Original Article

Digital subtraction angiography (DSA) is superior to duplex ultrasound in diagnosis of extracranial carotid stenosis - a comparative study

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Abstract

Digital subtraction angiography (DSA) is the gold standard investigation to assess the extracranial stenosis of carotid vessels. But this is an invasive diagnostic tool. So it is still a controversial issue whether duplex ultrasound is an alternative to DSA for measurement of stenosis of carotid vessels. This prospective crossectional observational study was conducted in the department of Neurology, BSMMU, Dhaka from May 2012 to April 2013 to assess the diagnostic accuracy of duplex ultrasound and its potential to replace DSA before performing carotid endarterectomy (CEA) and carotid stenting. Total of 38 patients, 33 patients of nondisabling ischaemic stroke and 5 patients with history of TIAs whose extracranial carotid stenosis was >50% on duplex ultrasound were selected for DSA. DSA was done on these vessels and stenosis was measured using NASCET criteria. Results of USD and DSA were compared to determine the sensitivity, specificity and accuracy of duplex ultrasound (USD). At 70% stenosis of right internal carotid artery and left internal carotid artery the sensitivity, specificity and accuracy were 93.8%, 63.7%, 89.5% and 93.3%, 75%, 89.5% respectively. This level of diagnostic efficiency of USD is less than that of DSA of carotid arteries. It was found in this study that, USD underestimates or overestimates the degree of carotid stenosis. DSA was safe and effective in determining stenosis in this study & there was no complication. So before taking any decision for carotid endarterectomy or carotid artery stenting, digital subtraction angiography of carotid vessels should be done.

Key words: Digital subtraction angiography, duplex ultrasound, carotid vessels

Introduction

World Health Organization (WHO) defined Stroke as a syndrome of rapidly developing clinical signs of focal (at times global) disturbance of cerebral function, lasting more than 24 hours or leading to death with no apparent cause other than that of vascular origin.[1] There are approximately 750,000 new or recurrent strokes annually in the United States.[2] Worldwide, stroke is also a leading cause of death, with stroke mortality being particularly high in Eastern Europe and Asia.[2] The incidence of an ischemic stroke increases with age.[3,4] About 85% of stroke is caused by primary cerebral ischemia resulting in infarction (ischemic stroke).[3,4] Atherosclerotic narrowing of the carotid bifurcation is the most important risk factor for stroke and can be cured by a surgical procedure or carotid stenting. Carotid endarterectomy (CEA) has been shown to confer a definite benefit in bifurcation stenosis in several large, randomized, multicentre trials, including the North American Symptomatic Carotid Endarterectomy Trial (NASCET), the European Carotid Surgery Trial (ECST), the Asymptomatic Carotid Atherosclerosis Study (ACAS) and The Veterans Affairs Cooperative Study (VACS).[5-8] In 659 patients with 70% to 99% stenosis randomized by NASCET, the cumulative risk of any ipsilateral stroke at 2 years was 26 % in medically treated patients and 9% in surgically treated patients.[5] For moderate carotid stenosis 50% to 69 %, the 5 years risk of any ipsilateral stroke is 15.7% with surgical treatment and 22.2% with medical treatment. On the basis of these results, symptomatic patients with 50% stenosis or asymptomatic patients with 60% stenosis are presently considered for carotid recanalization. Carotid recanalization can be done by endarterectomy or stenting.[7,9] Before doing any of the above procedures, diagnosis of site, size & severity of extracranial carotid stenosis should be confirmed. Duplex Ultrasound (USD), combining high-resolution imaging and Doppler spectrum analysis has proved to be popular, non invasive, accurate and cost effective means of detecting and assessing carotid disease.[10]

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Digital Subtraction Angiogram (DSA) is gold standard for carotid artery disease in demonstrating lesion but it is invasive, costly and uses radio contrast dye.[11] Keeping all these in mind, the purpose of this study was to assess the diagnostic accuracy of duplex ultrasound (USD) and its potential to replace digital substraction angiography (DSA) before carotid endarterectomy (CEA) and carotid stenting.

