A Scoring System for Evaluation of the Extent of Extracranial Carotid Atherosclerosis with B-Mode Imaging

Chien-Chung Chen, MD; Ming-Yao Chung, MD, MPH; Jiann-Shing Jeng, MD; Ping-Keung Yip, MD; Bao-Show Hwang, BS; Yang-Chyuan Chang, MD; Rong-Chi Chen, MD
Department of Neurology, National Taiwan University Hospital, Taipei, Taiwan

Abstract - We modified a scoring system (mainly based on the method developed by Sutton et al in 1992) to quantify the extent of extracranial carotid artery atherosclerosis by B-mode imaging. In order to perform subsequent studies on cerebrovascular atherosclerosis reliably in the future, we evaluate the reproducibility of this scoring system. Reproducibility data were obtained from forty-three study participants who have received carotid sonography operated by the same sonographer. Each scan was then scored by other two readers. Each reader independently assigned a grade from 0 to 4 to each of five segments in the carotid system bilaterally, based on the number and size of lesions present. Reproducibility of plaque grade was evaluated using segment as the unit of analysis. Perfect agreement was achieved in 91% of the entire segments (K=0.701). The reproducibility of plaque grade varied by segment. Kappa statistic reflected good agreement for the internal carotid artery (K=0.743), distal common carotid artery (K=0.722), proximal common carotid artery (K=0.677), external carotid artery (K=0.645), and carotid bulb (K=0.622). We conclude that the B-mode ultrasonography may provide a reliable and highly reproducible measurement of the extent of extracranial carotid atherosclerotic disease.
Key words: Atherosclerosis, Carotid arteries, Ultrasonography, Kappa

Acta Neurol Sin 1995; 4: 29–33

INTRODUCTION

Many studies have been conducted to evaluate the risk factors of large vessel atherosclerosis. Therefore methods to quantify the extent of large vessel atherosclerosis are of vital importance for prospective studies. In cardiology, the extent of coronary atherosclerosis has been evaluated by counting the number of coronary arteries with stenosis of 50% or more[1-4] or by more sophisticated scoring systems such as those suggested by the American Heart Association Grading Committee[5] or others[6-9] that include lesions at multiple sites in the coronary system. However, coronary angiography is an invasive examination with considerable complications which hinders repeated measurement in the long-term follow-up.

B-mode ultrasound is valuable in assessing a wide spectrum of carotid atherosclerosis, from minimal to moderate disease. Using this non-invasive technique, we can quantify the extent of extracranial carotid atherosclerosis

Received November 5, 1994. Revised December 21, 1994. Accepted January 28, 1995.
Address correspondence to Dr. Ping-Keung Yip, Department of Neurology, National Taiwan University Hospital, 7 Chung-Shan S. Rd, Taipei, Taiwan 100, R.O.C.

by counting all the plaques at different segments in the carotid system shown on B-mode images[10-12]. The extent of carotid atherosclerosis provides the better response variable to relate risk factors to cerebrovascular or cardiovascular disease in a dose-response fashion. Therefore, we modified a scoring system for extracranial carotid atherosclerosis. The aim of this study is to test the reproducibility of this scoring system.

MATERIALS AND METHODS

Forty-three patients with cerebrovascular or cardiovascular diseases were enrolled in this study. All patients underwent carotid duplex scanning at our vascular laboratory. A Diasonics DRF 400 duplex ultrasound system with a 7.5 MHz scanning frequency in real time B-mode and 3.0 MHz scanning frequency in pulsed Doppler mode was used for the evaluation. The examination was performed by an experienced sonographer (B.S. Hwang) while the patient was lying in the supine position. Scan images were recorded on super VHS videotapes and were interpreted independently by two different readers (C.C. Chen and J.S. Jeng).

The scoring system we developed is mainly based on the methods of Sutton et al in 1992[11]. The carotid system was divided into five segments bilaterally (Fig 1). The examination included longitudinal and transverse views of the proximal common carotid artery (CCA1, $\geq$ 20 mm proximal to bulb-bifurcation), distal common carotid artery (CCA2, < 20 mm proximal to bulb-bifurcation), carotid bulb-bifurcation areas, internal carotid artery (ICA) and external carotid artery (ECA). The longitudinal views include anterior, lateral, and posterior approaches; each patient received at least two of the approaching directions. A grade was assigned to each chosen segment (in the view with the most severe disease extent) by the following criteria: grade 0, no observable plaque; grade 1, one small plaque (<30% of the vessel diameter) or intimal thickening; grade 2, one medium plaque (30-49% of the vessel diameter) or multiple small plaques; grade 3, one large plaque (50-99% of the vessel diameter) or multiple

