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UNIVERSITÉ DE LYON

ESTIMATION AND MODELLING OF CAROTID WALL KINETICS FOR EARLY DETECTION OF ATHEROSCLEROSIS

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Introduction

Context:
Cardiovascular diseases remain the first cause of mortality and morbidity in the world. Atherosclerosis causes most of those cardiovascular events, Early detection may prevent these events and reduce the treatment cost. At early stage, atherosclerosis modifies mechanical properties of the arterial wall. Ultrasonography has a fine spatiotemporal resolution and is adapted for screening.

Aim of this work:
By analysing ultrasound (US) image sequences, assess dynamic parameters likely to become new atherosclerosis markers:

- cyclic compression of the arterial intima-media complex [1],
- arterial wall longitudinal kinetics (LOKI) [2-3],

Methods

Image acquisition:
B-mode US sequences of carotid-artery longitudinal sections were acquired by a cardiologist on both healthy and at high cardiovascular-risk subjects. All sequences contained at least two cardiac cycles.

Motion analysis:
The motion of selected points within the arterial wall was estimated using a Kalman-based block-matching method [4]. The trajectories have subsequently been visually analysed and grouped by an observer blinded to the subjects' pathological status. The groups were based on pattern similarity (Tab.1 and Fig 1).

Type	First-peak normalized average amplitude	Second-peak normalized average amplitude
1	0.5	1
2	0.3	1
3	1	Almost non-existent
4	1	1

Table 1. *Relative peak amplitudes used to cluster trajectories*

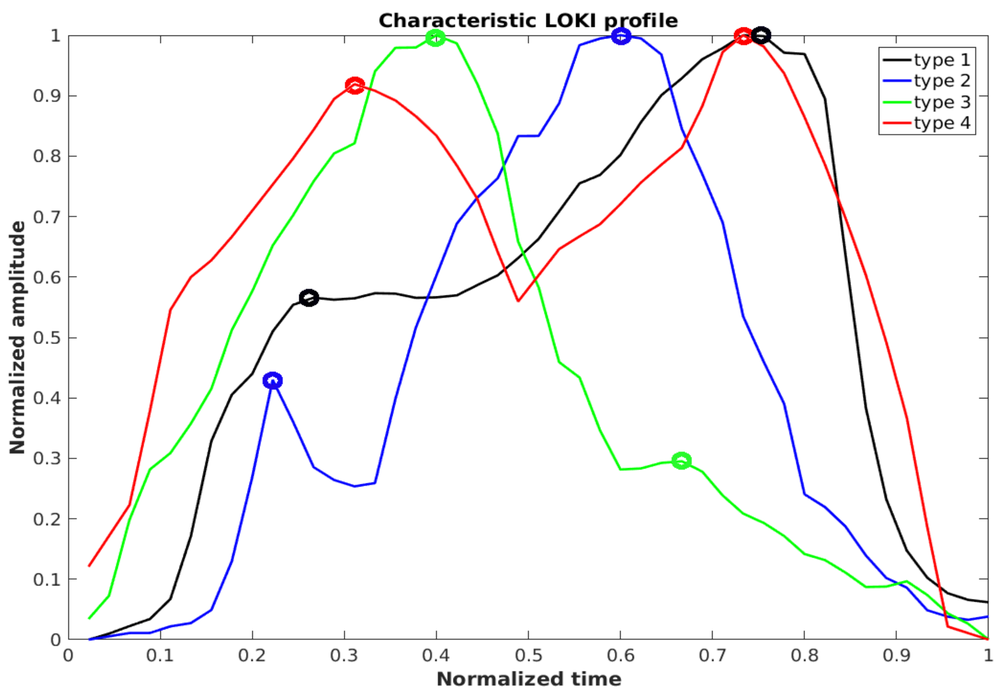

Figure 1. *Characteristic LOKI patterns, circles indicates peak position*

***Segmentation**:*
The contours of the intima-media complex in one frame were determined as a minimal cost path on a cost map built using a bank of shape-adapted filters [5-6]. Their location is used to initialise the segmentation in the next frame, etc., thus aiming to introduce a spatiotemporal consistency. While the method's accuracy can be assessed for an isolated frame by comparing its results with experts' tracings, the validation of intima-media thickness (IMT) temporal variability is challenging.

***Evaluation**:*
To evaluate the estimated IMT variations, only one IMT value per frame is needed. We therefore propose to draw contours in a *ty* slice from the *xyt* volume representing a B-Mode sequence (Fig. 2), thus ensuring temporal consistency. In this study three observers were involved in order to evaluate inter- and intra-observer variability.

