

## Protocol for TBSS analysis using the ENIGMA-DTI template

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The following steps will allow you to register and skeletonize your FA images to the DTI atlas being used for ENIGMA-DTI for tract-based spatial statistics (TBSS; Smith et al., 2006).

Here we assume preprocessing steps including motion/Eddy current correction, masking, tensor calculation, and creation of FA maps has already been performed, along with quality control.

Further instructions for using FSL, particularly TBSS can be found on the website:  
<http://www.fmrib.ox.ac.uk/fsl/tbss/index.html>

1. Download a copy of the ENIGMA-DTI template FA map, edited skeleton, masks and corresponding distance map from the following link into a directory (example /enigmaDTI/TBSS/ENIGMA\_targets/)

<http://enigma.loni.ucla.edu/wp-content/uploads/2012/06/enigmaDTItargets.tar.gz>

The downloaded archive will have the following files:

- mean\_FA.nii.gz
- mean\_FA\_mask.nii.gz
- mean\_FA\_skeleton.nii.gz
- mean\_FA\_skeleton\_mask.nii.gz
- mean\_FA\_skeleton\_mask\_dst.nii.gz

2. Copy all FA images into a folder  
`cp /subject*_folder/subject*_FA.nii.gz /enigmaDTI/TBSS/run_tbss/`
3. cd into directory and erode images slightly with FSL  
`cd /enigmaDTI/TBSS/run_tbss/  
tbss_1_preproc *.nii.gz`
  - This will create a ./FA folder with all subjects eroded images and place all original ones in a ./origdata folder
4. Register all subjects to template. Can choose registration method that works best for your data  
`<<< as a default use TBSS >>>  
tbss_2_reg -t target_enigma.nii.gz  
tbss_3_postreg -S`

Make sure to QC images to ensure good registration!

**\*\*NOTE\*\* If your field of view is different from the ENIGMA template – (example, you are missing some cerebellum/temporal lobe from your FOV) or you find that the ENIGMA mask is somewhat larger than your images, please follow Steps 5 and 6 to remask and recreate the distance map. Otherwise, continue to use the distance map provided\*\*\***

5. Create a common mask for the specific study if necessary and save as:  
`/enigmaDTI/study_mask.nii.gz`  
Mask ENIGMA target and skeleton with this and overwrite current files.  
To use FSL to mask:  

```

${FSLPATH}/fslmaths /enigmaDTI/TBSS/ENIGMA_targets/mean_FA.nii.gz
-mas /enigmaDTI/study_mask.nii.gz
/enigmaDTI/TBSS/ENIGMA_targets/mean_FA_mask.nii.gz

```

For mask and skeleton to get:  

```

/enigmaDTI/TBSS/ENIGMA_targets/mean_FA_mask.nii.gz
/enigmaDTI/TBSS/ENIGMA_targets/mean_FA_skeleton_mask.nii.gz

```
6. cd into directory where you have newly masked ENIGMA target and skeleton to create a distance map  

```

tbss_4_prestats -0.049

```

  - The distance map will be created but the function will return an error because the all\_FA is not included here. This is ok!
  - The skeleton has already been thresholded here so we do not need to select a higher FA value (ex 0.2) to threshold.

will output:

```

/enigmaDTI/TBSS/ENIGMA_targets/mean_FA_skeleton_mask_dst

```

7. For faster processing or parallelization, it is helpful to run the projection on one subject at a time. Move each subject FA image into its own directory and (*if masking was necessary as in steps 5 and 6 above*) mask with common mask. This can be parallelized on a multiprocessor system if needed.

```

cd /enigmaDTI/TBSS/run_tbss/
for subj in subj_1 subj_2 ... subj_N
do

mkdir -p ./FA_individ/${subj}/stats/
mkdir -p ./FA_individ/${subj}/FA/

cp ./FA/${subj}_*.nii.gz ./FA_individ/${subj}/FA/

####[optional/recommended]####
${FSLPATH}/fslmaths ./FA_individ/${subj}/FA/${subj}_*FA.nii.gz -
mas /enigmaDTI/study_mask.nii.gz
./FA_individ/${subj}/FA/${subj}_masked_FA.nii.gz

done

```

8. Skeletonize images by projecting the ENIGMA skeleton onto them:

```

cd /enigmaDTI/TBSS/run_tbss/
for subj in subj_1 subj_2 ... subj_N
do

```

```

${FSLPATH}/tbss_skeleton -i
/enigmaDTI/TBSS/ENIGMA_targets/mean_FA_mask.nii.gz -p 0.049
/enigmaDTI/TBSS/ENIGMA_targets/mean_FA_skeleton_mask_dst
${FSLPATH}/data/standard/LowerCingulum_1mm.nii.gz
./FA_individ/${subj}/FA/${subj}_masked_FA.nii.gz
./FA_individ/${subj}/stats/${subj}_masked_FAskel.nii.gz -s
/enigmaDTI/TBSS/ENIGMA_targets/mean_FA_skeleton_mask.nii.gz

```

done

Congrats! Now you have all your images in the ENIGMA-DTI space with corresponding projections.

All your skeletons are:

```

/enigmaDTI/TBSS/run_tbss/FA_individ/${subj}/stats/${subj}_masked_FAskel
.nii.gz

```