Ventricular Changes in Patients with Acute COVID-19 Infection: Follow-Up of The World Alliance Societies of Echocardiography (WASE-COVID) Study

Supplemental Material

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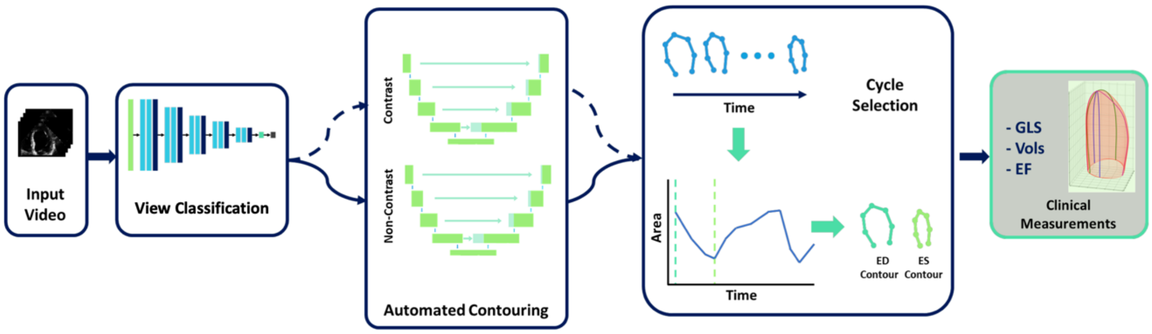
Supplemental Material – Description of EchoGo Methods

Development of View classification



Model development and validation was based on a dataset of clinical information and images extracted from several multicenter studies. Images had been acquired from hospitals with a range of sizes, type of operators and ultrasound vendor equipment representative of "real world" echocardiography. Data was accessed with participants informed consent and ethical approval for the study was obtained from Health Research Authority NRES Committee South Central – Berkshire (IRAS reference: 14/SC/1437). For model training, a set of images were identified that: included apical-4-chamber (A4C) and apical-2-chamber (A2C) views; had endocardial visualization in at least 14 of 16 segments in available images (based on consensus review by three 3 BSE accredited cardiac physiologists); had end-diastolic (ED) and end-systolic (ES) frames with a minimum of 4 frames between ED and ES. The echocardiograms were used to develop a series of sequential image processing algorithms. All studies consisted of a set of Digital Imaging and Communications in Medicine (DICOM) format 2D videos. Convolutional Neural Network (CNN) frameworks were developed using Python 3.5 with Keras 2.2.4 and TensorFlow 1.13. For the view classification model, a bespoke CNN was built using 10 convolutional layers which identifies A2C, A4C, SAX and apical-3-chamber (A3C) views acquired with and without contrast, respectively. Training data comprised of 1250 2D echocardiograms from 1014 subjects.

Development of View classification

Prior to view classification model training, images were processed using standard techniques to ensure homogenous and normalized image inputs to the training pipeline. Before processing, the data was split into 90% for model training (211,958 image frames), and 10% used as a testing dataset (23,946 frames). Image frames from different subjects were separated out entirely amongst the training and testing datasets. Furthermore, a separate validation dataset of 240 studies was acquired from the US testing data and used as an independent test dataset (39,401 frames).

Development of LV Segmentation

Following view classification, a U-net based CNN segmentation frameworks was developed to contour the LV endocardium in A2C and A4C views. End-diastolic (ED) and end-systolic (ES) image labels were used to train the CNNs images initially contoured manually by three British Society of Echocardiography (BSE) accredited echocardiographers. The model was trained from data comprised of 5,692 frames. The datasets were split into 80% training and 20% testing datasets for training the CNNs. Raw images were processed and fed into the modified U-net CNN framework. The CNNs produced contours that were able to track the endocardial walls smoothly through time. The efficacy of the network's segmentation performance was assessed using the Sørensen-Dice Coefficient (DC). An algorithm was established from the image clips and LV contours to identify the cardiac cycle and end-diastole and end-systole frames, comprising assessment of contour areas and R-wave triggers. Where the R-wave trigger was not available, the heart rate was inferred from the image LV segmentation. The HR extraction required the reduction of image dimensionality, followed by signal period extraction, using dimensionality reduction methodologies.

Performance of Auto-View Classification

Using an unseen dataset of 240 studies (23,946 frames), an overall accuracy of 95% was achieved for the CNN view classifier used to identify and label 8 echocardiographic views. Classification accuracy of non-contrast views (A2C, A3C, A4C and SAX) exceeded 97% while the accuracy of contrast A3C, A4C and SAX view classification was >93% and contrast A2C views was 85%. The differentiation between contrast from non-contrast views was 100%.

Performance of LV contouring and segmentation

For the auto-contouring model, a testing dataset of 436 image frames were contoured by the model, which demonstrated high concordance with manual contours from three BSE accredited echocardiographers, as measured by the Sørensen-Dice Coefficient (DC). The model achieved a mean contrast A2C and A4C DC of 93.25%, exceeding that seen in other works. The auto-contouring model performed consistently well on data captured using multiple ultrasound vendors and models and did not exhibit significant declines in DC scores across the range of image quality considered clinically acceptable for stress echocardiography.

Supplemental Figure S1. Changes in LV and RV according to time of follow-up. Patients were divided in 2 groups according to the time to follow-up echocardiograms (above and below the median -143 days-)