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● *Original Contribution*

AUTOMATIC MEASUREMENTS OF MITRAL ANNULAR PLANE SYSTOLIC EXCURSION AND VELOCITIES TO DETECT LEFT VENTRICULAR DYSFUNCTION

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Abstract—The purpose of the study described here was to evaluate an automatic algorithm for detection of left ventricular dysfunction, based on measurements of mitral annular motion indices from color tissue Doppler apical four-chamber recordings. Two hundred twenty-one patients, among whom 49 had systolic and 11 had diastolic dysfunction, were included. Echocardiographic evaluation by cardiologists was the reference. Twenty patients were also examined by medical students. The ability of the indices to detect systolic and diastolic dysfunction were compared in receiver operating characteristic analyses, and the agreement between automatic and reference measurements was evaluated. Mitral annular plane systolic excursion ≤10 mm detected left ventricular dysfunction with 82% specificity, 76% specificity, 56% positive predictive value and 92% negative predictive value. The automatic measurements acquired from expert recordings better agreed better with the reference than those acquired from student recordings. We conclude that automatic measurements of systolic mitral annular motion indices can be helpful in detection of left ventricular dysfunction. (E-mail: Bjorn.o.haugen@ntnu.no)

Key Words: **Atrioventricular, Displacement, Heart failure, HFpEF (heart failure with preserved ejection fraction), HFrEF (heart failure with reduced ejection fraction), Tissue Doppler.**

INTRODUCTION

Between 1% and 2% of the adult population in the Western world have heart failure, and 10% of people aged ≥70 y are affected (Ponikowski et al. 2016). Taking care of all these patients is a huge task for the specialized health care service. The complexity of echocardiography limits its usefulness for inexperienced users (Atherton 2010). Automated measurements and interpretations of findings may improve the use of echocardiography among non-expert users.

Heart failure is most often due to a variable degree of systolic and/or diastolic left ventricular (LV) dysfunction. Several echocardiographic parameters including LV ejection fraction (EF), Doppler-based indices and sizes of cardiac chambers are commonly combined to assess LV function (Ponikowski et al. 2016). This is a comprehensive task reserved for experts and requires the use of multiple echocardiographic modalities not feasible for incorporation into pocket-sized imaging devices (PSIDs). Therefore, simplified solutions are needed for automated detection of heart failure using PSIDs.

Left ventricular longitudinal function is reduced in patients with systolic and diastolic dysfunction, and can be quantified by measuring the mitral annular plane systolic excursion (MAPSE), peak systolic (S') and peak early (e') and late (a') diastolic velocity (Bruch et al. 2003; Garcia et al. 2006; Yip et al. 2002). All these parameters can be

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Conflict of Interest: B.O.H., H.D. and O.C.M. held positions at MI Lab, a center of research-based innovation that was funded by the Research Council of Norway (Grant 219282) and industry. The Center had a total budget of 124 million NOK from 2007 to 2015. B.O.H. also holds a position at CIUS, a similar center of research-based innovation that is funded by the Research Council of Norway and industry from 2016 to 2022. S.S., H.D. and O.C.M. held positions in a user-driven Research-based innovation project called Smartscan.

measured despite low image quality from the easily obtainable apical four-chamber view (Hu et al. 2013; Kadappu and Thomas 2015).

We have developed an algorithm that automatically measures MAPSE, *S′*, *e′* and *a′* from color tissue Doppler (CTD) recordings, with good agreement compared with reference measurements (Storve et al. 2016). This algorithm could be implemented on future PSIDs. The main aim of this study was to evaluate the ability of the automatic algorithm to detect systolic and/or diastolic LV dysfunction using experienced cardiologists' echocardiographic evaluations of LV function as the reference. In addition, we evaluated the agreement between automatic and reference measurements when the algorithm was run on recordings by both experts and novices.

