2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

Clinical Validation of AI-Based Automated 3D Liver Segmentation for Whole-Liver Fat Fraction Quantification Using mDixon-Quant MRI

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INTRODUCTION

Quantitative MRI is a reliable, noninvasive technique for assessing liver fat content. In current clinical practice, liver fat fraction (FF) is typically measured by placing manually drawn regions of interest (ROI) on a single liver slice. This approach requires expert observers to carefully exclude non-hepatic tissue, such as blood vessels, and is therefore time-consuming and impractical for comprehensive whole-liver assessment. In this study, we applied a published artificial intelligence (AI) trained model to automatically generate three-dimensional (3D) whole-liver segmentations for FF quantification and compared the calculated measurements with those obtained using the conventional manual ROI-based approach.

METHOD

Patient Population:

- Forty-five patients referred for liver fibrosis staging at 1.5 T were included. A retrospective sub-analysis of mDIXON-Quant–derived liver fat fraction was performed.

Fat Fraction:

- Philips 3D six-points axial mDixon-quant gradient-echo based sequence with TR/TE1/ΔTE=5.3ms/0.9ms/0.7ms covered the whole liver. Acquired voxel size was 2.5x2.5x6.0mm^3.

FF Calculation:

- 3D mDIXON-Quant derived water and FF images were exported for offline analysis. A 3D whole-liver mask was automatically segmented from the water images (Fig 1.A) using a published open-source AI model[1] (https://doi.org/10.1148/ryai.240777). Liver FF was computed using a Histo-Gaussian method[2] (Fig 1.D) with three ROI approaches: manual single-slice ROI excluding non-hepatic tissue (FF_{man}, Fig 1.C), 2D ROI extracted from the 3D mask at the same slice (FF_{2D}, Fig 1.B) as manual ROI, and whole liver 3D mask–based ROI (FF_{3D}).

Data analysis:

- The liver PDFF (FF_{man}, FF_{2D}, and FF_{3D}) for each subject calculated from the three ROI methods were processed using custom-built MATLAB script. Bland-Altman method was used to assess the agreement between FF_{man} and FF_{2D}, FF_{3D}.

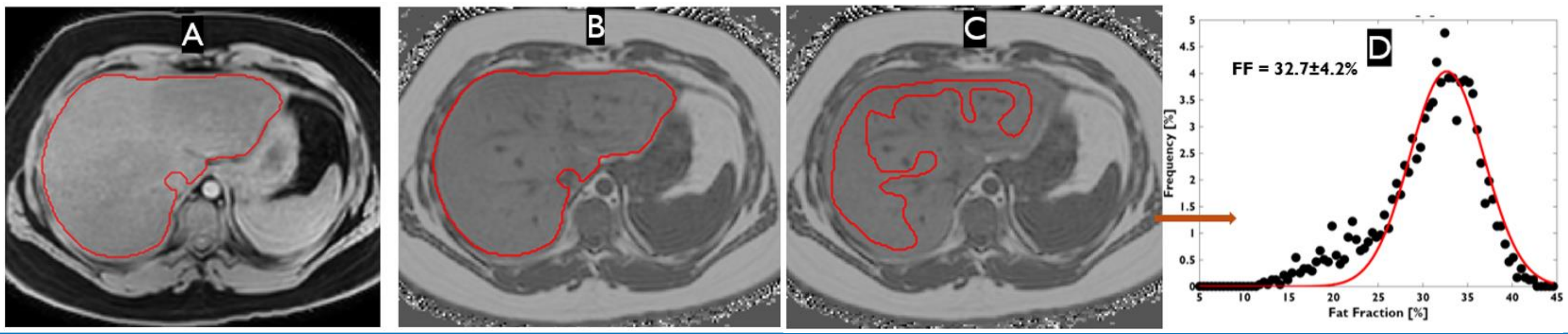

Figure 1. The largest axial liver cross sectional slice with overlaid liver ROI extracted automatically from the 3D AI segmentation model on the mDixon derived water image (A). The ROI on this slice was copied to the Fat fraction map (B) to estimate the Fat Fraction (FF) using our previous developed Histo-Gaussian[2] method (D). The manual ROI was drawn on the same slices to evaluate the FF with Hist-Gaussian method, carefully excluding the non liver tissue. The yielded FF_{man} = 32.7 ± 4.2% on this representative subject.

RESULTS

45 subjects was referred for liver fibrosis using MR elastography. mDixon-quant derived water and FF images were used for AI automated 3D liver segmentation and liver FF calculation.

- In the 45 subject's cohort, 14 had normal liver FF (<5%) and 31 had elevated FF (ranging from 1.7% to 42.4%).
- The 3D whole liver segmentation was successfully automatically performed on mDixon derived water images (Fig 1A) for all subjects.
- The Bland-Altman analysis of the estimated FF demonstrated the strong agreement (Fig 2.) with negligible bias and narrow confidence interval (bias ± 1.0SD): FF_{2D} vs FF_{man} and FF_{3D} vs FF_{man}: **-0.1 ± 0.2%** and **-0.1 ± 0.4%** respectively.

