

CASE STUDY

3D Compressed SPEEDER: Workflow acceleration in daily practice



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Benoit Doche de Laquintane, M.D. is a radiologist specialized in neuro imaging. He is working in collaboration with the University Hospital of Bordeaux on a Vantage Galan 3T / XGO system, for morphological and pre-surgical evaluation of epileptic patients. Pre-surgical evaluations consist of anatomical brain imaging and can also include fMRI and perfusion-weighted imaging.

Introduction

As magnetic resonance imaging (MRI) is more and more becoming the choice of radiologists for diagnostic imaging, it leads to a strong increase in the number of exam requests. However, this increase is not always compensated by the number of MR systems installed. Research communities and manufacturers are therefore jointly focusing on how to decrease scan time without affecting image and diagnostic quality. One of the solutions recently provided by Canon Medical Systems is based on compressed sensing¹ and is called Compressed SPEEDER (CS). This new approach can be applied to both 2D and 3D sequences and can accelerate existing protocols on all body regions. 3D protocols offer advantages over 2D protocols, but they are suffering from long scan times, making them less popular in clinical practice. The CS implementation reduces scan times and therefore allows the use of 3D scans in daily routines.

In this study, we focused on the added value of Compressed SPEEDER for 3D sequence (3D CS), evaluating its contribution to the workflow improvement and on additional benefits such as multi-planar reconstruction (MPR). Three patients with different pathologies have been scanned on a Vantage Galan 3T / XGO system, with a 32ch brain coil.

Compressed SPEEDER

Compressed SPEEDER (CS) is an acceleration technique based on compressed sensing approach, which allows scan time reduction by acquiring less k-lines (=undersampling). The loss in signal is compensated by using smart reconstruction and post-processing processes.

Where other acceleration methods use regular undersampling schemes, CS uses a form of random undersampling. Regular undersampling typically causes aliasing artefacts that need to be corrected for. The random undersampling causes these artefacts to have an incoherent noise character, which can be removed after a number of iterations with a signal threshold in the image domain (Figure 1). As an exception, the center of k-space is fully sampled and is used to build sensitivity maps for each coil element, allowing a better reconstruction of the final image.

The user has the possibility to adjust two parameters depending the quality and the scan time reduction needed. The first one is the "CS factor" which drives the acceleration strength. The higher the CS factor, the more the scan is accelerated, but at the cost of signal-to-noise ratio (SNR). The second one is "Regularization factor" which adjusts the threshold level. This parameter has an effect on the amount of incoherent noise that is removed, but can also affect the sharpness of the images when set too high. The optimal balance between acceleration and regularization level is key to get the most out of this technique.

"As a very powerful technique, 3D CS is part of Canon's acceleration methods such as Advanced intelligent Clear-IQ Engine (AiCE) and MultiBand SPEEDER. Their combination allows me to significantly speed-up protocols with 3D coverage while maintaining diagnostic image quality. Saving time can be used for workflow improvement or to perform extra and advanced sequences that are more time consuming."

Benoit Doche, M.D.

Clinical cases

Case 1: Probable colloid cyst accidentally discovered on a CT scan for headache (Figure 2)

The following sequences have been performed: Sagittal T1w 3D CS FFE (Res=0.8×0.8×1 mm³; Acq. Time=1:29 min), Sagittal T2w 3D CS (Res=1×1×1 mm³; Acq. Time=1:44 min), Sagittal 3D FLAIR with Advanced intelligent Clear-IQ Engine (AiCE) reconstruction (Res=1×1×1.4 mm³; Acq. Time=2:15 min) and Axial multiband diffusion tensor imaging (Res=1.9×1.5×4 mm³; Acq. Time=1:16 min).

A small cystic mass syndrome was found inside the ventricle, at the lower part of the right frontal horn and facing the Monro hole. It measured 4 by 5 mm and had iso-signal intensity on T1w, iso-signal intensity on FLAIR and hypo-signal intensity on T2w MRI, suggesting a small colloid cyst. No sign of trans-ependymal resorption has been found.

