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Estimation of mechanical properties of arterial wall from dynamic volume CT images

Masaharu Kobayashi[1*], Motoharu Hayakawa[2], Yoichi Sato[3] and Marie Oshima[4]

[1] Interfaculty Initiative in Information Studies, The University of Tokyo, 4-6-1 Komaba Meguro-ku Tokyo 153-8505, Japan, mkoba@iis.u-tokyo.ac.jp http://www.oshimalab.iis.u-tokyo.ac.jp

[2] Department of Neurosurgery, School of Medicine, Fujita Health University, 1-98 Dengakugakubo Kutukake Toyoake Aichi 407-1192, hayakawa@fujita-hu.ac.jp http://www.fujita-hu.ac.jp/~neuron/en/index.html

[3] Institute of Industrial Science, The University of Tokyo, 4-6-1 Komaba Meguro-ku Tokyo 153-8505, ysato@iis.u-tokyo.ac.jp http://www.hci.iis.u-tokyo.ac.jp/~ysato/

[4] Interfaculty Initiative in Information Studies/Institute of Industrial Science, The University of Tokyo, 4-6-1 Komaba Meguro-ku Tokyo 153-8505, Japan, marie@iis.u-tokyo.ac.jp http://www.oshimalab.iis.u-tokyo.ac.jp

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It is important to measure *in vivo* mechanical properties of arterial wall (MPAW) in order to observe pathogenesis and progression of atherosclerosis. Though *in vivo* measurement of mechanical properties has widely performed using ultrasonography and elastography[1], few studies examined mechanical properties at each position in artery. Recently electrocardiography (ECG)-gated dynamic volume computed tomography angiography (4D-CTA) using 320-row area detector CT scanner has been available to investigate evolution of arterial geometry[2], but estimation of MPAW has not been performed using 4D-CTA. It is possible to estimate MPAW by obtaining ECG-gated pressures and 4D-CTA because pressure change with cardiac pulsation leads to arterial morphological change. We have been developing an image-based modelling system with interactive graphical user interface to quantify three-dimensional vascular geometry and to evaluate temporal changes of geometry over time[3][4]. The aim of this study is to estimate *in vivo* MPAW by tracking arterial lumen in 4D-CTA.

The patient is 60-year-old male with a stenosis in the right internal carotid artery due to arteriosclerosis. The modelling system consists of four components: segmentation of arterial lumen, extraction of centerline of arterial lumen, surface reconstruction, tracking arterial lumen. We assume that the artery is thin-walled cylinder governed by linear isotropic elastic material model. Circumferential strain ε, Young' elastic modulus (YM) E_y and Pressure strain elastic modulus (PSM) E_p are respectively given as follows:

$$\varepsilon = \Delta R / R_{\min} \ , \qquad (1)$$

$$E_y = \Delta P R_{\min} R_{\max} / W_t \Delta R \ , \qquad (2)$$

$$E_p = \Delta P R_{\min} / \Delta R \ , \qquad (3)$$

where ΔP is pulse pressure, $R_{\min}, R_{\max}$ are minimum and maximum radius in cardiac cycle,

ΔR is the difference of those radii, and W_t is wall thickness.

The circumferential strain is obtained by tracking a reference point in the arterial centerlines (Fig.1). The distribution of strain shows the differences between right and left common carotid arteries (CCAs) with respect to the radius (Fig.2). Table 1 describes the result of mechanical properties in right and left CCA. The pulse pressure is calculated using the averaged blood pressures from 4 to 6 days after being hospitalized. The results imply that the right CCA with stenosis is stiffer than the left CCA because both YM and PSM of the right CCA is larger than those of the left.

The paper has developed the method to derive the mechanical properties of the arterial wall from tracking arterial lumen in 4D-CTA. The present method has applied to a 60-year-old male patient to obtain the *in vivo* distributions of the strain, YM, and PSM in left and right CCAs.

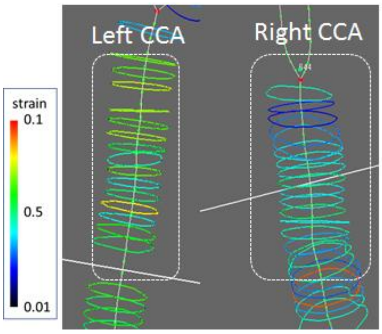

Figure 1. visualization of circumferential strain

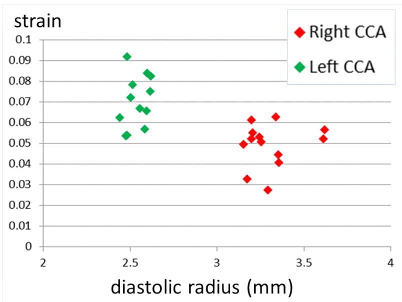

Figure 2. scatter plot between radius and strain in right and left CCA

	R_{max} (mm)	R_{min} (mm)	ε	W_t (mm)	ΔP (mmHg)	E_y (kPa)	E_p (kPa)
Left CCA	2.72	2.54	0.07	1.2	66.7	284	127
Right CCA (stenosis)	3.47	3.31	0.05	1.9	66.7	336	178

Table 1. results related to mechanical properties

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