The value of multi-directional movement of carotid artery as a novel surrogate marker for acute ischemic stroke assessed by Arterial Analysis

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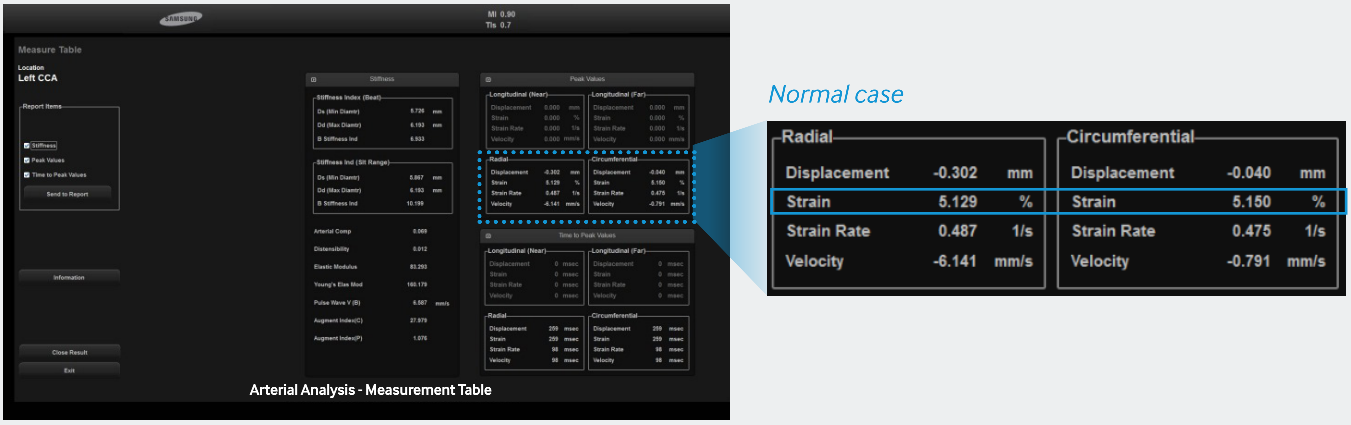

"Among the parameters of arterial stiffness, the lower displacement and strain of radial and circumferential were significantly associated with acute ischemic stroke. Adding circumferential and radial parameters of arterial stiffness to the CIMT, significantly improved the association of the acute ischemic stroke."

Introduction

The carotid ultrasound (CUS) is a useful tool for measuring surrogate marker of cardiovascular disease (CVD) such as carotid intima media thickness (CIMT) and presence of carotid plaque. Both CIMT and the parameters of arterial stiffness are related to coronary atherosclerosis, stroke, and cardiovascular mortality.[1-3] CIMT reflects the morphological changes of arterial wall after the development of atherosclerosis, while the parameters of arterial stiffness reflect the functional properties of carotid arteries and show changes before the development of structural change of arterial wall such as increased CIMT or carotid plaque.[4] Arterial stiffness can be measured non-invasively by B-mode ultrasound and by using a specialized software.[5] In this study, we sought to explore additional value of multi-directional functional mechanics of the carotid artery in relation to stroke event using CUS and specialized software.

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Method

A total of 181 patients who underwent CUS were enrolled. Among them, age-sex matched 69 patients were enrolled at stroke and control group, respectively. High-resolution B-mode CUS was performed using a linear array transducer (nominal band width of 5-10MHz) with 8MHz center frequency. The frame rate was 29fps for the image acquisition. For the analysis, at least 5 mm of the CCA below the origin of the carotid bulb was used. At least two consecutive beats were stored and multi-directional movement of the carotid artery data were analyzed with Arterial Analysis software (Samsung Medison Co., Ltd., Seoul, Korea). A minimum of four speckles on the carotid artery wall were identified and the movements of each speckle during the cardiac cycle were traced at both near and far walls. Circumferential, longitudinal and radial movements of carotid artery were analyzed by Arterial Analysis based on speckle-tracking technique, in the transverse and longitudinal B-mode images of carotid artery. Peak circumferential and radial displacements, strain and strain rate were measured. Beta stiffness index and elastic modulus of carotid artery were calculated from their circumferential and radial measurements. All parameters of arterial stiffness were calculated by Arterial Analysis software automatically.

