A comparison of combined acquisition and processing methods for DTI: a pediatric study

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PURPOSE

To investigate the effects of several motion correction techniques in DTI:

A) prospective, using navigated acquisition (vNav)[1];

B) retrospective, using two popular packages, FSL[2] and TORTOISE[3];

C) the combination of both retrospective and prospective.

Each was applied while also correcting for eddy current and EPI distortions.

METHODS

Subjects: Six healthy, unsedated children (4F/2M, age 7.20±0.06 yrs). *All subject motion was incidental (and typical of pediatric scans).*

Acquisition: Using a 3T Siemens Allegra, for each subject:

- T1w: T1-weighted anatomical, 1.3x1x1 mm^3, navigated MEMPRAGE[4];
- Basic: standard DTI using a twice refocused SE-EPI sequence, TR/TE=9500/86 ms, 2x2x2 mm^3 voxels, 4 b_0 volumes and 30 directions with b=1000 s/mm^2, a pair of AP and PA phase encoded sets;
- vNav: navigated DTI set, same as Basic but with TR=10026 ms and five reacquisitions enabled in case of excessive motion (translation >2.5 mm or rotation >1 deg).

Techniques: For each subject 'A-F', we compared 8 analyses, using either:

- standard (Basic) or navigated (vNav) acquisition;
- FSL-topup and eddy_correct (TOP) or TORTOISE (TORT) software;
- explicit retrospective motion correction (Retro) or none (NoRet).

Additional processing included AFNI[5] and FATCAT[6].

Comparisons: quantitative and visual analyses of results:

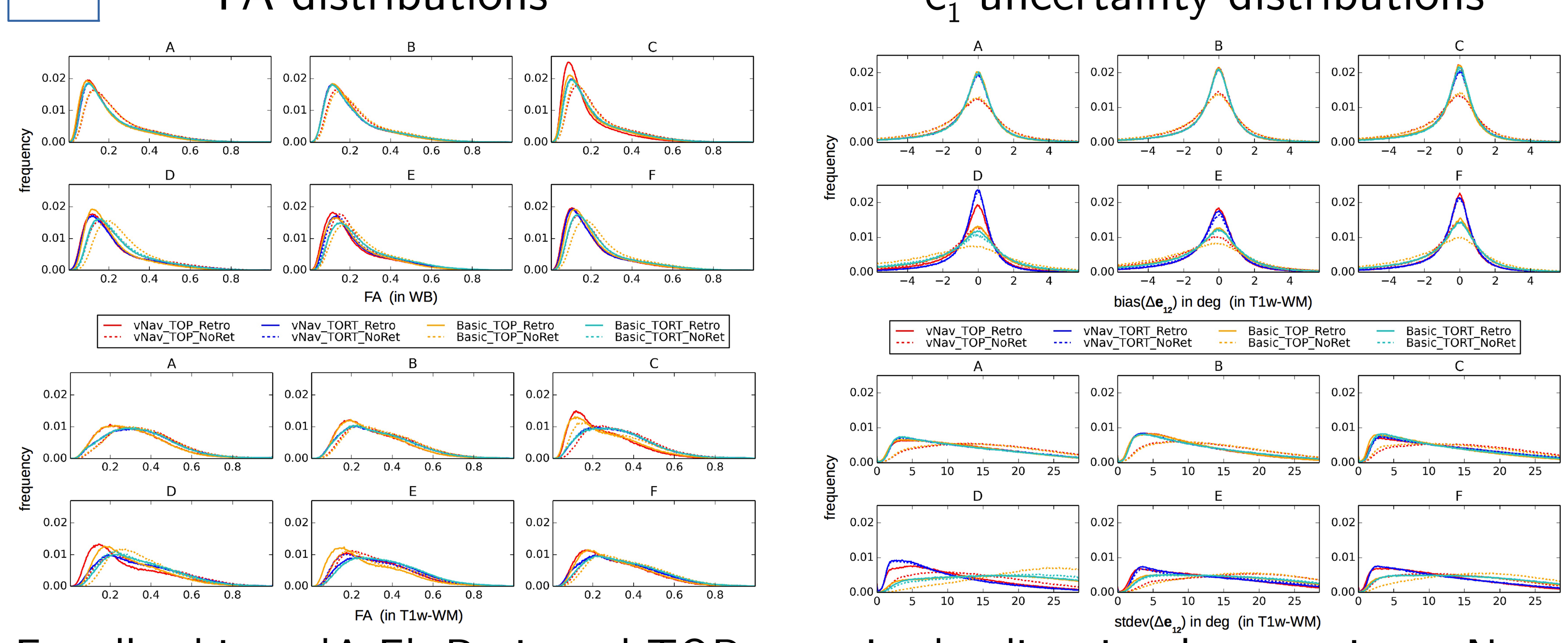
1) DTI parameter distributions: FA and first eigenvector (e_1) uncertainty;

