THE ELASTICITY-PALPOGRAPHY TECHNIQUE REVISITED: DETECTION OF ATHEROSCLEROTIC PLAQUES

Jacques Ohayon[1,2], Flavien Deleaval[1], Adeline Bouvier[1], Simon Le Floc'h[3], Gérard Finet[4], Guy Cloutier[5], Roderic I. Pettigrew[6]

[1] Laboratory TIMC-IMAG,UJF, CNRS UMR 5525, Grenoble, France; [2] University of Savoie, Polytech Annecy-Chambéry, Le Bourget du Lac, France; [3] Laboratory LMGC, CNRS UMR 5508, Montpellier, France; [4] INSERM Unit 886, Lyon, France; [5] Laboratory LBUM, Montréal, Canada; [6] National Institutes of Health, Bethesda, Maryland, USA

Introduction

A critical key in detection of vulnerable plaques (VP) is the accurate quantification of both the morphology [Ohayon, 2008] and the mechanical properties of the diseased arteries [Finet, 2004]. However, the elasticity map remains difficult to assess since the full inverse problem needs to be solved in continuum mechanics using sophisticated nonlinear mathematical optimization tools and complex procedures [Le Floc'h, 2009; Richards, 2011; Doyley, 2012; Le Floc'h, 2012]. Céspedes et al. (2000) first proposed the elasticity-palpography technique (E-PT) which allows a fast wall stiffness quantification based on the arterial strain and blood pressure measurements. However, this technique suffers from major limitations because it has been developed for homogeneous, isotropic, quasi incompressible, circular and concentric atherosclerotic plaques, only. Therefore in the current study, the native E-PT was revisited to account for complex VP geometries.

Methods

Six patients underwent coronary intravascular ultrasound (IVUS), and the extracted plaque geometries were used to simulate strain fields from which the performance of the improved E-PT (IE-PT) was tested. We computed an approximated correcting shape function $h^*(r,\theta)$ which accounts for anatomical cross-sectional plaque geometry. Such approximated correcting function was obtained by using a finite element (FE) analysis and by assuming the plaque homogeneous, isotropic and quasi incompressible with Young's modulus E. The FE simulation was performed under plane strain conditions, in linear elasticity with a loading blood pressure amplitude ΔP. This approximated shape function was used to revisit the E-PT formulation whatever the VP geometries and the palpography domains considered Ω_{palpo} (with $R_i(\theta) \le r \le R_p(\theta)$):

$$E_{palpo}^{\text{revisited}}(\theta) = \frac{\Delta P \left| \int_{R_i(\theta)}^{R_p(\theta)} h^*(r,\theta)\, dr \right|}{\varepsilon(\theta)} \qquad (1)$$

where $\varepsilon(\theta)$ is the circumferential distribution of the averaged measured radial strain along the radial axis. The center of gravity of the lumen, was used as the origin of the cylindrical coordinate system (r,θ).

Results

The performance of the IE-PT to detect a vulnerable plaque with two necrotic cores (nc) is showed on Figure 1.

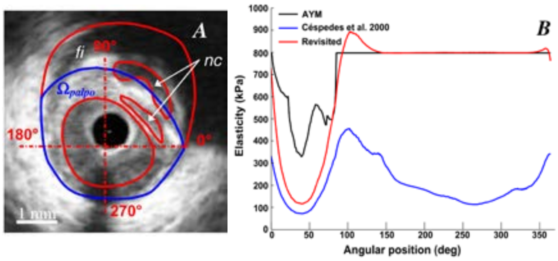

Figure 1: A) IVUS image. B) Comparisons between native (blue curve), improved (red curve) and averaged Young's modulus (AYM) (black curve) palpograms. "fi": fibrous region.

Conclusion

The IE-PT was successfully applied to the six coronary lesions of patients. Our results showed that the mean relative error decreased from $61.02 \pm 9.01\%$ to $15.12 \pm 12.57\%$ when considering the IE-PT instead of the E-PT.

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