Brain Extraction/Segmentation

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Brain Extraction 3 Different Attempts

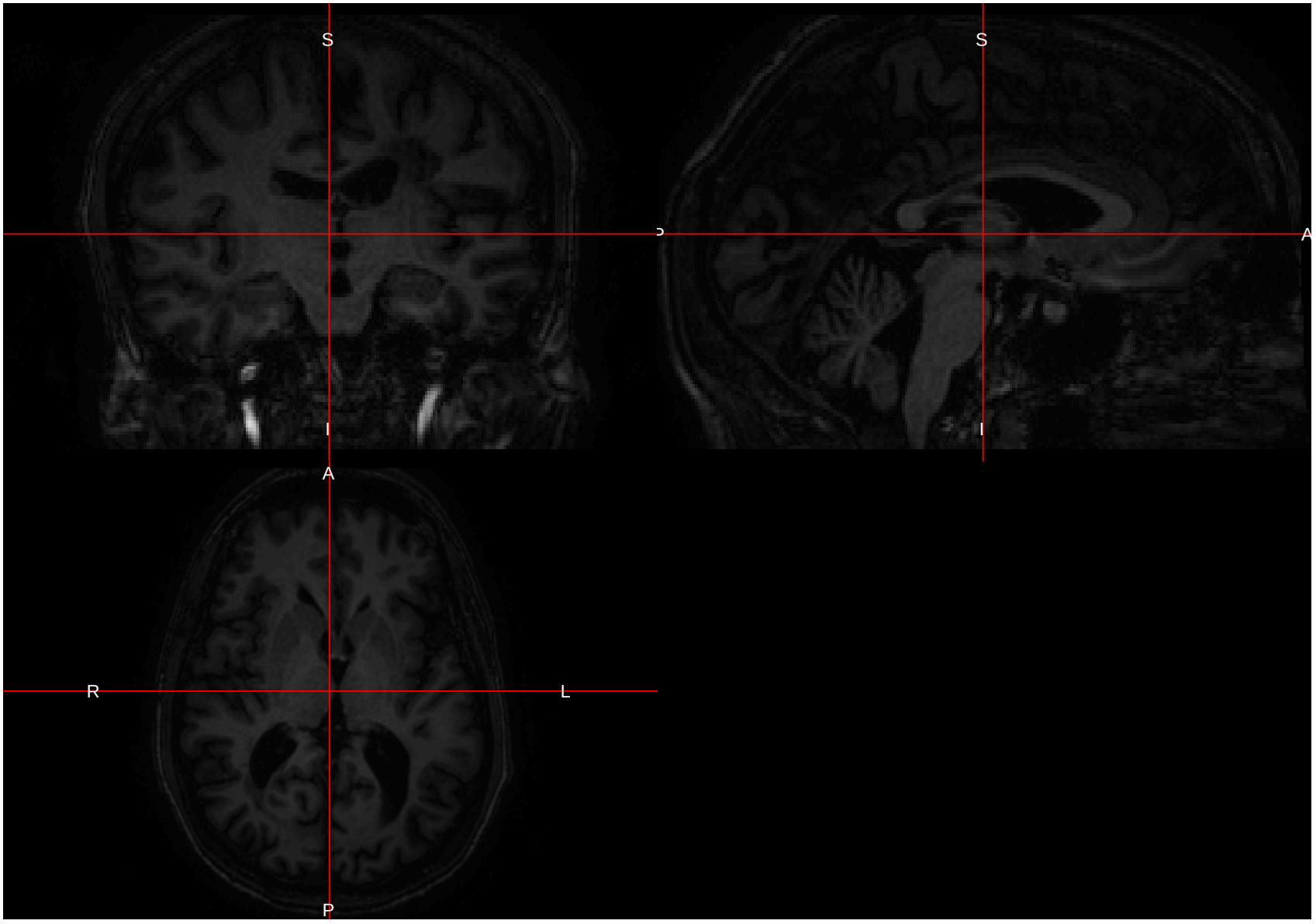
In this tutorial we will discuss performing brain segmentation using the brain extraction tool (BET) (Smith 2002) in `FSL` (Jenkinson et al. 2012), a robust version using a wrapper function in `extrantsr`, `fslbet_robust`, and a multi-atlas approach.

Loading Data from `ms.lesion`

```
library(ms.lesion)
library(neurobase)
files = get_image_filenames_list_by_subject()$training01
t1_fname = files["MPRAGE"]
t1 = readnii(t1_fname)
red0.5 = scales::alpha("red", 0.5)
```

