.9% and a specificity of 81.9% for the detection of ≥70% carotid artery stenoses (16). However, with sonography, visualization of the stenotic area in cases presenting with severely calcified plaques is not possible. Although the use of IV contrast may resolve this issue, this method has not gained acceptance yet. Thus, the application of ultrasound on its own, is not considered as an accurate diagnosis tool for cervical stenosis. Contrast-enhanced MR angiography is now a widely used noninvasive imaging technique in association with Doppler sonography (17-21). Borisch et al. demonstrated that use of contrast-enhanced MRA (CE MRA) and duplex sonography together, increases the sensitivity of diagnosis up to 100% (16).

For several years, CE MRA has been used successfully for evaluating supraaortic vessels. It has been clearly shown that stenosis and occlusions of the ICA can be accurately determined with CE MRA and interobserver agreement in these lesions were considered good (22-24). However, a number of limitations accompany the use of CE MRA; firstly, the jugular vein is enhanced with this method, which may reduce the visualization of the carotid artery (25). This problem is more likely to happen when longer scan times are used for image generation. The use of short scan time reduces the possibility of contrast flow into the veins (26, 27); however, shorter scan time also reduces spatial resolution which may cause loss of valuable data. Other than jugular vein superposition, one other difficulty in evaluation of coronal MIP images is when there is marked tortuosity of cervical arteries. Sometimes it may be difficult to determine the level of origins and follow up of the arteries if there is marked tortuosity. This may decrease the sensitivity, specificity and accuracy of stenosis measurement of the cervical arteries. Using axial images these difficulties related to marked tortuosity and jugular vein superposition could be overcome. Therefore, in this study we evaluated the efficacy of stenosis measurement on axial MPR images.

In our series, accuracy of stenosis measurement of larger arteries on axial MPR CE MRA images was higher (CCA and SA 77% and 81%, respectively) than the smaller arteries (ICA and VA 61%, and 51%, respectively). For ICA, while 26 of 27 mild stenoses were determined correctly, 9 of 30 moderate stenoses and 2 of 7 severe stenoses were determined on axial MPR CE MRA images (Fig. 1a, 1b and 1c). While 20 of 30 moderate stenoses were underestimated, 1 moderate stenosis was overestimated on axial images. Five of 7 severe stenoses of ICA were underestimated on axial images. Although the sensitivity, specificity and accuracy of measuring stenosis of CCA and SA on axial MPR CE MRA images were high, there was mild agreement between axial MPR CE MRA images and DSA. No agreement was found between axial MPR CE MRA images and DSA for VA. These results could be explained with the fact that, compared to MIP or conventional angiogram images, the measurements on MPR images seem to be more observer dependent, regardless of experience. One other reason could be that, when performing the NASCET method with MPR imaging, selection of the optimal site for measurement of the distal artery may not be possible without MIP images. Lower accuracy of stenosis measurement on axial MPR images for ICA and VA could be due to the difficulty of detecting the caliber changes of smaller caliber arteries comparing to CCA and SA at stenotic levels. Because while evaluating more than 150 axial images on scroll mode on the workstation it would be easier to detect the caliber changes of larger caliber arteries than smaller caliber arteries at stenotic levels.

Another drawback of duplex sonography is the difficulty of differentiating between occlusion and pseudo-occlusion with ultrasound. As therapeutic approach is almost entirely reliant on accurate evaluation, this is a major drawback. With axial MPR CE MRA, all 7 occlusions of cervical arteries (2 CCA, 3 ICA, 2 VA) were correctly detected (Fig. 2 and 3).

The major advantages of CE MRA are: less artifacts (which are usually caused by flow and movement of the patient), good spatial resolution, and the imaging of a larger area from the aortic arch up to the circle of Willis. These advantages allow for an accurate evaluation of the stenosis, which is vital when deciding for and planning treatment (28). In our series all MRA examinations were graded as diagnostic without any relevant motion or flow related artifacts. Another advantage of CE MRA is its reliability when a standard protocol is followed. MRA is not operator dependent while sonography may be highly subjective in regard to the operator.

