# DUPLEX COLOR DOPPLER EVALUATION OF CAROTID ATHEROSCLEROSIS IN PATIENT WITH SILENT CEREBRAL INFARCTION DETECTED BY MRI

KABIR K[1], QUDDUS MA[2], HAQUE R[3], RAHMAN M[4], NABI S[5], RAHMAN K[6], AHMED S[7], BHOWMIK B[8]

**Abstract:**

***Background****: Silent cerebral infarction (SCI) detected incidentally by MRI is considered the preliminary stage of accidental stroke and assumed to be secondary to atherosclerotic vascular disease (ASVD).The Duplex Color Doppler study is the initial screening non-invasive modality to identify carotid atherosclerotic changes and is the best approach for preoperative carotid artery evaluation in asymptomatic patients who can be expected to benefit of reduced risk of stroke in future. This cross- sectional study was carried out to assess the diagnostic usefulness of Duplex Color Doppler sonography in the evaluation of asymptomatic carotid atherosclerosis in prediction of silent cerebral infarction. Nature of extracranial carotid plaque and degree of luminal stenosis were compared & associated with MRI findings and risk factors of silent cerebral infarction.*

***Method:*** *This cross sectional study was carried out in the Radiology & Imaging Department of Dhaka Medical College Hospital during the period of July 2009 to June 2011 on 70 adult subjects of both sexes aged ≥50 years. Clinically suspected patients of silent cerebral infarction referred to Radiology & Imaging department of DMCH from OPD and Indoor Patient department underwent MRI of brain and among them those diagnosed as having Lacunar infarcts (Silent Cerebral Infarction) underwent Extra-cranial Carotid Duplex Color Doppler examination on both sides. Carotid lesions were evaluated by plaque score, maximum percent stenosis and the existence of ulcerated lesions. The relations between the carotid lesions and the incidence, size or localization of the brain lesions were investigated.*

***Results:*** *The incidence of SCI increases with age & more prevalent in male (P<0.05).Most SCI lesions were <1cm in size, single in number and is more prevalent in basal ganglia region (P<0.05) than subcortical white matter of right cerebral hemisphere (P<0.05) associated with ipsilateral high grade carotid stenosis & ulcerated plaque. The percentage of subjects with infarcts increased significantly as the plaque score increased (P<0.001) or subjects had high grade stenosis (P<0.001). The presence of pre-existing risk factors like HTN, DM, IHD, and Dyslipidaemia showed significant correlation with plaque score and SCI of brain.*

***Conclusion:*** *Both the severity and characteristics of asymptomatic carotid lesions estimated by Duplex color Doppler study were closely related to the appearance of silent infarcts.These results demonstrate that noninvasive assessment of carotid lesions can be useful in predicting the existence of silent cerebral infarction even in patients free from neurological deficits.*

***Key words:*** *Carotid atherosclerosis, silent cerebral infarction, magnetic resonance imaging, duplex color Doppler.*

*J Dhaka Med Coll. 2013; 22(1) : 19-25.*

## Introduction:

Stroke secondary to atherosclerosis is the leading cause of disability worldwide and third among the leading causes of death in the West. Even in a developing country like Bangladesh it still ranks among the top five causes of mortality. Carotid artery disease (CAD) is responsible for one third of all ischemic strokes. A third of these patients die, another third are permanently disabled. Thus the management of carotid artery disease is undergoing thorough scientific evaluation. 80% of strokes

1. Dr. Kaniza Kabir, Assistant Professor, Department of Radiology & Imaging, Enam Medical College, Savar, Dhaka.
2. Prof. M.A.Quddus, Head, Department of Radiology & Imaging, Ad-Din Medical College, Dhaka.
3. Dr. Rashimul Haque, Assistant Professor, Department of Neurology, Uttara Adhunik Medical College, Dhaka.
4. Dr.Mizanur Rahman, Assistant Professor, Department of Radiology & Imaging, Dhaka Medical College, Dhaka.
5. Dr. Shahryar Nabi, Assistant Professor, Department of Radiology & Imaging, Dhaka Medical College, Dhaka.
6. Dr.Khalilur Rahman, Assistant Professor, Department of Radiology & Imaging, Dhaka Medical College, Dhaka.
7. Dr.Shamim Ahmed, Assistant Professor, Department of Radiology & Imaging, Dhaka Medical College, Dhaka.
8. Dr. Bishwajit Bhowmik, Assistant Professor, Department of Radiology & Imaging, BSMMU, Dhaka.

