Ultrasound in Med. & Biol., Vol. 39, No. 7, pp. 1207–1214, 2013

0301-5629/$ - see front matter

http://dx.doi.org/10.1016/j.ultrasmedbio.2013.02.015

● *Original Contribution*

LEFT VENTRICULAR LONGITUDINAL STRAIN MEASURED BY SPECKLE TRACKING AS A PREDICTOR OF THE DECREASE IN LEFT VENTRICULAR DEFORMATION IN CHILDREN WITH CONGENITAL STENOSIS OF THE AORTA OR COARCTATION OF THE AORTA

J. Van der Ende,* Clara A. Vázquez Antona,† Julio Erdmenger Orellana,† Ángel Romero Cárdenas,‡ Francisco Javier Roldan,‡ and Jesús Vargas Barrón‡

*Department of Pediatric Cardiology, Leiden University Medical Center Leiden, The Netherlands; †Department of Pediatric Echocardiography, National Institute of Cardiology "Ignacio Chávez", Tlalpan, México; and ‡Department of Echocardiography, National Institute of Cardiology "Ignacio Chávez", Tlalpan, México

(*Received* 15 *June* 2012; *revised* 17 *January* 2013; *in final form* 21 *February* 2013)

Abstract—Children born with a left ventricular outflow tract obstruction (LVOTO) can present with symptoms of left ventricular (LV) failure while ejection fraction (EF) is normal. A more sensitive parameter of systolic function might be obtained with speckle tracking echocardiography, which describes ventricular longitudinal deformation in strain values. It is presumed that despite a normal or only slight decrease in ejection fraction, patients with a LVOTO demonstrate aberrations in the longitudinal deformation of the left ventricle. In addition, it is expected that after a successful intervention, longitudinal deformation returns to normal values. Standard trans-thoracic echocardiography was performed on 33 consecutive patients with a LVOTO, either an isolated aortic coarctation (AoCo) or an isolated aortic stenosis (AoSt). Before intervention a significant decrease in strain values was observed compared with the control group (N = 40), with an additional decrease in strain values in the first week after intervention (N = 16). Strain values recovered after a mean follow-up period of 42 wk (N = 9), though normal values were never reached. In addition, patients with an AoCo had a smaller decrease in strain values compared with patients with AoSt. All strain values were measured with a concomitant ejection fraction between normal limits. It is concluded that patients with a congenital LVOTO have decreased ventricular systolic function measured as strain values, whereas their ejection fraction is within the normal range. Therefore, as ejection fraction may not be an accurate measure, speckle tracking-based strain may be significant in the identification of subtle changes in longitudinal deformation and may create opportunities for patients to benefit from early treatment for heart failure. (E-mail: vanderende.jacob@gmail.com) © **2013 World Federation for Ultrasound in Medicine & Biology.**

Key Words: **Congenital heart defects, Strain, Left ventricular outflow tract obstruction, Ejection fraction, Aortic coarctation, Aortic stenosis, Speckle tracking.**

INTRODUCTION

Children born with left ventricular outflow tract obstructions (LVOTOs) like aortic coarctation (AoCo) and aortic stenosis (AoSt) are likely to suffer from pressure overload to the left ventricle and are at risk of developng left ventricular hypertrophy, which may progress to ventricular fibrosis and heart failure (Pacileo et al. 2003). Because the majority of these patients present with a normal ejection fraction, it would be advantageous to reveal ventricular abnormalities that may indicate ventricular dysfunction. With a prevalence of 401 aortic stenoses and 409 coarctations per million live births, AoCo and AoSt are anomalies that are frequently encountered within the scope of pediatric health care (Hoffman and Kaplan 2002). When echocardiography was established as a valuable technique in the diagnostics of cardiac congenital diseases, ejection fraction (EF) was accepted as a measure of global functioning of the left ventricle. Today, EF is the preferred measure of systolic function of the left ventricle and can be calculated for almost every patient. Recent innovative research used a model that calculated the separate effects of LV wall

