

# Reliability of Carotid Doppler performed in a dedicated Stroke Prevention Clinic

N. Dean, H. Lari, M. Saqur, N. Amir, K. Khan, M. Mouradian, Abdul Salam, H. Romanchuk, A. Shuaib

**ABSTRACT: Introduction:** Doppler ultrasound (DUS) is used as a screening tool to assess internal carotid artery (ICA) disease. Recent reports suggest that the DUS may be inaccurate in over 28% of patients. We sought to evaluate the accuracy of DUS, when performed in a dedicated stroke prevention clinic (SPC). **Methods:** We retrospectively reviewed the charts of patients who had a DUS performed in our SPC, followed by conventional cerebral angiography. Three groups of patients were defined. Group I had DUS measured ICA stenosis of >50%; Group II had a DUS measured ICA stenosis of <50%; Group III had complete ICA occlusion on DUS. **Results:** Sixty-seven patients (69 arteries) were included in the study. There were 45 patients in Group I and based on the findings of cerebral angiography, carotid endarterectomy was considered inappropriate in only one patient. - a misclassification rate of 2.2% (95%CI: 0 – 6.5%). Group II consisted of 19 patients and on cerebral angiography, none of these patients had a stenosis of >50% - a misclassification rate of 0%. Group III consisted of five patients in whom DUS showed complete ICA occlusion. The angiogram confirmed the occlusion in all five patients – a misclassification rate of 0%. Overall, misclassification rate was 1.45% (95% CI: 0 - 4.3%). **Conclusions:** Doppler ultrasound when performed in a stroke prevention clinic (SPC), has a high accuracy in measuring ICA stenosis of >50%. Doppler ultrasound is reliable in detecting complete ICA occlusion and finally DUS is a reliable screening tool to rule out clinically significant ICA stenosis.

**RÉSUMÉ: Un service d'ultrasonographie dans une clinique de prévention de l'accident vasculaire cérébral améliore-t-il la fiabilité de l'examen Doppler dans la maladie carotidienne? Introduction:** L'ultrasonographie Doppler (UD) est utilisée comme méthode de dépistage pour l'évaluation de la carotide interne (CI). Des études récentes suggèrent que l'UD serait inexacte chez plus de 28% des patients. Nous avons évalué l'exactitude de l'UD faite dans une clinique de prévention de l'accident vasculaire cérébral. **Méthodes:** Nous avons procédé à une revue rétrospective de dossiers de patients qui ont subi une UD à notre clinique, suivie d'une angiographie cérébrale conventionnelle. Les patients ont été répartis en trois groupes: à l'UD, le groupe 1 avait une sténose de la CI de plus de 50%, le groupe 2 avait une sténose de moins de 50% et le groupe 3 avait une occlusion complète de la CI. **Résultats:** Soixante-sept patients (69 artères) ont été inclus dans l'étude. Il y avait 45 patients dans le groupe 1 et, tenant compte des résultats de l'angiographie cérébrale, l'endartérectomie carotidienne était indiquée chez tous les patients sauf un, soit un taux de classification erronée de 2,2% (IC à 95% de 0 à 6,5%). À l'angiographie cérébrale, aucun des 19 patients du groupe 2 n'avait une sténose de plus de 50%, un taux de classification erronée de 0%. L'angiogramme a confirmé l'occlusion complète chez les 5 patients du groupe 3, un taux de classification erronée de 0%. Dans l'ensemble le taux de classification erronée était de 1,45% (IC à 95% de 0 à 4,3%) **Conclusions:** L'UD en clinique de prévention de l'accident vasculaire cérébral, a un haut degré d'exactitude pour mesurer une sténose de la CI de plus de 50%. L'UD est fiable pour détecter une occlusion complète de la CI et constitue également un outil de dépistage fiable pour exclure une sténose significative de la CI.

Can. J. Neurol. Sci. 2005; 32: 327-331

Patients suffering from a transient ischemic attack (TIA) or stroke need urgent evaluation of their internal carotid arteries because the future risk of stroke and stroke recurrence, in these patients, is dependent on the degree of carotid artery disease.<sup>1</sup> Various non-invasive imaging techniques are used for evaluation of carotid disease, including Doppler Ultrasound (DUS), magnetic resonance angiography and computed tomography angiography<sup>2,3</sup>. Despite improvements in non-invasive imaging technology, conventional cerebral angiography currently remains the gold standard<sup>4</sup> for evaluating the degree of carotid stenosis and to assess the suitability for carotid endarterectomy (CEA). Cerebral angiography however is invasive, expensive

and may cause procedural complications<sup>5,6</sup>. Non-invasive techniques are therefore useful screening tools to identify patients who may require more invasive tests.