METHODS

Patients

The study population consisted of inpatients and outpatients referred for echocardiographic examination at the Department of Cardiology, St. Olavs hospital, Trondheim University Hospital, Trondheim, Norway. Inclusion criteria were age ≥18 y and referral for echocardiographic evaluation at the hospital. Patients were excluded if the echocardiographic recordings could not be interpreted by the cardiologists because of poor image quality. Demographic characteristics and cardiovascular comorbidity were obtained from the hospital's patient charts and the echocardiographic archive. Written informed consent was obtained from all patients. The Regional Committee for Medical and Health Research Ethics and the Norwegian Social Science Data Service approved the study, which was conducted according to the Declaration of Helsinki.

Echocardiographic examinations

All reference echocardiographic examinations were performed by experienced cardiologists or experienced sonography technicians, using a commercially available Vivid E9 with an M5S-D cardiac transducer (bandwidth 1.5–4.6 MHz) or Vivid 7 with an M3S cardiac transducer (bandwidth 1.5–4.0 MHz) (both GE Vingmed Ultrasound, Horten, Norway). The sonographers' recordings and measurements were approved by a cardiologist. The patients were examined in the left lateral decubitus position. An additional experienced cardiologist contributed in the post-processing. The recordings were analyzed online or in EchoPAC SWO (Version 113, GE Vingmed Ultrasound).

Student examinations. Medical students from the Norwegian University of Science and Technology (NTNU, Trondheim, Norway) participated in the study. On the day of participation, the students were explained how to acquire an apical four-chamber view, with printed image examples of correct and wrong views. The images were kept by the students for help during scanning. The apical four-chamber view is provided in Figure 1.

Immediately after the reference examination, patients were transferred to another room in the same department for examination by a medical student. The students used a Vivid 7 scanner with an M3S cardiac

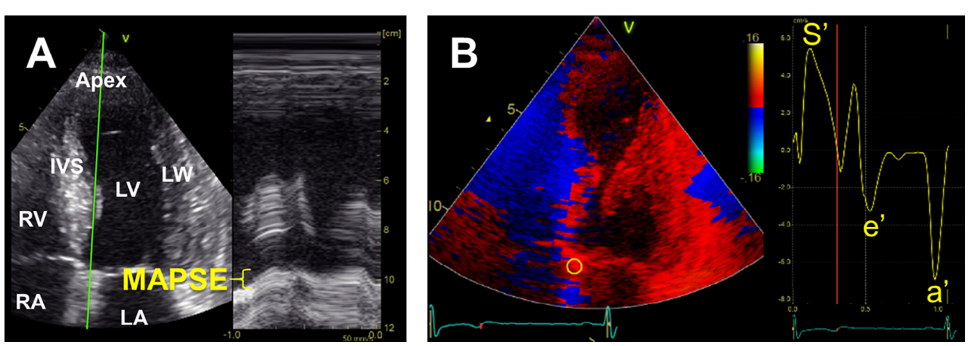

Fig. 1. The acquisition of reference measurements of mitral annular motion indices. (a) The mitral annular plane systolic excursion (MAPSE) is here measured using anatomic M-mode on a B-mode apical four-chamber recording, revealing the left (LV) and right (RV) ventricles, the left (LA) and right (RA) atria, the apex, the interventricular septum (IVS) and the left ventricular lateral wall (LW). The principle is the same as for regular M-mode measurements. A virtual M-mode scan line (*green*) is pointed at the edge of the mitral annulus (here at the septal side), as seen to the left. The echo signal along this 1-D line during one cardiac cycle is seen to the right. A caliper is used to measure the displacement of the annulus during systole, which corresponds to the distance within the *yellow, curly bracket*. The same process is repeated at the lateral side. Septal and lateral measurements from three consecutive heart cycles are averaged. (b) The mitral annular velocities are measured from apical four-chamber color tissue Doppler recordings. A stationary 5 × 5-mm sample volume is placed at the septal (*yellow ring*) and lateral (not marked here) sides of the annulus, as seen on the left. The septal tissue velocity curve from one cardiac cycle is seen on the right. The maximum positive velocity is the systolic peak velocity (*S′*) and the maximum negative velocities are the early (*e′*) and late (*a′*) diastolic peak velocities. As for MAPSE, septal and lateral measurements from three consecutive heart cycles are averaged to calculate each index.