Evaluation of different statistical shape models for segmentation of the left ventricle from magnetic resonance images

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INTRODUCTION Over the last two decades, patient-specific modeling has become a powerful tool for intervention planning and diagnosis of human disease. Using a 3D statistical shape model (SSM) to segment cardiac structures gives better results because the model incorporates a priori knowledge from the training datasets, and is then deformed based on the features of the image to be analyzed. The aim of this work is to evaluate segmentation accuracy of the left ventricle (LV) on magnetic resonance images (MRI) using four different SSMs built on a database of 3D echocardiographic (3DE) LV surfaces.

METHODS Four different SSMs based on segmented LV surfaces (4D LV analysis, Tomtec) from 3DE datasets of 435 patients were created. The first three models contained respectively end-diastolic (ED) frames, end-systolic frames (ES), and both ED and ES frames. The fourth model was built using all frames from each patient. Each model was then scaled in order to match the ED and ES cardiac magnetic resonance imaging short-axis (SAX) image stack of 14 consecutive patients with normal LV function. All images were properly realigned to compensate misalignment and were initialized by a user (LV base and apex). The deformation process automatically updated the model so as to match the information of all the SAX planes contemporaneously and it was iterated until a stable condition was reached. The result was an endocardial LV 3D mesh which volume is compared to ED and ES volumes derived from the same SAX images analyzed by an experienced cardiologist.

RESULTS Semi-automatic and manual 'gold standard' volumes were evaluated using linear correlation and Bland–Altman analyses for all models. The model created using ED frames and the model created using ES frames showed the highest correlation (r^2=0.91) with the manual gold standard compared to the other two models (r^2=0.86 and r^2=0.89). In all four cases, Bland-Altman showed an underestimation with non-significant biases and narrow limits of agreement.

DISCUSSION Our study showed that using a 3D SSM built from 3DE ED frames or ES frames results in endocardial segmentation of MRI SAX images of the LV whose volume is more accurate rather than using the other models built using both ED and ES frames, or all frames. This is due to the fact that different frames from ED or ES ones could lead to an inaccurate statistical deformation of the model, thus not exactly matching the current image information.