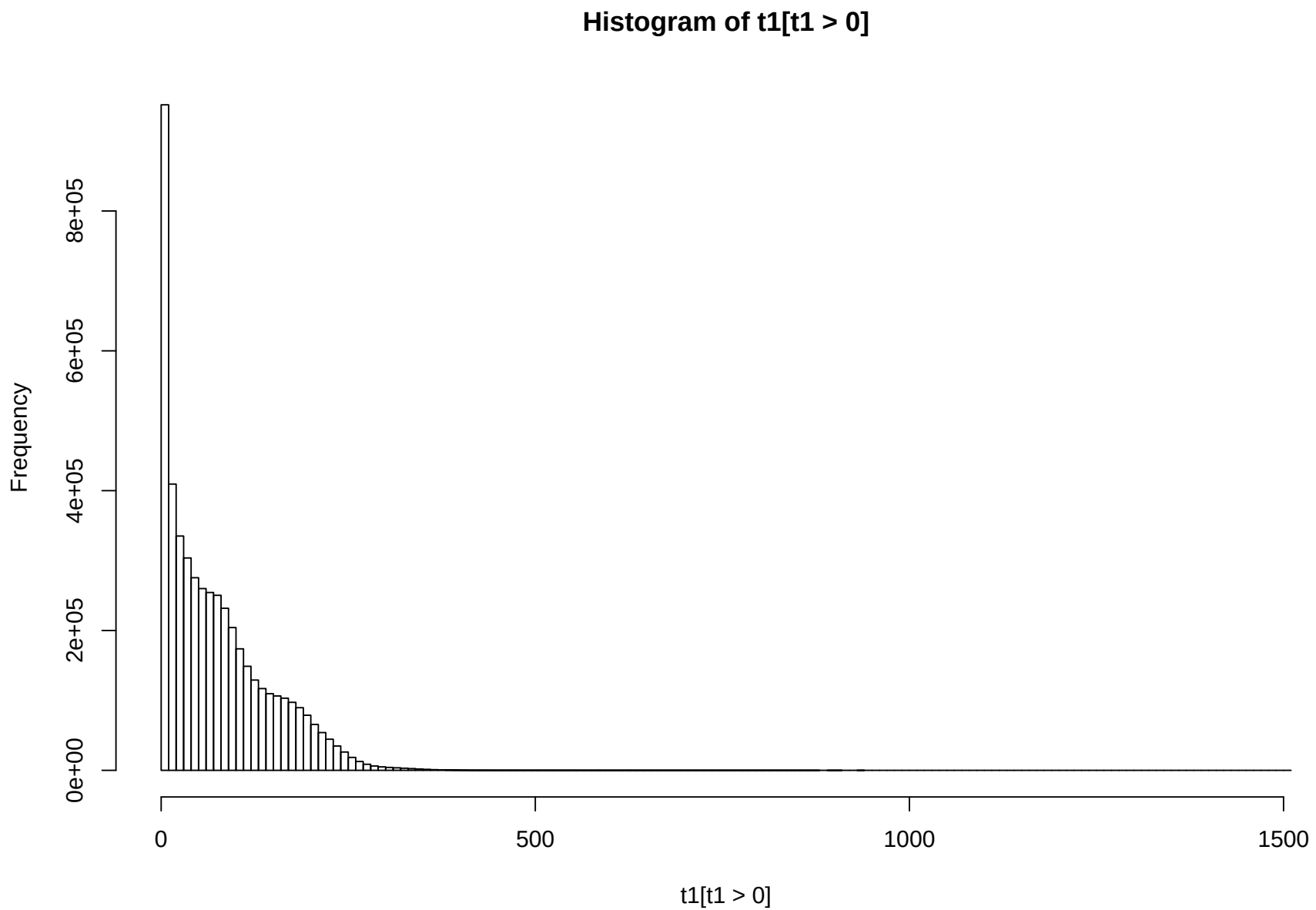
T1 image: high intensity values

```
ortho2(t1)
```



