Development of Deep Learning Virtual Native Enhancement for Gadolinium-Free Myocardial Infarction and Viability Assessment

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Background

Late gadolinium enhancement (LGE) on cardiovascular magnetic resonance (CMR) is the imaging gold standard for assessment of chronic myocardial infarction (MI) and myocardial viability. However, LGE requires intravenous contrast agent administration, which increases the cost and lengthens the CMR procedure. Artificial intelligence-based virtual native enhancement (VNE)[1] has recently emerged as a promising alternative to LGE and is well-validated in patients with hypertrophic cardiomyopathy. We hypothesized that VNE can be further extended to assess chronic MI.

Methods

Information on myocardial tissue properties and wall motion is derived from native T1-mapping, inversion recovery-weighted images, and cine images, which are input into a deep learning generator to produce VNE images[1]. We collected 1602 sets of images of chronic MI to train the neural networks, using a modified conditional generative adversarial network approach. The trained VNE imaging module was tested on 145 independent image materials from 43 patients with chronic MI. Five blinded observers independently assessed the image quality of VNE and LGE using a scale from 0-100 guided by 5 categories from "uninterpretable" to "excellent". Regions of interest of the left ventricle, remote myocardium, and blood pool were segmented semi-automatically for scar quantification. Interobserver variability was calculated as standard deviation (SD) and intra-class correlation (ICC). Correlation between scar quantification by VNE and LGE was assessed using linear regression and ICC.

Results

VNE provided significantly better image quality than LGE, as assessed by all 5 operators ($p<0.001$; Figure 1A). Interobserver variability was SD=9.6±1.1 with ICC=0.79±0.04. For "uninterpretable" (Figure 1A, red clusters; n=4) or "poor" (blue; n=19) LGE cases, VNE significantly improved the quality of all but 1 image. Conventional LGE can be affected by breathing artefacts and low signal-to-noise ratio (Figure 1B), while VNE produced better and more consistent image quality with better-defined myocardial borders. VNE detected and located areas of infarction in high visuospatial agreement with LGE (Figure 2). Scar burden quantification by VNE correlated strongly with LGE in 43 test patients (Figure 3; $R=0.83$, $p<0.001$, ICC=0.91).

Conclusion

Deep learning-based VNE produces "virtual LGE" by effectively serving as a "virtual contrast agent" that enhances native CMR signals, with significantly better image quality, high agreement in visuospatial distribution and quantification of scar burden compared to conventional LGE in chronic MI. VNE has enormous potential to replace LGE in common cardiac pathologies to significantly improve clinical practice, reduce CMR scan time and costs, and expand the reach of CMR in the near future.

References

1. Zhang, Q. *et al.* Toward replacing Late Gadolinium Enhancement with artificial intelligence Virtual Native Enhancement for gadolinium-free cardiovascular magnetic resonance tissue characterization in hypertrophic cardiomyopathy. *Circulation* **144**, 589–599, DOI: https://doi.org/10.1161/CIRCULATIONAHA.121.054432 (2021).