**Correspondence:** Dr. Kaniza Kabir, Assistant Professor, Department of Radiology & Imaging, Enam Medical College, Savar, Dhaka. E-mail:kanizakabir@yahoo.com

are thromboembolic in origin often carotid plaque as the embolic source.[1, 2]

Asymptomatic lacunar infarction or silent cerebral infarction (SCI) detected incidentally by MRI of brain are frequently demonstrated in the subcortical white matter or basal ganglia in patients who demonstrate no localized neurological symptoms of stroke or TIA. Silent cerebral infarction (SCI) is considered the preliminary stage of accidental stroke and assumed to be secondary to atherosclerotic vascular disease (ASVD). The size of SCI lesions are generally too small to be confirmed on CT, MRI is diagnostically superior to CT for diagnosing small cortical and brainstem lacunar infarcts with almost 80% infarcts being detected in 1st few hours.[3,4,5,6]

Duplex Color Doppler sonography combining high resolution B-mode imaging, Color flow and spectral analysis has proved to be popular, non-invasive, accurate and cost effective means of detecting and assessing carotid atherosclerosis and is the best approach for preoperative carotid artery evaluation in asymptomatic patients who can be expected to benefit of reduced risk of stroke in future.[7,8]

By high resolution B-mode, minimal plaque formation may be detected by measuring the total intima- medial thickness (IMT) which is up to 0.8mm is normal. A measurement greater than 1.2mm indicates the presence of plaque. Color flow identifies any flow channel narrowing, turbulence and high velocity at stenotic segment can differentiate occlusive from preclusive lesion of vessel. By spectral tracing helps in assessing velocity of blood flow and carotid stenosis which is more reliable for stenosis above 50%-60%. Image directed grading of stenosis is reliable in less than 50%. Thus Duplex Color Doppler sonography has largely replaced angiography for suspected extra cranial carotid atherosclerosis.[9, 10]

There have been extensive works in the developed countries regarding the role of Duplex Color Doppler study as an initial screening modality for evaluation of carotid atherosclerosis with silent cerebral infarction of brain detected at MRI. But no works has been done in our country in such regard. Hence this study was designed to evaluate carotid atherosclerosis by Duplex Color Doppler sonographic imaging in patients with Silent cerebral infarction (SCI) of brain detected at MRI.

**Materials and Methods:**

A total of 70 patients aged ≥50 years were selected in this cross sectional study. Clinically suspected patients of silent cerebral infarction referred to Radiology & Imaging department of DMCH from OPD and Indoor Patient department underwent MRI of brain and among them those diagnosed as having Lacunar infarcts (Silent Cerebral Infarction) were included in this study and patients with stroke even TIA or with neurological deficit and cardioembolic risk factors and Patients refused to go for Duplex Color Doppler study and MRI were excluded from the study. All included patients underwent Extra-cranial Carotid Duplex Color Doppler examination from July 2009 to June 2011 in the department of Radiology and Imaging, DMCH. Plaque sonomorphology and percentage of extra-cranial carotid stenosis were recorded on both left and right sides and associated with MRI findings of brain and risk factors of silent cerebral infarction. . The clinical diagnosis of Hypertension, IHD, Dyslipidaemia, Diabetes Mellitus and smoking was considered present if the medical record substantiated it.

Silent cerebral infarction (SCI) was evaluated with a 0.3 tesla MRI machine (HITACHI AIRIS II).SCI was defined exclusively as a low signal intensity area (≥ 3mm but all were d" 15 mm in size) depicted on T1W images with corresponding hyper-intensity in T2WI. The diagnosis was made when a lesion was surrounded by a hyperintense gliotic rim in FLAIR sequences to exclude peri-vascular space. Number, size and localization of lesions in each subject will be recorded.