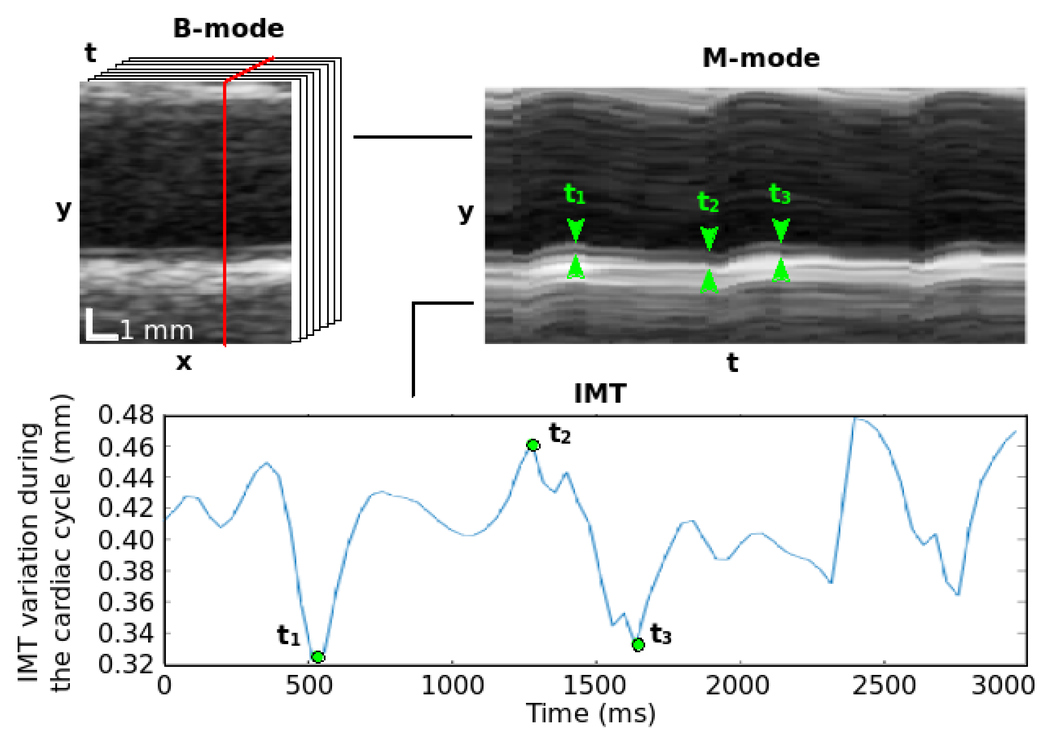

Figure 2. *M-mode image simulated from a B-mode sequence, and IMT variation obtained for this image.*

Preliminary results

Motion analysis:
In one third of the sequences (67 subjects) clear reproducible periodic motion patterns could be extracted and visually classified. Nevertheless, an association between curve shape and cardio-vascular risk seams to exist with an exploratory value p=0.09,

***Segmentation**:*
Reproducible periodic compression was also observed in a subset of the sequences (see Fig. 2). Overall, the average inter- and intra-observer variabilities of the IMT(*t*) curves respectively were of 68±59µm and 71±89µm,

Discussion and Conclusion

Motion analysis:
The major limitation of this work was that two thirds of the sequences could not be used in the statistics because of unclear periodicity. Motion estimation may be improved by introducing a biomechanics-inspired model to the algorithm. Also, visual curve grouping by only one observer may be too subjective, and a consensus of several observers or an **automated classification** may be necessary. Investigating the biomechanical phenomena underlying different motion patterns may be clinically relevant.

Segmentation:
This work confirmed the periodic compression of the carotid wall. Nevertheless, the curves obtained were not sufficiently reproducible, In future work, additional interactive tools will be designed to guide the observer in the segmentation process and help take full advantage of the spatio-temporal consistency.

Acknowledgements

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References:

(1) Ilea DE *et al*. IEEE UFFC, 60(1):158-177, 2013.
(2) Cinthio M. *et al*. Am J Physiol Heart Circ Physiol, 291:H394–H402, 2006
(3) Gastounioti A. *et al*. Phys. Med. Biol. 58:8647-8661, 2013
(4) Zahnd G. *et al*. Med Image Anal, 17 :573–585, 2013
(5) Zahnd G. et al. Int J CARS, 9:645-658, 2014.
(6) Zahnd G. *et al*. Ultrasound Med Biol, 43:239-257, 2017.

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