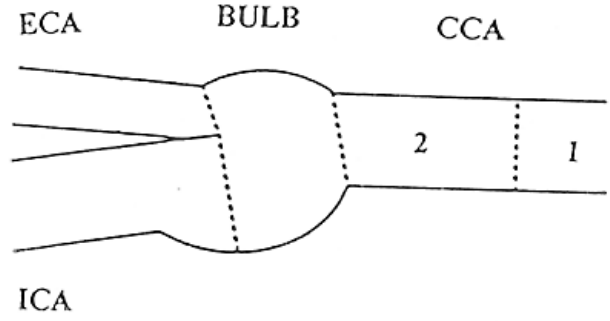

Fig 1. Schematic drawing of segments of carotid artery: see text for details.

plaques with at least one medium plaque; and grade 4, total occlusion of the vessel. The grades were then summed to create a variable called the carotid plaque index (CPI), which was used as a measure of the extent of atherosclerosis.

Variation due to the reader was assessed by comparing records for which the sonographer was the same but the readers differed. The reproducibility of plaque grade was assessed using the Kappa statistic, a measure of the agreement that occurs over and above chance. Values of Kappa from 0.21 to 0.40 are interpreted as representing fair agreement, those from 0.41 to 0.60 as representing moderate agreement, those from 0.60 to 0.80 as representing good agreement, and those above 0.80 as representing excellent agreement.

RESULTS

There were 86 carotid arteries (each patient had scans of right and left carotid arteries) available to evaluate the reproducibility of this scoring system. When atherosclerotic disease was present, it was most often found in the carotid bulb, proximal ICA, or distal CCA (Table 1).

When the total of 430 comparisons were analyzed (5 segments times 86 scans), readers had perfect agreement in 90.7% of the entire segments, corresponding to a Kappa of 0.701 (Table 2).

The reproducibility of plaque grade varied little by segment (Table 3). The Kappa statistic was highest for the ICA (0.743) and low-

Table 1: *Distribution of plaque grade by segment for reader A only*

	Plaque grade							
	0		1		2		3	
Segment	N	%	N	%	N	%	N	%
CCA1	75	87.2	7	8.1	3	3.5	1	1.2
CCA2	70	81.4	10	11.6	6	7.0	0	0.0
Bulb	56	65.1	26	30.2	3	3.5	1	1.2
ICA	73	84.9	9	10.5	2	2.3	2	2.3
ECA	79	91.8	3	3.5	3	3.5	1	1.2

CCA1: proximal common carotid artery, ≥20 mm proximal to bulb-bifurcation
CCA2: distal common carotid artery, <20 mm proximal to bulb-bifurcation
ICA: internal carotid artery
ECA: external carotid artery

Table 2: *Reproducibility of plaque grade*

	Reader B				
Reader A	0	1	2	3	Total
0	340	11	2	0	353
1	9	33	13	0	55
2	1	1	13	2	17
3	0	0	1	4	5
Total	350	45	29	6	430

Perfect agreement = 90.7%, Kappa = 0.701

est for the bulb (0.622), but all five segments reached good agreement. When disagreements occurred, they were most often within one grade (92.5%). The most common disagreement was between no disease (grade 0) and little disease (grade 1) (Table 4).

DISCUSSION

Carotid duplex ultrasound imaging, which incorporates Doppler and B-mode ultrasound, has been accepted as a valuable and reproducible alternative to angiography in the diagnosis of extracranial carotid atherosclerosis. With its unique ability to visualize the arterial wall as well as the lumen, sonography offers advantage over other imaging modalities to evaluate the extent and severity of extacranial carotid atherosclerosis.

Table 3: *Reproducibility of plaque grade by segment*

	Interreader variation		
Segment	N	% perfect agreement	Kappa
CCA1	86	93	0.722
CCA2	86	90.7	0.677
Bulb	86	80.2	0.622
ICA	86	94.2	0.743
ECA	86	95.3	0.645

CCA1: proximal common carotid artery, ≥20 mm proximal to bulb-bifurcation
CCA2: distal common carotid artery, <20 mm proximal to bulb-bifurcation
ICA: internal carotid artery
ECA: external carotid artery

Table 4: *Analysis of disagreement in plaque grade*

	Disagreements when readers differed (n = 40)	
Disagreement within	No.	%
One grade		
0 vs. 1	20	50
1 vs. 2	14	35
2 vs. 3	3	7.5
Two grade		
0 vs. 2	3	7.5
1 vs. 3	0	0

A number of authors have reported the correlation between the severity of carotid atherosclerosis and clinical events, e.g., stroke[13-18]. Researches focusing on the correlation of clinical events with extent of carotid atherosclerosis is a recent trend in the studies of atherosclerotic disease[12, 19-23]. From a clinical viewpoint, physicians are usually more interested in the severity of disease rather than extent. The Doppler component of the scan is best suited to measure disease severity because it directly measures the effect of carotid stenosis on blood flow. Therefore, some authors have concentrated on quantifying carotid disease based primarily on analysis of the Doppler spectrum[24,25]. But in investigations of the etiology of carotid atherosclerosis, measurement of the extent of disease as the

response variable provides the opportunity to relate risk factors to disease in a dose-response fashion. In fact, measure of the extent of atherosclerosis has been confirmed to correlate better with risk factors than measure of the severity of disease[10,26].

