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LETTER TO THE EDITOR

Myocardial Stiffness Assessment Using Shear Wave Imaging in Pediatric Hypertrophic Cardiomyopathy

The pathophysiology of hypertrophic cardiomyopathy (HCM) is characterized by an increase of ventricular stiffness in most patients. Diastolic dysfunction in HCM is related to the alteration of the myocardial passive stiffness (MS) that modifies left ventricular relaxation. However, evaluation of diastolic function in HCM still remains challenging. Indeed, the conventional echocardiographic parameters used for evaluation of diastolic function are difficult to apply to children, mostly because the use of these parameters does not seem to be applicable with robustness to children with cardiomyopathy (1). Today, we lack reproducible quantitative tools independent of loading conditions and anthropometric parameters to evaluate diastolic left ventricular function in children with HCM.

Shear wave imaging (SWI) by ultrafast imaging is an ultrasound-based technique for quantitative, local, and noninvasive mapping of soft tissue elastic properties. This technique has proved to be clinically efficient in evaluating tissue stiffness in numerous organs. The technological validation of MS by SWI has previously been reported (2). In addition, it has been compared with invasive gold standard parameters for left ventricular diastolic function (3). Its clinical feasibility has been demonstrated in adults (4) and children. However, no clinical studies determining the interest and the contribution of this technology to the assessment of diastolic function in pediatric HCM have yet been reported.

The purpose of our study was to quantify diastolic MS noninvasively using myocardial SWI in pediatric HCM patients compared with an age- and sex-matched control group of healthy children.

We prospectively included 28 patients with HCM and 28 healthy controls matched for age (range 5 to 18 years) and sex. Standard echocardiography and SWI were performed. Twenty-one HCM patients underwent a cardiopulmonary exercise test. SWI was performed using an ultrafast ultrasound system (Aixplorer, Supersonic Imagine, Aix-en-Provence, France) and a phased-array probe (2.75 MHz). SWI acquisitions were performed on the anteroseptal basal segment during end-diastole in 2 orthogonal views (Figure 1). Fractional anisotropy (FA) estimated by shear wave speed was also evaluated (5).

Median MS in the control group was 1.7 kPa (95% confidence interval [CI]: 1.3 to 1.8 kPa). MS was significantly higher in the HCM group (7.9 kPa; 95% CI: 7.2 to 10.5 kPa; $p < 0.01$) (Figure 1A). FA was lower in the HCM group (0.084; 95% CI: 0.058 to 0.130) compared with controls (0.138; 95% CI: 0.086 to 0.222; $p = 0.01$) (Figure 1B). Based on receiver-operating characteristic curve analysis, no unique echocardiographic parameter could predict MS >4 kPa with high specificity and sensitivity. Strong correlations were found between MS and peak oxygen uptake ($r = -0.752$; $p < 0.01$) or peak oxygen pulse ($r = -0.773$; $p < 0.01$). Among the 7 HCM patients who had MS >95% CI (>10.5 kPa), 6 had an echocardiographic restrictive profile assessed by left atrial volume index >48 ml/m^2, E/A >2, E-wave deceleration time <150 ms, and e′ medial <6 cm/s.