2) FA and T1w white matter (WM) map overlap and Dice coefficients;

3) Probabilistic tractography, calculating WM specificity and sensitivity;

RESULTS

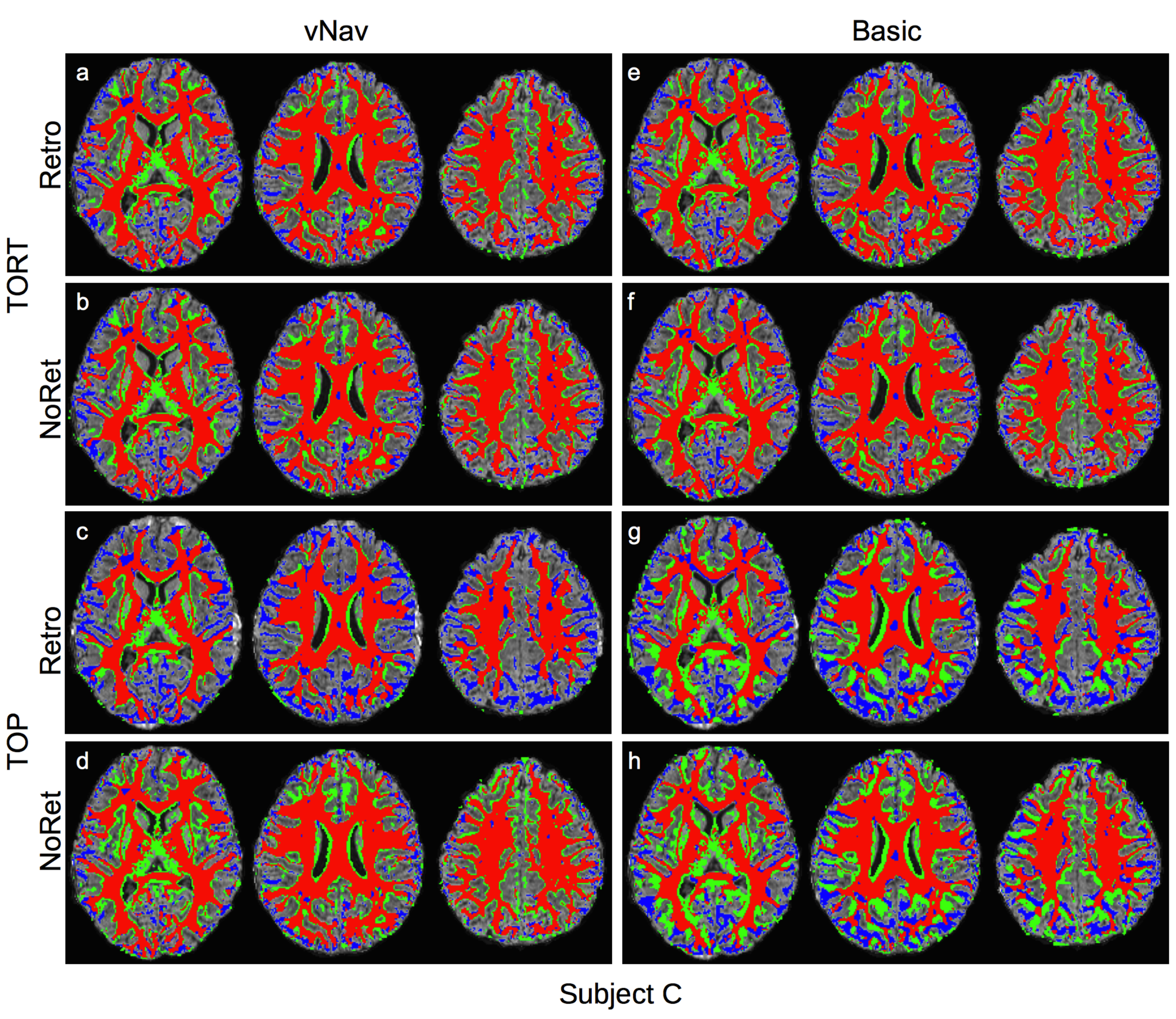
1. FA distributions / e_1 uncertainty distributions



For all subjects 'A-F', Basic and TOP results were the least left-shifted in the whole brain (WB) cases. In T1w-WM, TORT and BASIC_TOP_NoRet were the least left-shifted, suggesting the least amount of smoothing.