An important limitation of our study is low statistical power due to the evaluation of a small number of patients. However, it is difficult to gather a larger number of patients because DSA is currently not used routinely in the detection and evaluation of patients suspected to have cervical artery lesions.

In our institution, in addition to the screening of patients, preoperative and preinterventional evaluation of these lesions is done with CE MRA. DSA is used only in unclear cases. During the evaluation of CE MRA, we routinely use MIP images and coronal MRA source images in addition to MPR images.

Conclusion

In recent years, many noninvasive imaging methods such as CE MR angiography have been developed for the evaluation of stenoses, all of which are aimed at reducing the risks associated with DSA. Many clinical studies suggest that CE MRA could be implemented as a fast and safe alternative to DSA for the detection of supraaortic vessel disease. Our results indicated that axial MPR images alone may not be sufficient in the evaluation of CE MRA. However, if there is jugular vein enhancement or marked tortuosity of the arteries that may cause difficulty in evaluation of contrast-enhanced MRA, axial MPR images may be used as an adjunctive to MIP and coronal source images.

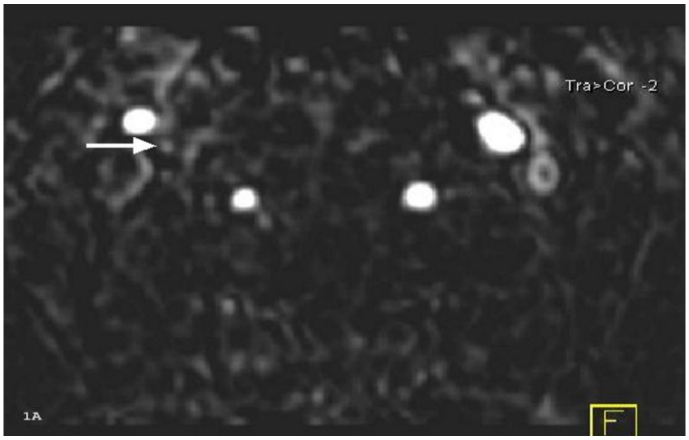
References

1. Korn A, Bender B, Brodoefel H, Hauser TK, Danz S, Ernemann U, Thomas C. Grading of carotid artery stenosis in the presence of extensive calcifications: dual-energy CT angiography in comparison with contrast-enhanced MR angiography. Clin Neuroradiol, 2015; Vol 25, Issue 1, pp 33-40.
2. North American Symptomatic Carotid Endarterectomy Trial Collaborators. Beneficial effect of carotid endarterectomy in symptomatic patients with high-grade carotid stenosis. N Engl J Med 1991;325:445-453
3. Barnet HJ, Taylor DW, Eliasziw M, et al. Benefit of carotid endarterectomy in patients with symptomatic moderate or severe stenosis: North American Symptomatic Carotid Endarterectomy Trial Collaborators. N Engl J Med 1998; 339:1415-1425
4. Endarterectomy for asymptomatic carotid artery stenosis: Executive Committee for the Asymptomatic Carotid Atherosclerosis Study. JAMA 1995; 273:1421-1428
5. Kuntz KM, Skillman JJ, Whittemore AD, Kent KC. Carotid endarterectomy in asymptomatic patients: is contrast angiography necessary? A morbidity analysis. J Vasc Surg 1995; 22:706-716
6. Levy RA, Prince MR. Arterial-phase three-dimensional contrast-enhanced MR angiography of the carotid artery. AJR 1996; 167:211-215
7. Krinsky G, Rofsky N, Flyer M, et al. Gadolinium-enhanced three-dimensional MR angiography of acquired arch vessel disease. AJR 1996; 167:981-987
8. Cloft HJ, Murphy KJ, Prince MR, Brunberg JA. 3D gadolinium-enhanced MR angiography of the carotid arteries. Magn Reson Imaging 1996; 14:593-600
9. Serfaty JM, Chirossel P, Chevallier JM, Ecochard R, Froment JC, Douek PC. Accuracy of three-dimensional gadolinium-enhanced MR angiography in the assessment of extracranial carotid artery disease. AJR 2000; 175:455-463
10. Cloft HJ, Kallmes DF. Gadolinium-enhanced MR angiography for carotid artery disease. AJR 1999; 172:833-834
11. Korosec FR, Turski PA, Carroll TJ, Mistretta CA, Grist TM. Contrast-enhanced MR angiography of the carotid bifurcation. J Magn Reson Imaging 1999; 10:317-325
12. Jeong HJ, Cashen TA, Hurley MC, Eddleman C, Getch C, Batjer HH, Carroll TJ. Radial sliding-window magnetic resonance angiography (MRA) with highly-constrained projection reconstruction (HYPR). Magnetic Resonance in Medicine 2009; 61:1103-1113
13. Steffens JC, Link J, Heller M. Contrast-enhanced magnetic resonance angiography of the cervical arteries. Invest Radiol 1998; 33:573-577
14. Krinsky G, Maya M, Rofsky N, et al. Gadolinium-enhanced 3D MRA of the aortic arch vessels in the detection of atherosclerotic cerebrovascular occlusive disease. J Comput Assist Tomogr 1998; 22:167-178
15. The (NASCET) North American Symptomatic Carotid Endarterectomy Trial Steering Committee. North American Symptomatic Carotid Endarterectomy Trial. Methods, patient characteristics and progress. Stroke 1991; 22:711-720

