Autonomous CMR: Prescription to Ejection Fraction in less than 3 Minutes

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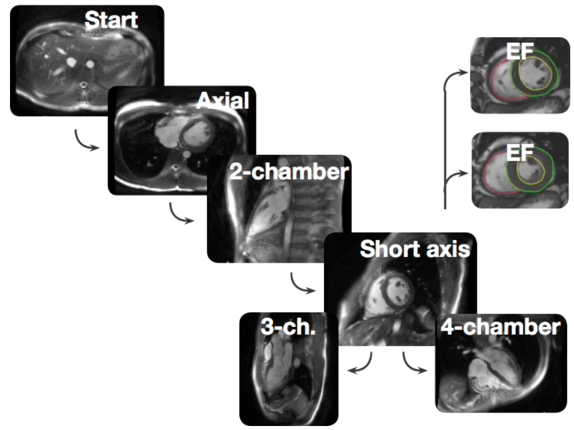
Purpose

One of the difficulties of providing consistent cardiac MRI across numerous clinical sites is the lack of highly trained technicians. To address this, we have trained a machine learning (ML) model to completely automate the examination of LV function, including determination of standard cardiac imaging planes, prescribing and scanning an appropriate free-breathing short-axis CINE stack, automatically drawing contours, and determining functional parameters such as ejection fraction (EF) and cardiac output. With our real-time based approach, we can go from initial image to completed EF assessment in less than 3 minutes.

Methods

A typical cardiac LV function exam begins by localizing the patient's standard cardiac planes. Then, a short-axis stack of CINE images is acquired, LV endocardial contours are segmented, and functional measures like EF are calculated.



To automate this process, we trained a convolutional neural network (CNN) in TensorFlow [1] using data from 58 patient studies acquired with the HeartVista Cardiac Package (HeartVista, Inc.; Los Altos, CA). From a total of 59,456 images, different networks were trained to perform the following prescription state transitions (Fig.): moving from an arbitrary axial slice to a central cardiac axial slice; from there to a two-chamber view; from there to a short-axis view; and from there to either four-chamber or three chamber views. These trained networks could then be used sequentially to locate the complete set of standard views, in real time. After this localization, a stack of short-axis slices covering the left ventricle was automatically prescribed and HeartVista's real-time, free-breathing CINE "HART" scan [2] was acquired and automatically analyzed.

During inference, the network continuously analyzed a series of real-time frames until a stable average prescription was determined. This minimized the effects of cardiac and respiratory motion. Using a single GeForce GTX Titan X GPU, total inference time was less than 60 ms.

To integrate this model into the scan, TensorFlow capabilities were added to HeartVista's pipeline-based reconstruction engine to allow seamless bidirectional data transfer between MRI reconstruction nodes and TensorFlow graphs. Outputs of this hybrid MR/ML reconstruction were applied to update scan parameters. A separate TensorFlow graph was trained to automatically draw endocardial and epicardial contours (Fig.).

In-vivo imaging was performed on a 1.5 T GE Signa scanner with the HeartVista Cardiac Package. Real-time spiral imaging was performed at 114 ms true temporal resolution, reconstructed at 30 frames per second and 15 inferences per second.

Results

The Figure shows resulting image planes determined by the automatic procedure with a scan begun with an axial orientation inferior to the heart. In a feasibility test of 4 patients, the network successfully found all standard views and segmented both ventricles without operator intervention. All scans and reconstructions completed in under 3 minutes.

Conclusions

We have demonstrated the feasibility of using a neural network within the MR control system to automatically prescribe standard cardiac views and assess cardiac function. This was implemented within an extensible platform that can reduce the dependence of imaging quality on operator experience.

References

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2. Ingle RR, Konkle JJ, Addy NO, et al. Rapid left ventricular function MRI with an accelerated real-time-based spiral acquisition. JCMR 2016. 18(Suppl 1):P326.