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Efficacy of Duplex Ultrasound for the Evaluation of Carotid Artery Stenosis in Comparison to Digital Subtraction Angiogram

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Abstract:

Background: *Carotid artery stenosis is one of the important causes of ischemic stroke. This is responsible for 10% of all ischemic stroke events. This may be diagnosed as duplex Ultrasound (USD) and DSA both of which have some advantages and disadvantages.* ***Objective:*** *The aim of this study was to assess efficacy of duplex USD for the evaluation of extra-cranial carotid artery stenosis among patients of ischemic stroke and Transient Ischemic Attack (TIA) in comparison to (DSA).* ***Materials and Methods:*** *This observational cross sectional study was conducted among 50 patients in the Dept of Neurology in BSMMU and National Institute of Nuclear Medicine and Allied Sciences (NINMAS), BSMMU campus, Dhaka. Duplex USD of neck vessels of all cases were performed and reported by selected specialist of (NINMAS). Patients were also referred to cathlab of BSMMU for DSA performed by two interventional neurologists blinded of USD finding. Diagnostic performance test was done between duplex USD and DSA at e" 50%, e" 70%, 100% cut off point of stenosis of right internal carotid artery (RICA) and left internal carotid artery (LICA).* ***Results:*** *This study showed that in RICA for e" 50%, e" 70% and 100% stenosis sensitivity were 82%, 89% and 93% respectively. In LICA for e" 50%, e" 70% and 100% stenosis sensitivity were 82%, 91%, 95% respectively. The study revealed that in RICA for e" 50%, e" 70% and 100% stenosis specificity were 86%, 83% and 80% respectively. In LICA for e" 50%, e" 70% and 100% stenosis specificity were 85.2%, 93%, 86% respectively. The present study also showed that in RICA for e" 50%, e" 70% and 100% stenosis efficacy were 84%, 88% and 92% respectively. In LICA for 70% and 100% stenosis efficacy were 88%, 92%, 94% respectively.* ***Conclusion:*** *In present study the sensitivity, specificity and efficacy of duplex USD is high at different degree of cut off point of carotid stenosis keeping DSA as standard. Results of this study are also matched with other similar type of studies done abroad.*

Key Words: *Stroke, Digital Subtraction Angiogram (DSA), Duplex Ultrasound, Internal Carotid Artery.*

Introduction

Stroke stands second among the leading causes of death in the developed world[1]. Even in Bangladesh, stroke is a significant cause of mortality, morbidity and disability[2]. About 85% of stroke is ischemic stroke (infarct) and 15% is hemorrhagic stroke. There are many risk factors for ischemic stroke. Atheromatous carotid artery stenosis is one of the important causes of ischemic stroke. This is responsible for 10% of all ischemic strokes events[3].

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Atheroma may cause transient ischemic attacks (TIAs) and ischemic stroke as it obstructs the blood stream to the brain or generates emboli that obstruct the cerebral arteries. The first part of internal carotid artery immediately beyond the bifurcation is the most frequently involved anatomical site of stenosis in carotid system. Carotid artery stenosis may be diagnosed by various investigations like duplex USD, CT-angiogram, Magnetic resonance angiogram (MRA) but DSA is thought to be gold standard. Carotid artery stenosis has different treatment options like medical, surgical, interventional measures according to different clinical settings. Medical treatment includes - use of statin agent, aspirin, control of HTN, good glycemic control and cessation of smoking whereas surgical option is carotid end- arterectomy or stenting.

Ability to accurately assess the degree of carotid artery stenosis and its importance for management of ischemic stroke and TIA has become significant with studies like NASCET[4] (North American symptomatic carotid end arterectomy, ECST[5] (European carotid surgery trial. ACAS[6] (Asymptomatic carotid atherosclerosis study), ACST[7] (Asymptomatic carotid surgery trial).

Symptomatic Carotid stenosis was studied in the NASCET[4] and ECST[5] trial. Both showed a substantial benefit for surgery in patients with a stenosis >70%. In 659 patients with 70% to 90% stenosis randomized by NASCET[4] study the cumulative risk of any ipsilateral stroke at 2 years was 26% in medically treated patients and 9% in surgically treated patients. NASCET[4] study also showed a significant, although less robust benefit for patient with 50%-70% stenosis.