"Compressed SPEEDER allowed us to perform a full exam with 3D scans in a short total examination time (Total acquisition time=6:34 min) combined with MPR."

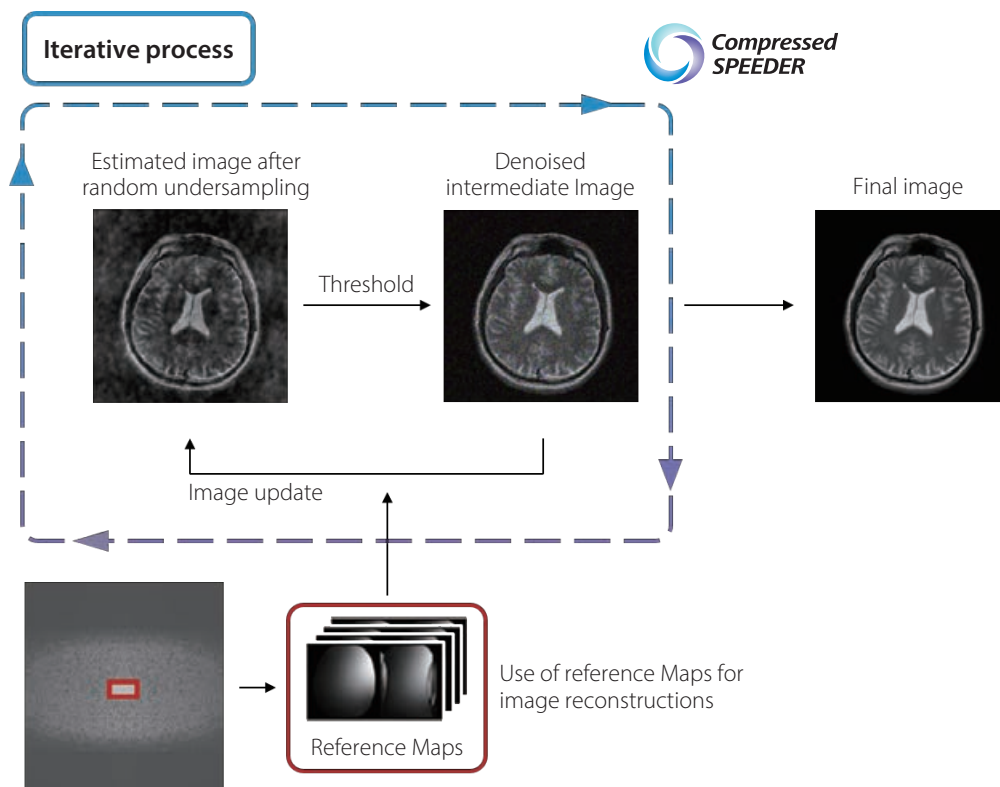


Figure 1 Flowchart summarizing the Compressed SPEEDER process

Case 2: Follow-up of a right acoustic schwannoma (Figure 3)

The following sequences have been performed: high resolution axial T2w 3D CS (Res= $0.7 \times 0.5 \times 0.6 \text{ mm}^3$; Acq. Time=1:30 min), Axial T1w 3D CS FFE before and after gadolinium injection (Res= $0.8 \times 0.8 \times 1 \text{ mm}^3$; Acq. Time=1:29 min).

The sequences centered on the internal auditory canals (IAC) found a mass syndrome in the right internal auditory canal. The cerebellar pontine angle presented a homogeneous enhancement, measuring 9 by 4 mm, and corresponding to a perfectly stable known grade II schwannoma. No mass syndrome signal abnormality in the left cochleovestibular bundle was found. No signal or morphological anomalies have been found in the vestibular cochlea and semicircular frame, on both right and left sides.

"3D CS was used in all sequences and allowed us to perform a full exam in less than 5 minutes (Total acquisition time = 4:28 min)."