A number of studies have evaluated the sensitivity and specificity of non invasive techniques (including DUS) in

From the Division of Neurology, The Al Owen and Family Stroke Prevention Clinic, University of Alberta, Edmonton, Alberta, Canada

RECEIVED MAY 21, 2004. ACCEPTED IN FINAL FORM FEBRUARY 15, 2005

Reprint requests to: Ashfaq Shuaib, Division of Neurology, The Al Owen and Family Stroke Prevention Clinic, University of Alberta, 2E3 Walter C. Mackenzie Health Sciences Centre, Edmonton, Alberta T6G 2B7 Canada

comparison to conventional cerebral angiography. In a prospective study of 103 patients being considered for carotid endarterectomy, clinical assessment and DUS were sufficient for the preoperative assessment in 93% of cases. It was concluded that cerebral angiography should be used selectively for a minority of patients who can be identified on the basis of clinical characteristics and atypical DUS findings.<sup>7</sup> However, these results were challenged by a recent study of noninvasive vascular studies in 569 patients undergoing an angiogram at an academic medical centre and a community hospital. The misclassification rate for Doppler ultrasound alone in detecting internal carotid artery (ICA) stenosis was 28%, and for magnetic resonance angiography alone 18%. They concluded that surgical decisions based on the results of non invasive vascular imaging, particularly DUS alone, should be made with caution.<sup>8</sup>

The accuracy of DUS in measuring degree of carotid stenosis is probably dependent on the experience and skill of the technician. The discrepancy between the previously published reports may in part be explained by difference in the technical skills of the sonographers. To further study the relationship between the degree of stenosis measured by DUS and cerebral angiography, we reviewed the records of patients who underwent clinical assessment and a DUS in our stroke prevention clinic (SPC). Subsequently these patients underwent cerebral angiography to measure the degree of carotid stenosis, confirm complete occlusion of carotid artery or to detect other vascular abnormalities. The goal of our study was to determine the accuracy of DUS performed in a designated SPC with a dedicated stroke team and vascular technologist.

## METHODS

The study was conducted in the A.H. Owen Stoke Prevention Clinic at the University of Alberta Hospital. The clinic is a tertiary care referral centre in western Canada and receives referrals from Emergency Department physicians, primary care physicians and peripheral hospitals. It serves a population of 1.5 million. The SPC has a team of stroke neurologists, clinical stroke fellows, specialist nurses and a registered vascular technologist (RVT). All patients presenting with symptoms attributable to the carotid circulation and selected patients with posterior circulation events have a DUS performed in the clinic on a Hewlet Packard Sonos 5500 system with linear array transducer 11-3L. The tests are performed by an experienced RVT under the supervision of an accredited Stroke Neurologist. The Doppler studies are interpreted according to the Strandness criteria for 0-50%, 80 – 99% and 100% levels and secondary criteria using Montepas values for the 60% and 70% levels<sup>9,10</sup>. Symptomatic patients who have DUS measured ICA stenosis of >50% and are considered suitable for CEA on the basis of other clinical features are referred for contrast angiography<sup>11</sup>.

From April 2000 to December 2001, 67 patients underwent cerebral angiography, after having a DUS study performed in the SPC (trans-cranial doppler was not done on any of these patients). The average time between the DUS and angiography was 3-8 days. All had a history of a recent TIA or ischemic stroke. We retrospectively reviewed the clinic records, results of DUS and cerebral angiograms of these patients. Data collected

from the DUS reports included the degree of internal carotid artery (ICA) stenosis and presence or absence of complete occlusion. The degree of carotid stenosis reported on DUS is usually within a range as opposed to a single number. For the purpose of this study we selected the upper limit of the reported range of stenosis. Angiographic data were collected from radiology reports and included the reported degree of carotid stenosis and presence of angiographic contraindications to endarterectomy (carotid artery occlusion, severe proximal stenosis or severe distal or intracranial arterial disease). Medical and demographic data was obtained from the clinic records.

The collected data were analyzed in three steps:

**STEP 1:** Two of our stroke fellows were designated to make a decision regarding suitability of CEA for each patient. This decision was to be based on the DUS results and the available clinical data. They were blinded to the results of cerebral angiography.

**STEP 2:** Two other stroke fellows, who were blinded to the results of DUS were asked to make a decision regarding CEA on the basis of the results of cerebral angiography and the clinical data.