T1 image has long tails

```
hist(t1[ t1 > 0], breaks = 200)
```

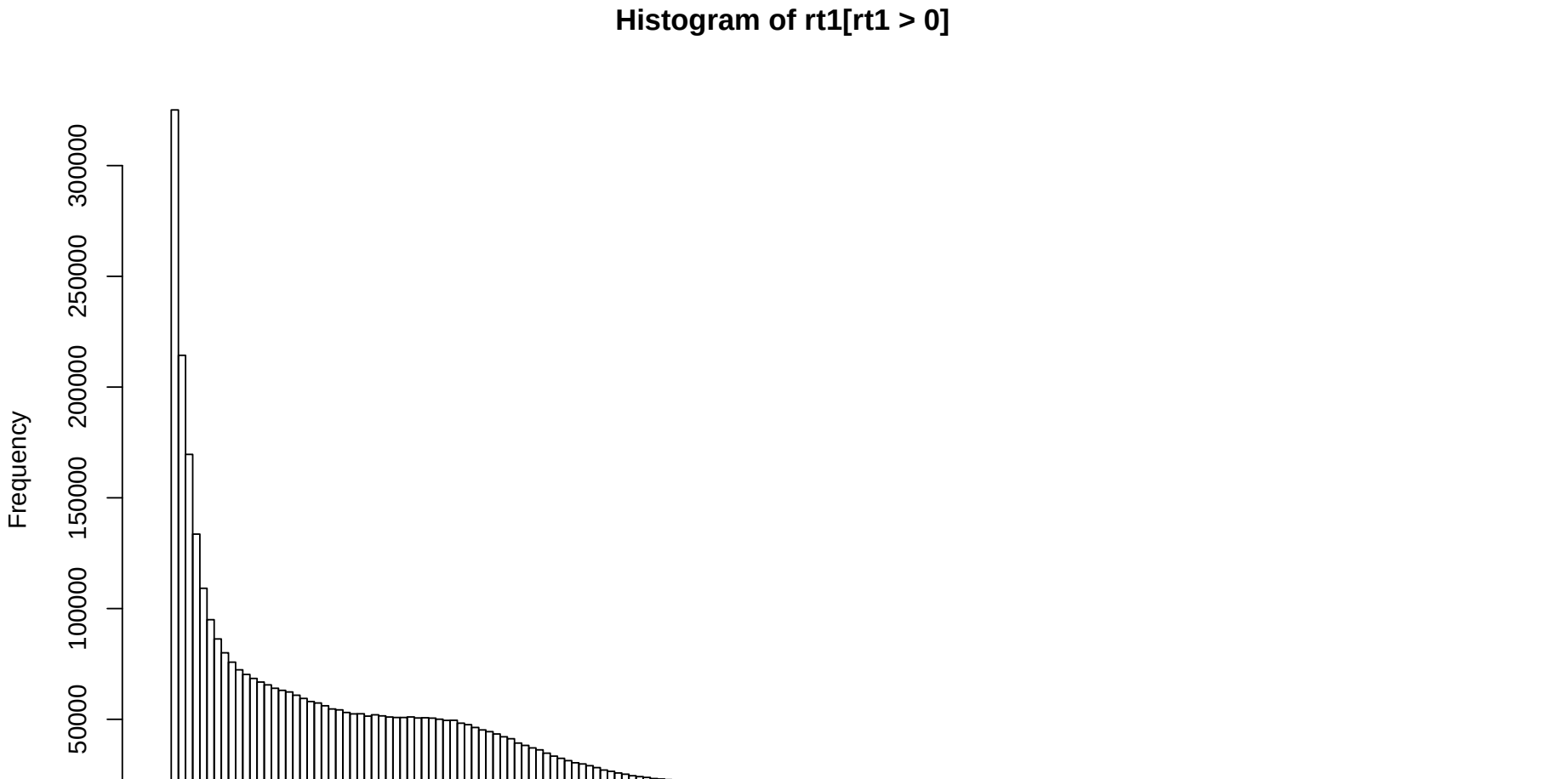


Limiting extreme values

`robust_window` essentially performs Winsorizing to limit extreme values

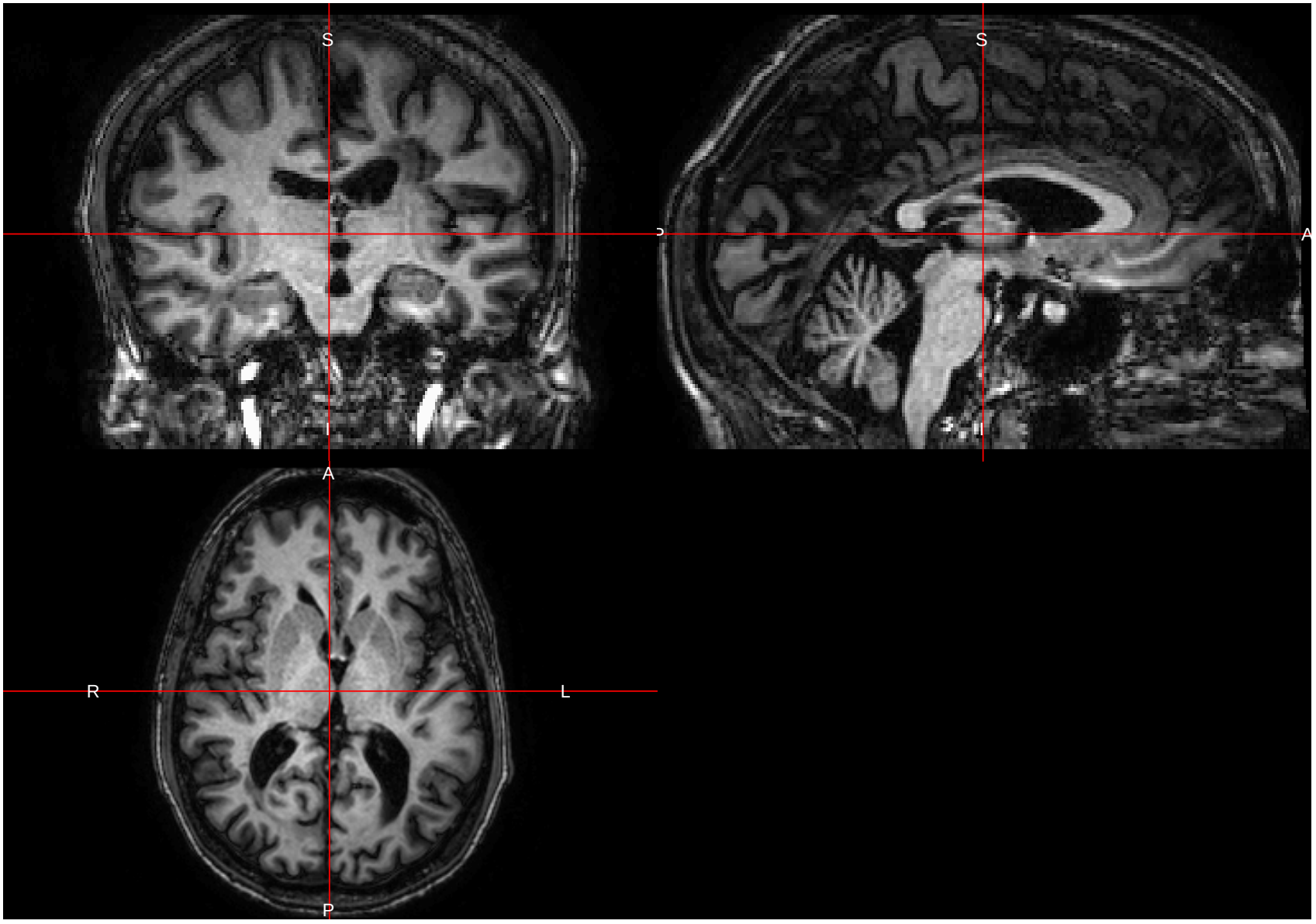
- sets them to 99.9^{th} quantile

```
rt1 = robust_window(t1); hist(rt1[ rt1 > 0], breaks = 200)
```