The indication for surgical treatment of asymptomatic carotid disease have been clarified by the results of the study of ACAS[6] and ACST[7]. ACAS[6] study randomized asymptomatic patients with >60% stenosis to medical treatment with aspirin or the same medical treatment plus carotid end- arterectomy. The surgical group had a risk over five years for ipsilateral stroke of 5.1% compared to a risk in the medical group of 11%. In both ACAS[6] and ACST[7] study the perioperative complication rate was higher in women, perhaps negating any benefit in the reduction stroke risk within five years. The natural history of asymptomatic stenosis is 2% per year stroke rate while symptomatic patient experience 13% per year risk of stroke.

Patients with either symptomatic stenosis e” 50% or asymptomatic stenosis

e”70% are presently considered for carotid recanalization done by endarterectomy or stenting. Before doing any of the above procedures, diagnosis of site, size and severity of extra cranial carotid artery stenosis should be confirmed.

Materials and Methods:

This observational cross-sectional study was carried out on 50 patients who had symptoms and signs of stroke or TIA from July 2013 to July 2015 for a period of 2 years. This study was done in Department of Neurology in Bangabandhu Sheikh Mujib Medical University (BSMMU) and National Institute of Nuclear Medicine and Allied Sciences (NINMAS), BSMMU. All patients of ischemic stroke and TIAs in outdoor and indoor of department of Neurology, BSMMU were enrolled in study population. Patients were selected using purposive sampling technique without any age, sex, ethnic, or socioeconomic discrimination. A detailed history and thorough physical examination were carried out on a questionnaire. Risk factors such as hypertension, diabetes mellitus, smoking, and ischemic heart disease were documented. The patients underwent computed tomography (CT) scan study prior to the DSA of carotid arteries and findings were documented. Cases with history, clinical and CT scan findings consistent with cerebral ischemic stroke were included in this study. Patients having symptoms suggestive of hemorrhagic stroke, vertebrobasilar insufficiency, head injuries, and those having primary and metastatic brain tumors were excluded from the study.

Patients were referred to cathlab of BSMMU for intra arterial DSA performed by two interventional neurologists blinded of USD finding. DSA included right and left CCA and ICA angiography with a 5 F

H_1 picard catheter and imaging in at least two planes (45° anterior oblique and 90° lateral on both side).

Data was collected in a data collection sheet. Diagnostic performance test of DSA was done at 50%, 50%-69%, 70%-99%, 100% cut off point of stenosis of RICA and LICA.

The collected data were analyzed with the aid of a calculator and presented in the form of tables, figures, graphs, and diagrams wherever necessary.

Results and observations:

Among 50 patients 3 patients belonged to age group 41-50, 15 patients in 51-60, 27 in 61-70, 05 in > 70 year group. Maximum 54 % (n-27) patients were in age group 51-60. Minimum age was 50 and maximum was 74 years with a mean of 61 ± 11.42 years (Table I). In this study maximum cases were diagnosed as < 50% stenosis of carotid artery by duplex USD in stroke patients (26 cases of RICA, 23 cases of (LICA) (Table II). This study showed that 50% cut off point of stenosis of RICA, out of 50 cases, DSA diagnosed 28 cases as <50% and 22 cases as ≥50% stenosis. Sensitivity, specificity, Positive predictive value (PPV), negative predictive value (NPV), efficacy were 82%, 86%, 88%, 79% and 84% respectively (Table III). This study found at 70% cut off point of stenosis of RICA out of 50 cases DSA diagnosed 38 cases as <70% and 12 cases as ≥70% stenosis. Sensitivity, specificity, PPV, NPV, efficacy were 89%, 83%, 94%, 71% and 88% respectively (Table IV). At 100% cut off point of stenosis of RICA out of 50 cases DSA diagnosed 45 cases as <100% and 05 cases as 100% stenosis. Sensitivity, specificity, PPV, NPV, efficacy were 93%, 80%, 97%, 57% and 92% respectively (Table V). The present study revealed that 50% cut off point of stenosis of LICA, out of 50 cases, DSA diagnosed 23 cases as <50% and 27 cases as ≥50% stenosis. Sensitivity, specificity, PPV, NPV, efficacy were 82.6%, 85.2%, 82.6%, 85.2% and 88% respectively (Table VI). At 70% cut off point of stenosis of LICA out of 50 cases, DSA diagnosed 35 cases as <70% and 15 cases as ≥70% stenosis. Sensitivity, specificity, PPV, NPV, efficacy were 91%, 93%, 97%, 82% and 92% respectively (Table VII). The present study found that at 100% cut off point of stenosis of LICA out of 50 cases DSA diagnosed 43 cases as <1,00% and 07 cases as 100% stenosis. Sensitivity, specificity, PPV, NPV, efficacy were 95%, 86%, 97.6%, 75% and 94% respectively (Table VIII).

