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Noise effects in hepatic fat fraction estimation methods by using magnitude MRI

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Aims & objectives

Magnetic resonance imaging (MRI) has been used over the last three decades for the assessment of hepatic steatosis by estimating proton density fat fraction (FF) (fig. 1). However, magnitude images and derived FF estimation methods are known to be affected by Rician noise, which are signal dependent.

This poster presents simulations of the performance at different signal-to-noise ratios (SNR) of four FF estimation methods: dual-echo [1], triple-echo [2], current state-of-art multi-interference and ANN [3], a novel method based of neural networks proposed by our group.

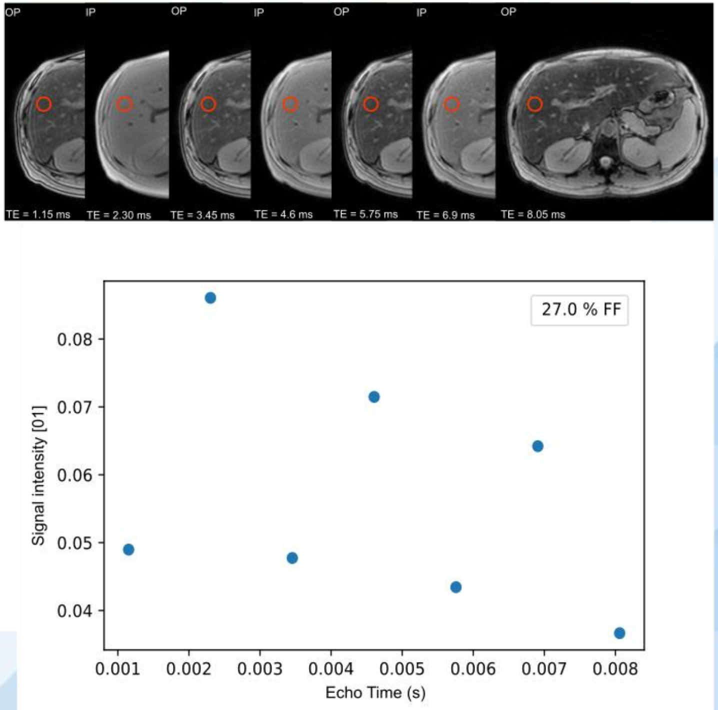


Fig. 1: Fat fraction can be estimated as the signal varies in a set of MR images.

Aims & objectives

- Use simulations to compare the following methods for fat fraction estimation (fig. 2):
    - Dual-echo
    - Triple-echo
    - Multi-interference
    - ANN
- At the following values for SNR:
    - 25
    - 50
    - 100
    - 200

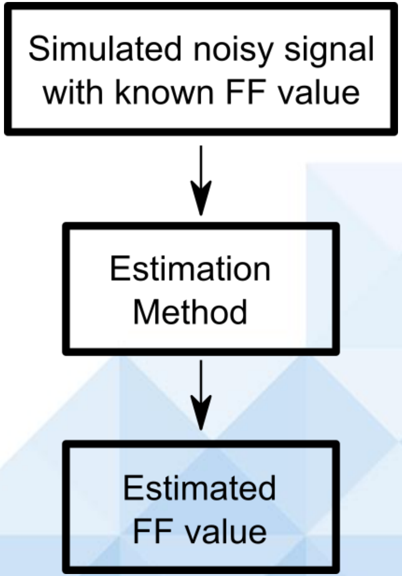


Fig. 2: Flowchart for simulations

Materials and methods

Each method was tested with simulated datasets consisting of 5000 instances of gradient-echo (GRE) in-phase/opposed-phase magnitude MR data modeled from the GRE equation for low flip angles (eq. 1) where water and fat proton densities were chosen within the range from 0.1 to 40% FF (eq. 2).

$$S = \left| \, k \, \alpha \sum_{n} \rho_n \, \exp(-TE/T2^{*}{}_{n}) \, \exp(2\pi i f_n TE) \, \right| \qquad \text{(Eq. 1)}$$

$$FF = \frac{\rho_f}{\rho_w + \rho_f} \qquad \text{(Eq. 2)}$$

Materials and methods

Each instance had 7 data points corresponding to different echo times and carried a single combination of T2* decays representing water and six lipids modelling hepatic tissue [4].