Re-plotting the image

```
ortho2(rt1)
```



Attempt 1: Brain Extraction of T1 image using BET

Here we will use FSL's Brain Extraction Tool (BET) to extract the brain tissue from the rest of the image (general overview):

- 2nd and 98th percentiles are calculated. (98th - 2nd) * 10% + 2nd value used to threshold out background
- From non-thresholded voxels - calculate center of gravity (COG)
- Calculate radius of brain and median intensity of all points within "spherical brain"
- Perform region growing and iterating to get brain surface
- Smooth surface
- Use median intensity to shrink surface to the "real" surface

Attempt 1: Brain Extraction of T1 image using BET

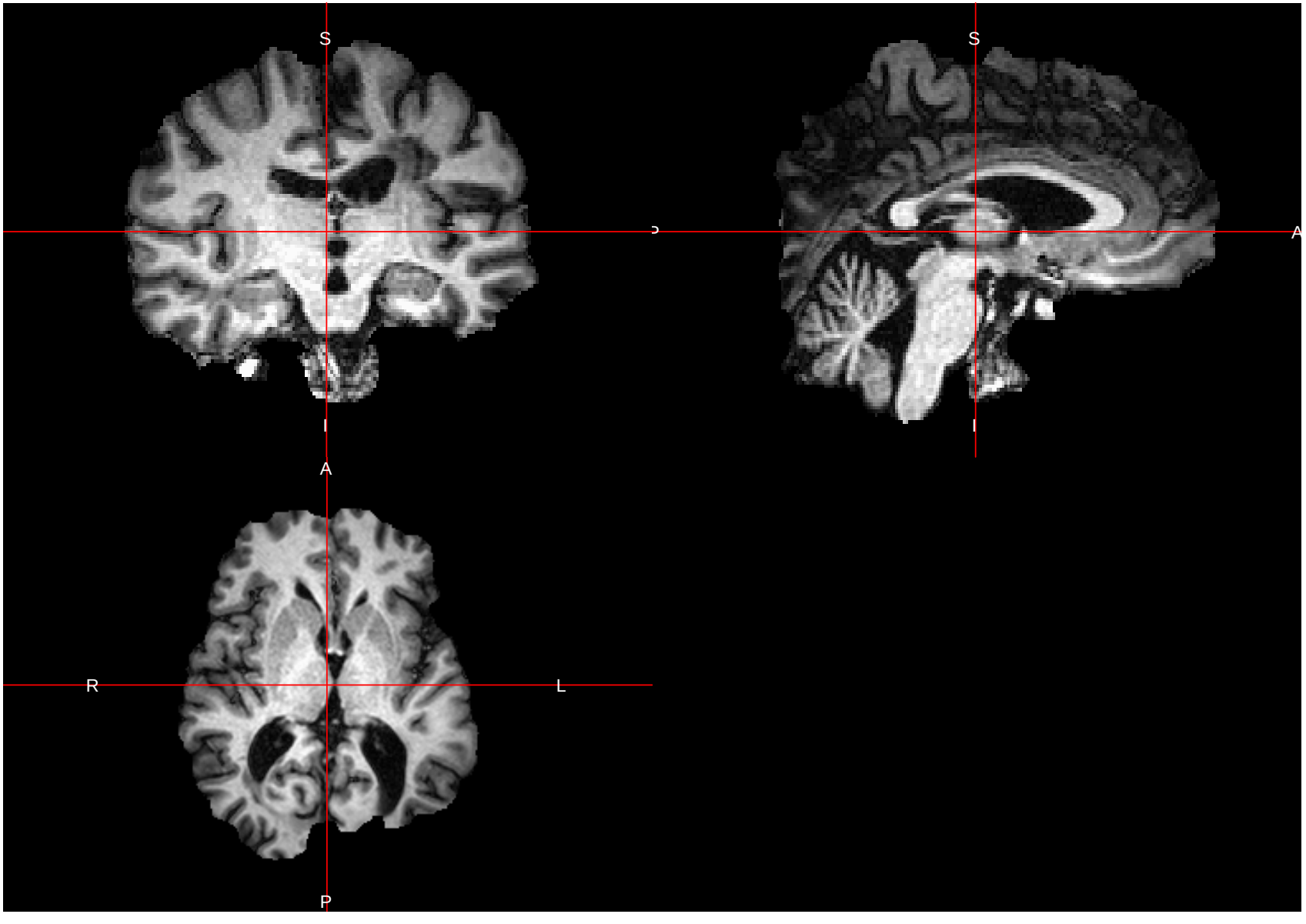
`fslr::fslbet` - takes in a filename/nifti

- additional options can be passed to FSL command in using `opts`

```
library(fslr)
ss = fslbet(infile = t1_fname)
```