Table-I

Distribution of age and gender of patients (n = 50)

Age group (year)	Age Number	Percentage
41-50	3	6
51-60	15	30
61-70	27	54
>70	05	10
Total	50	100

Table-II

Distribution of patients by diagnosis of carotid stenosis by duplex USD (n=50)

Degree of stenosis (%)	RICA (n=50)	LICA (n=50)
<50	26	23
50-69	10	10
≥70 but less than near occlusion	10	09
Total occlusion	04	08

Table-III

Comparison between duplex USD and DSA findings at 50% cut off point of stenosis of right internal carotid artery (RICA) (n=50)

USD-RICA-50, DSA- RICA-50, Cross tabulation

USD-RICA 50	DSA 50		Total
	<50% (+ve)	50% (-ve)	
<50% (+ve)	23 (TP)	3 (FP)	26
50% (-ve)	5 (FN)	19 (TN)	24
Total	28	22	50

Sensitivity = 82%, Specificity= 86%, PPV=88%, NPV= 79%, Efficacy= 84%

Table-IV

Comparison between duplex USD and DSA findings at 70% cut off point of stenosis of right internal carotid artery (RICA) (n=50)

USD-RICA-70, DSA- RICA70, Cross tabulation

USD-RICA 70	DSA 70		Total
	<70% (+ve)	>70% (-ve)	
<70% (+ve)	34 (TP)	02 (FP)	36
70% (-ve)	04 (FN)	10 (TN)	14
Total=	38	12	50

Sensitivity = 89%, Specificity = 83%, PPV = 94%, NPV = 71%, Efficacy = 88%

Table-V

Comparison between duplex USD and DSA findings at 100% cut off point of stenosis of right internal carotid artery (RICA) (n=50)

USD-RICA-100, DSA- RICA-100, Cross tabulation

USD-RICA 100	DSA 100		Total
	<100% (+ve)	100 (-ve)	
<100% (+ve)	42 (TP)	01 (FP)	43
100% (-ve)	03 (FN)	04 (TN)	07
Total	45	05	‘50

Sensitivity = 93%, Specificity = 80%, PPV =97%, NPV= 57%, Efficacy = 92%

Table-VI

Comparison between duplex USD and DSA findings at 50% cut off point of stenosis of left internal carotid artery (LICA) (n=50)

USD-LICA-50, DSA- LICA-50, Cross tabulation

USD-LICA 50	DSA 50		Total
	<50% (+ve)	>50% (-ve)	
<50% (+ve)	19 (TP)	04 (FP)	23
50% (-ve)	04 (FN)	23 (TN)	27
Total	23	27	50

Sensitivity= 82.6%, Specificity = 85.2%, PPV = 82.6%, NPV=85.2%, Efficacy = 88%

Table-VII

Comparison between duplex USD and DSA findings at 70% cut off point of stenosis of left internal carotid artery (LICA) (n=50)

USD-LICA-70, DSA- LICA70, Cross tabulation

USD-LICA 70	DSA 70		Total
	<70% (+ve)	>70% (-ve)	
<70% (+ve)	32 (TP)	01 (FP)	33
> 70% (-ve)	03 (FN)	14 (TN)	17
Total	35	15	50

Sensitivity = 91%, Specificity = 93%, PPV = 97%, NPV = 82%, Efficacy = 92%

Table-VIII

Comparison between duplex USD and DSA findings at 100% cut off point of stenosis of left internal carotid artery (LICA) (n=50)

USD-LICA-100, DSA- LICA-100, Cross tabulation

USD-LICA 100	DSA 100		Total
	<100% (+ve)	>100% (-ve)	
100% (+ve)	41 (TP)	01 (FP)	42
100% (-ve)	02 (FN)	06 (TN)	08
Total	43	07	50

