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Carotid artery non invasive elastography (NIVE) to detect early changes of cardiovascular diseases in overweight and obese children

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***Abstract*—Increased arterial stiffness is one of the first signs of atherosclerosis. The objective of this study was to use non-invasive elastography (NIVE) to detect early changes in vascular biomechanics associated with obesity in children. The NIVE algorithm also measured the intima-media thickness (IMT) for comparison.**

NIVE was applied in 120 children, 60 with elevated body mass index (BMI) (≥ 85th percentile for age and sex) and 60 non-overweight (BMI < 85th percentile). Participants were randomly selected from a longitudinal cohort, evaluating consequences of obesity in healthy children with one obese parent. The carotid wall was automatically segmented and elastograms were computed to measure the cumulated axial strain (CAS), cumulated axial translation (CAT), and maximal shear strain (Max |SSE|); IMT was also computed from segmented contours. Elastogram features were compared between groups with multivariate analyses to control for age, sex, Tanner stage, blood pressure, and low-density lipoprotein cholesterol (LDL).

After Bonferroni correction, CAT was significantly higher in the elevated BMI group (0.68 ± 0.24 mm vs. 0.52 ± 0.18 mm), $p < 0.001$. CAS/CAT was significantly lower in the elevated BMI group (9.54 ± 4.8 %/mm vs. 13.34 ± 6.46 %/mm), $p = 0.001$; the lower CAS/CAT ratio suggests stiffer arteries with less deformation for a similar translation. Before Bonferroni correction, IMT was significantly higher in the elevated BMI group (0.36 ± 0.05 mm vs. 0.32 ± 0.05 mm), $p = 0.013$. IMT statistical difference was no longer significant after Bonferroni correction.

After Bonferroni correction, NIVE detected differences in CAT and CAS/CAT biomarkers in elevated BMI children, whereas IMT failed to show a difference. NIVE is a promising technique to monitor radiological biomarkers of subclinical atherosclerosis in the pediatric population.

Keywords— Ultrasound, Elastography, Obesity. Children

I. Introduction

Atherosclerosis has been known to start early in childhood and progress into lesions during adulthood [1]. Childhood overweight and obesity, that have increased over the last decades, are known risk factors for atherosclerosis and cardiovascular diseases later in life [2]. Common carotid artery intima-media thickness (IMT) is a marker of subclinical atherosclerosis [3]. In children, increased IMT has been associated with obesity and with an enhanced risk of cardiovascular events in adulthood. However, in the pediatric population, IMT is subjected to high variability depending on the technique. In a systematic review, an association was found

between childhood and adolescent obesity and greater arterial stiffness [4]. Non-invasive vascular elastography (NIVE) evaluates vessel wall biomechanical markers of translation motion, strain, and shear occurring during the natural cardiac pulsation. The objective of this study was to use NIVE to detect early changes in vascular biomechanics associated with obesity in childhood.

II. Methods

A total of 120 children participant were recruited: 60 overweight/obese children (body mass index (BMI) $\geqslant$ the 85th percentile) and 60 non-overweight children (BMI $<$ 85th percentile) from a longitudinal cohort study on obesity in childhood [5].

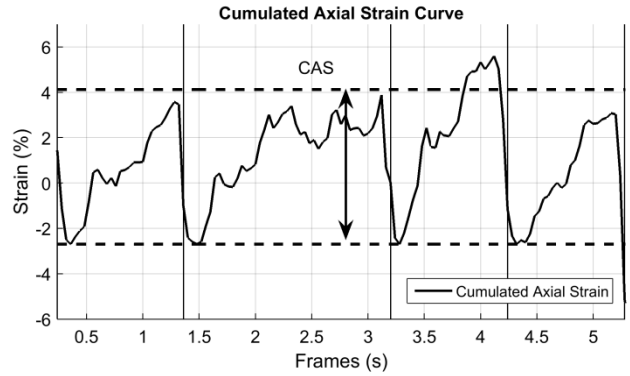
Ultrasound cine-loops of images of the far wall of the common carotid artery in the longitudinal view were acquired within 2 cm from the carotid bifurcation following the Mannheim consensus [6]. Radiofrequency ultrasound images were acquired with the Esaote MyLab70 platform with a linear array L10-5 40-mm ultrasound transducer. Segmentation of the carotid artery wall and NIVE computation were performed on all frames of the cine-loop. Two contours were used to delineate the carotid artery wall (the lumen-intima and the media-adventitia interfaces). These contours were manually traced on one frame of the cine-loop and they were then automatically adapted to segment the carotid artery wall on the remaining cine-loop frames [7]. Noninvasive elastography was then applied to the segmented area to generate 2D displacement maps between consecutive ultrasound frames [8]. Elastography provided axial and lateral translations, strain and shear strain (axial and lateral indicate respectively the directions along and perpendicular to the ultrasound beam). The segmentation and NIVE computations were implemented into a commercial imaging platform (Visual, Object Research Systems, Montreal, Canada). A detailed description of the study methodology can be found in [9].