In order to evaluate the extent of extracranial carotid atherosclerosis, different methods had been developed to quantify the disease extent based on the number and size of plaques present on B-mode sonography[10-12]. After reviewing the scoring systems developed by other authors, we developed our own modified scoring system to measure the extent of extracranial carotid atherosclerosis. Crouse et al[10] measured the scores for two sites 5 mm above and below the bifurcation of the carotid artery, and claimed the reproducibility was almost as good as that for entire carotid system. Kim Sutton-Tyrrell and associates[11] divided the carotid system into seven segments with the thesis that additional information will be gained by evaluating the entire carotid vascular bed, and the variability of plaque index due to the decision on the location of the plaque will be eliminated. Undoubtfully, there is an inherent methodological advantage in considering potential for disease at several sites. With increasing number of lesions used to develop the score, the reproducibility increases. This likely occurs because carotid atherosclerosis tends not to be limited to one single site, and the average (or sum) is a better representation of the overall process. The site of lesions also influences the reproducibility of such scoring systems. Some authors have reported that reproducibility decreases as one moves higher in the carotid system[27]. In our experience, the position of bulb, ICA and ECA with respect to the skin surface results in a less optimal angle of insonation than in the CCA and thus a lower-quality image. Therefore, we simplified the measurement of disease in the ECA and ICA due to the lack of high-quality images in these vessels.

Assessing the reproducibility of the B-mode component of the scanning protocol was difficult because the variation can come from both the sonographer and the reader. According to other authors' reports[10-12], most of the variation in measurement is due to the sonographer and relatively little to the reader. This reflects the complexity of performing a high-quality scan and underscores the necessity for extensive training and experience of the sonographer. Meanwhile, the reports published by Crouse et al and Sutton et al were multi-center studies, so careful monitoring is necessary to watch for problems with sonographer and reader variability. In contrast, our researches on cerebrovascular disease are single-center studies and all the ultrasonographic scans were performed by the same well-experienced sonographer (B.S. Hwang, who had performed more than five thousand cases of carotid ultrasonography before this study began) which greatly reduces the possible variability due to technical problems.

The present scoring protocol offers a method for the measurement of carotid atherosclerosis in cross-sectional studies; but for studies which require longitudinal follow-up of carotid atherosclerosis, the reproducibility for repeated examinations should also be determined. In fact, several reports have demonstrated that the reproducibility remained high in carotid sonographic examinations performed at different times[10,12].

In conclusion, our modified scoring system by use of B-mode sonography is a reliable and highly reproducible method for measurement of the extent of extracranial carotid atherosclerotic disease and may provide an ideal tool in studying extracranial carotid atherosclerosis and cerebrovascular disease.

ACKNOWLEDGEMENT

This study was supported in part by the National Taiwan University Hospital grants NTUH—84261—B37.

REFERENCES

1. Pearson TA, Bulkley BH, Achuff SC, Kwiterovich PO, Gordis L. The association of low levels of HDL cholesterol and arteriographically defined coronary artery disease. Amer J Epidemiol 1979; 109: 285-95.
2. Barboriak JJ, Rimm AA, Anderson AJ, Tristani FE, Walker JA, Flemma RJ. Coronary artery occlusion and blood lipids. Amer heart J 1974; 87: 716-21.