Sensitivity = 95%, Specificity =86%, PPV = 97.6%, NPV=75%, Efficacy = 94%

Discussion:

In this study sensitivity is the proportion of patients with carotid stenosis on DSA that was correctly diagnosed by duplex USD. In RICA for ≥50%, ≥70% and 100% stenosis sensitivity were 82%, 89% and 93% respectively. In LICA for ≥50%, ≥70% and 100% stenosis sensitivity were 82%, 91%, 95% respectively. Chowdhury R.N et al[8] studied 40 patients of ischemic stroke in 2008 and measured the sensitivity at ≥50%, at ≥70% cutoff point which was 63.33%, 91.18% for RICA and 69.44%, 86.83% for LICA respectively. Balaji SK et al[9] included 36 patients in his study and calculated sensitivity of duplex USD for ≥50%, 7 ≥0% and 90% stenosis of RICA were 72.3%, 93.8%, 92.4% respectively and similarly for LICA results were 71.4%, 93.3% and 98% respectively. Cheng Dong et al[10] studied over 400 patients of ischemic stroke in China and yielded sensitivity of USD for ≥50%,

≥70% and 100% stenosis were 71%, 85% and 91% respectively. Dinkel H-P et al[11] studied on 116 patients and yielded sensitivity of USD for ≥50% and ≥70% stenosis were 91.4% and 89.2% respectively. Nederkoom RI et al[13] in their systemic review found pooled sensitivity of USD 96% (94%-98%, at 95% confidence interval for 100% stenosis or total occlusion. The present study showed that in RICA for ≥50%, ≥70% and 100% stenosis specificity were 86%, 83% and 80% respectively. In LICA for ≥*50*%, ≥70% and 100% stenosis specificity were 85.2%, 93%, 86% respectively. Chowdhury R.N et al[8] calculated the specificity at ≥50% and ≥70% cutoff point which was 50%, 50% for RICA and 50%, 50% for LICA respectively. Balaji SK et al[9] included 36 patients in his study and calculated specificity of duplex USD for 50%, 70% and 90% stenosis of RICA were 77%, 67.8%, 100% respectively and similarly for LICA results were 64.5%, 76.5% and 100% respectively. Cheng D et al[10] studied over 400 patients of ischemic stroke in China and yielded specificity of USD for 50%, 70% and 100% stenosis were 74%, 87% and 92.6% respectively. H-P Dinkel et al[11] yielded specificity of USD for 50% and 70% stenosis were 93.2% and 96.2% respectively. Nederkoorn PJ et al[12] in their systemic review found pooled specificity of USD 100% (99%-100%) at 95% confidence interval for 100% stenosis. Efficacy is the probability of correct diagnosis (positive and negative). The present study also showed that in RICA for 50%, 70% and 100% stenosis efficacy were 84%, 88% and 92% respectively. In LICA for 50%, 70% and 100% stenosis efficacy were 88%, 92%, 94% respectively. In 2008 Chowdhury R.N et al[8] measured efficacy at 50%, 70% and 90% cutoff point which was 60%, 85% and 90% for RICA and 67.5%, 85% and 87.50% for LICA respectively. Balaji SK et al[9] included calculated accuracy of duplex USD for 50%, 70% and 90% stenosis of RICA were 74.5%, 88.5%, 96% respectively and similarly for LICA results were 69.4%, 92.4% and 100% respectively. Cheng D et al study[10] yielded accuracy of USD for 50%, 70% and 100% stenosis were 80%, 89.4% and 92% respectively. The results of the present study are similar with the study of H-P Dinkel series, Nederkoom PJ series, and Cheng Dong series but a bit higher than that of Chowdhury R.N series and Balaji SK series. No perioperative complication was observed during the present study.

Conclusion:

Doppler ultrasound of carotid vessels is safe, cheap, less sensitive- Specific and accurate than digital subtraction angiogram for evaluation of carotid stenosis. With expert hand DSA is safe and it is more sensitive, specific and accurate than USD. So before endarterectomy or carotid stenting DSA is mandatory and doppler USD is supportive to measure extracranial carotid stenosis.

Ethical Issue:

All patients gave informed written consents and the study was approved by Institutional Review Board of Bangabandhu Sheikh Mujib Medical University.

Conflict of Interest: None

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