Time-varying curves were obtained by spatially averaging elastogram component over each elastogram frame. Cumulative curves were computed by accumulating values of the time-varying curves over separate cardiac cycles. Cumulative parameters were defined as the maximum minus minimum value during a cardiac cycle. All descriptive indexes were averaged over manually selected cardiac cycles. The following elastogram features were extracted from the time-varying and cumulated curves: cumulated axial strain (CAS); cumulated axial translation (CAT); ratio of cumulated axial strain to cumulated axial translation (CAS/CAT); and maximum absolute shear strain (Max |SSE|).

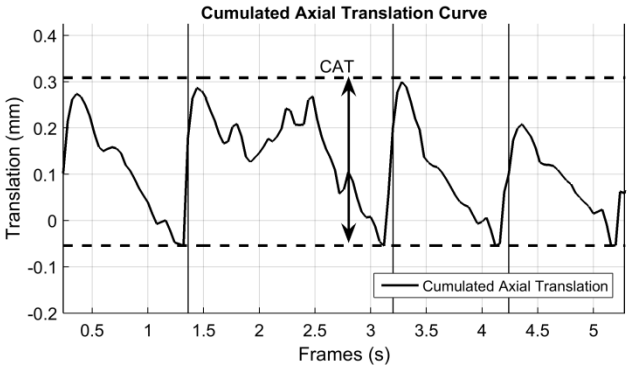
III. Results

A total of 120 children participant were recruited. There were statistically significant differences in mean age, low-density cholesterol (LDL) concentration, systolic and diastolic blood pressures, and Tanner stage; higher values were observed for all variables in the elevated BMI group as compared to normal BMI. All values of these clinical characteristics can be found in [9].

Comparisons were made between the elastogram features of normal and elevated BMI groups. Groups were also compared while adjusting for the following confounding factors: age, sex, Tanner stage, blood pressure, and LDL. CAT and CAS/CAT were statistically significantly different between groups after Bonferroni correction (0.68 ± 0.24 mm vs. 0.52 ± 0.18 mm, $p < 0.001$ for CAT in elevated and normal BMI groups, respectively; and 9.54 ± 4.8 %/mm vs. 13.34 ± 6.46 %/mm, $p = 0.001$ for CAS/CAT in elevated and normal BMI groups, respectively). A lower value of CAT and a correspondingly higher value of the CAS/CAT ratio were observed in the normal BMI group compared to the elevated BMI group. When comparing the values unadjusted for the confounding factors, Max |SSE| was also significantly lower in the normal BMI group (0.48% vs. 0.53% for normal and elevated BMI groups, respectively; $p = 0.04$). There was no difference between the IMT measurements of both groups after Bonferroni correction. Detailed results of this study can be found in [9]. Figure 1 shows examples of NIVE curves for the parameter CAS and CAT.



(a)



(b)

Fig. 1. Graphs of (a) cumulated axial strain and (b) cumulated axial translation curves during four cardiac cycles. Curves correspond to the accumulation of spatially averaged elastogram component within the segmented area of the carotid artery from every elastogram frame. The parameter CAS indicates the cumulated strain averaged over all cycles. The cumulated axial translation (CAT) corresponds to the displacement of the vessel wall during the cardiac cycle.

IV. Discussion

There were differences in the common carotid elastography measurements between groups of elevated BMI children and normal BMI children. These differences remained after adjusting for the confounding factors of age, sex, blood pressure, and Tanner stage. CAT was statistically significantly higher in the elevated BMI group but a statistically significantly lower CAS/CAT was observed in that group. A lower axial strain per unit of axial translation indicates that arteries were stiffer in the elevated BMI group.

Childhood obesity is a concern as it is a recognized risk factor for cardiovascular disease in adulthood and its prevalence has increased in recent decades. Monitoring of subclinical atherosclerosis in the pediatric population could be improved by using NIVE radiological biomarkers.

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