Performance of user independent echocardiographic border detection algorithm: comparison with human observer variability

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Abstract

Introduction: We evaluated a method for autonomous, user-independent automated border delineation (ABD) developed by Geiser and Wilson, by comparing the accuracy of ABD relative to manual border tracing. Methods: Short axis echocardiographic images of 84 patients from 3 clinical sites were analyzed using ABD and by manual tracing performed by two observers at each site and two observers at a core laboratory. The centerline method was used to measure the distance between each pair of computer-generated and hand-traced borders. Cardiac parameters were also measured from all sets of borders: LV area, fractional area change, antero-posterior diameter, wall motion, and wall thickening. Results: The distance between computer-generated and hand-traced borders was slightly but significantly greater than human interobserver variability between the clinical sites and the core laboratory (0.34±0.25 (N = 328) vs. 0.26±0.16 (N = 320) cm for the endocardium at end diastole, p = 0.0001). Measurements of LV area and fractional area change were similar by ABD and manual tracing. Other cardiac parameters showed greater deviation between ABD and manually traced borders than between human observers. Conclusion: Autonomous ABD provides accurate measurements of LV area and area-derived indices. However measurements dependent on border point location deviate more by ABD.

Introduction

Much effort has been expended over the past 15 years to develop an automated border delineation (ABD) algorithm for echocardiograms. Geiser et al. have developed a computer algorithm for performing user independent automated detection and delineation of the left ventricular (LV) endocardial and epicardial borders from 2D echocardiograms displaying the heart in the parasternal short axis view at the mid papillary muscle level [1, 2]. Their algorithm incorporates not only temporal information, but also knowledge about the expected homogeneity of regional wall thickness by considering both the endocardial and epicardial contours. In addition, knowledge concerning the expected shape of the LV has been applied to assist in connecting edge segments together into a contour.

The present study sought to determine whether this ABD algorithm delineates the endocardial and epicardial borders of the LV from 2D...
echocardiographic images in the same way as human observers.

**Methods**

**Patient population**

The population comprised 84 patients from three clinical sites recruited prospectively for this study. The sites are St. Paul’s Hospital/ University of British Columbia, University of Florida, and University of Washington. Candidates for this study were an unselected series of patients undergoing routine diagnostic echocardiographic investigation. They were screened in the echocardiography laboratory at each site. Patients were included in the study if they were at least 18 years of age and were willing and able to give informed consent for participation in this study. Patients were excluded if they lacked image quality adequate for visual assessment of regional left ventricular (LV) function or if they had previously participated in this study. At one site that recorded this information, 15% of screened patients were excluded for poor image quality. If criteria for enrollment were met, the study procedures and potential risks were explained to the patient. A written informed consent was obtained. The investigator assigned a patient identification number reflecting that patient’s position in the series for that site. This protocol was approved by the Human Subjects Review Committee at each participating institution.

**Image acquisition**

All studies were performed using an ATL HDI-3000 ultrasound machine. Images were acquired with the patient lying in the left lateral position, using the parasternal window to visualize the heart in a short axis view at the mid papillary muscle level. Either the sonographer or the investigator then assessed whether the image quality was adequate for visual assessment of regional LV function.

If the patient’s images were considered adequate, the ultrasound machine settings were adjusted to optimize the image contrast for manual border tracing. The image field was set to show the right ventricle (RV) to the right of the septum. Ninety-nine image frames containing at least two consecutive cardiac cycles at end expiration were recorded in digital format. The images were then transferred to a Silicon Graphics Indy computer workstation for processing. Image acquisition was performed three times.

**Image analysis at the clinical site**

One operator reviewed the three digital acquisitions to select and save the two best cardiac cycles for automated analysis. Two cycles were analyzed to permit assessment of intercycle variability. The criteria for selection were: image quality (endocardial and epicardial definition; contrast quality) and accuracy of image plane positioning (minimum chamber area indicating that the image plane is orthogonal to the ventricular wall; having an open RV anteriorly; central location of the LV within the sector). The end diastolic (ED) and end systolic (ES) frames were tagged manually in each selected cycle and then the ABD algorithm was used to delineate the endocardial and epicardial LV borders at ED and ES. The images, automatically detected borders, and frame selections were automatically recorded.

The person performing the manual border tracing was either (1) blinded from the results of the ABD, or (2) waited a minimum of 4 weeks after observing or operating the ABD algorithm before doing any tracing. Using custom software from the Core Laboratory at the University of Washington, the selected cardiac cycle of digital images was reviewed in conventional orientation with the RV located to the left of the LV. The endocardial and epicardial contours were manually traced from the same ED and ES frames as were analyzed by the ABD algorithm. All borders were traced counterclockwise with the papillary muscles considered part of the chamber. Tracing could begin at any part of the contour and proceeded to complete the contour. The core laboratory later reordered the border points so that all borders began at the 6:00 position prior to performing border comparisons.