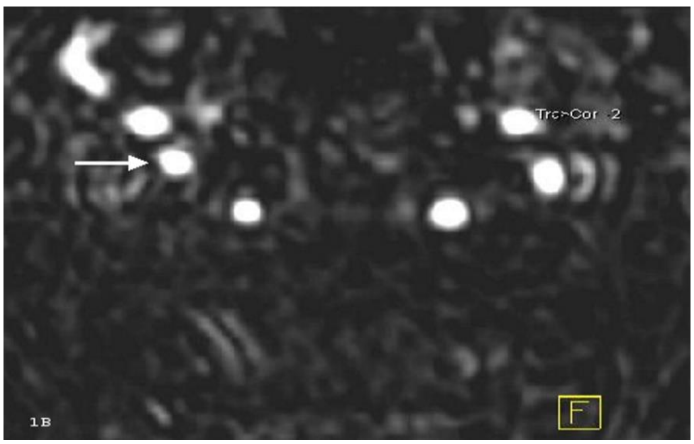
16. Borisch I, Horn M, Butz B, et al. Preoperative evaluation of carotid artery stenosis: Comparison of contrast-enhanced MR angiography and duplex sonography with digital subtraction angiography. AJNR 2003; 24:1117-1122
17. Qureshi AI, Suri MFK, Ali Z, et al. Role of conventional angiography in evaluation of patients with carotid artery stenosis demonstrated by doppler ultrasound in general practice. Stroke 2001; 32:2287-2291
18. Mattle HP, Kent KC, Edelman RR, Atkinson DJ, Skillman JJ. Evaluation of the extracranial carotid arteries: correlation of magnetic resonance angiography, duplex ultrasonography, and conventional angiography. J Vasc Surg 1991; 13:838-845
19. Turnipseed WD, Kennell TW, Turski PA, Acher CW, Hoch JR. Combined use of duplex imaging and magnetic resonance angiography for evaluation of patients with symptomatic ipsilateral high-grade carotid stenosis. J Vasc Surg 1993; 17:832-840
20. Riles TS, Eidelman EM, Litt AW, Pinto RS, Oldford F, Schwartzenberg GW. Comparison of magnetic resonance angiography, conventional angiography, and duplex imaging. Stroke 1992; 23:341-346
21. Pan XM, Saloner D, Reilly LM, et al. Assessment of carotid artery stenosis by ultrasonography, conventional angiography, and magnetic resonance angiography: correlation with ex vivo measurement of plaque stenosis. J Vasc Surg 1995;21:82-89
22. Leclerc X, Martinat P, Godefroy O, et al. Contrast-enhanced three-dimensional fast imaging with steady-state precession (FISP) MR angiography of supraaortic vessels:preliminary results. AJNR 1998; 19:1405-1413
23. Slosman F, Stolpen AH, Lexa FJ, et al. Extracranial atherosclerotic carotid artery disease: evaluation of non-breath hold three-dimensional gadolinium-enhanced MR angiography. AJR 1998; 170:489-495
24. Scarabino T, Carriero A, Magarelli N, et al. MR angiography in carotid stenosis: a comparison of three techniques. Eur J Radiol 1998; 28:117-125
25. Sundgren PC, Sunden P, Lingren A, Lanke J, Holtas S, Larsson EM. Carotid artery stenosis: contrast-enhanced MR angiography with two different scan times compared with digital subtraction angiography. Neuroradiology 2002; 44:592-599
26. Jäger HR, Moore EA, Bynevelt M, et al. Contrast-enhanced MR angiography in patients with carotid artery stenosis: comparison of two different techniques with an unenhanced 2D time-of-flight sequence. Neuroradiology 2000; 42:240-248
27. Kim JK, Farb RI, Wright GA. Test bolus examination in the carotid artery at dynamic gadolinium-enhanced MR angiography. Radiology 1998; 206:283-289
28. Remonda L, Senn P, Barth A, et al. Contrast-enhanced 3D MR angiography of the carotid artery: Comparison with conventional digital subtraction angiography. AJNR 2002; 23:213-219.