Case 3: Acute and chronic motor impairment of the 4 limbs in a patient with a history of temporo-parietal fracture (right side) in 1973 on a road accident. Research of an argument in favor of an amyotrophic lateral sclerosis (Figure 4)

The following sequences have been performed: Sagittal T1w 3D CS FFE (Res= $0.8 \times 0.8 \times 1 \text{ mm}^3$; Acq. Time=1:29 min), Sagittal 3D FLAIR with AiCE reconstruction (Res= $1 \times 1 \times 1.4 \text{ mm}^3$; Acq. Time=2:15 min), Axial Flow Insensitive Black Blood (FIBB) with AiCE reconstruction (Res= $0.9 \times 0.9 \times 2 \text{ mm}^3$; Acq. Time=1:19 min), Axial multiband diffusion tensor imaging (Res= $1.9 \times 1.5 \times 4 \text{ mm}^3$; Acq. Time=1:16 min).

An enlargement of the ventricular system and of the cortical sulcus has been found, correlating with cerebral aging, with a predominance of atrophy signs in bilateral temporal lobes. There were porencephalic cavities in the left orbito-frontal and left temporal regions, in the middle and the lower temporal gyrus, suggesting parenchymal contusion sequelae in conformity with the accidental history.

An enlargement of the choroidal fissure and the temporal horn have also been found, associated with a decrease of the hippocampus thickness, predominant on

the left side, in favor of a moderate bilateral hippocampal grade II Scheltens' atrophy on the right, grade III Scheltens' on the left.

No significant signal abnormality of the white matter has been demonstrated elsewhere apart from the post-traumatic sequelae already described. No systematized signal abnormality has been found in a vascular territory neither. The diffusion sequences did not show any sign of recent ischemia.

The pre-central gyrus observed with the FIBB sequence, with high magnetic susceptibility, had a hypo-intense aspect with hemosiderin deposits on both sides, with a predominance on the right which could be associated with a motor neuron pathology such as amyotrophic lateral sclerosis. No micro-bleed, hemosiderosis and pericerebral collection have been observed.

"The combination of 3D CS, AiCE reconstruction and MultiBand SPEEDER allowed us to perform the full exam of a complex case in less than 7 minutes (Total acquisition time = 6:19 min)."

Conclusions

For these three clinical cases, the use of Compressed SPEEDER allowed performing 3D explorations in a short scan time, with the addition of other benefits such as the possibility to do multi-planar reconstructions.

References

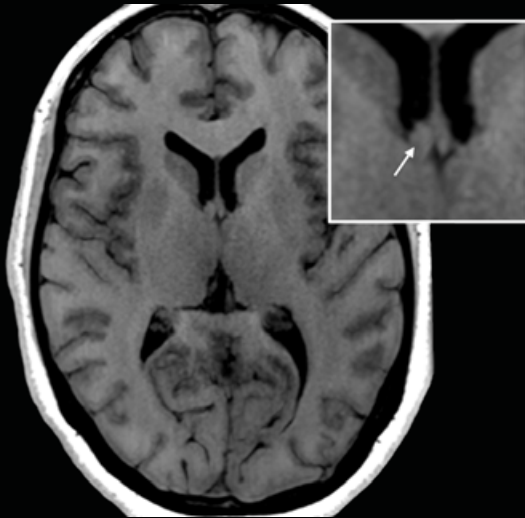
1. Donoho, D. L. Compressed sensing. IEEE Transactions on information theory, 2006. 52(4), 1289-1306.