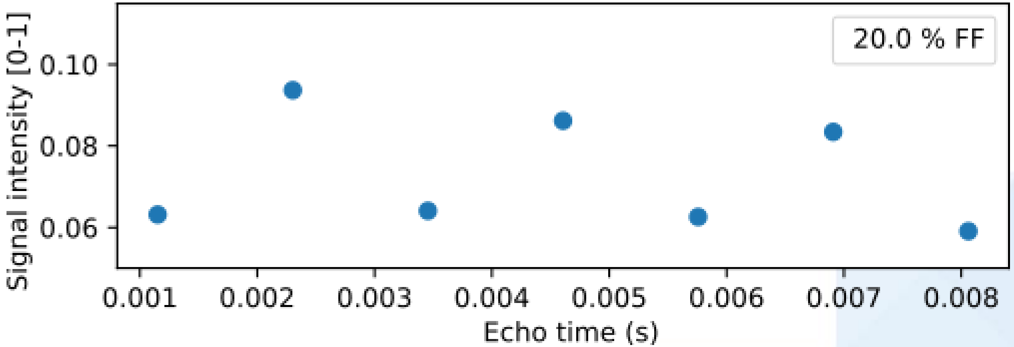


Fig. 3: Example of one simulated signal with 20% fat fraction, SNR 200 and various T2* values.

Materials and methods

Estimated and simulated FF values were compared by linear regression and binary accuracy using 10% FF threshold. Results are presented in the following order: dual-echo, triple-echo, multi-interference and ANN.

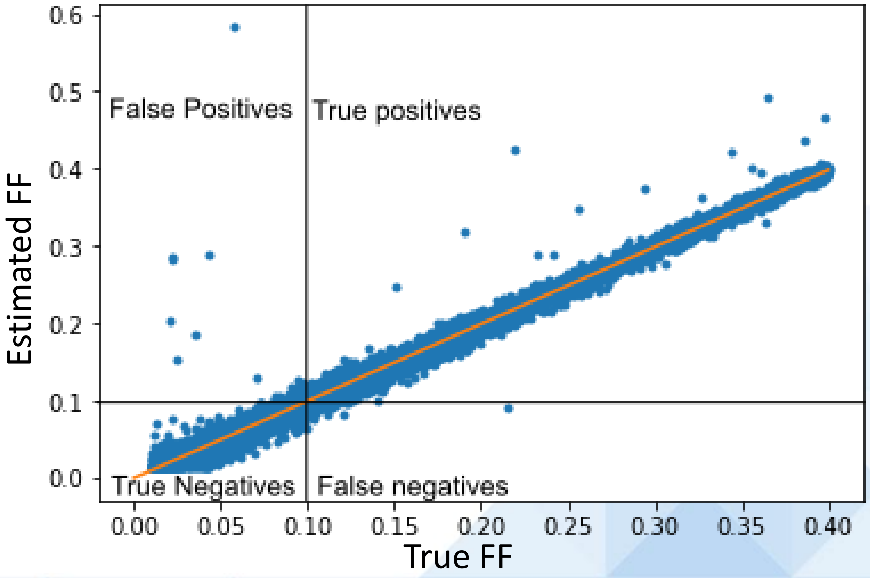
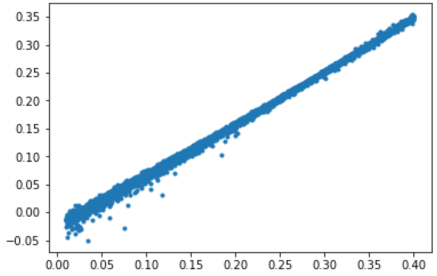


Fig. 4: Example regression for true and estimated fat fractions. Yellow line shows perfect regression (intercept = 0, slope = 1), crosshair defines regions for binary accuracy calculation.