List of Figures

Figure 1



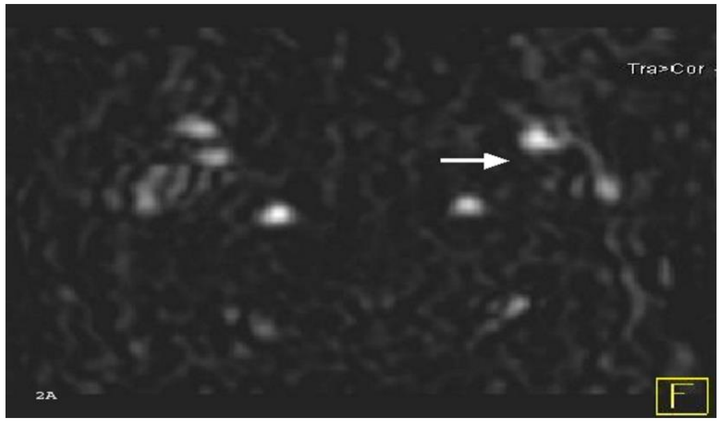
(A) Axial MPR CE MRA image demonstrates very small caliber of the origin of right internal carotid artery suggesting severe stenosis (arrow).

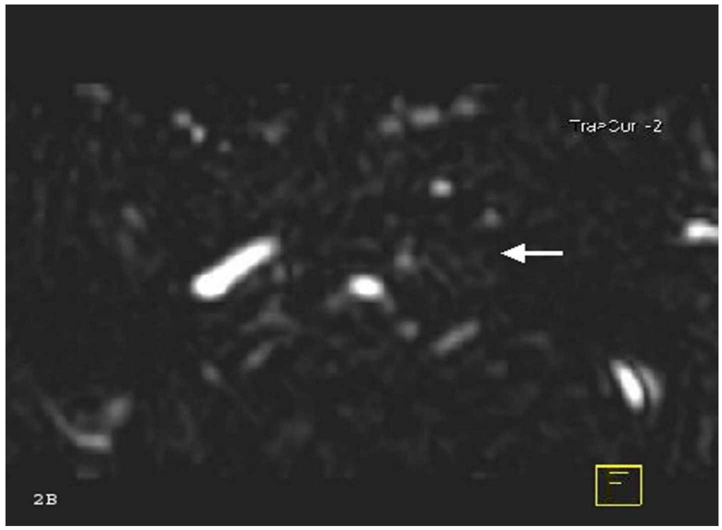


(B) Axial MPR CE MRA image reveals normal caliber of right internal carotid artery distal to stenosis (arrow).