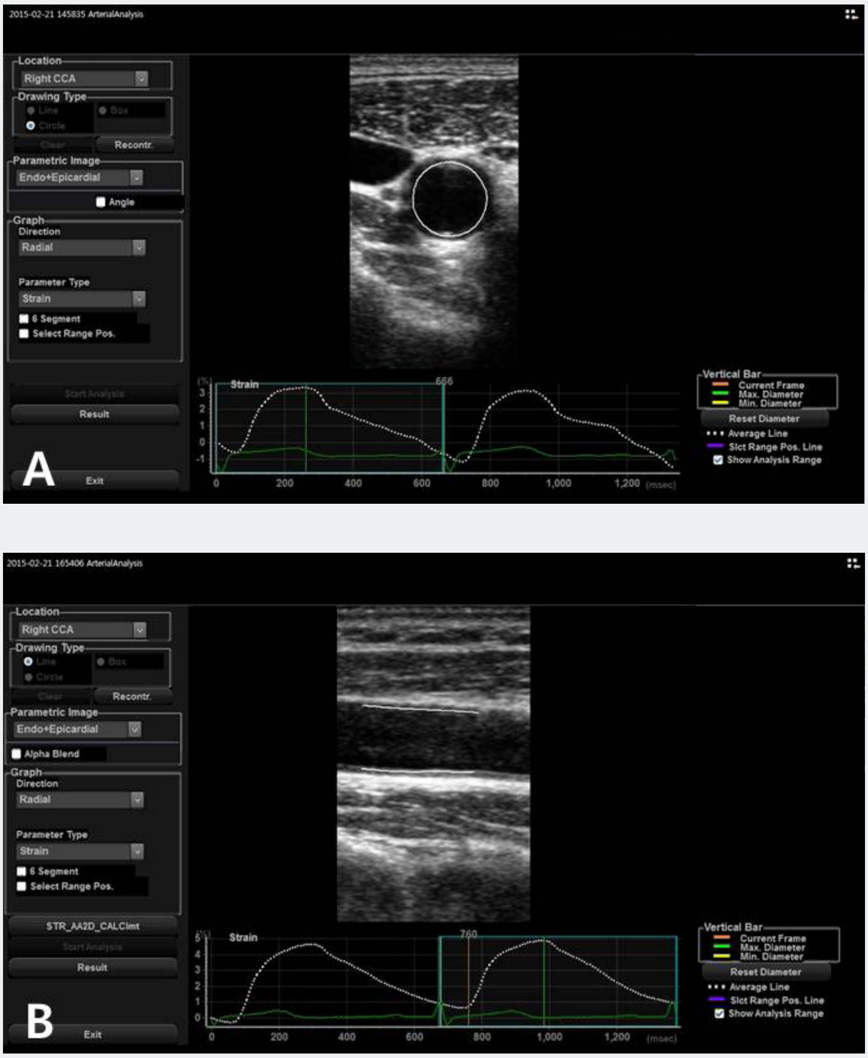


Figure 1. Assessment of arterial stiffness in transverse plane (A) and longitudinal plane (B) by Arterial Analysis software.

Results

Table 1 shows odds ratio (OR) of parameters for acute ischemic stroke to total study population. Among the parameters of arterial stiffness, the lower radial displacement and strain (OR: 0.044 and 0.765; *p*=0.028 and 0.008, respectively) and the lower circumferential displacement and strain (OR: 0.001 and 0.785; *p*=0.033 and 0.012, respectively) were significantly associated with acute ischemic stroke. The lower radial and circumferential strain (OR: 0.780and 0.801; *p*=0.015 and 0.023, respectively) were independently associated with acute ischemic stroke after adjusting age, gender and CIMT (Table 2).

Variable	Odds ratio	95% CI	*p*-value
Age	0.997	0.963-1.032	0.863
Men	1.675	0.829-3.385	0.150
Carotid IMT	0.066	0.004-1.114	0.059
Carotid plaque	0.000	0.000-0.000	0.998
PWV	0.951	0.808-1.119	0.543
Radial displacement	0.044	0.003-0.717	*0.028
Radial strain	0.765	0.629-0.932	*0.008
Radial strain rate	2.086	0.645-6.746	0.219
Circumferential displacement	0.001	0.000-0.160	*0.033
Circumferential strain	0.785	0.650-0.949	*0.012
Circumferential strain rate	2.115	0.642-6.970	0.218

Table 1. Univariate logistic regression model for acute ischemic stroke to total study population.