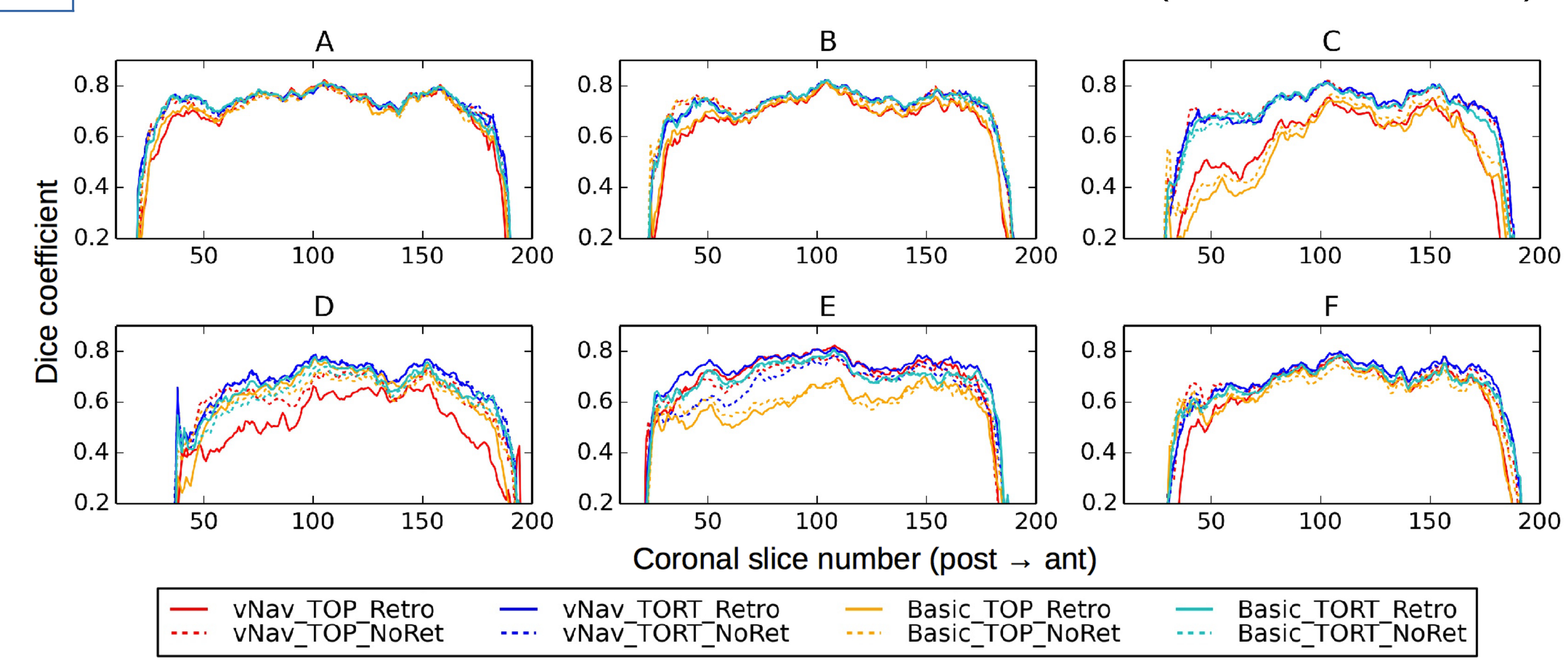
In the directional uncertainty, vNav acquisitions with TOP- or TORT-Retro were typically similar, having the narrowest bias at zero and the stdev peak at the smallest values (i.e., smallest angular uncertainty).

