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Carotid bruit for detection of hemodynamically significant carotid stenosis: the Northern Manhattan Study

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Abstract

Objective—The prevalence of carotid bruits and the utility of auscultation for predicting carotid stenosis are not well known. We aimed to establish the prevalence of carotid bruits and the diagnostic accuracy of auscultation for detection of hemodynamically significant carotid stenosis, using carotid duplex as the gold standard.

Methods—The Northern Manhattan Study (NOMAS) is a prospective multiethnic community-based cohort designed to examine the incidence of stroke and other vascular events and the association between various vascular risk factors and subclinical atherosclerosis. Of the stroke-free cohort (n=3298), 686 were examined for carotid bruits and underwent carotid duplex. Main outcome measures included prevalence of carotid bruits and sensitivity, specificity, positive predictive value, negative predictive value and accuracy of auscultation for prediction of ipsilateral carotid stenosis.

Results—Among 686 subjects with a mean age of 68.2 ± 9.4 years, the prevalence of ≥60% carotid stenosis as detected by ultrasound was 2.2% and the prevalence of carotid bruits was 4.1%. For detection of carotid stenosis, sensitivity of auscultation was 56%, specificity was 98%, positive predictive value was 25%, negative predictive value was 99% and overall accuracy was 97.5%.

Discussion—In this ethnically diverse cohort, the prevalence of carotid bruits and hemodynamically significant carotid stenosis was low. Sensitivity and positive predictive value were also low, and the 44% false-negative rate suggests that auscultation is not sufficient to exclude carotid stenosis. While the presence of a bruit may still warrant further evaluation with carotid duplex, ultrasonography may be considered in high-risk asymptomatic patients, irrespective of findings on auscultation.

Keywords

Carotid bruit; auscultation; vascular ultrasonography; carotid stenosis

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INTRODUCTION

Auscultation for carotid bruits was once considered as part of the standard cardiovascular examination. With the constant influx of new technologies, however, the physical examination is often neglected in teaching and in practice[1]. While auscultation may be an effective method for selecting further diagnostic tests, relatively few studies have looked at the sensitivity and positive predictive value of the carotid bruit for detecting carotid stenosis, particularly among asymptomatic subjects. The sensitivity of carotid bruit may be quite low; its prognostic value depends upon how the degree of stenosis is defined as well as the clinical scenario[2].

The aim of the present study was to establish the prevalence of carotid bruits and the diagnostic accuracy (sensitivity, specificity, positive predictive value and negative predictive value) of bruit auscultation for detection of hemodynamically significant carotid stenosis among asymptomatic patients, using carotid duplex as the gold standard. A secondary aim was to assess the utility of bruit auscultation for prediction of carotid plaque. In addition, we performed transthoracic echocardiography to examine the possible confounding role of referred cardiac murmurs.

METHODS

Subjects

The study population included subjects from the Northern Manhattan Study (NOMAS), a prospective community-based cohort designed to document the incidence of stroke and other vascular events, to identify novel risk factors, and to examine the association between various vascular risk factors and subclinical atherosclerosis in different race-ethnic groups in northern Manhattan[3,4]. NOMAS consists of a cohort of 3298 stroke-free adults. Between January 1993 and August 2001, 686 NOMAS subjects were examined for carotid bruits and underwent carotid duplex scanning. The study was approved by the Columbia University Medical Center Institutional Review Board, and all subjects gave written informed consent. A total of 1372 arteries were imaged.

Clinical characteristics including age, gender, race-ethnicity and vascular risk factors were documented. Race-ethnicity was based on self-identification with questions modeled after the US census, conforming to standard definitions outlined by Directive 15. Vascular risk factors included hypertension, diabetes, hypercholesterolemia, smoking and coronary artery disease (CAD). Hypertension was defined as a systolic blood pressure ≥140 mmHg or a diastolic blood pressure ≥90 mmHg, or the subject's self-report of hypertension or antihypertensive medication use. Diabetes was defined as a fasting blood glucose ≥126 mg/dl or the subject's self-report of diabetes, insulin use, or the use of oral hypoglycemic agents. Hypercholesterolemia was defined as a total cholesterol >240 mg/dl or the subject's self-report of high cholesterol or the use of cholesterol-lowering medications. Smoking was defined current or former smoking (≥100 cigarettes, cigars or pipes in a lifetime). CAD was defined as a prior history of MI, coronary artery bypass graft (CABG) surgery or angioplasty.