Duplex study was performed with standard US machine (Siemens Sonoline, G60S) by using 5-7.5 MHz linear probe according to the physical built of the patient.The severity of carotid atherosclerosis in each patient was evaluated by using three indexes –

**1**. **Plaque score assessment**- is computed by summing the maximum axial plaque thickness in millimeter on the near and far

wall of each four divisions of both sides of the carotid arteries. Subjects will be classified into three groups according to the plaque score-Mild -1.1 to 5.0 mm, Moderate -5.1 to 10.0 mm & Severe-> 10 mm.

**2. Maximum percent stenosis assessment**-by

i. Color flow,

ii. Image guided grading of stenosis by diameter reduction or area reduction. The outer measurement is taken from the original diameter which is measured as a distance between estimated luminal edge of both near and far wall intima and residual diameter excluding the plaque. Vessels are grouped into two according to the present stenosis :

- Low grade stenosis – Maximum percent stenosis <50%
- High grade stenosis – ≥ 50%

**3. Evaluation of ulcerated lesion** -Large obvious excavations or multiple cavities or cavernous vessel with color flow within

To analyze the results, unpaired't' test, chi-square test, Z-test and correlation test were done.

**Results:**

The mean±SD age of the study 70 patients were 66.4±9.5 years and ranged from 50-89 years. They were divided into five age groups and the highest incidence was between 70-79 years of age. [Fig-1] Among the 70 patients 47(67.1%) were males and 23(32.9%) were females. This difference was significant (p<0.05). [Fig-2]

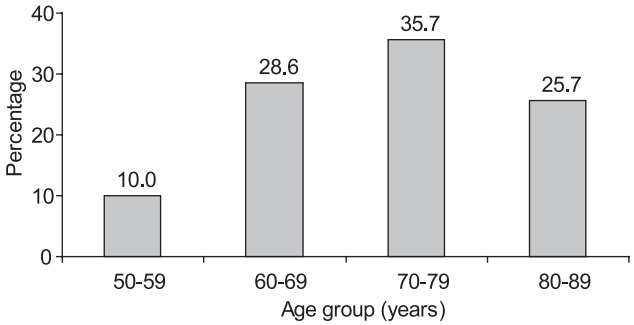



**Fig.-1:** *Bar diagram showing the age distribution of the study patients*

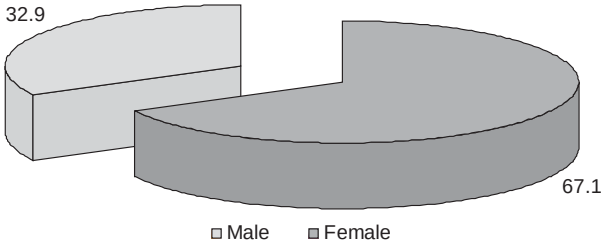



**Fig 2:** *Sex distribution of the study patients. Z value = 2.82; p <0.05.*

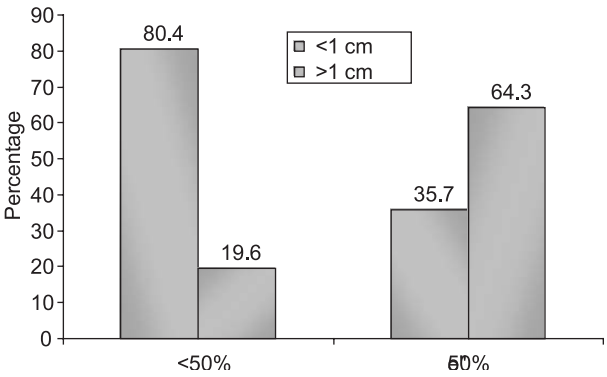
Considering presenting complaints 50(71.4%) had vertigo, 39(55.7%) had headache, 37(51.4%) had dizziness and 22(31.4%) had light headedness.

Regarding associated risk factors 65(92.9%) were hypertensive, 60(85.7%) were diabetic, 30(42.9%) had IHD, 55(78.6%) had dyslipidaemia & 44(62.9%) were smokers.

In MRI of brain SCI were found most commonly in the basal ganglia regions 42(60.0%) & least commonly 28(40.0%) in subcortical white matter region. This difference was significant (p<0.05).

