Validation of a deep learning reconstruction framework for 3D delayed myocardial enhancement imaging

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Introduction:
Myocardial delayed enhancement (MDE) MRI plays an important role in the identification of several cardiac conditions, both ischemic and non-ischemic (e.g. myocarditis, IDC, amyloidosis). 3D imaging offers increased resolution, full heart coverage and better depiction of complex pathologies, but its image quality is limited by long acquisition times.

Deep learning (DL) models enable advanced reconstruction algorithms that yield regularized images in practical computation times. In this study we evaluate a novel 3D-DL reconstruction to overcome the trade-off between reconstructed quality and acquisition time on MDE data.

Methods:
A group of 14 subjects referred for CMR (5 F / 9 M, 59±11 y.o., 78±13 kg) were scanned with a 3D MDE sequence prototype: SPGR with IR preparation, fat & spatial saturation, respiratory navigator, ARC 2x, FOV 40x40cm, ST 1.4-2.4mm, matrix 280²-320², FA 20deg, BW 62.5 kHz, TE 2.1±0.1ms, TI based on a CINE IR scout. All were retrospectively reconstructed using a 3D DL algorithm, trained on a database of over 700 datasets to reconstruct high-quality images with adjustable noise reduction.

The images were compared with standard 3D Cartesian reconstruction by two experienced cardiologists, to identify alterations in morphology or contrast distribution. Noise was estimated using the intensity standard deviation on a blood pool ROI. Feature preservation was estimated using the structural similarity index (SSI).

Results:
The new method improved perceived image quality without loss of structural information or resolution (fig 1). Quantitative analysis (fig 2) confirmed these results: The average coefficient of variation in the blood was 0.08±0.02 in the reference and 0.05±0.02 with the new method; Given a target image noise level, DL reconstruction yielded up to 10% better SSI, compared to anisotropic filtering.

The clinical review didn’t reveal diagnostically significant alterations of structure or uptake pattern. A perceived reduction of sharpness was initially reported but individual examination of landmarks (e.g. pulmonary and coronary arteries) confirmed that no relevant features were being lost with the new reconstruction.

Discussion:
The 3D MDE images obtained with DL reconstruction improved the trade-off between image noise -estimated by the blood pool intensity deviation- and feature preservation -estimated by SSI-.

Consistent improvement of image quality without morphological alterations of diagnostic relevance indicates that
the new method can be considered for clinical practice. The next step in the validation process will require testing the robustness over a large set of cases with heterogeneous acquisition settings.

Conclusion:

We presented the preliminary evaluation of a deep learning reconstruction method with 3D myocardial delayed enhancement data. The results show systematic improvement of overall image quality without loss of relevant diagnostic information.

Figure 1. Axial view and coronal detail of a 3D myocardial delayed enhancement series, reconstructed with the standard (left) and Deep Learning method (right).

Figure 2. Structural similarity to the standard reconstruction method, compared to Gaussian and anisotropic post-reconstruction filtering results (over a range of their respective parameter settings). Notice how Deep Learning reconstruction yields the best compromise between noise reduction and structural similarity.