Auscultation

Auscultation of the bilateral mid-cervical region was performed by study neurologists. After listening to the heart in the standard manner, the examiner listened over the course of the carotid artery up to the angle of the jaw with the head in the neutral position and then facing the contralateral side. Auscultation was repeated as needed to confirm the presence or absence of a bruit. If present, bruits were characterized as left, right or bilateral.

Carotid duplex

The extracranial carotid arteries were assessed with high-resolution B-mode ultrasound as well as spectral Doppler. All measurements were performed in the research laboratory by ultrasound technologists who were trained according to a standard scanning protocol using a GE LOGIQ 700 system with a multifrequency 9−13 MHz linear-array transducer. The sonographers were blind to the subjects' clinical history and bruit status. The carotid arteries were imaged in transverse (short-axis) and longitudinal planes (anterior, lateral and posterior views). On each side, the common carotid artery (CCA), the bifurcation and the internal carotid artery (ICA) were examined for the presence of atherosclerotic plaque, defined as an area of focal wall thickening or protrusion into the lumen at least 50% greater than the surrounding wall thickness. Each subject was classified as having plaque or not. Ultrasound technologists and interpreting physicians were unaware of the subjects' bruit status. The degree of stenosis was classified as <60% or ≥60% based on standard velocity criteria. Sixty percent stenosis refers to diameter reduction of the artery. Criteria for ≥60% stenosis included an ICA peak systolic velocity >170 cm/s and an ICA end-diastolic velocity >40 cm/s.

Echocardiography subgroup

A substantial subset of this cohort underwent echocardiography (n=563). Two-dimensional echocardiographic studies were performed according to the recommendations of the American Society of Echocardiography. Among other variables, thickening of the aortic valve was classified as none, mild, moderate or severe by an experienced observer. Doppler examination of the valve was performed to assess for aortic stenosis. The frequency of aortic valve thickening among subjects with and without bruits was analysed. In addition, the frequency of mitral annular calcification (MAC) among subjects with and without bruits was examined; data on MAC were available for 557 subjects.

Statistical analysis

All statistical analyses were performed using SAS 9.1 (SAS Institute, Cary, NC, USA). Student's t-tests and chi-square tests were employed to assess differences between groups. The sensitivity, specificity, positive predictive value, negative predictive value and overall accuracy were calculated using the carotid duplex results as the gold standard. A p value of less than 0.05 was considered statistically significant.

RESULTS

Baseline characteristics

A total of 686 asymptomatic subjects were included in the analysis. Overall, the mean age was 68.2 ± 9.4 years (range: 40−96 years); 60.6% were female; 58% were Hispanic, 21% were African-American and 19% were Caucasian. The clinical characteristics of the study population are shown according to bruit status in Table 1. Subjects in the bruit group were significantly older (p<0.0001). There were no significant differences between the two groups with regard to gender, race-ethnicity or vascular risk factors although there was an insignificant trend towards more CAD in the bruit group.

Carotid bruits

Carotid bruits were detected in 28 subjects, or 4.1% of the study population. Among the bruits, 12 were detected on the left, eight were on the right and eight were bilateral.

Ipsilateral carotid stenosis

Of the 686 subjects, 15 (2.2%) had ≥60% stenosis of which one was bilateral. A total of 1372 arteries were examined. Of these, eight arteries had ≥60% stenosis on the left and eight arteries

had ≥60% on the right. As shown in Table 2, the positive predictive value of an ipsilateral carotid bruit for ≥60% ipsilateral carotid stenosis was 25% [95% confidence interval (CI): 10.4 −39.6%]. The negative predictive value was 99% (95% CI: 98.9−100%). Sensitivity was 56% (95% CI: 30.3−82.2%); specificity was 98% (95% CI: 97.0−99.1%) and overall accuracy was 97.5% (95% CI: 96.8−98.3%).

Carotid plaque

All 686 subjects were examined for the presence of carotid plaque (ipsilateral or contralateral). Plaque was detected in 400 subjects, or 58.3%. Among the 28 subjects with carotid bruits, 25 had carotid plaque. As illustrated in Table 3, the positive predictive value of any bruit (ipsilateral or contralateral) for predicting any plaque (ipsilateral or contralateral) was 89% (95% CI: 77.8−100%). The negative predictive value was 43% (95% CI: 39.2−46.8%). Sensitivity was 6.25% (95% CI: 3.9−8.6%), specificity was 99% (95% CI: 97.8−100%) and overall accuracy was 45% (95% CI: 41.2−48.6%).