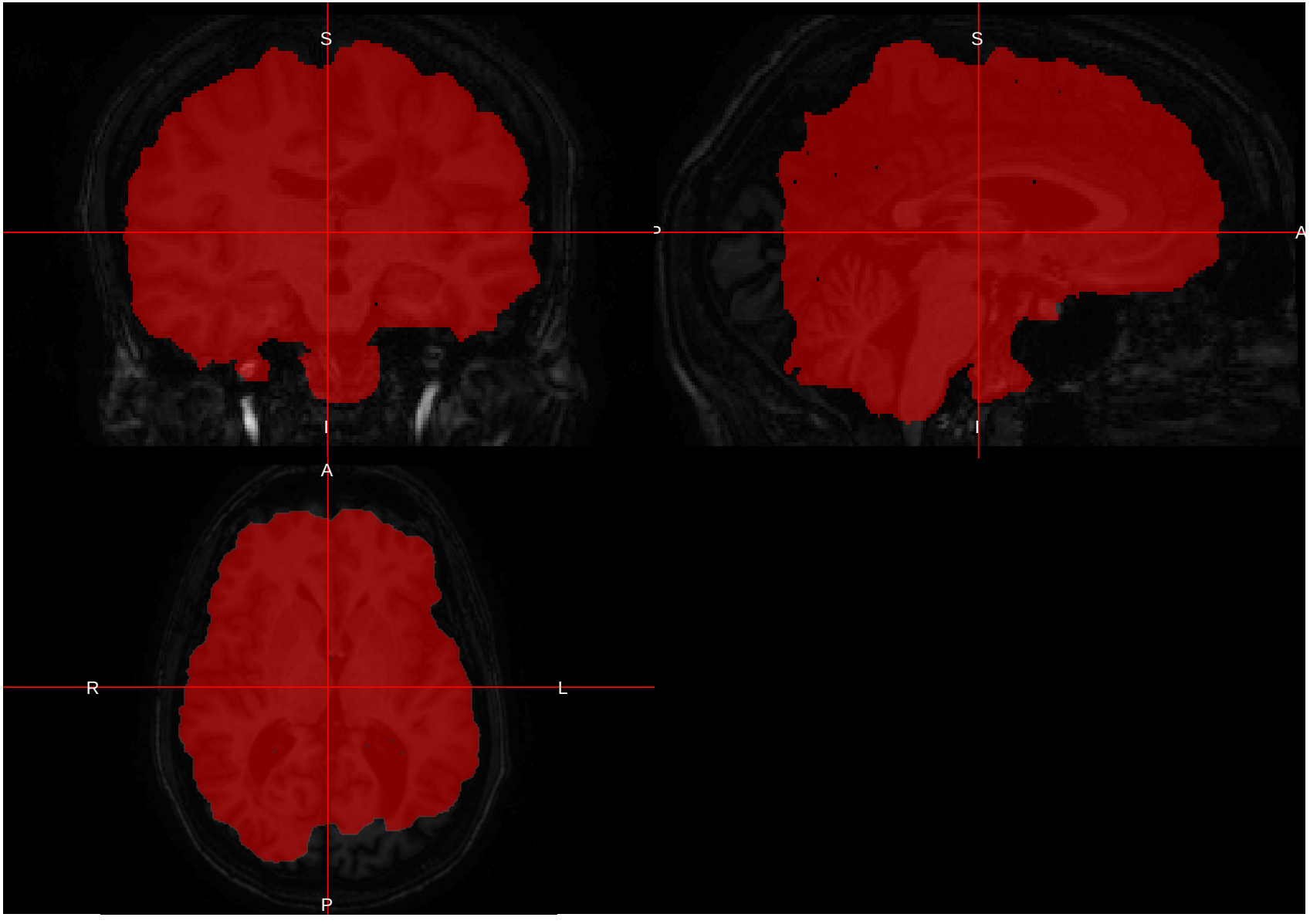
FSL BET Results - Missing Brain Tissues (Posterior)

```
ortho2(robust_window(ss))
```