2a. FA- and T1w-WM overlaps



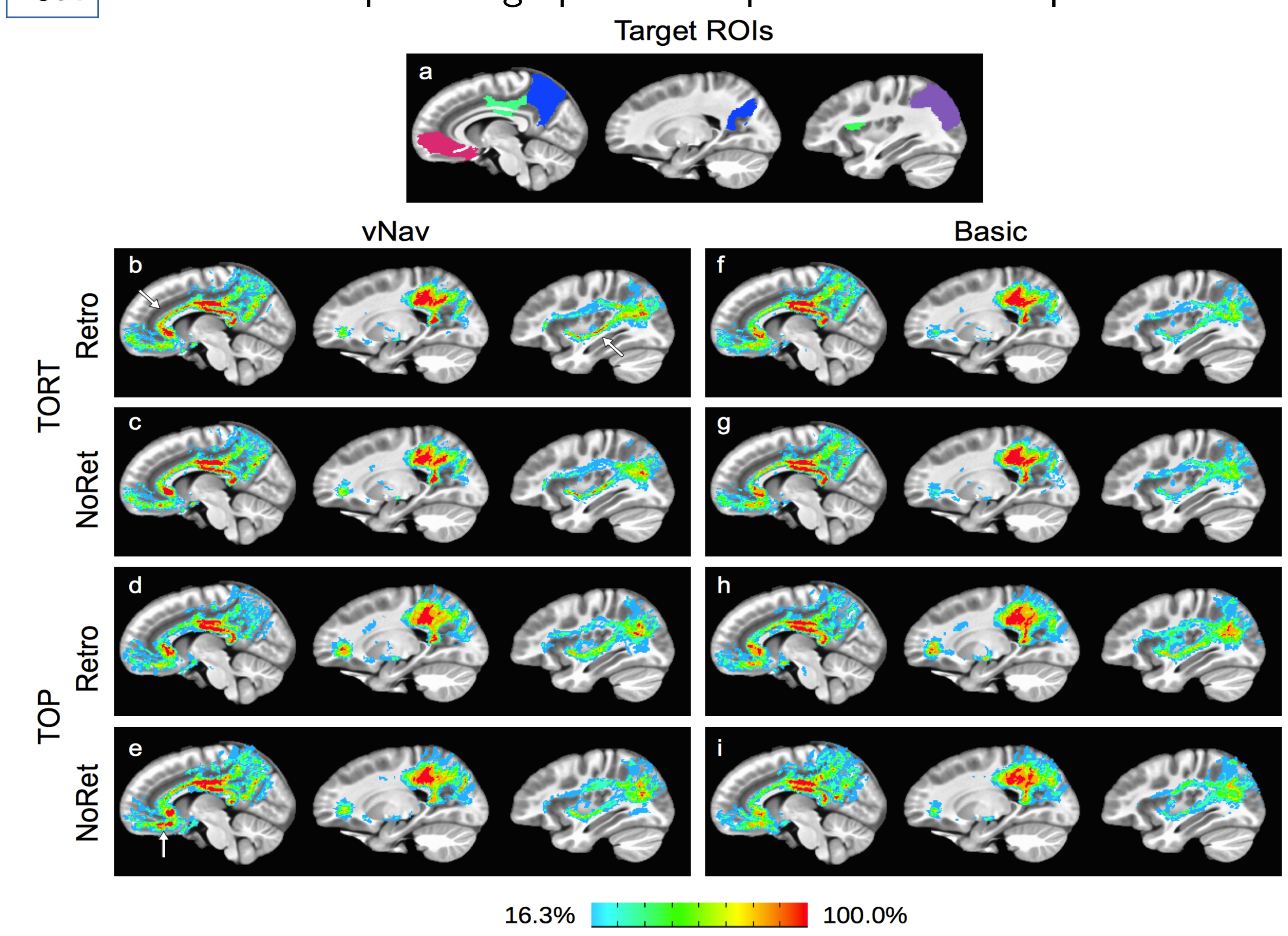
Locations of FA- and T1w-WM overlap are shown in red; false positive FA-WM is blue; false negative FA-WM is green. In each panel the axial slices are arranged inferior (left) to superior (right). Basic_TOP images show systematic differences in WM locations, and TORT_Retro shows the highest matches.

2b. Dice coefficients of FA- and T1w-WM masks (per coronal slice)



For all subjects 'A-F', Dice values were mainly constant across the brain, decreasing at the anterior and posterior ends. vNav_TORT_Retro consistently showed the highest values.