**STEP 3:** In the final step we calculated the misclassification rate for the DUS (percentage of patients in which the results of cerebral angiography altered the decision for CEA, made in STEP 1).

After review of the clinic records, all the 67 patients were divided into three groups and the misclassification rate was calculated separately for each group.

**GROUP 1:** Consisted of patients who had DUS measured ICA stenosis of >50%. After assessment in the SPC, these patients had been considered suitable candidates for CEA and subsequently had cerebral angiography.

**GROUP 2:** Consisted of symptomatic patients with normal ICA or <50% stenosis on DUS. These individuals underwent angiography for reasons other than CEA, e.g. to rule out arterial dissection or presence of intracranial arterial disease.

**GROUP 3:** Consisted of patients in whom the DUS showed complete ICA occlusion and cerebral angiography had been performed to rule out trickle of blood flow.

## RESULTS

We identified 67 (69 arteries in 67 patients) patients who had carotid DUS performed in the SPC and subsequently underwent cerebral angiography. The demographic data are listed in Table 1 and the results are summarized in Table 2.

There were 45 patients in Group 1. All these patients had symptoms related to carotid artery territory. Analysis of DUS results showed that 17 of these patients had ICA stenosis of 50-69% (moderate) and 28 had stenosis of 70-99% (severe). On the basis of clinical features and DUS findings all these patients were considered to be suitable candidates for CEA (STEP 1).

After review of angiogram results (STEP 2), CEA was considered to be inappropriate in one patient. Thus, the misclassification rate in this group was 2.2% (95%CI: 0–6.5%).

There were 19 patients in Group 2 and most of them had symptoms in the carotid territory. A few patients in this group had symptoms in the posterior circulation territory and underwent DUS to assess the vertebral arteries. All the patients in Group 2 had DUS measured ICA stenosis of <50% with the majority ranging from 0 to 15%. Cerebral angiogram in these patients was performed to rule out arterial dissection or intracranial arterial disease as a cause of their symptoms. Angiography did not detect narrowing of more than 50% in any of these patients. In STEP 1 of the analysis, none of these patients was considered to be a suitable candidate for CEA and the review of angiogram results (STEP 2) did not alter this decision. The misclassification rate in this group was 0%.

In Group 3 there were five patients. Doppler ultrasound in these patients was suggestive of complete ICA occlusion. The angiogram in these patients confirmed the occlusion. The misclassification rate in this group was 0%. Two patients in this group had symptomatic stenosis (50% – 69 %) of ICA contralateral to the occluded side and these data were analyzed with Group 1.

In our study the overall misclassification rate was 1.45% (95% CI: 0-43%)

## DISCUSSION

Doppler ultrasound is a useful screening tool for assessment of carotid disease in patients with TIA or ischemic stroke. It is non invasive, relatively inexpensive (compared with other non invasive techniques eg. magnetic resonance (MRA) and computed tomogram (CT) angiography) and is readily available. In comparison with the previous studies the misclassification rate for DUS performed in our SPC was quite encouraging i.e. 0% for ICA stenosis of <50%, 0% for complete ICA occlusion and 2.2% for ICA stenosis of 50-99%. In our study the only patient with misclassification was in Group 1 (ICA stenosis >50%). This patient presented with left hemispheric symptoms and the DUS showed bilateral ICA stenosis of >80%. The Doppler study in this patient was technically difficult because of residual scarring from previous bilateral endarterectomies. A subsequent cerebral angiogram showed a completely occluded left ICA and right ICA stenosis of 80%. Angiography was done three days after the Doppler study. It is possible that the artery may have thrombosed and occluded in the time period between the two studies. In our study there were two other patients who previously had bilateral carotid endarterectomies. These patients were considered to be suitable for CEA in the STEP 1 of our study and the review of the results of cerebral angiogram did not alter this decision.