FSL BET Results not Satisfactory

```
ortho2(t1, ss > 0, col.y = red0.5)
```



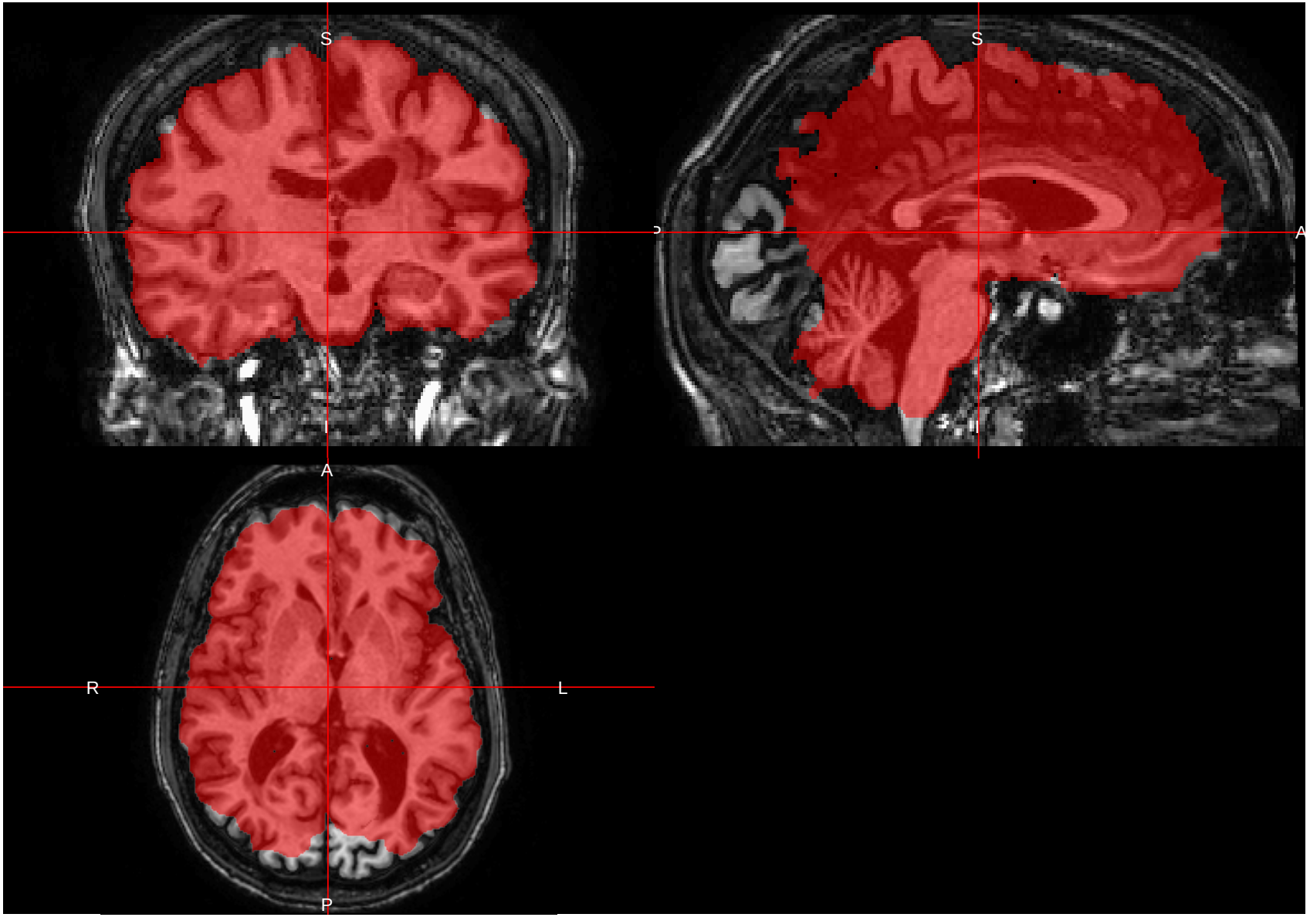
Bias Correct before BET (recommended)

Before doing skull-stripping/brain extraction, we would do bias correction:

```
library(extrantsr)
bc_img = bias_correct(file = t1, correction = "N4")
```

BET on N4 Corrected Image Unsatisfactory

```
bc_bet = fslbet(bc_img); ortho2(bc_img, bc_bet > 0, col.y =
```



Attempt 3: Brain Extraction of T1 image using MALF

Multi-Atlas Fusion:

- Register templates to an image using the T1 for that subject
- Apply transformation to the label/mask
- Average each voxel over all templates
- there are "smarter" (e.g. weighted) ways
- `malf.templates` package has templates provided by by Neuromorphometrics, Inc. (`http://Neuromorphometrics.com/`) form MICCAI 2012 Challenge on Multi-atlas Labelling (Bennett Allan Landman et al. 2012)

