

Paracingulate Sulcus Measurement Protocol

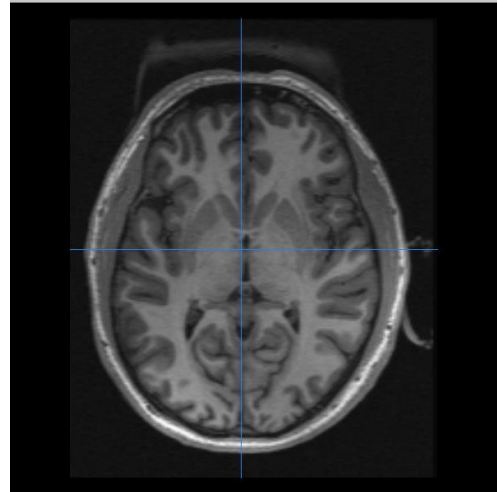
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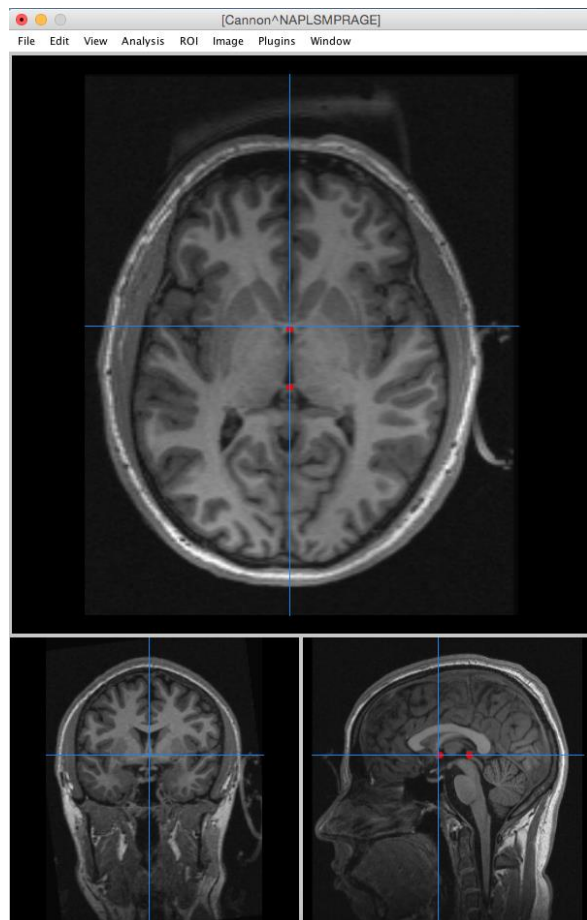
This guide provides what is hopefully a user friendly protocol for measuring the length of the paracingulate sulcus (PCS) from structural MRI scans using the freely available Mango software.

The PCS measurement protocol was first reported in the paper by Garrison, J. R., Fernyhough, C., McCarthy-Jones, S., Haggard, M., The Australian Schizophrenia Research Bank, & Simons, J. S. (2015). Paracingulate sulcus morphology is associated with hallucinations in the human brain. *Nature Communications*, 6, 8956. <https://doi.org/10.1038/ncomms9956>.

1. Open Mango (Available from <http://ric.uthscsa.edu/mango/download.html>)
2. Open the dicom folder for structural scan (double click on first slice).
3. Take the colour bar down by half to improve contrast (if needed)
4. Choose 'world space' by selecting globe, third icon on toolbar, and select an MNI atlas
5. Image/transform/rotate
6. Use Y and Z rotations so the image is straight, and the cross hairs are central. Switch to an axial view using the spacebar.
7. Identify the anterior and posterior commissures (AC and PC); these should be aligned on the same slice. If not, use Rotate-X until they look like this:

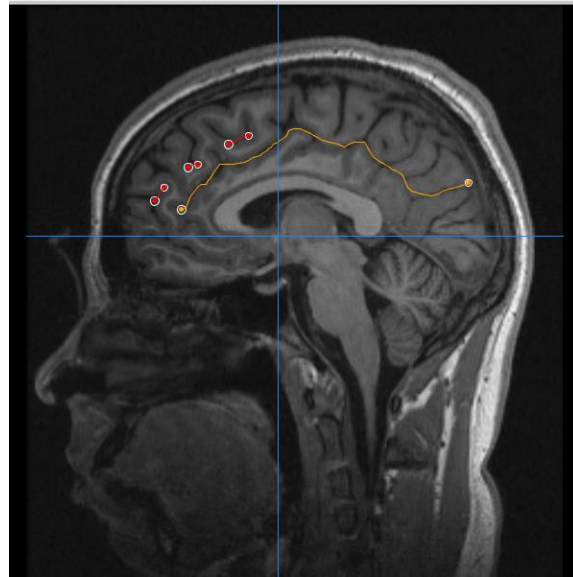


8. When the image is aligned, put the cursor on the AC, and reset this as the origin using edit/origin
9. Mark the AC and PC with dots: using 'Add Points' found under 5th icon on toolbar, third down. (Note, to return to cursor, select top icon again)
10. Switch to sagittal view, both dots should be visible. If not highlight them using Command-A and delete to redo.