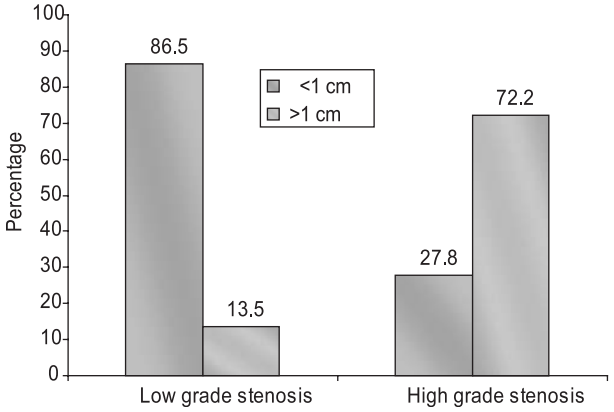
In MRI of brain size of SCI were <1 cm in 50(71.4%) patients and >1 cm were in 20(28.6%) patients. Significant association (p<0.002) & (p<0.001) were found for ≥50% RICA and LICA stenosis respectively for ipsilateral > 1 cm SCI in brain. [Fig-3 & 4]

In MRI in brain single SCI were in 51(72.9%) and ≥2 SCI were in 19(27.1%). Significant association (p<0.008) and (p<0.001) were found




*Chi value =10.94, df=1, p=0.001, P value reached from chi square test.*

**Fig 3:** *Bar diagram showing the association between size of SCI and ipsilateral carotid stenosis in RCCA*



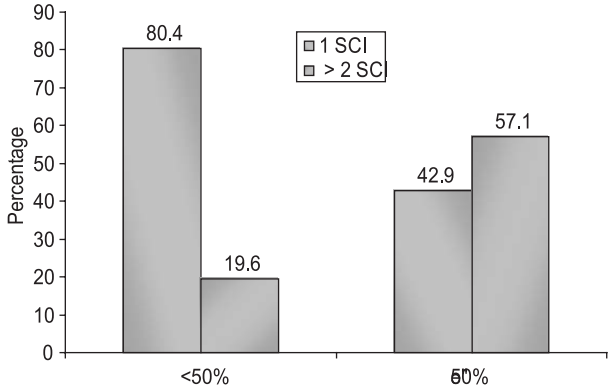

*Chi value =22.62, df=1, p=0.001, P value reached from chi square test.*

**Fig 4:** *Bar diagram showing the association between size of SCI and ipsilateral carotid stenosis in LCCA.*

for ≥50% RICA and LICA stenosis respectively for ipsilateral ≥2 SCI in brain. [Fig-5 & 6]

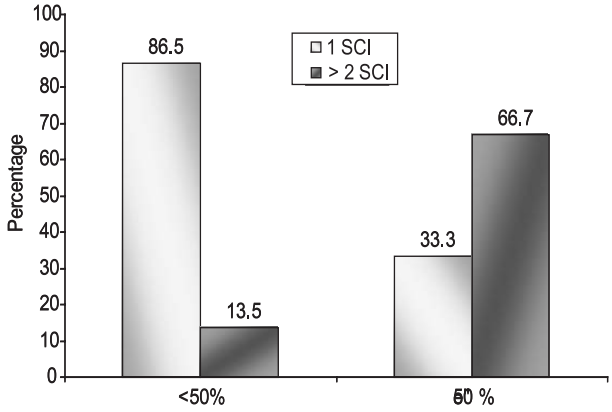
In MRI of brain involvement of RCH was in 42(60.0%) and 28(40.0%) in LCH. The difference was significant (p<0.05). Duplex color Doppler USG showed ipsilateral right carotid involvement in 42(60.0%) and ipsilateral left carotid involvement 28(40.0%).