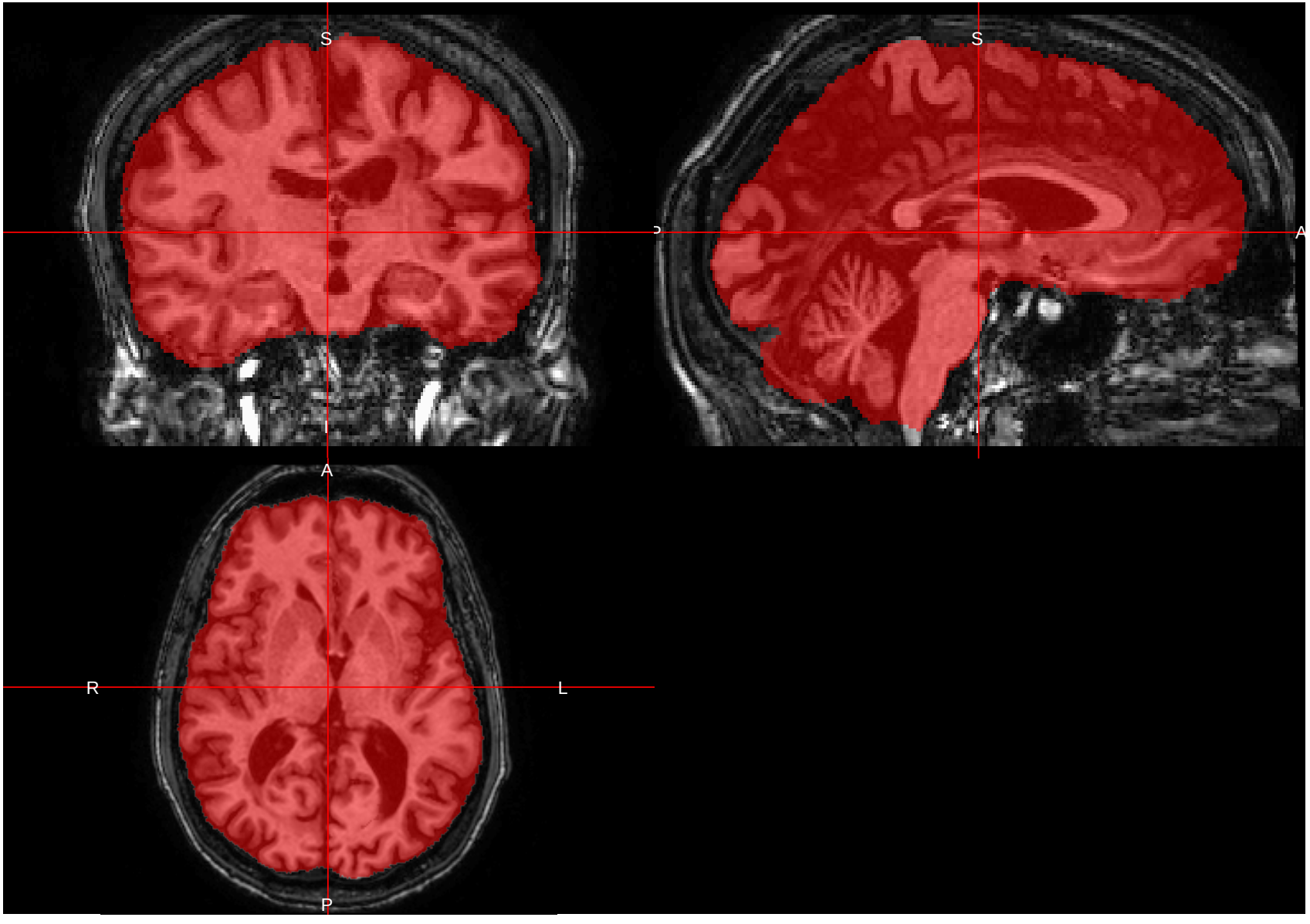
MALF - use extrantsr::malf

- Requires `template.images` (T1-weighted images in this case) and `template.structs` (labels/structures/masks, brain masks here)
- Performs non-linear registration (discussed later) using `SyN` (B. B. Avants et al. 2008)

```
library(malf.templates)
library(extrantsr)
timgs = mass_images(n_templates = 5)
ss = extrantsr::malf(
  infile = bc_img,
  template.images = timgs$images,
  template.structs = timgs$masks,
  keep_images = FALSE
)
```

MALF performs well

```
ortho2(bc_img, ss > 0, col.y = red0.5)
```



Processed Results Available in `ms.lesion`

In the `ms.lesion` package, we have the brain masks for each subject located in the `coregistered` folder. You can access this data using the `type = "coregistered"`

```
files = get_image_filenames_list_by_subject(type = "coregis
files["Brain_Mask"]
```

```
[1] "library/ms.lesion/extdata/coregistered/training01/brai
```

Kirby21 - Remove Neck

To illustrate another common problem with brain extraction, we will look at a subject from the kirby21 dataset (Bennett A Landman et al. 2011).

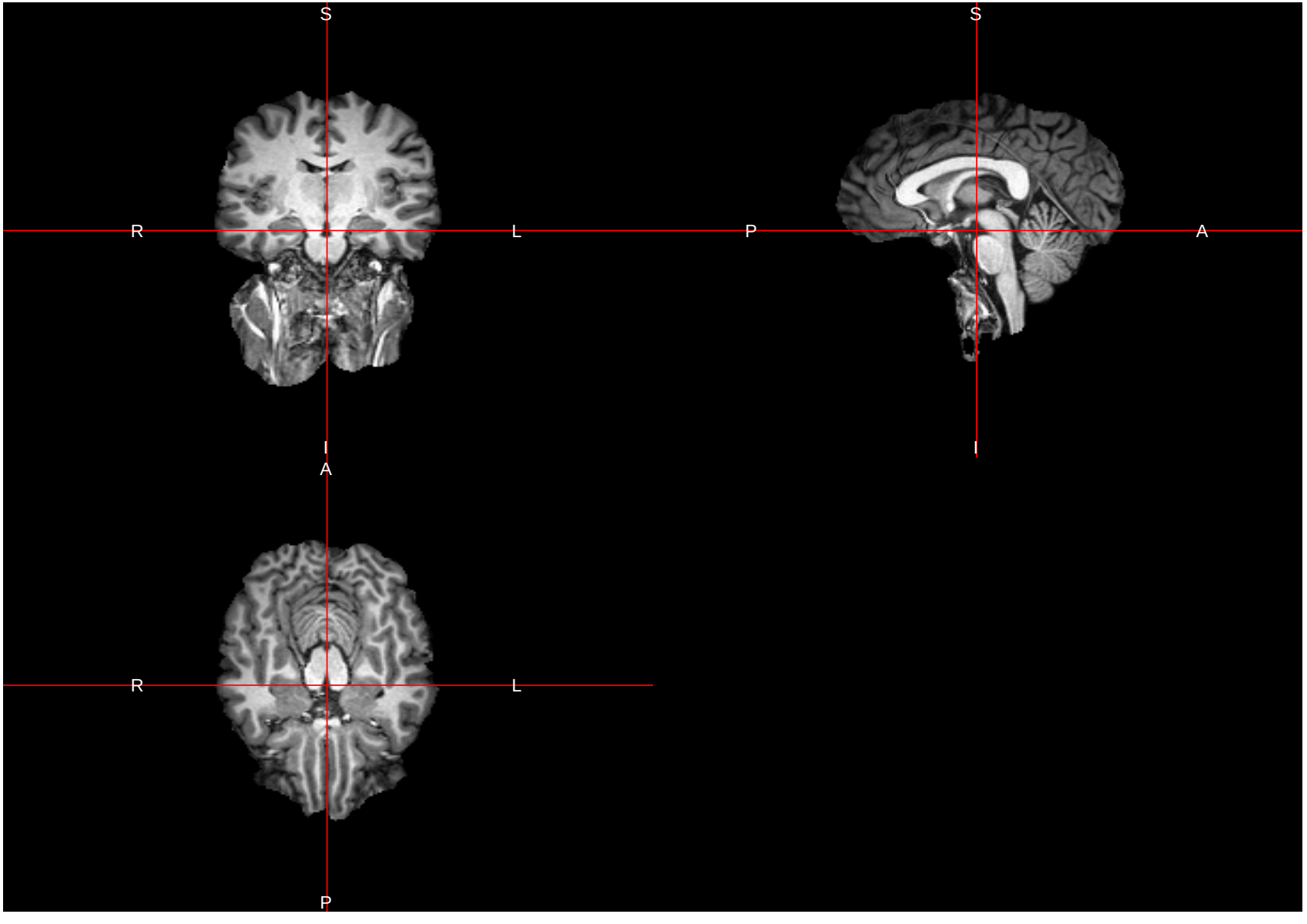
```
library(kirby21.t1)
t1_fname = get_t1_filenames()[1]
t1 = readnii(t1_fname)
```