Clinical and Scientific Canon Medical Systems support



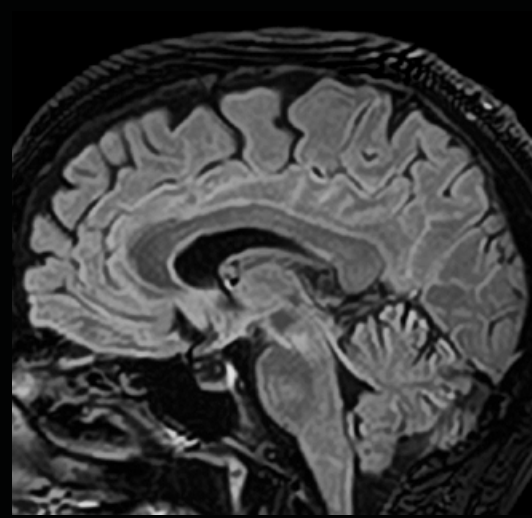
Valentin H. Prevost, Ph.D.
MR Clinical Scientist
Canon Medical Systems Corporation

3D T1 FFE



Acq. Time 1:29

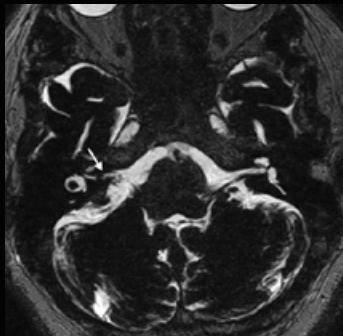
3D FLAIR



2:15

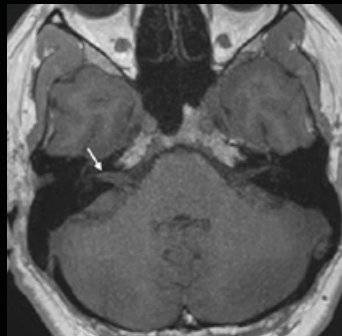
Figure 2 Illustrative axial reconstruction of 3D CS T1w ($0.8 \times 0.8 \times 1 \text{ mm}^3$) and sagittal 3D FLAIR ($1 \times 1 \times 1.4 \text{ mm}^3$) combined with AiCE reconstruction, performed for case 1. White arrows are pointing a small colloid cyst in the right Monro hole measuring 4 by 5 mm.