11. Using left arrow, move three slices into the left hemisphere (measure at $x = \pm 4\text{mm}$ so select closest slice). First identify the cingulate sulcus (CS) as the first major sulcus lying dorsal to the corpus callosum. It is easiest to do this by moving more slices into the hemisphere and identifying the dominant sulcus.
12. Identify the PCS if present. This is defined as being dorsal, parallel to the CS and predominantly horizontal. Sometimes it is very clear, other times completely absent, but usually there in part and often broken.

13. On this image the CS is clear (marked in yellow). Areas of PCS are marked in red. The PCS can be difficult to identify – rules used:



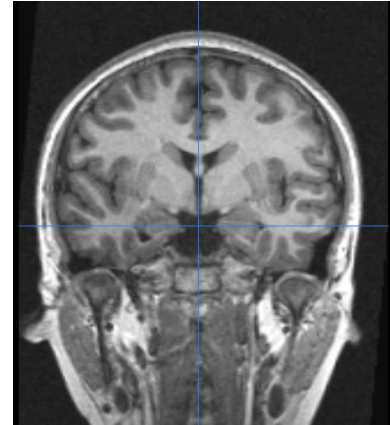
- Measure from the point in the first quadrant when the PCS moves in a posterior direction (it can help to imagine a vertical line from the horizontal crosshair, and the PCS should move away from this towards the back of the brain).
 - PCS must be predominantly parallel to the CS and essentially horizontal. Include non-horizontal segments when these are parallel to the CS. Measure additional segments such that the total distance between segments is no greater than 2cm (use Pythagoras theorem to check if necessary)
 - Measure PCS to its end if this runs outside of the first quadrant, but add no new segments that start outside of this quadrant.
14. Trace the PCS using the ‘trace line’ function in Mango (switch from Add points) – click and drag then enter to accept line. Highlight with Command A then right click with the cursor on the line to smooth it (or delete if necessary).
 15. Make sure all segments are highlighted with Command-A. Analysis/ROI statistics/All slices at the end gives the stats – copy and paste into Excel. Be careful to select the ‘Size’ option.
 16. Grab screenshots of the lines using the camera function in Mango and save as a record.

Fine-tuning issues for orienting the scan

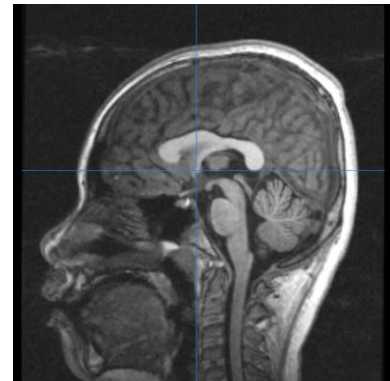
Lining up the scan and transformation

On an axial view, straighten the scan using Rotate-Z

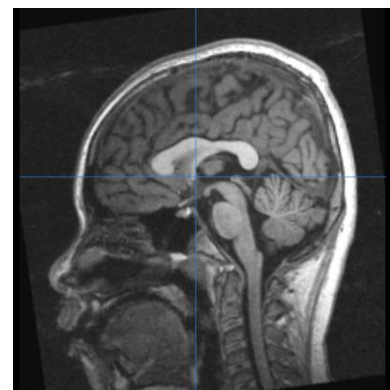
Switch to coronal and straighten with Rotate-Y. Have the cross-hair run from the central point to the V shape at the top of the brain.



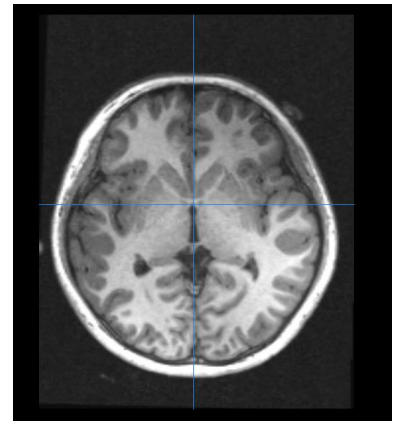
Switch to sagittal view and put the cursor on the AC.



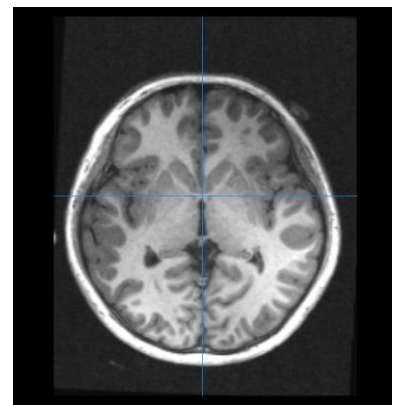
Rotate-X just enough that the PC is lined up with the AC. Do not over-rotate.



Switch to axial view where the AC and PC should be shown as aligned:



Ensure the cursor is placed in the middle of the AC and Z-Rotate as necessary to ensure the vertical cross-hair lies between the two hemispheres.



Switch to coronal view and check the alignment, using Y-Rotate as necessary. The scan should then be correctly aligned and the origin can be set to the position of the cursor using edit/origin.