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PATCH-BASED SUPER-RESOLUTION FOR ARTERIAL SPIN LABELING MRI

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CONTEXT

In clinical conditions, ASL images are often acquired at low resolutions (LR). This implies partial volume effects (PVE), limiting the validity of cerebral blood flow (CBF) quantifications.

PROPOSITION

We propose an adaptation of a **super-resolution algorithm**[1], taking advantage of a high resolution (HR) structural image to reconstruct CBF maps at a higher resolution, without increasing the acquisition time.

PROTOCOL

- **Scanner:** 3T Siemens Verio (VB17)
- **HR pCASL:** 1.75x1.75x3mm^3, 100 control-label pairs, FOV=224x224mm^2
- **M0 image** acquired at the same resolution than the pCASL series
- **Structural image:** MPRAGE 3DT1 1x1x1mm^3, FOV=156x200mm^2

PREPROCESSING

The images were processed using an **inhouse processing pipeline** based on Nipype[2], SPM8 and Python functions.
The ASL series were realigned on the first volume.
The M0 and structural images were registered on the perfusion maps.
The CBF maps were estimated using the general kinetic model[3].

CONCLUSION

The proposed algorithm enables the generation of HR CBF images, without increasing the actual acquisition time. It provides more reliable CBF values than traditional interpolation methods, especially in gray matter, which is of particular interest in clinical practice.

REFERENCES

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2. Gorgolewski & al., Nipype: a Flexible, Lightweight and Extensible Neuroimaging Data Processing Framework in Python, Frontiers in Neuroinformatics, 2011;5:13
3. Buxton & al., A General Kinetic Model for Quantitative Perfusion Imaging with Arterial Spin Labeling, MRM, 1998;40:383:396

METHOD

The purpose of the super-resolution algorithm is to retrieve a HR CBF map x from a LR one y provided by the scanner, subject to a decimation operator D, a degradation model H and noise η :

$$y = DHx + \eta$$

X, the estimation of x obtained by reconstruction from y, is the result of the minimization of the optimization function :

$$\tilde{x} = \arg\min_x ||y - DHx||_2^2 + \gamma\Phi_S(x)$$

with γ a scalar and Φ_S a non-local patch-based regularization term, including information from the structural image S.

The proposed algorithm therefore consists in:

- a 3rd order spline interpolation to increase the image dimensions
- iterations between the non-local patch-based regularization and an original data fidelity term until convergence

$$X_i^{t+1} = \frac{1}{Z_i}\sum_{j\in V_i} X_j^t \exp -\left(\frac{||N(S_i) - N(S_j)||_2^2}{2\sigma_{i,S}^2} + \frac{||N(X_i^t) - N(X_j^t)||_2^2}{2\sigma_i^2}\right)$$

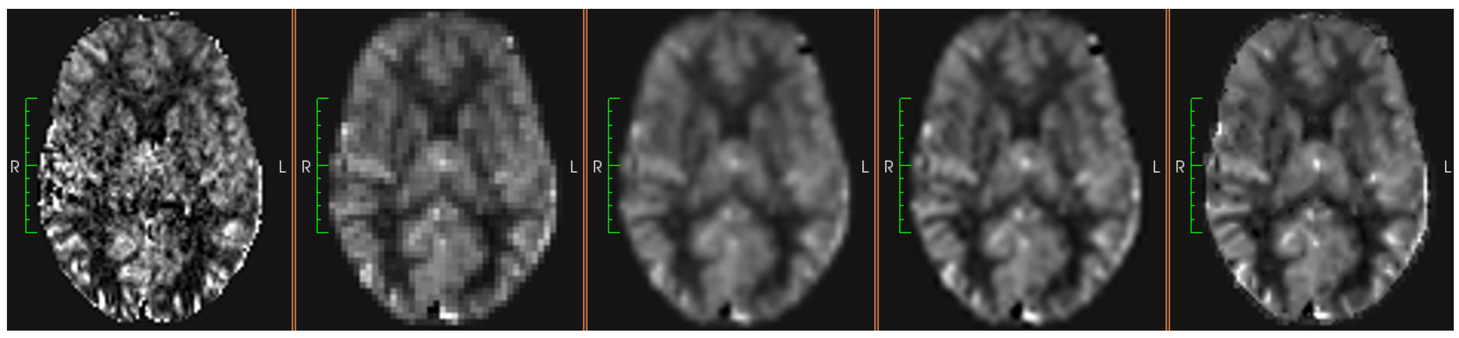
$$X^{t+1} = X^{t+1} - (DHX^{t+1} - y)$$

with $N(X_i)$ a $3*3*3$ neighborhood, V_i a $7*7*7$ search volume around voxel i, σ_i the empirical variance and Z_i a scaling parameter.

In order to validate the ability of the algorithm to retrieve a HR image, we applied it to an original HR CBF map downsampled by a factor of 2 in each direction.
The dimensions of the CBF maps were also increased using nearest neighbor, trilinear and 3rd order spline interpolation as a matter of comparison.

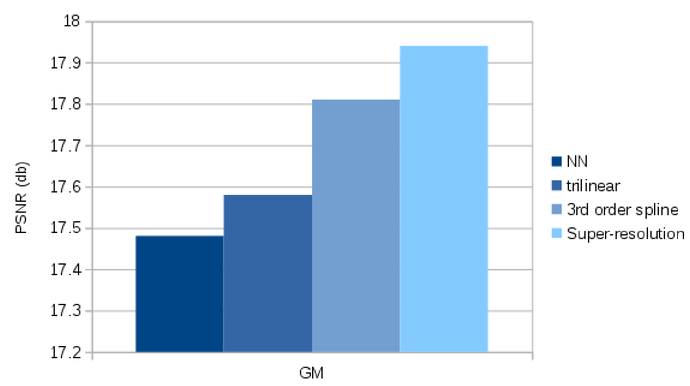
RESULTS

The following images present the CBF maps obtained with the different methods:



From left to right: HR CBF image, nearest neighbor, trilinear, 3rd order spline and super-resolution reconstructions

The original HR CBF map being considered as the reference image, the quality of the reconstructions was evaluated by calculating the PSNR between this reference and the generated images.



PSNR between the reference HR CBF map and the maps reconstructed using nearest neighbor, trilinear, 3rd order spline and the proposed super-resolution algorithm.

PARTNERS