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# Proposing novel methods for simultaneous cardiac cycle phase identification and estimating maximal and minimal left atrial volume (LAV) from apical four-chamber view in 2-D echocardiography

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1 ABSTRACT

Left atrial volume (LAV) estimation is an important issue for prognosis of some adverse cardiovascular events. Manual estimation of LAV is a tedious and time-consuming labor. LAV measurement is a challenging task due to some factors such as artifacts and speckle noise generated by ultrasound imaging, vague boundaries of anatomical structures, viewpoint variations and different scanning angles. Therefore, using automatic methods for estimating LAV is necessary. In this study, our aim is estimating maximal and minimal LAV from echocardiographic images. Moreover, cardiac cycle phase is identified via recognizing end-systole and end-diastole frames as the main prerequisite of LAV measurement. Different from the previous studies, this study proposes novel methods which does not require any image segmentation to perform simultaneously key-frame identification and LAV estimation. For this purpose, four different scenarios are designed, evaluated and compared using a 5-fold cross-validation strategy. Our collected dataset includes the apical four-chamber (A4C) view of 2-D echocardiography videos (621 videos with the resolution of 768 × 1024 pixels) taken from patients in Tehran Heart Center. The key-frames and their corresponding minimal and maximal LAV are determined by experts for this dataset. Experimental results show that the fourth proposed scenario outperforms the compared methods with an average accuracy of 93.68 ± 0.74 for key-frame identification and mean square error of 0.08 ± 0.01 for LAV estimation. The proposed scenario can be used in a fully automated manner for CAD software and mobile applications.

## 1. Introduction

The left atrium (LA) has been referred to as forgotten chamber as compared with the left ventricle (LV) [1], but it plays a critical role in diagnosis of heart and cerebrovascular disease [1].

Left atrial volume (LAV) estimation is an important issue for prognosis of some adverse cardiovascular events [2]. Previous studies have considered indexed left atrial volume (LAVi) as a robust indicator of adverse cardiovascular events [3] such as atrial fibrillation [4].

The recent guidelines have proposed a method for estimating LA size by 2-dimensional echocardiography (2DE) in which the maximum value of LAV could be calculated using either the disk summation (Simpson rule) or the area–length biplane algorithms [5].

The previous studies have used Apical 4 Chamber (A4C) view and 2 Chamber (A2C) view for measurement of left ventricular (LV) size, shape and function and LA size [5–8]. For this purpose, end-systole and end-diastole frames must be identified and their corresponding LV or LA size is estimated. The systolic and diastolic phases correspond to contraction and relaxation heart states, respectively.

Aune et al. have defined the normal reference range for left atrial volume. They have proposed Upper normal reference values of 41 mL/$m^2$ for the maximum value of LAV (max-LAV) and 19 mL/$m^2$ for the minimum value of LAV (min-LAV) according to the old guideline [9] but in the new guideline which was presented by Lang et al. normal and abnormal LAV is determined based on the body surface [5] and no general range of normal LAV can be defined. Henriksen et al. have shown that the maximum value of LAVi is independent of age and sex but the minimum value of LAVi is correlated with age [10].

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