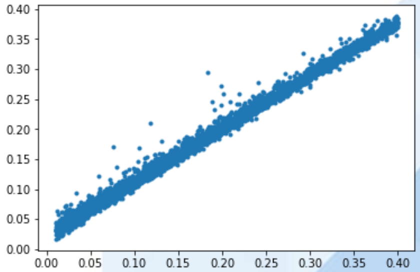
Results & discussion

For SNR 200, regression intercept and slope were:
Dual echo: -0.0273 and 0.9312,
Triple echo: 0.0249 and 0.881,
Multi- interference: 0.0033 and 0.0421,
ANN: -8.428e-05 and 0.9976.
Accuracy values were 0.90, 0.97, 0.99, and 0.99, respectively.
All regression values were significant with $P < 0.001$.

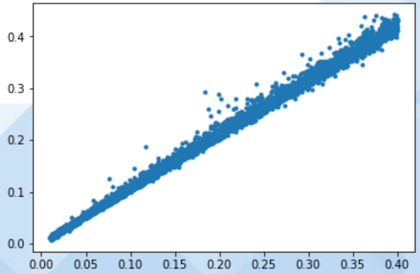
Dual echo



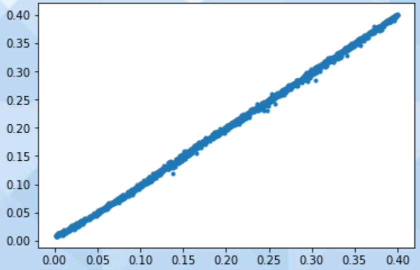
Triple echo



Multi-interference



ANN

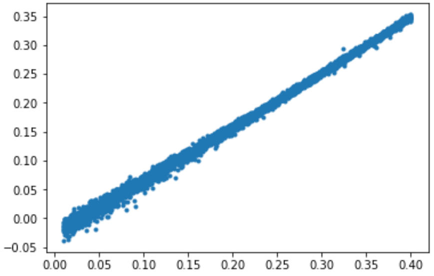


Results & discussion

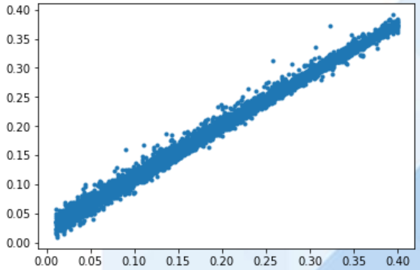
For SNR 100, regression intercept and slope were:
Dual echo: -0.0273 and 0.9311,
Triple echo: 0.0247 and 0.8823,
Multi- interference: 0.0030 and 1.0421,
ANN: 0.0002 and 0.9960.
Accuracy values were 0.90, 0.97, 0.98, and 0.99, respectively.

Dual echo performs better at high FF values whilst multi-interference is better at low FF values. ANN outperforms both.

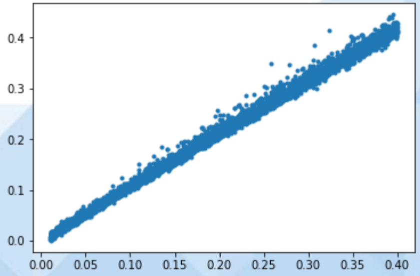
Dual echo



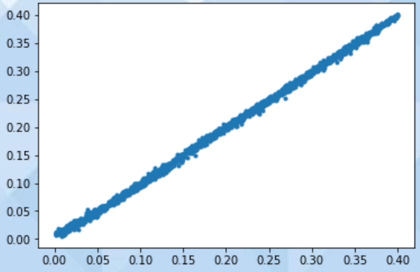
Triple echo



Multi-interference



ANN

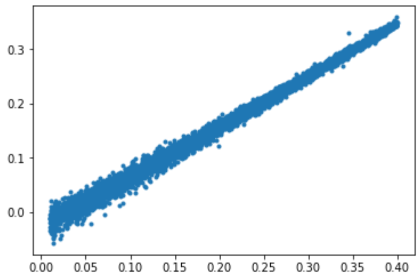


Results & discussion

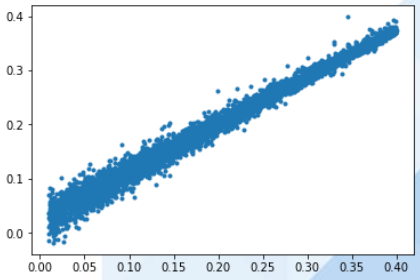
For SNR 50, regression intercept and slope were:
Dual echo: - 0.0278 and 0.9329,
Triple echo: 0.0241 and 0.8843,
Multi- interference: 0.0033 and 1.0404,
ANN: 0.0002 and 0.9964.
Accuracy values were 0.90, 0.95, 0.98, and 0.99, respectively.