Echocardiography

Of the 686 total subjects, 563 (82%) had echocardiography data available for analysis. Thickening of the aortic valve was classified as none, mild, moderate or severe. Moderate or severe thickening was considered clinically relevant with the potential for a radiating murmur. Four out of 20 (20%) in the group with bruits had moderate or severe thickening, as compared to 24 out of 543 (4%) in the group without bruits, a difference which was statistically significant (p=0.0016). Conversely, among the 28 subjects with moderate or severe aortic valve thickening, a carotid bruit was present in 14.3% compared to 3.0% in the group with mild or no thickening. These data are shown in Table 4. Among the 557 subjects with echocardiography data available on MAC, there were 20 subjects with bruits. Of these, 13 (65%) had MAC compared to 135 out of 537 (25%) in the group without bruits, a difference which was statistically significant (p<0.0001).

DISCUSSION

The present study examines the prevalence and utility of carotid bruits for predicting ultrasound-detected carotid stenosis among asymptomatic community-based subjects. In this ethnically diverse cohort, 4.1% of 686 subjects had carotid bruits. Only 2.2% of the subjects had hemodynamically significant stenosis ≥60%. The sensitivity of bruit auscultation was low at 56% but the specificity was quite high at 98%. Unlike sensitivity and specificity, the positive and negative predictive values depend on the prevalence of the disease. In part, because of the low prevalence, the positive predictive value was low at 25% but the negative predictive value was high at 99%.

Several conclusions may be drawn from these results. First, the prevalence of both bruits and ≥60% carotid stenosis are low in the asymptomatic general population. Second, if a bruit is heard on physical exam in an asymptomatic patient, there is a 25% chance that the patient has ≥60% carotid stenosis. This finding most likely warrants further non-invasive testing with carotid duplex, especially if revascularization is a consideration. Third, while auscultation appears to be useful if a bruit is heard, it is not completely reliable if the goal is to exclude carotid stenosis, given a false-negative rate of 44% (seven out of 16 subjects with ≥60% stenosis had no bruit). While the negative predictive value is excellent at 99%, this number is also affected by prevalence and may be lower in high-risk populations with a higher prevalence of disease. Among the 1268 patients in the North American Symptomatic Carotid Endarterectomy Trial (NASCET), bruits were also absent in over a third of the patients with ≥70% stenosis[5].

Although controversial, screening for carotid stenosis may also be clinically important as part of the preoperative assessment. For example, because of concern regarding perioperative cerebrovascular events, recent studies have looked at screening for carotid stenosis before CABG for example. Sonecha *et al.*[6] looked at the utility of asymptomatic bruits for predicting ≥50% carotid stenosis in 153 patients undergoing CABG. Their specificity (95.8%), positive predictive value (25%), negative predictive value (95.5%) and overall accuracy (91.8%) were remarkably similar to ours (98, 25, 99 and 97.5%, respectively, in the present study). Their sensitivity, however, was lower at 23.5% compared to our 56%.

These results are consistent with prior studies, which have traditionally reported a suboptimal sensitivity of bruit auscultation. Of note, other previous studies have included mostly symptomatic patients in whom the prevalence is likely to be higher, affecting the positive predictive value[5, 7–10]. For example, the largest study to date included 2000 patients (1873 of whom were symptomatic) and found a positive predictive value of 51%[8]. In 1971, Ziegler *et al.*[7] found the bruit to be a 'highly fallible indicator' of carotid stenosis using angiography as the gold standard in 199 patients; the false-positive rate was 10% with a false-negative rate of 73%. A more recent study of 145 mostly symptomatic patients found the sensitivity to be 56% with a positive predictive value of 27%[10], results of which are strikingly similar to ours.

The asymptomatic status of the subjects distinguishes the present study from most of its predecessors and adds strength to the clinical importance of the results. The busy clinician needs to know whether auscultation is useful and how the presence or absence of a bruit changes the likelihood that the patient has carotid disease. One may argue that the predictive value of a carotid bruit in the symptomatic population is interesting but immaterial. Many would recommend that patients with cerebrovascular symptoms suggestive of potential carotid stenosis (i.e. stroke, transient ischemic attack or amaurosis fugax) should have a carotid duplex regardless of auscultatory findings; the risk/benefit ratio is favorable and the 'number needed to treat' is low for carotid revascularization if a significant stenosis is found[11].

Our secondary aim was to examine the utility of the carotid bruit for predicting carotid plaque, which also has important implications for the practicing clinician. While the positive predictive value of a bruit for predicting ≥60% carotid stenosis was relatively low at 25%, the positive predictive value for predicting carotid plaque was quite high at 89%. The high positive predictive value is again driven by the prevalence, which is high at 58% in our population. While the sensitivity of bruit auscultation for prediction of plaque was very low at 6%, the high positive predictive value suggests that carotid duplex is still useful in patients with bruits. Detection of carotid plaque could potentially change the patient's medical management. Based on current data, a practitioner may choose to prescribe aspirin, HMG CoA reductase inhibitors ('statins')[12],and/or angiotensin-converting enzyme inhibitors[13] for cardiovascular risk reduction. However, randomized trials are needed to establish the benefit of pharmacological therapy for atherosclerosis detected in the form of isolated carotid plaque.