Address correspondence to: J. Van der Ende, Department of Pediatric Cardiology, Leiden University Medical Center, Albinusdreef 2, 2300 RC, Leiden, The Netherlands. E-mail: vanderende.jacob@gmail.com

thickening and reduced longitudinal deformation on EF and stroke volume, concluding that EF may be of less value in quantifying systolic function than was previously thought (Maciver and Townsend 2008). The model indicated that under certain conditions, EF could be preserved within the normal range despite the presence of systolic failure. For example, an increase in ventricular muscle volume leads to additional endocardial displacement, leading to an increase in EF when longitudinal shortening is unchanged. However, when LV hypertrophy develops and, at the same time, long-axis deformation decreases, the non-dilated hypertrophic left ventricle masks the deprived ventricular function by preserving its "normal" ejection fraction. The model therefore suggests that in certain circumstances, the ejection fraction is a poor index of systolic function (Remme and Swedberg 2001). Symptoms of heart failure in the presence of a normal EF constitute a pathophysiology described earlier as heart failure with normal ejection fraction (HFNEF) (Sanderson and Yip 2009). In these patients, EF is an insufficient descriptor of systolic or diastolic ventricular dysfunction, because it indicates the left ventricle is functioning well while aberrations in ventricular contraction exist. Correspondingly, in a study including asymptomatic children with severe AoSt, left ventricular EF and fractional shortening appeared not to be related to strain and strain rate measurements at follow-up (Marcus and de Korte 2012a). Therefore, a more prognostic tool is required to visualize aberrations in ventricular contraction. Although more invasive than more recently developed techniques such as magnetic resonance imaging and radionuclide ventriculography, echocardiography is still regarded as the preferred imaging modality for determination of left ventricular function (Domanski and Nanda 2006). In the search for more sensitive techniques strain echocardiography was able to detect aberrations within the myocardium indicative of subclinical ventricular dysfunction (Pellerin et al. 2003).

In 1998 the real-time strain rate technique, based on tissue Doppler echocardiography (TDE), was introduced. With this method, it was possible to discriminate between normal and reduced regional ventricular function (Heimdal et al. 1998). Patients with congenital aortic stenosis had decreased tissue Doppler (TD) and TD-based strain parameters compared with healthy controls (Poulsen et al. 2007; Vitarelli et al. 2007). Balloon dilation or aortic valve replacement in patients with AoSt induced an increase in ventricular deformation values during follow-up compared with the same deformation values before intervention (de Kort et al. 2006). There have been studies on the implementation of strain and strain rate imaging in longitudinal deformation abnormalities, but many of these have used TD imaging. TD imaging has the important limitation of angle dependency and inaccuracy caused by cardiac translation (Hashimoto et al. 2003; Kowalski et al. 2001). Recently, other studies on longitudinal deformation abnormalities have been performed using speckle tracking (Kiraly et al. 2003). With speckle tracking, a two-dimensional technique independent of angle and cardiac translation, deformation parameters can be measured easily and with great accuracy (Perk et al. 2007). With automated functional imaging (AFI), a new utility integrated into EchoPAC software, measuring longitudinal ventricular deformation is objective and easily accessible for daily practice within the clinic. The first results with this technique are promising (Marcus et al. 2012b; Reisner et al. 2004). However, to date there are no published data on longitudinal left ventricular deformation in children with an isolated AoCo and few studies in which strain is analyzed during early and late follow-up. Our hypothesis is that children with either an isolated CoAo or an isolated AoSt have longitudinal deformation abnormalities of the left ventricle despite a normal or only slightly decreased EF. Furthermore, successful intervention with either surgery or catheterization is expected to induce a subsequent decrease in the observed deformation abnormalities.

METHODS

Study population

Thirty-three patients with a LVOTO underwent diagnostics in our hospital between December 2007 and February 2009 and were enrolled in the prospective study. Twenty-one patients were diagnosed primarily with AoSt and 12 patients with AoCo. Patients were included when the obstruction was symptomatic; a second criterion for inclusion was an obstruction that produced a peak gradient of at least 80 mm Hg (Keane et al. 1993). None of the 33 patients had concomitant cardiac anomalies. The first echocardiogram was acquired within the week preceding the intervention. Three patients underwent catheterization, and 13 patients underwent surgery. One patient died from ventricular failure during surgery. A second echocardiogram was acquired for 16 patients in the first week after intervention. A smaller number of patients were included in this early follow-up group as many patients had a difficult echocardiographic window after the intervention, most probably because of local post-operative tissue reactions. These echocardiographic acquisitions were discerned not usable for strain analysis. Because of inconsistent communication with rural parts of the country, only 9 of the 16 patients could be reached and were included in the late follow-up group. With a mean follow-up time of 42 weeks, these patients returned to our institute for the third echocardiogram.