The study 70 patients were divided into three groups according to plaque score. 13(31.0%) was mild, 22(52.4%) moderate and 7(16.0%) sever in RCCA. In LCCA all patients were in mild grading. Plaque score was 6.2±2.5 mm ranged 2.4-10.3 mm and 2.0±0.4 mm ranged 1.2-2.8 mm in RCCA and LCCA respectively. The difference of plaque score between RCCA and LCCA was significant (p<0.001). [Table-I]




*Chi value =7.96, df=1, p=0.008, P value reached from chi square test.*

**Fig 5:** *Bar diagram showing the association between number of SCI and ipsilateral carotid stenosis in RCCA*




*Chi value =19.14, df=1, p=0.001, P value reached from chi square test.*

**Fig 6:** *Bar diagram showing the association between number of SCI and ipsilateral carotid stenosis in LCCA.*

**Table I**

*Distribution of the patients according to plaque score in RCCA and LCCA (n=70)*

| Plaque score (mm) Grading | RCCA (n=42) | | LCCA (n=28) | | p value |
|---|---|---|---|---|---|
| | n | % | n | % | |
| Mild | 13 | 31.0 | 28 | 100.0 | |
| Moderate | 22 | 52.4 | 0 | 0.0 | |
| Sever | 7 | 16.7 | 0 | 0.0 | |
| Plaque score (mm) | | | | | |
| Mean SD | 6.2 | 2.5 | 2.0 | 0.4 | 0.001 |
| Range (min - max) | (2.4 | -10.3) | (1.2 | -2.8) | |

t- value =8.94, df=68, p value =0.001

**Plaque score (mm) grading**

Mild: 1.1-5.0
Moderate: 5.1-10.0
Severe: >10

**Table II**

*Distribution of the patients according to percent stenosis of carotid arteries in SCI patients (n=70)*

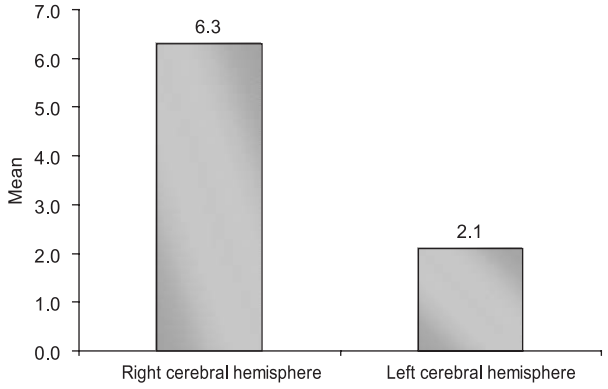
| Percent stenosis of carotid | RCCA RICA & Bulb(n=70) | | LCCA LICA & Bulb (n=70) | | P value |
|---|---|---|---|---|---|
| | n | % | n | % | |
| Low grade stenosis <50% | 56 | 80.0 | 52 | 74.3 | 0.420$^{ns}$ |
| High grade stenosis ≥50% | 14 | 20.0 | 18 | 25.7 | |

Chi value =0.648, df=1, p value =0.420, P value reached from Chi square test.

Study patients were divided also into two groups according to percent stenosis of carotid. 56(80.0%) and 52(74.3%) in <50% low grade stenosis in RCCA and LCCA respectively. ≥50% high grade stenosis was found 14(20.0%) and 18(25.7%) in RCCA and LCCA respectively. [Table-II]

Plaque ulcer was present in 15(21.4%) and was absent in 55(78.6%).

The RCCA plaque score 6.3±2.5 mm ranged 2.4-10.4 mm for SCI in RCH. The LCCA plaque score was 2.1±0.8 mm ranged 1.2-5.5 mm for SCI in LCH. Significantly higher (p<0.001) RCCA plaque was found for RCH SCI. [Fig-7]




*t value =8.583, df=68, p=0.001, P value reached from unpaired t-test.*

**Fig 7:** *Bar diagram showing the mean plaque score with SCI of the study patients.*

A positive correlation (r=0.83) was found between carotid plaque score and age of SCI patients. [Fig-8]

Carotid plaque score in males were 5.8±2.6 mm (mean±SD) found significantly higher (p<0.001) than plaque score 1.9±0.4 mm (mean±SD) in females.

Positive correlation was found between age and plaque score of hypertensive(r=0.8748), diabetic (r=0.8829), IHD (r=0.8997) & dyslipidaemia (r=0.8458) patients.