3D T2 FASE



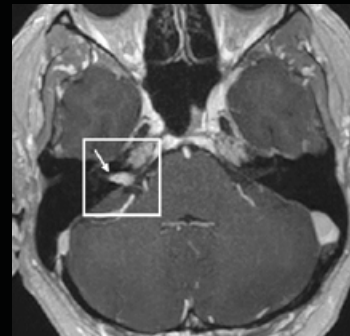
Acq. Time 1:30

3D T1 FFE

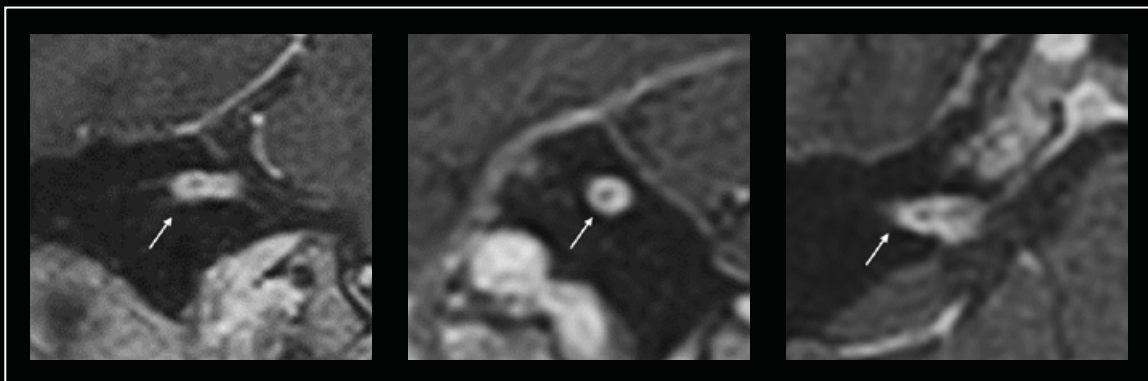


1:29

3D T1 FFE + Gado



1:29



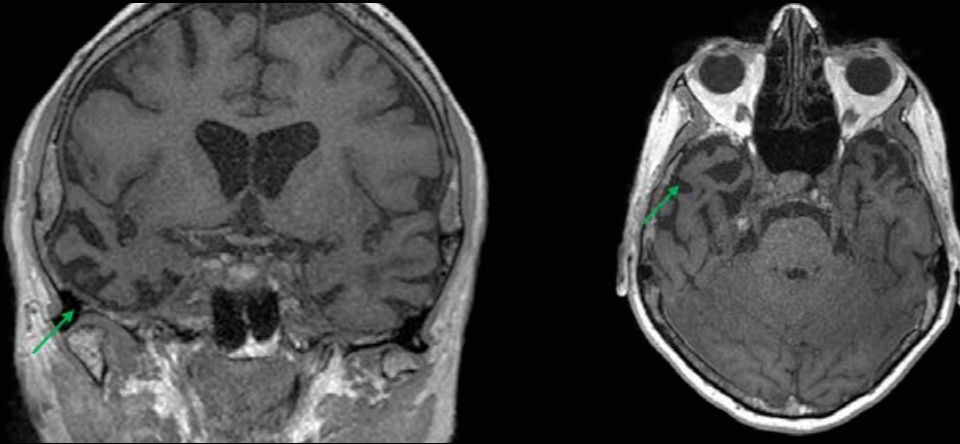
Coronal MPR

Sagittal MPR

Axial MPR

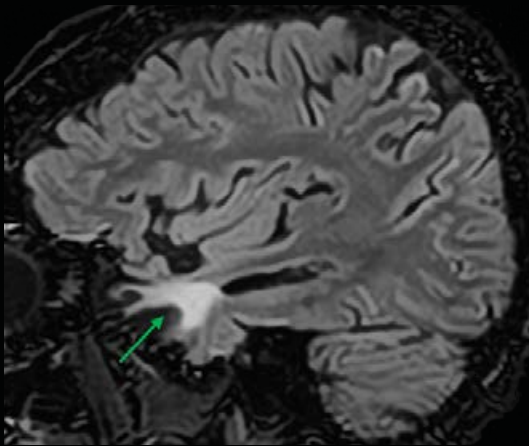
Figure 3 Illustrative axial reconstructions of 3D CS T2w ($0.7 \times 0.5 \times 0.6 \text{ mm}^3$), 3D CS T1w pre and post gadolinium ($0.8 \times 0.8 \times 1 \text{ mm}^3$), and oblique MPR performed for the case 2. A small mass syndrome (white arrows) was observed in the right internal auditory canal with a signal enhancement compatible with a grade II Schwannoma.

3D T1 FFE



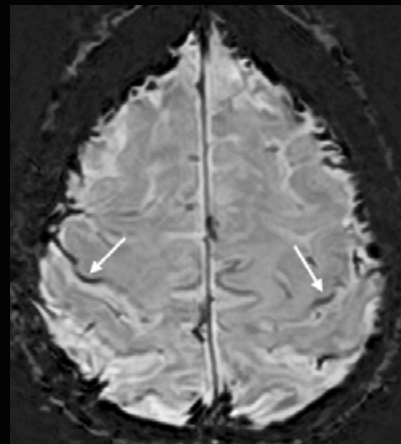
Acq. Time 1:29

3D FLAIR



Acq. Time 2:15

Ax FIBB



1:19

Figure 4 Illustrative coronal and axial reconstructions of T1w 3D CS ($0.8 \times 0.8 \times 1 \text{ mm}^3$), sagittal 3D FLAIR ($1 \times 1 \times 1.4 \text{ mm}^3$) and axial FIBB ($0.9 \times 0.9 \times 2 \text{ mm}^3$) combined with AiCE reconstructions, performed for case 3. Bilateral temporal sequelae (green arrows) were observed and were in conformity with traumatic history. A linear hypo-signal was observed in the precentral gyrus (white arrows), suggesting hemosiderin deposits compatible with an amyotrophic lateral sclerosis.

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