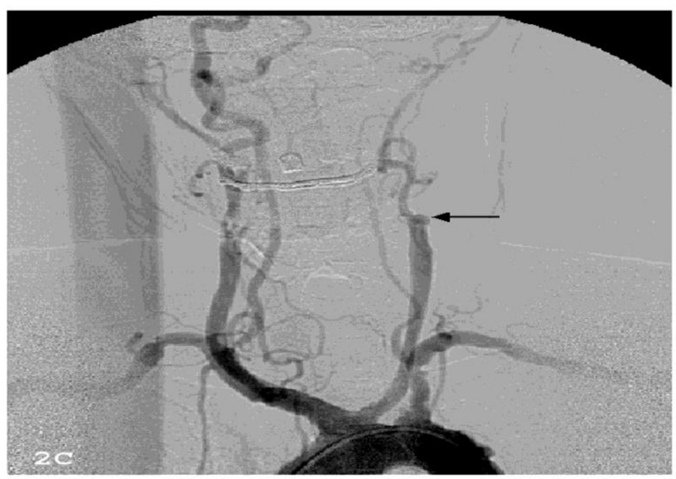
(C) Lateral projection right common carotid DSA image confirms severe stenosis at the origin of right internal carotid artery secondary to large plaque on the posterior wall (arrow).

Figure 2



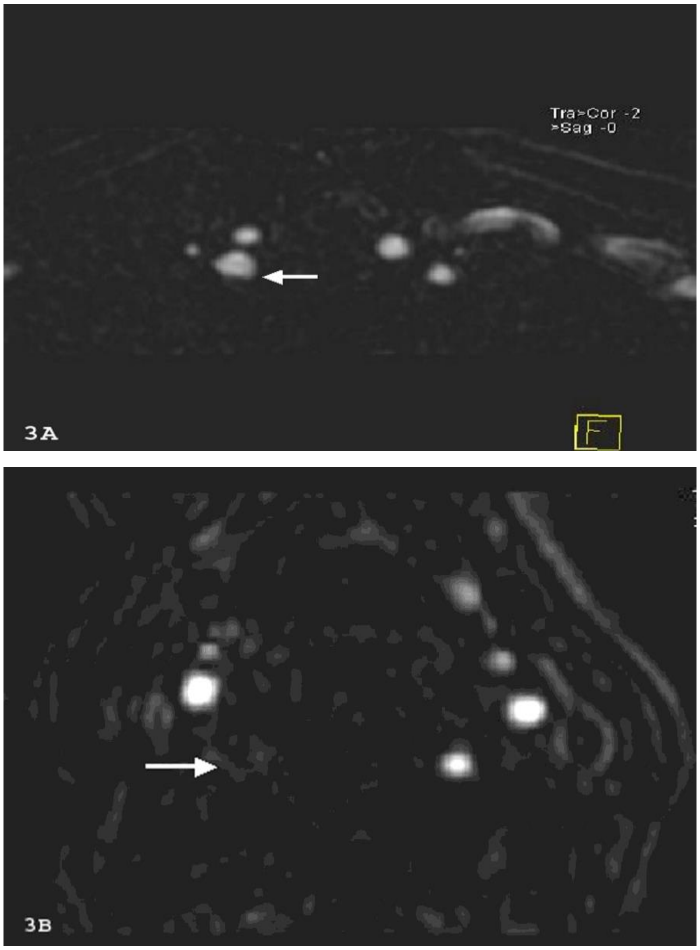


Axial MPR CE MRA images at the origin **(A)** and petrous segment levels **(B)** of left internal carotid artery demonstrate no visible left internal carotid artery suggesting occlusion (arrows).