Methods

This was a prospective cross-sectional observational study. This study was carried out from May 2012 to April 2013 for a period of one year in Neurology Department of Bangabandhu Sheikh Mujib Medical University (BSMMU). Patients of TIAs and non-disabling ischaemic stroke admitted or attending Department of Neurology were included in this study. Estimated sample size was 38. Patient of haemorrhagic stroke, unconscious patients, echocardiographic evidence of a cardiac source of embolism were excluded from this study. Right and left carotid arteries were evaluated for carotid stenosis by USD and DSA. So, total 76 vessels were studied. Data were collected by a semi-structured questionnaire. Both common carotid arteries, bulb, cervical segment of ICA were examined in transverse and longitudinal way in gray-scale, color doppler and power doppler mode with digital high resolution liner transducer. Thirty eight patients of significant carotid stenosis (symptomatic 50% or asymptomatic 60% stenosis on USD) were then selected for Intra-arterial DSA. Angiography was performed via a femoral arterial approach by two interventional neurologist. Intra-arterial DSA was done within 2 weeks of USD. Each patient was advised to attend Neurology outpatient department for subsequent follow-up. During both the procedures (USD and DSA), the investigator was present and maintained equal standard for all the patients. Analysis of data was done by SPSS program.

Results

Mean age of the patient was 50.58 ± 9.52 years. In case of right internal carotid artery, out of 32 ≤70% angiographic extra-Cranial carotid stenosis, USD could identify 30 cases. 2 cases were false negative. So at 70% cutoff point, sensitivity and accuracy of USD were higher than lower degree of stenosis. Here Sensitivity = 93.8%, Specificity =66.7%, Accuracy = 89.5%, PPV = 93.8% and NPV = 66.7 %. (Table-I) In case of RICA, out of 34 ≤ 90% angiographic extra-cranial carotid stenosis, USD could identify 34 cases. So at 90% cutoff point, sensitivity and accuracy of USD were high than lower stenosis. Here Sensitivity = 94.4% Specificity =100%, Accuracy = 94.7%, PPV = 100%, NPV = 50%. (Table-II)

Table-I: Direct comparison between USD & DSA findings of right internal carotid artery at cut-off point of 70% stenosis

	DSA RICA-70		
USD RICA-70	≤70	>70	Total
≤70	30 (93.8)	2 (33.3)	32 (84.2)
>70	2 (6.3)	4 (66.7)	6 (15.8)
Total	32 (100.0)	6 (100.0)	38 (100.0)

Figure within parentheses indicates in percentage.
RICA- right internal carotid artery

In case of RICA, out of 34 ≤ 90% angiographic extra-cranial carotid stenosis, USD could identify 34 cases. So at 90% cutoff point, sensitivity and accuracy of USD were high than lower stenosis. Here Sensitivity = 94.4% Specificity =100%, Accuracy = 94.7%, PPV = 100%, NPV = 50%. (Table-II)

Table-II: Direct comparison between USD & DSA findings of right internal carotid artery at cut-off point of 90% stenosis

	DSA RICA-90		
USD RICA-90	≤90	>90	Total
≤90	34 (94.4)	0 (.0)	34 (89.5)
>90	2 (5.6)	2 (100.0)	4 (10.5)
Total	36 (100.0)	2 (100.0)	38 (100.0)

Figure within parentheses indicates in percentage
RICA- right internal carotid artery

The ROC graph of RICA comparing sensitivity & specificity of USD with DSA findings shows that sensitivity at the level of 50% was 73.3 % and specificity was 75%. The sensitivity at the level of 70% was 93.8% and specificity was 66.7%. The sensitivity at the level of 90% was 94.4 % and specificity was 100%. (Figure-1)

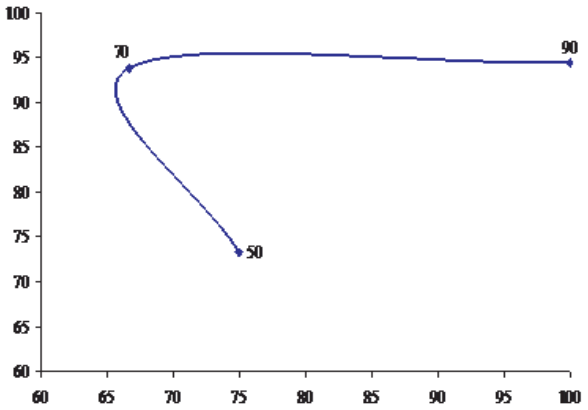

Figure-1: *ROC Graph of RICA - the most left upper point of the curve lies at the level of 70% stenosis. (Here Y axis: Sensitivity, X axis: Specificity)*