3. Bloch A, Dinsmore RE, Lees RS. Coronary arteriographic findings in type-II and type IV hyperlipoproteinaemia. Lancet 1976; 1: 928-30.
4. Scott DW, Gotto AM, Cole JS, Gorry GA. Plasma lipid as collateral risk factors in coronary artery disease °- A study of 371 males with chest pain. J Chron Dis 1978; 31: 337-45.
5. Austen WG, Edwards JE, Frye RL. AHA Committee Report: A reporting system on patients evaluated for coronary artery disease. Report for the Ad Hoc Committee for Grading of Coronary Artery Disease, Council on Cardiovascular Surgery, American Heart Association. Circulation 1975; 51: 7-40.
6. Miller NE, Hammett F, Saltissi S, Rao S, van Zeller H, Coltart, et al. Relation of angiographically defined coronary artery disease to plasma lipoprotein subfractions and apolipoproteins. Brit Med J 1981; 282: 1741-4.
7. Jenkins PJ, Harper TW, Nestel PJ. Severity of coronary atherosclerosis related to lipoprotein concentration. Brit Med J 1978; 2: 388-91.
8. Cashin-Hemphill L, Kramsch DM, Azen SP, DeMets D, DeBoer LW, Hwang I, et al. The Monitored Atherosclerosis Regression Study (MARS). Design, methods, and baseline results. The On-Line Journal of Current Clinical Trials. Document 26; 1992.
9. Mack WJ, Selzer RH, Pogoda JM, Lee PL, Shircore AM, Azen SP, et al. Comparison of computer and human coronary angiographic endpoint measures for controlled therapy trials. Arterioscler Thromb 1992; 12: 348-56.
10. Crouse JR, Harpold GH, Kahl FR, Toole JF, McKinney WM. Evaluation of a scoring system for extracranial carotid atherosclerosis extent with B-mode ultrasound. Stroke 1986; 17: 270-5.
11. Sutton KC, Wolfson Jr. SK, Thompson T, Kelsey SF. Measurement variability in duplex scan assessment of carotid atherosclerosis. Stroke 1992; 23: 215-20.
12. O'Leary DH, Polak JF, Wolfson SK, Bond MG, Bommer W, Sheth S, et al. Use of sonography to evaluate carotid atherosclerosis in the elderly. The Cardiovascular Health Study. Stroke 1991; 22: 155-63.
13. Barnett HJM. Progress towards stroke prevention: Robert Wartenberg Lecture. Neurol 1980; 30: 1212-25.
14. Ruff RL, Talman WT, Petito F. Transient ischemic attacks associated with hypotension in hypertensive patients with carotid artery stenosis. Stroke 1981; 12: 353-5.
15. Harrison MJG, Marshall J. Prognostic significance of severity of carotid atheroma in early manifestations of cerebrovascular disease. Stroke 1982; 13: 567-9.
16. Ziegler DK, Hassanein RS. Prognosis in patients with transient ischaemic attacks. Stroke 1973; 4: 666-73.
17. Busuttil RW, Baker JD, Davidson RK, Machleder HI. Carotid artery stenosis °- haemohynamic significance and clinical course. J Amer Med Assoc 1981; 245: 1438-41.
18. Moore WS, Boren C, Malone JM. Natural history of nonstenotic asymptomatic ulcerative lesions of the carotid artery. Arch Surg 1978; 113: 1352-8.
19. Craven TE, Rye JE, Espeland MA, Kahl FR, McKinney WM, Toole JF, et al. Evaluation of the associations between carotid artery atherosclerosis and coronary artery stenosis °- A case-control study. Circulation 1990; 82:1230-42.
20. Jeng JS, Chung MY, Yip PK, Hwang BS, Chang YC. Extracranial carotid atherosclerosis and vascular risk factors in different types of ischemic stroke in Taiwan. Stroke 1994; 25:1989-93.
21. Ogren M, Hedblad B, Isacsson SO, Janzon L, Jungquist G, Lindell SE. Non-invasively detected carotid stenosis and ischaemic heart disease in men with leg arteriosclerosis. Lancet 1993; 342: 1138-41.
22. Crouse JR, Toole JF, McKinney WM, Dignan MB, Howard G, Kahl FR, et al. Risk factors for extracranial carotid artery atherosclerosis. Stroke 1987: 18: 990-6.
23. Prisant LM, Zemel PC, Nichols FT, Zemel MB, Sowers JR, Carr AA, et al. Carotid plaque associations among hypertensive patients. Arch Intern Med 1993: 153: 501-6.
24. Langlois Y, Roederer GO, Chan A, Phillips DJ, Beach KW, Martin D, et al. Evaluating carotid artery disease: The concordance between pulsed Doppler spectrum analysis and angiography. Ultrasound Med Biol 1983; 9: 51-63.
25. Roederer GO, Langlois YE, Jager KA, Lawrence RJ, Primozich JF, Phillips DJ, et al. A simple spectral parameter for accurate classification of severe carotid disease. Bruit 1984: 8: 174-8.
26. Sutton KC, Wolfson SK Jr, Kuller LH. Carotid and lower extremity arterial disease in elderly adults with isolated systolic hypertension. Stroke 1987; 18: 817-22.
27. O'Leary DH, Polak JF, Wolfson SK Jr, Bond MG, Bommer W, Sheth S, et al. On behalf of the CHS Collaboratory Research Group: Use of sonography to evaluate carotid atherosclerosis in the elderly: The Cardiovascular Health Study. Stroke 1991; 22: 1155-63.