Carotid bruits were significantly associated with aortic valve thickening. One possible explanation is that some of the bruits were in fact radiating cardiac murmurs. Another possibility, however, is that thickening of the aortic valve is associated with bruits because of its correlation with systemic atherosclerosis. The latter theory is supported by the finding that the number of subjects with MAC was also significantly higher among subjects with bruits than among subjects without bruits (p=0.0001). While MAC is known to be a marker of systemic atherosclerosis, physiologically it should not cause a bruit. These results imply that abnormal findings on neck auscultation, regardless of the presence of aortic stenosis, are perhaps best evaluated by carotid duplex.

Given the systemic nature of atherosclerosis, the presence of disease in other vascular territories (i.e. CAD or peripheral arterial disease) may better predict carotid stenosis than the presence of a bruit. In a study by Marek *et al*.[14], the incidence of significant carotid disease (≥50% or occlusion) was 24.5% among patients referred for claudication. A low ankle-brachial index may indeed be more predictive of carotid stenosis than a carotid bruit. Future studies are needed to confirm the benefit of carotid duplex in asymptomatic but high-risk populations.

The present study is one of the largest to date examining the prevalence and test characteristics of carotid bruits in asymptomatic subjects. The ethnic diversity of the cohort also adds to the strength of the study. In addition, no prior studies to our knowledge have included data from echocardiography to explore the role of valvular heart disease. One weakness is that echocardiography data unfortunately were not available for the entire group. Results of cardiac auscultation would also have been helpful for clarifying the possible confounding role of radiating murmurs. Information on interobserver variability for bruit auscultation, which has not been looked at in prior studies, would be informative but was unavailable. Another potential weakness is that carotid duplex was used as the 'gold standard' for all calculations rather than angiography.

In conclusion, auscultation for carotid bruits remains worthwhile in the general population because the presence of a bruit means that there is a one in four chance that the patient has hemodynamically significant carotid stenosis. Therefore, a bruit heard on physical examination should continue to prompt further evaluation with a carotid duplex. However, the sensitivity and positive predictive value are low, and a false-negative rate of 44% confirms that bruit auscultation is not sufficient for excluding significant carotid stenosis. Ultrasonographic evaluation could be considered in asymptomatic patients at high risk for vascular disease, irrespective of the findings on auscultation.

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Table 1

Baseline characteristics of study subjects by bruit status

	Bruit	No bruit	*p* value
Total	28 (4.1%)	658 (95.9%)	
Mean age (years)	75.1 ± 9.4	67.9 ± 9.3	<0.001
Gender (female)	15 (53.6%)	401 (60.9%)	0.43
Race-ethnicity			0.29
Hispanic	12 (42.9%)	384 (58.4%)	
African-American	6 (21.4%)	135 (20.5%)	
Caucasian	9 (32.1%)	124 (18.8%)	
Other	1 (3.6%)	15 (2.3%)	
Hypertension	20 (71.4%)	454 (69.0%)	0.78
Diabetes	6 (21.4%)	160 (24.3%)	0.73
Hypercholesterolemia	14 (50%)	303 (46.0%)	0.68
Smoking	19 (67.9%)	353 (53.6%)	0.14
Coronary artery disease	5 (17.9%)	56 (8.5%)	0.09

Table 2

Relationship between bruit and ipsilateral carotid stenosis (*n*=1372 arteries)

	Ipsilateral ≥60% stenosis	Ipsilateral <60% stenosis	Total
Ipsilateral bruit	9 (25%)	27 (75%)	36
No bruit	7 (0.5%)	1329 (99.5%)	1336
Total	16	1356	1372

Table 3

Relationship between bruit and the presence of carotid plaque (*n*=686 subjects)

	Any plaque	No plaque	Total
Any bruit	25 (89%)	3 (11%)	28
No bruit	375 (57%)	283 (43%)	658
Total	400	286	686

Table 4

Relationship between bruit and aortic valve thickening (*n*=563 subjects)

	Moderate or severe aortic valve thickening	Mild or no aortic valve thickening	Total
Any bruit	4 (20%)	16 (80%)	20
No bruit	24 (4%)	519 (96%)	543
Total	28	535	563