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Compressed SENSE in MRI of Multiple Sclerosis: Halving scan time without quality loss

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Purpose

Recently, Compressed SENSE (CS), a technique to accelerate MR imaging, was introduced into clinical praxis. It uses sparsity constraints to undersample the k-space and therefore requires less readout measurements.

We investigated, whether sensitivity for pathologies is preserved when using CS. To this end, we compared the performance of CS accelerated Double inversion recovery (DIR) sequences in MR scans of patients with Multiple Sclerosis (MS) with conventionally acquired DIR sequences.

Methods

Subjects:
109 consecutive scans in patients with MS

MR Protocol:
- 3D DIR Compressed SENSE* (CS factor: 8.5)
- 3D DIR (conventional) SENSE*
- 3D FLAIR
- 3D T1
- 3D T2

*: These sequences shared the same parameters (apart from CS), resolution and FOV.
Acquisition time CS DIR: **3:12 min**
Acquisition time conventional DIR: **6:30 min**

Field strength:
3 Tesla (Philips Achieva dStream)

Additional postprocessing:
- Co-Registration of all images from a single patient

Data analysis:
Direct visualization of focal intensity differences via subtraction maps.
Those differences were counted and rated by 2 neuroradiologists.

The intensity differences were classified into:

Definite lesions:
Lesions that were rated as typically inflammatory by both readers.

Possible lesions:
Hyperintensities that could be caused by inflammation but either did no show clear correlates in other sequences or missed the 3mm size threshold (as defined in the McDonald-Criteria).

Definite artifacts:
Hyperintensities that clearly reflect technical artifacts.

Results

In total only very few focal intensitiy differences were counted:

Definite lesions: No differences. In total, both sequences appeared indistinguishable for the readers:

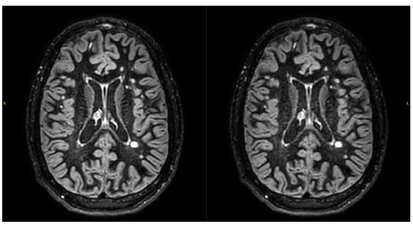

Figure 1: *Typical example for the comparison of conventional DIR (left) and CS DIR (right). Note the high grade of similarity between both sequences.*

- **Possible lesions:** 2 only visible in conventional DIR, 1 only visible in CS DIR (see Figure 2)

- **Definite artifacts**: 5 in subcortical location in the conventional DIR, none in the CS DIR. 22 in cortical/sulcal location in the conventional DIR, 1 in the CS DIR.
The conventional DIR performed significantly worse for both locations (p=0.024 for subcortical and p<0.001 for sulcal artifacts). (see Figure 3)

Discussion

In our study, not a single definite lesion would have been overlooked when using the CS instead of the conventional DIR.

Moreover, the CS DIR proved to be less prone to artifacts. These artifacts appeared to be due to venous structures (small pial veins and perivascular spaces), which are known to cause artifacts in DIR sequences. By using random readouts which are more robust to quickly changing flow dynamics within the veins, CS may help to cancel out those venous flow artifacts.

Implementing CS for our whole MS protocol helped to reduce scan times from 23:12 min to 16:40 min even with re-investing part of the saved time into a higher resolution of the FLAIR and T2 sequences.

In summary, CS can contribute to saving acquisition time considerably without risking diagnostic accuracy.

Examples of focal intensity differences

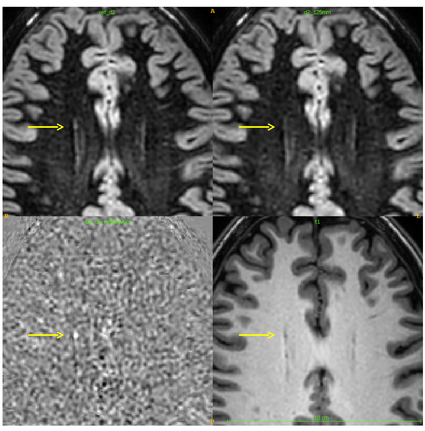

Figure 2: Example of a possible lesion

Upper left: *Conventional DIR*
Upper right: *CS DIR*
Lower left: *Subtraction map*
Lower right: *T1*

The structure marked with an arrow was only visible in the conventional DIR. As it is smaller than 3mm, it fails the minimum lesion size threshold defined by the McDonald criteria

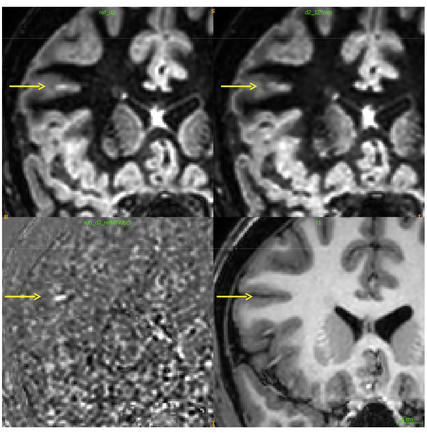

Figure 3: Example of a definite artifact

Upper left: *Conventional DIR*
Upper right: *CS DIR*
Lower left: *Subtraction map*
Lower right: *T1*

The hyperintensity marked with an arrow only occurred in the conventional DIR. As correlation with other sequences did not show any correlate and proved this hyperintensity to be in a sulcus, it was rated as artifact caused by small pial veins. Note that without crosschecking such structures with other sequences they may be mistaken as cortical lesion.