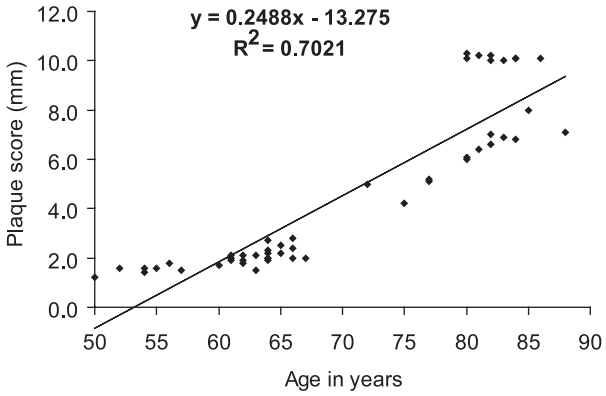



**Fig 8:** *The Scatter diagram shows positive correlation (r=0.838) between plaque score and age in patient with silent cerebral infraction.*

**Discussion:**

In the present study it was found that elderly male hypertensive patients frequently had SCI lesions in brain. this suggests that the progression of arteriosclerotic change in the brain was paralleled by systemic atherosclerosis and conversely that assessment of systemic atherosclerosis could predict latent damage to the brain, almost similar findings reported by various investigators from different countries.[3,4,5,11,12,13,14]

The characteristics of SCI lesions were similar to the results of other studies.[13,15,16,17]that is,

they were usually smaller than 1cm,were mostly in the basal ganglia (P<0.01) and had a higher incidence in right cerebral hemisphere (P<0.05) signified non-dominant hemisphere predominance for SCI.

The appearance of SCI was closely associated with the severity of plaque score and high grade stenosis of right internal carotid artery with sever plaque score had significant (P<0.001) direct hemodynamic influence on the ipsilateral right cerebral hemisphere lesions. Significant association (P<0.008) and (P<0.001) for ipsilateral ≥2 SCI is found in ipsilateral ≥50% right internal carotid artery and left internal carotid artery stenosis respectively. These findings were consistent with the findings of some other investigators.[12, 13, 17,18,19,20] although the possibility of embolic events from these lesions could not be wholly excluded because vessels with high grade stenosis showed combined ulcerated lesions. Significant association (P<0.002) and (P<0.001) were found for ≥50% right internal carotid artery and left internal carotid artery stenosis respectively for ipsilateral >1cm SCI in brain.

Regarding risk factors, the percentage of subjects with SCI increased as the number of risk factors in each subjects increased. Positive correlation was found between age and plaque score of hypertensive (r=0.8748), diabetic (r=0.8829), IHD (r=0.8997) and dyslipidaemic (r=0.8458) patients. Similar type of findings were also observed by other investigators.[3-5,12-15,21] age, hypertension and plaque score strongly and independently correlated with the occurrence of SCI of brain, compatible with results of other studies.[22,23,24]

**Conclusion**

Silent cerebral infarction (SCI) detected incidentally by MRI is considered the preliminary stage of accidental stroke and assumed to be secondary to atherosclerotic vascular disease (ASVD). Investigating its clinicopathology may elucidate the underlying mechanism of stroke onset and help to prevent this disabling disease. In the present study it was found that number and size of SCI is more prevalent in basal ganglia region of right cerebral hemisphere associated with ipsilateral high grade carotid stenosis and ulcerated plaque. The incidence of SCI increases with age and more prevalent in male in the presence of pre-existing risk factors like HTN, DM, IHD, Dyslipidaemia, smoking, high carotid plaque score and stenosis evaluated by Duplex color Doppler study which is the initial screening non-invasive modality to identify carotid atherosclerotic changes and is the best approach for pre-operative carotid artery evaluation in asymptomatic patients who can be expected to benefit of reduced risk of stroke in future.