In previous studies the misclassification rate for measuring ICA stenosis by DUS has been quite variable. In a recently published study the misclassification rate was 28% for DUS alone, 18% for MRA alone and 7.9% when both studies were performed<sup>8</sup>. Previously, it had been reported that clinical assessment and DUS were sufficient for pre-operative assessment in 93% of patients who were suitable candidates for CEA<sup>7</sup>. In this study, the authors concluded that clinical evaluation and DUS findings could be used to identify a minority

of patients for whom conventional angiography is necessary prior to CEA. Recently another study reported a false positive rate of 20% for DUS (ICA stenosis  $\geq$ 50%) in identifying symptomatic patients who are appropriate candidates for CEA, and 41% for asymptomatic patients (ICA stenosis  $\geq$ 60%) when compared to angiographic findings<sup>12</sup>. The false positive rate for the 19 external DUS laboratories was 41% overall, compared to 20% (p=0.03) for the hospital's own internal service. In this study, the major problem was with DUS measured stenosis of 50-69%, found to be <50% by angiography in 63% of cases. Misdiagnosis was less frequent in patients with 70-99% stenosis, but angiography again found <50% stenosis in 22% of these cases. In our study none of the 17 patients with DUS measured stenosis of 50-69% had <50% stenosis on angiogram. Out of 28 patients with DUS measured stenosis of 70-99%, a subsequent angiogram altered the decision for CEA in only one patient. The DUS measured ICA stenosis in this patient was >80%, but as described above, the angiogram performed three days later showed a complete occlusion.

It is critical to distinguish between a complete ICA occlusion and severe stenosis since it determines the prognosis and management of the patient. A previous study in 1987 reported a sensitivity of 96%, specificity of 95% and accuracy rate of 95% in 62 patients with an occluded artery demonstrated by duplex scanning.<sup>13</sup> In a more recent study, out of 16 patients with DUS diagnosed complete occlusion, two had stenosis of 70-99% on a subsequent angiogram<sup>12</sup>. This variation in reported diagnostic accuracy of DUS in differentiating between a tight stenosis and complete occlusion has resulted in angiographic confirmation of the ultrasound findings, a widely accepted practice. In our study there were five patients in whom the DUS was suggestive of a complete ICA occlusion. This was confirmed by the cerebral angiogram in all the five patients. In addition, DUS did not falsely detect an occluded ICA in the patients with severe ICA stenosis. It is our observation that if the diagnostic accuracy of ultrasound is high and the occlusion can be imaged accurately, the need for angiographic confirmation may be alleviated. We believe that such a degree of accuracy with DUS can be achieved with attention to detail.

A diagnosis of ICA occlusion can be made if the arterial lumen is filled with echogenic material in the absence of color flow or Doppler signals within the vessel, and if the common carotid arterial Doppler waveforms show abnormal high resistance flow with abnormal flow to zero in diastole. Other additional features include distal common carotid arterial Doppler waveforms showing "stump" flow and the presence of a diminutive artery when the occlusion is chronic<sup>14</sup>. Often occlusion may be difficult to differentiate from trickle flow. These low flow states are often too slow to produce a Doppler shift. The color display parameters must be set low enough to detect very low flow states<sup>14</sup>. Finally, it is also important to remember that with severe or complete unilateral obstruction, collateral flow increases on the contralateral side. This may lead to artifactual overestimation of Doppler velocity measurements and subsequent interpretation errors<sup>14</sup>.

Some conditions that require attention in order to improve sensitivity and specificity of carotid DUS are described as follows:

- Acoustic shadowing is created by calcified plaque generating strong reflections and shadows which obscure the arterial lumen or the wall surface opposite the plaque and are a frequent cause of technical difficulties. These shadows block out colour flow and Doppler spectral information<sup>14</sup>.
- Off-diameter scans can create over or under estimation of plaque thickness and create misleading Doppler spectral wave form characteristics<sup>14</sup>.
- Vessel tortuosity may cause angle-induced errors in velocity readings and is a common cause for errors in calculations. Velocity measurements correlate to the degree of stenosis. It is therefore very important to interrogate the entire vessel to determine the course of blood flow. Angle correction must be used to determine the correct velocity of blood flow in tortuous vessels<sup>15</sup>.

Currently DUS remains the primary diagnostic tool for assessment of carotid artery disease. A high accuracy rate is important because too many false positive results can result in unnecessary exposure to the hazards of cerebral angiography and unnecessary expense. At the same time, too many false negative results will deprive patients of the potential benefits of carotid endarterectomy. In comparison to previous studies, our results are encouraging. We report a high accuracy rate of carotid DUS when performed in the SPC. The misclassification rate in our study for symptomatic stenosis (50-99%) was 2.2 % (95%CI: 0