In case of left internal carotid artery, out of 30 ≤70% angiographic extra-Cranial carotid stenosis, USD could identify 28 cases. 2 cases were false negative. So at 70% cutoff point sensitivity and accuracy of USD were higher than that of 50% stenosis. Here Sensitivity = 93.3% Specificity =75%, Accuracy = 93.3%, PPV =75%, NPV = 89.5 %.(Table-III)

Table-III: Direct comparison between USD & DSA findings of left internal carotid artery at cut-off point of 70% stenosis

	DSA LICA-70		
USD LICA-70	≤70	>70	Total
≤70	28 (93.3)	2 (25.0)	30 (78.9)
>70	2 (6.7)	6 (75.0)	8 (21.1)
Total	30 (100.0)	8 (100.0)	38 (100.0)

Figure within parentheses indicates in percentage.
LICA- left internal carotid artery

In case of left internal carotid artery, out of 32 ≤ 90% angiographic extra-cranial carotid stenosis, USD could identify 32 cases. So at 90% cutoff point sensitivity and accuracy of USD were higher than that of lesser degree of stenosis. Here Sensitivity = 100%, Specificity =100%, Accuracy = 100%, PPV =100%, NPV = 100%. (Table-IV)

Table-IV: Direct comparison between USD & DSA findings of left internal carotid artery at cut-off point of 90% stenosis

	DSA LICA-90		
USD LICA-90	≤90	>90	Total
≤90	32 (100.0)	0 (.0)	32 (84.2)
>90	0 (.0)	6 (100.0)	6 (15.8)
Total	32 (100.0)	6 (100.0)	38 (100.0)

Figure within parentheses indicates in percentage.
LICA - left internal carotid artery

The ROC graph of left internal carotid artery comparing sensitivity & specificity of USD with DSA findings shows that sensitivity at the level of 50% was 72.7 % and specificity was 62.5%. The sensitivity at the level of 70% was 93.3% and specificity was 75%. The sensitivity at the level of 90% was 100 % and specificity was 100%.

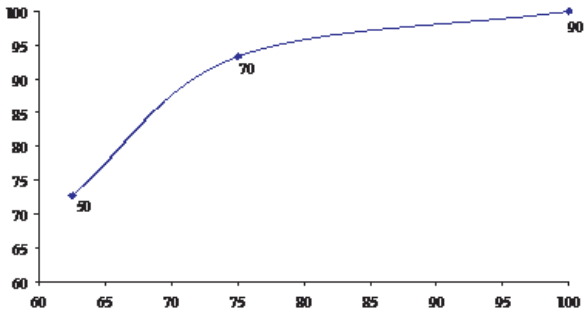

Figure-2: *ROC Graph of LICA: The most left & upper point of the curve lies at the level of 70% stenosis. (Here Y axis: Sensitivity, X axis: Specificity)*

Discussion

Colour doppler study is usually done to know whether a carotid bifurcation stenosis is present or not and, if present, whether it is significant enough to warrant treatment. Significance can be assumed when the stenosis exceeds 50% in diameter. The VACS trial found a significant benefit from surgery in asymptomatic patients with colour flow doppler ultrasound before carotid endarterectomy with this degree of stenosis.[8] The NASCET study, however, has shown a benefit from surgery in symptomatic patients only if the stenosis is greater than 70% in diameter. Thus, quantification of the grade of stenosis is of clinical importance. The crucial task is to determine that which of the following three categories a patient belongs to: A-"no significant stenosis" (<50%); B-"significant stenosis" (50–70%); and C-"high grade stenosis" (>70%). Category A does not require surgery whereas Category C does. Management of patients with 50–70% stenosis (Category B) is still controversial. Our results show that USD is very reliable at discriminating Categories A from B, and B from C. Irrespective of the individual surgical decision to select a specific cut-off for "significant stenosis", USD provides a powerful, reproducible and reliable means of diagnosing and quantifying carotid occlusive disease. The potential limitations of USD may arise if carotid atherosclerosis is one of the main risk factors. Among investigations Duplex ultrasound (USD)is the screening method of choice, as it is cheap and noninvasive. Carotid angiography is the gold standard for diagnosis of carotid stenosis.[11]