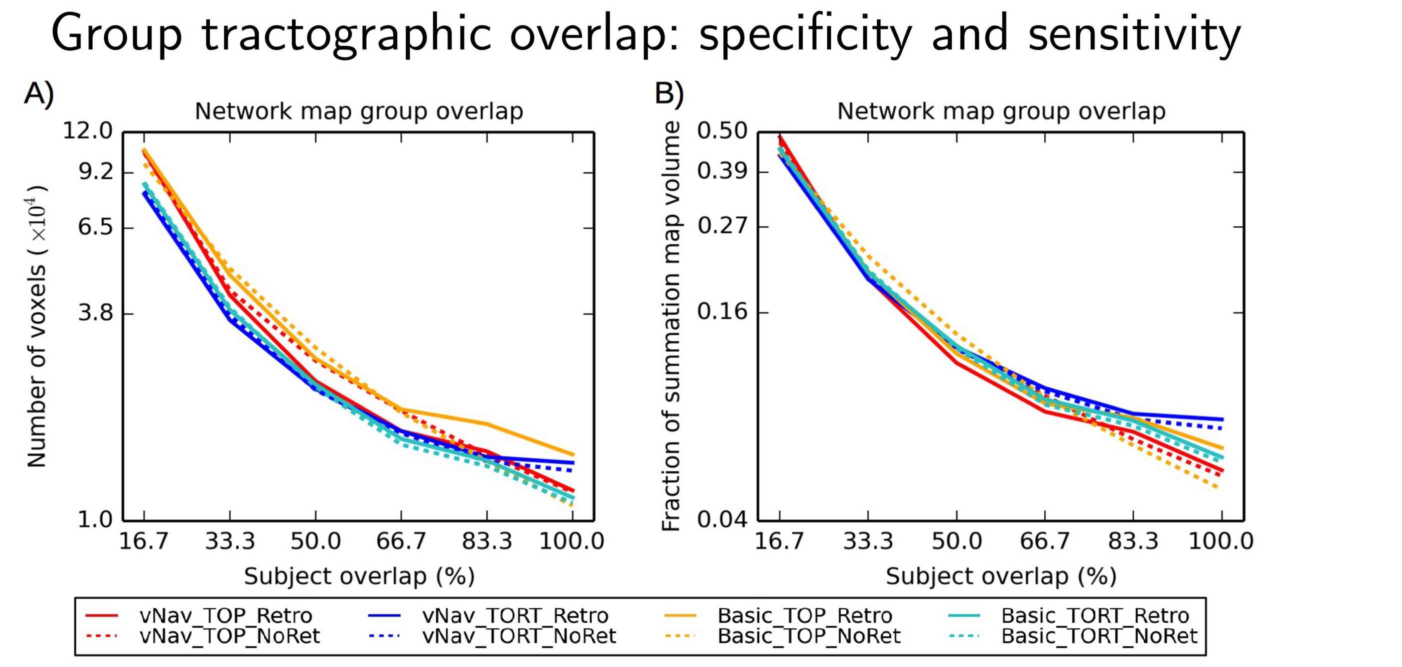
3a. Group tractographic overlap: summation maps



Panel 'a' shows a map of the target ROIs (based on default mode network) used for tractography, with each cortical region labelled using a unique color.

In panels 'b-i' masks of each subject's estimated intra-network WM have been summed to highlight overlap across the group. In these summation maps the regions where WM was found for all group members are shown in red, and regions where only one subject had WM are shown in blue. In each panel sagittal images are arranged medial (left) to lateral (right).

3b. Group tractographic overlap: specificity and sensitivity



Here, a method with greater ***specificity*** would produce fewer voxels with low percentages of overlap (i.e., exhibiting less heterogeneity); one with greater ***sensitivity*** would produce more voxels with 100% subject overlap. Panel A shows the volume of the summation map with a given group percentage of overlap; panel B displays the same volume as a fraction of each method's summation map volume. In both panels, TORT-processed data (particularly with vNav acquisition) had the highest specificity. The greatest sensitivity was observed for Basic_TOP_Retro and vNav_TORT_Retro in panel A and for both vNav_TORT approaches in panel B.

CONCLUSIONS

It's good to use navigation (vNav[1]) during DTI acquisitions.

It's good to process and motion correct DTI data with TORTOISE.

It's *best* to do both!

REFERENCES: [1] Alhamud et al., 2012. Magn Reson Med 68:1097-1108. [2] Smith et al., 2004. Neuroimage 23:208-219. [3] Pierpaoli et al., 2010. Proc ISMRM p. 1597. [4] van der Kouwe et al., 2008. Neuroimage 40:559-569. [5] Cox RW, 1996. Comput Biomed Res 29:162-173. [6] Taylor and Saad, 2013. Brain Connect 3:523–525.

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