**Table 1: Demographics**

Mean Age (years)	64.5 (SD 12.5)
<b>Gender</b>	
Male	50 (74.6%)
Female	17 (25.4%)
<b>Cerebrovascular Risk Factors</b>	
Hypertension	43 (64.2%)
Atrial fibrillation	03 (4.5%)
Diabetes Mellitus	17(25.4%)
Previous TIA	10 (14.9%)
Coronary artery disease	15 (22.4%)
Previous stroke	06 (9.0%)
Dyslipidemia	22 (32.8%)
Smoker	13 (19.4%)
<b>Type of cerebrovascular event</b>	
TIA (Anterior circulation)	35 (52.2%)
TIA (Posterior circulation)	03 (4.5%)
Stroke (Anterior circulation)	20 (29.9%)
Stroke (Posterior circulation)	04 (6.0%)
Undetermined	05 (7.5%)

**Table 2: Summary of Results**

	No. of Patients	US measured stenosis	% Misclassification rate (95% CI)
GROUP 1	45	>50%	2.2% (CI 0 - 6.5%)
GROUP 2	19	<50%	0 : 0%
GROUP 3	5	100%	0 : 0%

– 6.5%), and overall 1.45% (95%CI: 0 – 4.3%), which is much lower than the recently reported misclassification rate of 28%<sup>8</sup> and the false positive rate of 20%<sup>12</sup>. The wide variation in the reported accuracy rates of DUS cannot solely be explained on the basis of difference in the experience or skill of the technologist, because all these studies were carried out in institutions where DUS imaging is performed by fully trained and accredited ultrasonographers. However, in our study the high accuracy rate of DUS in measuring the degree of ICA stenosis could be explained by the structure of our SPC. All our Doppler studies are performed in the clinic, under the supervision of a stroke neurologist, by a fully trained technologist who only performs carotid imaging. In most institutions, after initial assessment in the SPC, the patients are referred for DUS to busy ultrasound laboratories where the ultrasonographers also have the responsibility for conducting general ultrasound imaging. We believe that a SPC with a dedicated DUS service may improve the diagnostic accuracy of the Doppler studies. Regular audit of the clinic charts and comparison of the DUS results with cerebral angiography is vital in improving the accuracy of this extremely useful technique.

**REFERENCES**

1. NASCET collaborators. Beneficial effect of carotid endarterectomy in symptomatic patients with high grade stenosis. *N Engl J Med* 1991;325:445-453.
2. Rofsky NM, Adleman MA. Gadolinium enhanced MR angiography of the carotid arteries: a small step, a giant leap? *Radiology* 1998;209:31-34.
3. Anderson GB, Ashforth R, Steinke DE. CT angiography for the detection and characterization of carotid artery bifurcation disease. *Stroke* 2000;31:2168-2174.
4. Barnett HJ, Broderick JP. Carotid endarterectomy: another wake up call. *Neurology* 2000;55:746-747.
5. Pryor JC, Setton A, Nelson PK, Bernstein A. Complications of diagnostic cerebral angiography and tips on avoidance.



- Neuroimaging Clin N Am 1996;6:751-757.
6. Warnock NG, Gandhi MR, Bergvall U, Powell T. Complications of intra-arterial digital subtraction angiography in patients investigated for cerebrovascular disease. *Br J Radiol* 1993;66:855-858.
  7. Dawson DL, Zierler RE, Strandness DE. The role of duplex scanning and arteriography before carotid endarterectomy: A prospective study. *J Vasc Surg* 1993;18:673-683.
  8. Johnston DCC, Goldstein LB. Clinical carotid endarterectomy decision making. *Neurology* 2001;56:1009-1015.
  9. Taylor DC, Strandness DE. Carotid artery duplex scanning. *J Clin Ultrasound* 1987;15:635-644.
  10. Moneta GI, et al. Correlation of North American Symptomatic Carotid Endarterectomy Trial ( NASCET ) angiographic definition of 70% to 99% internal carotid artery stenosis with duplex scanning. *J Vasc Surg* 1993;17:152-159.
  11. Barnett HJM, Taylor DW, Eliasziw M, et al. Benefit of carotid endarterectomy in patients with moderate or severe stenosis. *N Engl J Med* 1998;339:1415-1425.
  12. 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.
  13. Bornstein NM, Beloev ZG, Norris JW. The limitations of Diagnosis of carotid occlusion by Doppler Ultrasound. *Ann Surg* 1998; 207: 315-317.
  14. Zwiebel WJ. Introduction to Vascular Technology. W.B. Saunders Company. Philadelphia, USA; 1992: 108, 115-116, 129.
  15. Labs KH, Jager KA, Fitzgerald DE, Woodcock JP, D Neurberg-Heusler. Diagnostic Vascular Ultrasound. Edward Arnold 1992: 198.