In this study the mean age of ischaemic stroke and TIA was 50.58 ± 9.52. Minimum age was 34 and maximum 65 years. This study shows that male patients (n-34) outnumbers female (n-4), with a ratio of 8.5:1. Stroke is a male predominant disease as shown in different studies.[13, 14] 38 patients of ischaemic stroke and TIAs were included with having significant carotid stenosis >50% on Duplex

ultrasound (USD). Degree of stenosis was measured in each internal carotid artery by DSA using NASCET criteria. Findings of USD and DSA were directly compared. There were 3 standard angiographic cut-off points e.g. 50%, 70%, and 90%. Sensitivity, Specificity, accuracy, PPV and NPV of USD was calculated at these 3 cut-off points. In this study sensitivity is the proportion of patients with carotid stenosis on DSA that could be diagnosed by USD. In right internal carotid artery for 50%, 70% and 90% stenosis sensitivity were 73.3%, 93.8%, 94.4% respectively. In left internal carotid artery for 50%, 70% and 90% stenosis sensitivity were 72.7%, 93.3%, 100% respectively. In right internal carotid artery for 50%, 70% and 90% stenosis specificity were 75%, 66.7% and 100% respectively. In left internal carotid artery for 50%, 70% and 90% stenosis specificity were 62.5%, 75%, 100% respectively. The combined power of the diagnostic efficiency of the test is the accuracy. In right internal carotid artery for 50%, 70% and 90% stenosis accuracy were 73.7%, 89.5% & 94.7% respectively. In left internal carotid artery for 50%, 70% and 90% stenosis accuracy were 68.4%, 93.3% & 100% respectively. In right internal carotid artery for 50%, 70% and 90% stenosis PPV were 91.7%, 93.8% & 100% respectively. In left internal carotid artery for 50%, 70% and 90% stenosis PPV were 72.7%, 93.3%, and 100% respectively. In right internal carotid artery for 50%, 70% and 90% stenosis NPV were 42.9%, 66.7%, and 50% respectively. In left internal carotid artery for 50%, 70% and 90% stenosis NPV were 62.5%, 75%, 100% respectively. Dinkel in their study on 116 patients yielded the following diagnostic performance of USD: sensitivity for a 50% stenosis 91.4%, specificity 93.2% and accuracy 92.4%; sensitivity for a 70% stenosis 89.2%, specificity 96.2% and accuracy 92.4%.[15] Another retrospective study found that for carotid stenosis >70% USD had sensitivity and specificity of 94% and 84%, in relation to DSA. For >90% stenosis it was 96% and 99% respectively.[16] A comparative study between carotid angiography and carotid ultrasound of 53 patients showed poor sensitivity in the 50-69% and 70-79% grades but 80-99% had the best sensitivity.[17] Findings of these studies correlate well with the present study carried out in the Department of Neurology, BSMMU. Another comparative study among 158 ischaemic stroke patients found positive predictive value of carotid ultrasound for identifying appropriate symptomatic candidates for intervention (angiographic stenosis 50%) was 70%, with a false positive value of 30%.[18] Qureshi et al also found same PPV (80%) of USD for symptomatic patients for intervention (angiographic stenosis 50%) with a false positive value of 20%. Positive predictive value of carotid ultrasound for identifying appropriate asymptomatic candidates for intervention (angiographic stenosis≥60%) was 59%, with a false positive value of 41%.[19] In this study sensitivity was high at 90% stenosis in both right internal carotid artery (100%) and left internal carotid artery (91.89%). Accuracy was 90% for right internal carotid artery and 87.5% for left internal carotid artery. But at 50% and 70% angiographic stenosis sensitivity and accuracy is much lower in both right internal carotid artery and left internal carotid artery. In case of right internal carotid artery, 2 vessels with >90% stenosis and 4 vessels with >70% were missed by USD, that was reported to be positive by DSA. In case of ≤ 50% stenosis USD reported 2 cases were nonsignificant which later were proved to have significant stenosis by DSA. In this study there was no mortality or morbidity during DSA procedure.

Duplex ultrasound of carotid vessels is 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 duplex USD is supportive to measure extracranial carotid stenosis.

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