Highly Accelerated Time-Encoded Dynamic ASL Angiography

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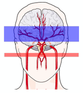
#1620

Introduction

Arterial Spin Labelling

Arterial spin labelling (ASL[1,2]) is a non-invasive MRI method that relies on inverting magnetization in a **labelling plane** and subsequently imaging the bolus in the **imaging region**. In standard ASL, two images are acquired, one 'tag' and one 'control' without labelling. Subtraction of the two gives an image of just blood signal (either **angiography**[3,4] or **perfusion** depending on how far the blood has travelled)



Benefits:
- **Endogenous contrast agent (blood)**
- **Dynamic imaging possible**

Time encoding

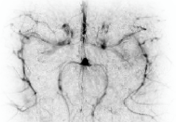
In time encoded (TEnc[5]) ASL, the signal is acquired during a shorter **readout period** and temporal information is instead encoded in the **labelling phase** (Fig. 1). Linear decoding recovers images with different post labelling delays.

Benefits:
- **Can use larger flip angles than for Look-Locker readout (higher SNR)**

Limitations:
- **More encodings needed than for standard tag-control (longer scan time for the same undersampling factor)**

Acceleration

Angiograms are **spatially sparse** and **temporally smooth**, and therefore suitable to compressed sensing type[6,7] reconstruction of accelerated acquisitions.



Benefits:
- **Shorter scan times to counteract extra scan time from time-encoding**

Limitations:
- **Non-linear methods can introduce bias**

Methods

Acquisition

- 2D pseudo-continuous ASL dataset with **three readout frames** and **three time-encoded blocks** using a **3T Siemens Verio** system, with a 32-channel head-coil.
- **Effective PLD:** 60 to 1020 ms in steps of 120 ms.
- **Spatial resolution:** 0.63x0.63 mm^2, slice thickness: 70 mm, FOV = 220x220 mm^2, 46 repeats of each encoding (12 spokes/frame/repeat, fully sampled = 552 spokes/frame)
- **Total scan time 4.5 min**
- A variable flip angle scheme was used[8]
- Retrospective undersampling. **R = 12, 23, and 46**

Reconstruction

1. **A naïve re-gridding** using the NUFFT (**x = E'd**) .
2. **Non-Cartesian SENSE** parallel imaging reconstruction
3. **Compressed sensing** with sparsity in decoded image space and a temporal smoothness constraint

$$cost = \frac{1}{2}|\mathbf{Ex} - \mathbf{d}|_2^2 + \lambda_1|\mathbf{x}|_1 + \frac{1}{2}\lambda_2|\nabla\mathbf{x}|_2^2$$

E: encoding operator (including time-encoding, coil sensitivities, and trajectory),

x: the angiogram, **d**: the measured k-space data, ∇: the temporal finite difference operator. The parameters λ_1 and λ_2 : regularisation factors for spatial sparsity and temporal smoothness constraints.

- Optimisation using FISTA (100 iterations step size: 0.01)
- For SENSE: $\lambda_1 = \lambda_2 = 0$.
- For CS: $\lambda_1 = 10^{-6}$, $\lambda_2 = 0.1$.
- Coil sensitivities were estimated from the time and encoding combined data using the adaptive combine approach.

More reconstruction details: https://github.com/SophieSchau/Accelerated_TEASL

Results

- See Figure 2 and 3
- **The simple re-gridding:** high SNR, considerable blurring
- **The SENSE reconstruction:** better sharpness, noise amplification
- **The CS reconstruction:** very little artefact

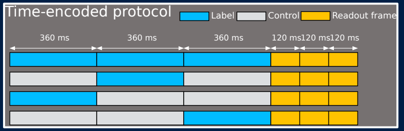


Figure 1: Schematic diagram of time-encoding scheme. The three time-encoding blocks and three readout frames combine to form nine total effective PLDs.

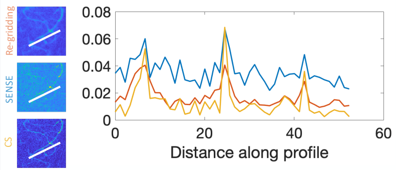


Figure 2: Line profile through three vessels reconstructed at R=12. CS (yellow) has both higher and narrower peaks compared to both SENSE (blue) and re-gridding (orange).

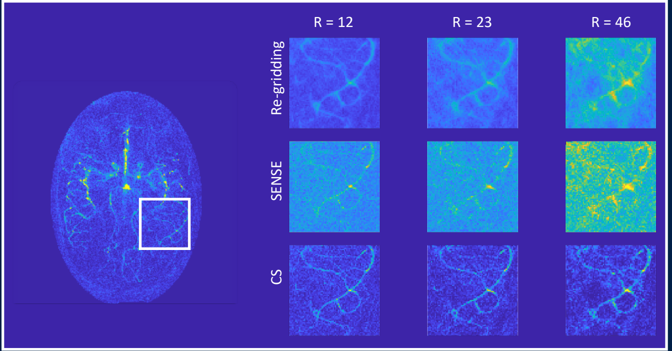


Figure 3: Time average of reconstruction details at all trialled acceleration factors, reconstructed using re-gridding, SENSE, and spatiotemporal CS. Small subtle vessel features that are well captured in the CS reconstruction are either missing due to lower SNR or only partially captured or blurred in the SENSE and gridding reconstructions.

Discussion

- TEnc ASL Angiography benefits from CS
  - Increased SNR, decreased blurring, high acceleration possible
- Same reconstruction framework can be used in both VE-ASL and TEnc-ASL
- Quantification challenging due to non-linear nature of CS reconstruction
- Same trajectory for each encoding, more information potentially accessible if different trajectories are used. For more info **see abstract #3683**

Watch a pre-recorded presentation here

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