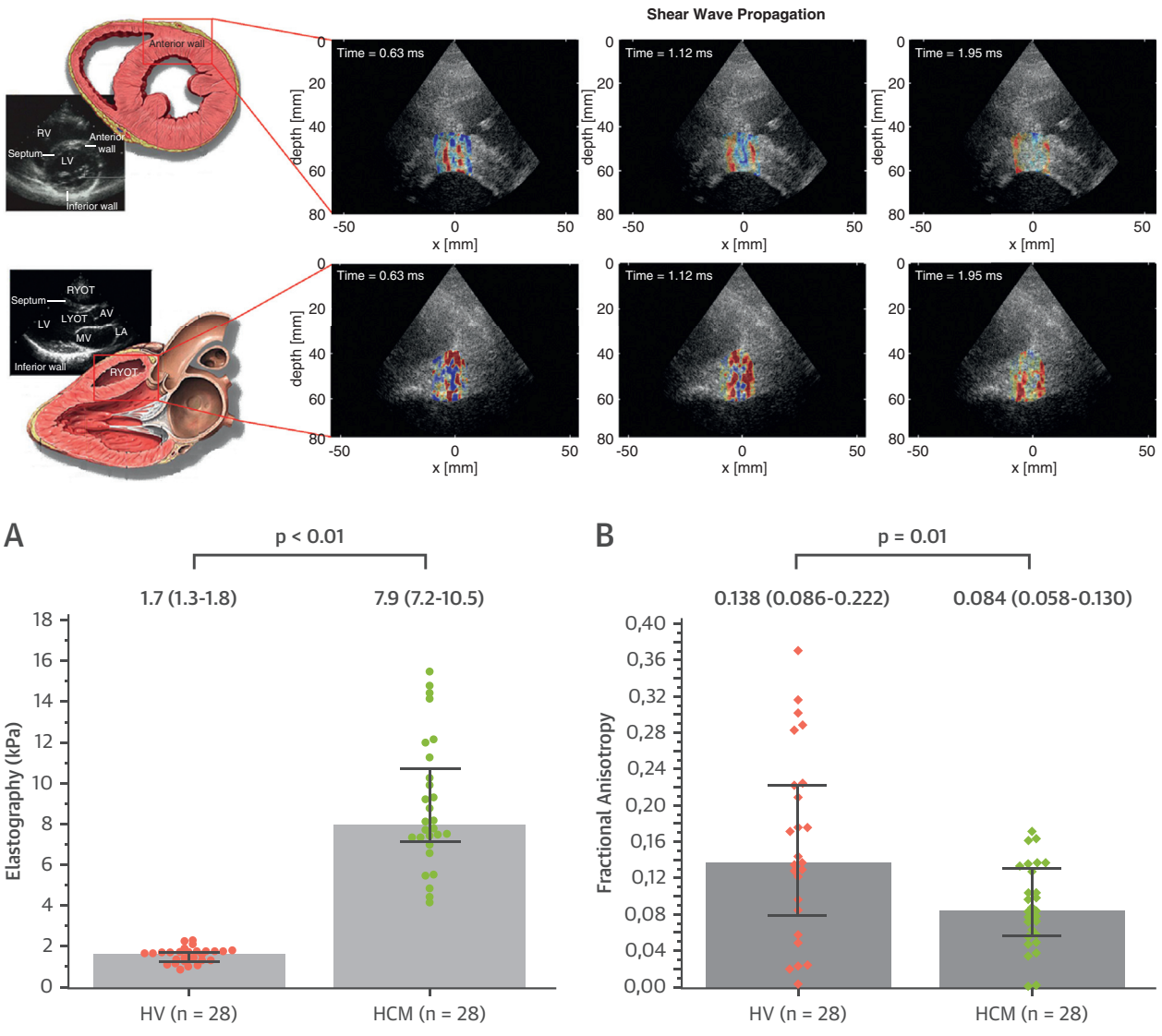
The intraoperator standardized coefficient of variability (CV) was 5.2% over the studied population. There was no significant difference between the 4 successive series of measurements made by the 2 different operators (Kruskal-Wallis test), and the corresponding CV was 4.7%.

The last ESC Guidelines on HF specified that "no treatment has yet been shown, convincingly, to reduce morbidity or mortality in patients with HFpEF." This is due to the fact that the physiopathology of this disease is still misunderstood, but also because we lack quantitative and reproductive tools to evaluate heart failure with preserved ejection fraction, specifically for HCM. We believe that the MS estimated by SWI may be an interesting predictor of outcome and may help to stratify patients for the evaluation of treatment strategies. In addition, it might be interesting to evaluate the effect of drugs currently used in HCM on MS values. If any positive effect is seen in association with changes in outcomes, MS could be used as a surrogate or as a therapeutic target in future trials.

In this study, we quantitatively assessed the diastolic MS in children using SWI in healthy volunteers and pediatric HCM. MS was high in children with HCM and even higher in those with a restrictive physiology. In addition, the fractional anisotropy obtained by SWI could help provide additional information on the myocardial structure.

Our study remains descriptive, but it offers the perspective to evaluate this new noninvasive marker as a potential predictor of outcome and as a potential therapeutic target.

FIGURE 1 Myocardial Elastography and Fractional Anisotropy by Shear Wave Imaging



(Top) B-mode and shear wave elastography imaging examples from an HCM patient. Shear wave propagation in short- and long-axis views (tissue axial velocity images). **(A)** Elastography results. **(B)** Fractional anisotropy results. HCM = hypertrophic cardiomyopathy; HV = healthy volunteer.

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