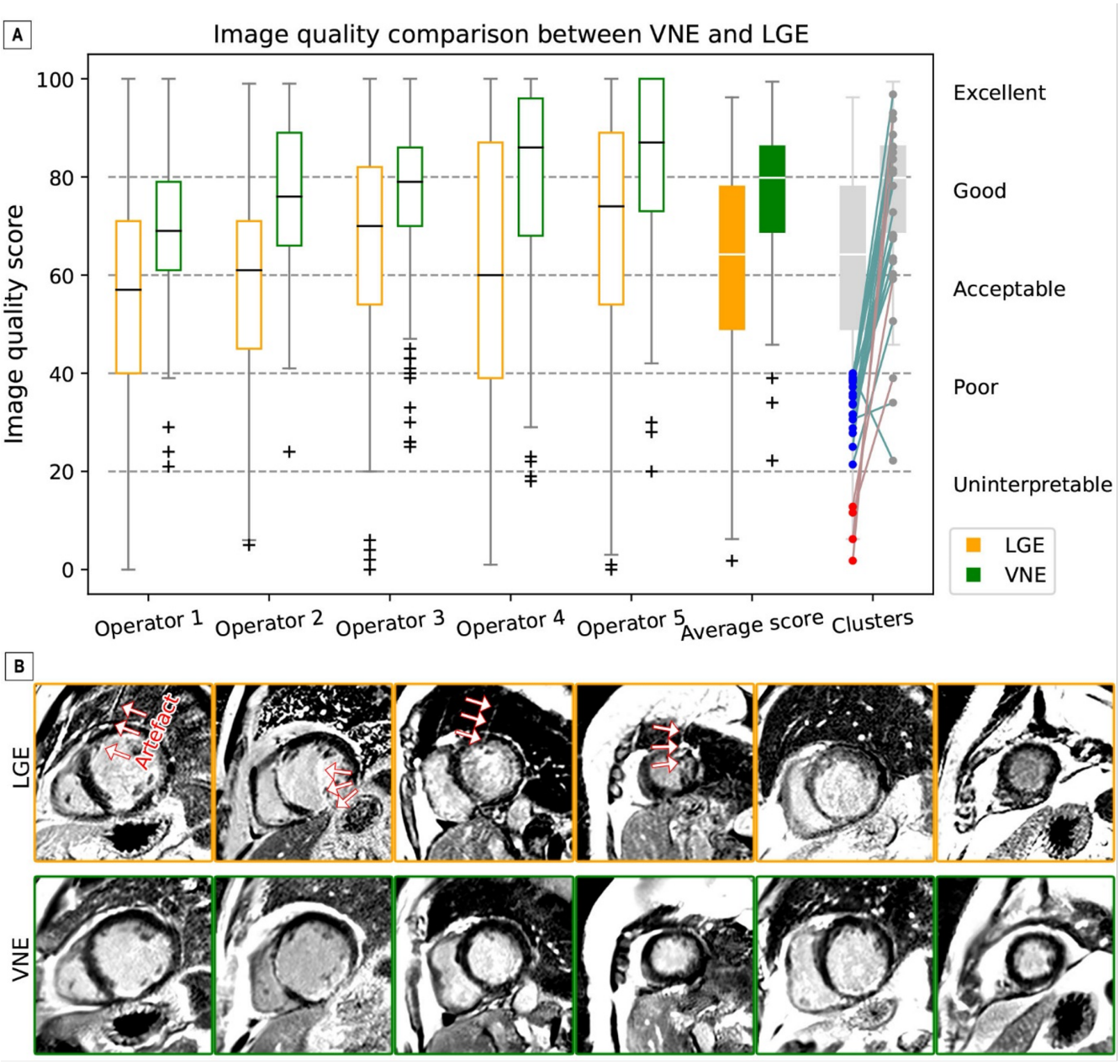

Figure 1. LGE and VNE image quality assessment on chronic infarction cases. A: VNE offers significantly better image quality, as assessed by 5 blinded operators and their average scores (all p<0.001). B: Examples of image quality improvement by VNE. Arrows point to artefacts and poor contrast in the LGE images.

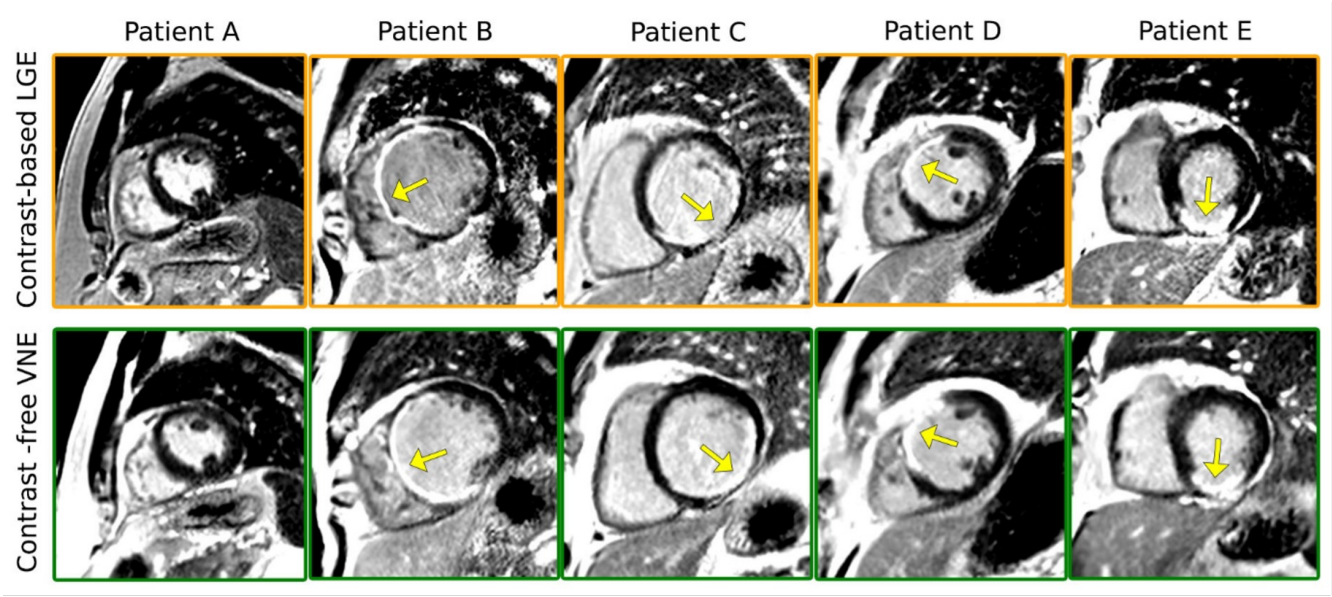

Figure 2. Examples to illustrate high visuospatial agreement between virtual native enhancement (VNE) and conventional late gadolinium enhancement (LGE) for the detection of chronic myocardial infarction (arrows).

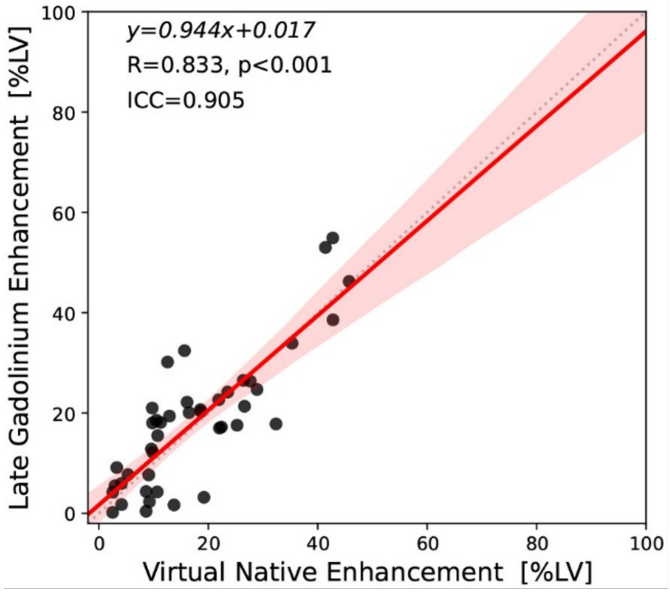

Figure 3. VNE correlated strongly with conventional LGE in quantifying myocardial infarction scar burden in 43 test patients.