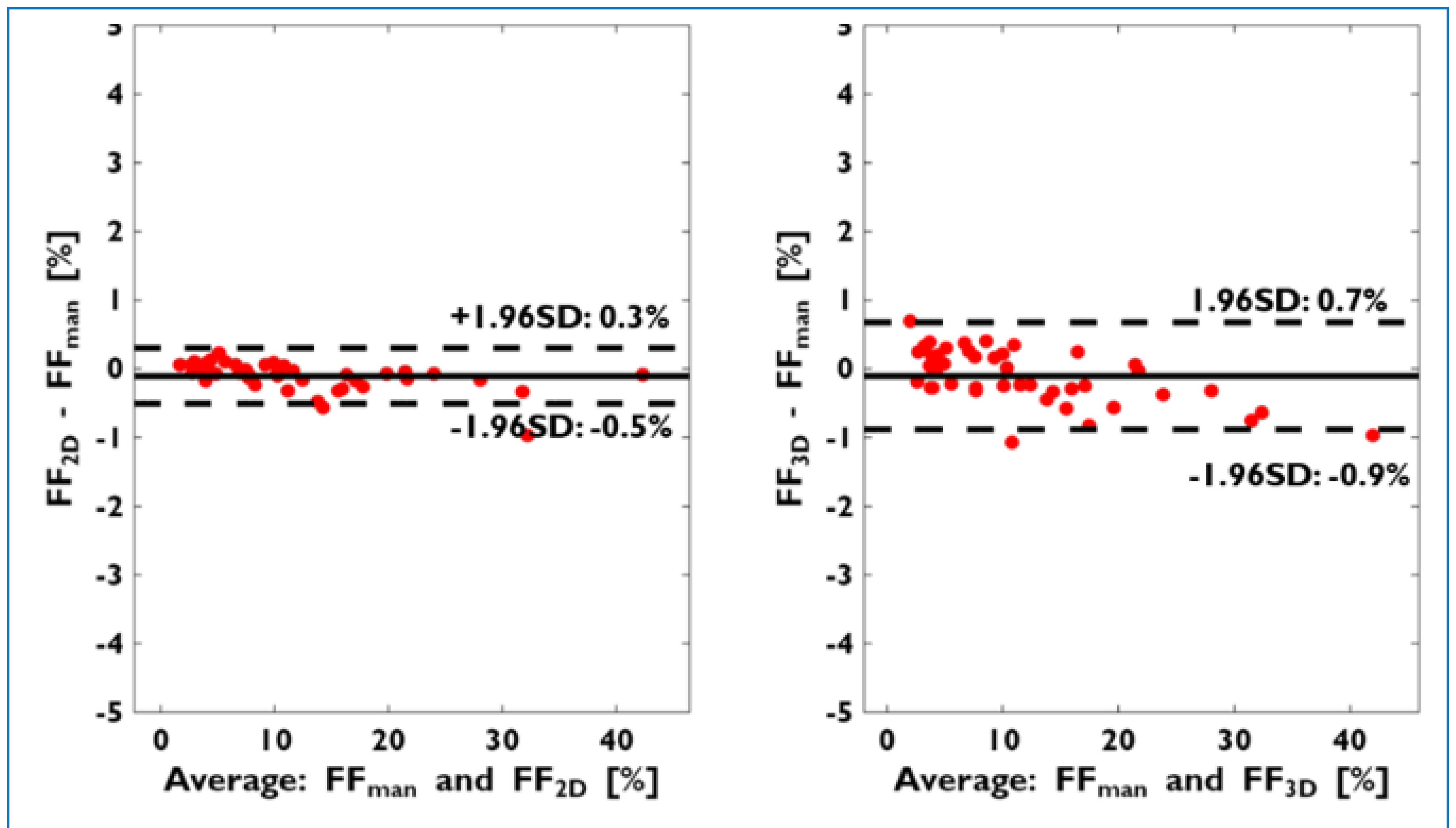

Figure 2. The Bland-Altman analysis demonstrated the strong agreement of Fat Fraction (FF) estimated from the whole Liver automatically AI segmented ROI (FF_{3D}) and extracted single slice ROI (FF_{2D}) to carefully manual drawling ROI (FF_{man}): FF_{2D} vs FF_{man} (Left), and FF_{3D} vs FF_{man} (right). The solid line shown the mean bias and dashed lines corresponding 95% limits of agreement.

CONCLUSIONS

- It's practical to automatically segment out the whole-liver on the 3D mDixon water images using MRSegmentator[1].
- FF estimated from both 3D whole liver and single slice ROIs automatically extracted from the trained AI model strongly agreed with manual ROI analysis approach.
- The need for expert-prescribed carefully drawn ROIs was eliminated.
- 3D whole liver FF assessment is feasible and potentially increases diagnostic confidence in hepatic steatosis evaluation.

CONTACT INFORMATION

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REFERENCES

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