As noise increases, residuals also increase for every method.

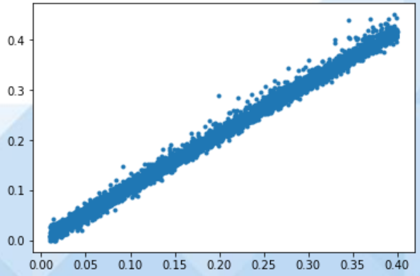
Dual echo



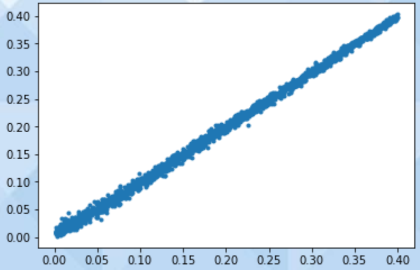
Triple echo



Multi-interference



ANN

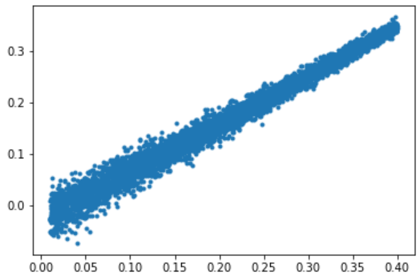


Results & discussion

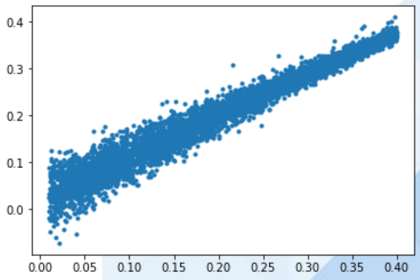
For SNR 25, regression intercept and slope were:
Dual echo: -0.0284 and 0.9354,
Triple echo: 0.0247 and 0.8827,
Multi- interference: 0.0022 and 1.0452,
ANN: 0.0007 and 0.9933.
Accuracy values were 0.91, 0.93, 0.97, and 0.98, respectively.

A large increase in estimation errors can be observed for the lowest SNR. A single outlier appears for ANN method.

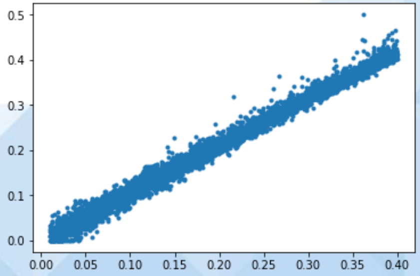
Dual echo



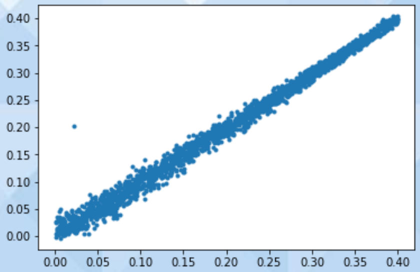
Triple echo



Multi-interference



ANN



Conclusion

Accuracies did not seem to change significantly within each method for diferent SNR values, which may be due to the chosen metric. Regression and accuracy values were best in the order ANN > multi-interference > dual-echo > triple-echo at any SNR. Triple echo was expected to perform better than dual echo but did not, perhaps due to the variety of tested parameters that could not be well fit by a single exponential model. Dual echo seems to perform better at larger FF values and the opposite is valid for multi-interference. ANN outperformed all tested methods at any SNR in the simulations, indicating that *in vivo* validation should be performed as this seems to be a robust method that uses a simple imaging acquisition technique.

References

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Conflict of interest

The authors have no conflict of interest to declare.

Acknowledgement

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