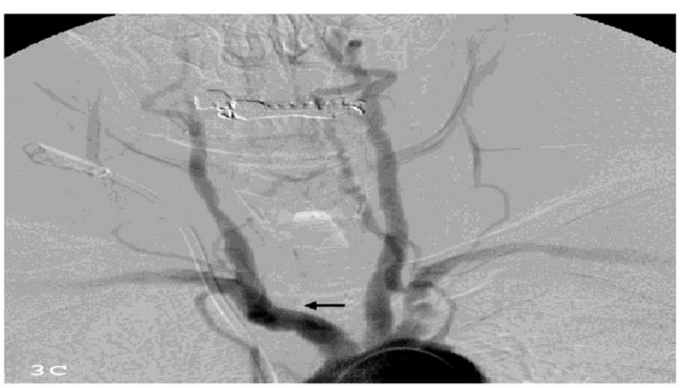


(C) Left anterior oblique arch aortogram confirms occlusion of left internal carotid artery from its origin (arrow). Marked atherosclerotic plaques throughout subclavian arteries and aortic arch are also noted

Figure 3



Axial MPR CE MRA images at the origin **(A)** and distal cervical levels **(B)** of right vertebral artery demonstrate no visible right vertebral artery suggesting occlusion (arrows).



(C) Left anterior oblique arch aortogram confirms occlusion of right vertebral artery from its origin (arrow). Marked atherosclerotic plaques throughout left subclavian artery are also noted.

Table 1: Comparison between axial multiplanar reconstruction MR angiography (MPR MRA) and digital subtraction angiography (DSA) in evaluation of common carotid arteries (CCA)

Axial MPR CE MRA (CCA)	DSA (CCA)					
	Normal	**Mild**	**Moderate**	**Severe**	**Occlusion**	**Total**
Normal	7	-	8	-	-	15
Mild	-	32	2	1	-	35
Moderate	2	-	5	-	-	7
Severe	-	1	-	-	-	1
Occlusion	-	-	-	-	2	2
Total	9	33	15	1	2	60

Sensitivity: 78%; Specificity: 70%; Accuracy: 77%

Table 2: : Comparison between axial MPR MRA and DSA in evaluation of internal carotid arteries (ICA)

Axial MPR CE MRA (ICA)	DSA (ICA)					
	Normal	**Mild**	**Moderate**	**Severe**	**Occlusion**	**Total**
Normal	1	1	17	1	-	20
Mild	-	26	3	1	-	30
Moderate	1	-	9	3	-	13
Severe	-	-	1	2	-	3
Occlusion	-	-	-	-	3	3
Total	2	27	30	7	3	69

Sensitivity: 62%; Specificity: 50%; Accuracy: 61%

Table 3: : Comparison between axial MPR MRA and DSA in evaluation of vertebral arteries (VA).

Axial MPR CE MRA (VA)	**DSA (VA)**					
	Normal	**Mild**	**Moderate**	**Severe**	**Occlusion**	**Total**
Normal	3	-	15	1	-	19
Mild	-	6	2	-	-	8
Moderate	1	-	11	3	-	15
Severe	-	1	-	2	-	3
Occlusion	-	-	-	-	2	2
Total	4	7	28	6	2	47

Sensitivity: 50%; Specificity: 60%; Accuracy: 51%

Table 4: : Comparison between axial MPR MRA and DSA in evaluation of subclavian arteries (SA).

Axial MPR CE MRA (SA)	**DSA (SA)**					
	Normal	**Mild**	**Moderate**	**Severe**	**Occlusion**	**Total**
Normal	10	-	6	-	-	16
Mild	-	22	1	-	-	23
Moderate	-	-	2	1	-	3
Severe	-	-	-	-	-	-
Occlusion	-	-	-	-	-	-
Total	10	22	9	1	-	42

Sensitivity: 75%; Specificity: 100%; Accuracy: 81%