Variable	Odds ratio	95% CI	*p*-value
Age	1.010	0.973-1.050	0.591
Men	1.961	0.925-4.158	0.079
Carotid IMT	0.044	0.002-1.021	0.052
Radial strain	0.780	0.639-0.952	*0.015

Variable	Odds ratio	95% CI	*p*-value
Age	1.012	0.974-1.051	0.550
Men	1.941	0.917-4.104	0.083
Carotid IMT	0.042	0.002-0.959	*0.047
Circumferential strain	0.801	0.661-0.970	*0.023

Table 2. Multivariate logistic regression model for acute ischemic stroke.

Figure 2 shows examples of circumferential and radial strain values of the carotid artery acquired by Arterial Analysis in both control group and acute ischemic stroke. The parameters of arterial stiffness reflect the functional properties of carotid arteries and show changes before the development of structural change of arterial wall such as increased CIMT or carotid plaque. CIMT was similar but, circumferential and radial strain value were lower in patients of acute ischemic stroke.

CIMT is a well-known parameter with respect to cardiovascular disease; thus, we analyzed incremental value of multi-directional movement of carotid artery over CIMT to determine the stroke by the likelihood ratio (LR) χ^2 with age-sex matched data (Table 3). In table 3, adding circumferential and radial parameters of arterial stiffness to the CIMT significantly improved the association of the acute ischemic stroke.

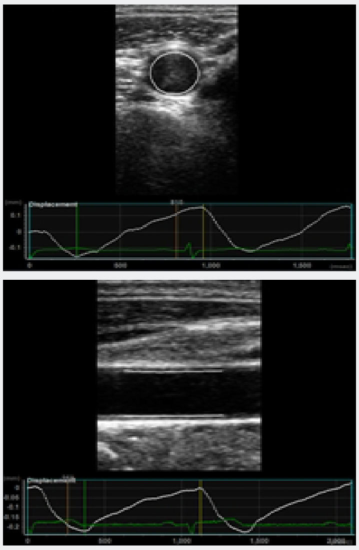
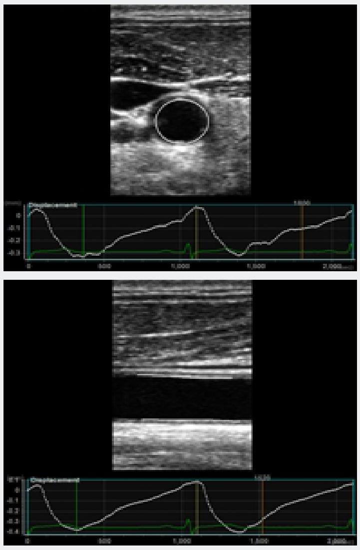
	(A) Control group	(B) Acute ischemic stroke group
		
CIMT	0.79	0.8
Circumferential strain	5.408	1.055
Radial strain	6.340	1.025

Figure 2. Examples of carotid echocardiographic data from circumferential and radial strain values of the carotid artery by Arterial Analysis with a 71-year-old man in control group(A) and a 66-year-old man in acute ischemic stroke group(B).

Variable	Likelihood ratio	*p*-value
Carotid IMT	88.95	
Carotid IMT + Circum. velocity	83.37	0.018[a]
Carotid IMT + Circum. velocity + Time to peak circum. strain	78.72	0.002[b]
Carotid IMT	88.95	
Carotid IMT + Radial velocity	82.83	0.013[c]
Carotid IMT + Radial velocity + Time to peak Radial strain	78.40	0.035[d]

Table 3. The incremental value of multi-directional movement of carotid artery over CIMT to determine the stroke by the likelihood ratio (LR) χ^2 with matched data.

a. Carotid IMT vs. Carotid IMT + Circumferential velocity
b. Carotid IMT + Circumferential velocity vs. Carotid IMT + Circumferential velocity + Time to peak circumferential strain
c. Carotid IMT vs. Carotid IMT + Radial velocity
d. Carotid IMT + Radial velocity vs. Carotid IMT + Radial velocity + Time to peak Radial strain

Conclusion

The lower radial and circumferential strains of carotid artery were significantly associated with acute ischemic stroke. In addition, parameters of arterial stiffness also had incremental value over CIMT to determine acute ischemic stroke. Arterial Analysis aided in providing not only multi-directional movement information of the carotid artery, but also arterial stiffness could be evaluated. Further studies on functional changes of carotid artery by using Arterial Analysis may be useful in early diagnosis of cardiovascular diseases.

Supported System

- RS80A with Prestige

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