**References:**


1. Desai SB, Ghodke BV, Maheshwari S. Carotid artery disease: role of angioplasty and stenting. Kodak 2000: 22-7.
2. Chaubal N, Padwal M. Carotid Doppler .Kodak 2000: 4-15.
3. Eguchi k, Kario K, Shimada K. Greater impact of coexistence of Hypertension and Diabetes on Silent Cerebral infarcts. Stroke 2003; 34: 2471-4.
4. Vermeer SE, Heijer TD, Koudstaal PJ, Oudkerk M,Hoffman A, Breteler MB. Incidence and risk factors of silent brain infarcts in the population-based Rotterdam scan study. Stroke 2003; 34: 392-396.
5. Uehera T,Tabuchi M,Mori E. Risk factors for silent cerebral infarcts in subcortical white matter and basal ganglia. Stroke 1999; 30: 378-82.
6. Rothrock JF, Lyden PD, Hesselink JR, Brown JJ, Healy ME. Brain magnetic resonance imaging in the evaluation of lacunar stroke. Stroke 1987; 18: 781-6.
7. Carrol BA. Carotid sonography. Radiology 1991; 178(2): 303-13.
8. Adaikappan M, Sampath r, Felix AJW, Sethupathy S. Evaluation of carotid atherosclerosisby B-mode ultrasonographic study in hypertensive patients compared with normotensive patient. Ind. J Radiol Imag 2002; 12(3): 365-8.
9. Zwiebel wj. Ultrasound Assessment of Carotid Plaque. In: Introduction to Vascular Ultrasonography.5th edn.WB Saunders Philadelphia, USA; 2000: 155-66.
10. Khandelwal N, Chowdhury V, Gupta AK. Imaging and Interventions in Cerebral Ischemia. In: Diagnostic Radiology Neuroradiology Including Head and Neck Imging.3rd edn. Gaikwad SB, Jaypee Brothers, New Delhi; 2010: 87-106.

11. Romero JR, Beiser A, Polak JF, Vasan RS, Wolf PA. Carotid artery atherosclerosis, MRI indices of brain ischaemia, aging and coqnitive impairment. Stroke 2009; 40:1590-6.

12. Hougaku H,Matsumoto M,Handa N,Maeda H,Itoh T,Tsukamoto Y,Kamada T. Asymptomatic carotid lesions and silent cerebral infarction. Stroke 1994; 25: 566-70.

13. Brott T, Tomsick T, Biller J, Kelly M, Frey J. Baseline silent cerebral infarction in the asymptomatic carotid atherosclerosis study. Stroke 1994; 25: 1122-9.

14. Cupini LM, Diomedi M, Rizzato B, Bernardi G. Carotid artery intima media thickness and lacunar versus nonlacunar infarcts.Stroke 2003; 33: 689-94.

15. Wardlaw JM. What causes lacunar stroke. Stroke 2003; 34: 806-12.

16. Furuta A, Ishii N, Horie A. Medullary arteries in aging and dementia. Stroke 1991; 22: 442-6.

17. Norris JW, Zhu CZ. Silent stroke and carotid stenosis. Stroke 1992; 23: 483-5.

18. Tejada J, Balbo O, Tajedor D. The fall and rise of lacunar infarction with carotid stenosis. Stroke 2003; 34: 1404-11.

19. Handa N, Matsumoto M, Kamada T. Ultrasonic assessment of carotid lesion. Stroke 1993; 25:1247-51.

20. Rothrock JF, Lyden PD, Hesselink JR, Brown JJ, Healy ME. Brain magnetic resonance imaging in the evaluation of lacunar stroke. Stroke 1198; 78: 781-6.

21. Polak JF, Kronmal RA, Manolio TA, O'Leary DH. Carotid artery intima and media thickness as risk factors for MI and stroke in older adults. N Eng J Med 1999; 340: 14-22.

22. Okada K, Kobayashi S, Yamashita K. Incidence of silent lacunar lesion in normal adults and its relation to cerebral blood flow and risk factors. Stroke 1991; 22:1379-83.

23. Inzitari D, Peter G, Brenda BS, Chan R. The causes and risk of stroke in patients with asymptomatic internal carotid artery. N Eng J Med 2000; 342:1693-700.

24. Nomura K, Yoshiyuki H,Takahara S,Kikuchi O, Honjo S. Relationship between carotid intima-media thickness and silent cerebral infarction in Japanese subjects with type 2 diabetes. Stroke 2010; 33:168-70.