T1 image has the neck!

```
ortho2(robust_window(t1))
```

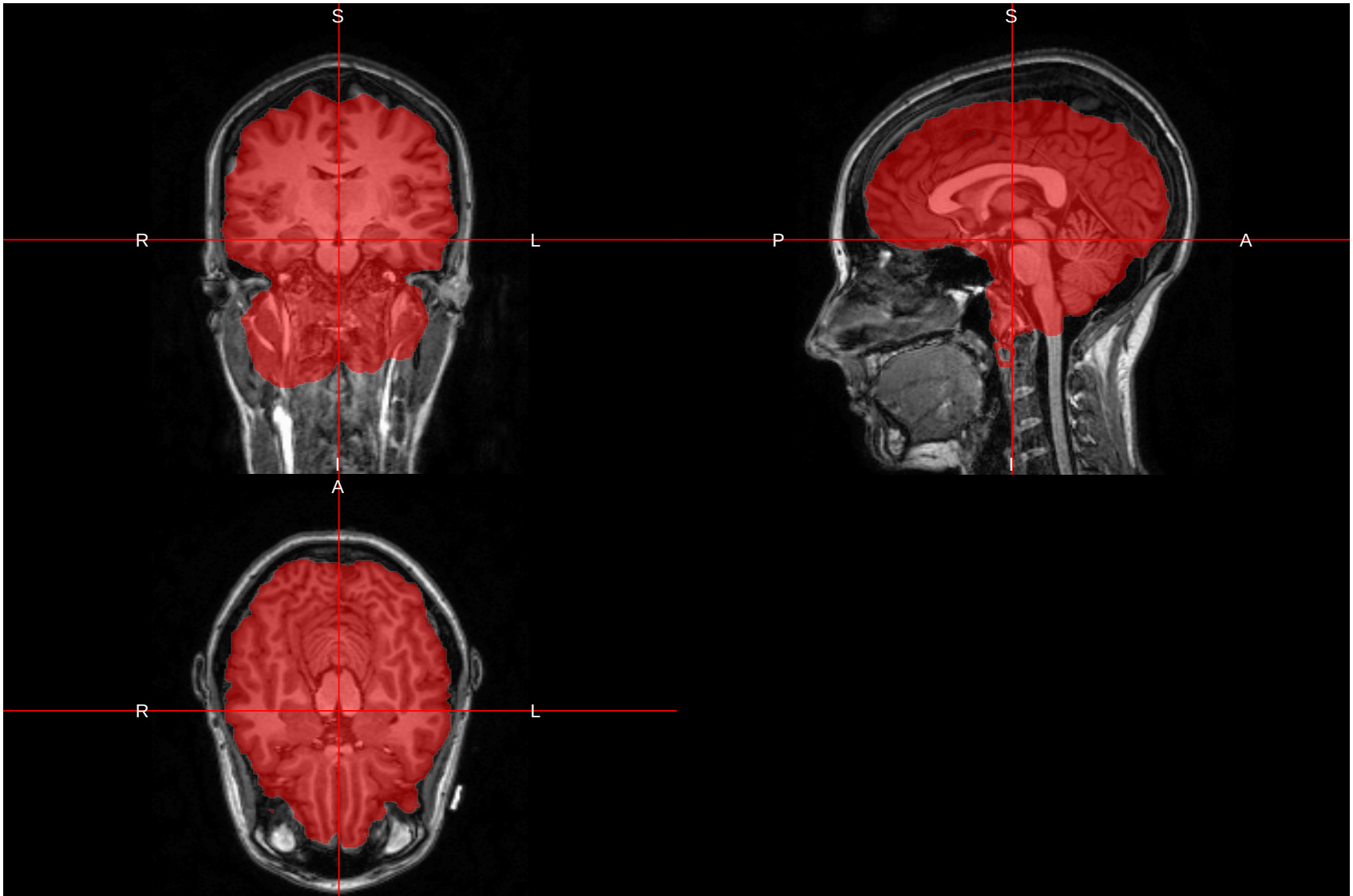
Neck messes up BET

```
ss = fslbet(infile = t1_fname); ortho2(robust_window(ss))
```



Recommend to Bias Correct first: not fixed

```
bc_img = bias_correct(t1, correction = "N4"); bc_bet = fslb
ortho2(robust_window(t1), bc_bet > 0, col.y = red0.5)
```



BET with neck removal

We use the modification of BET in `extrantsr`, which is called through `fslbet_robust`. `fslbet_robust`:

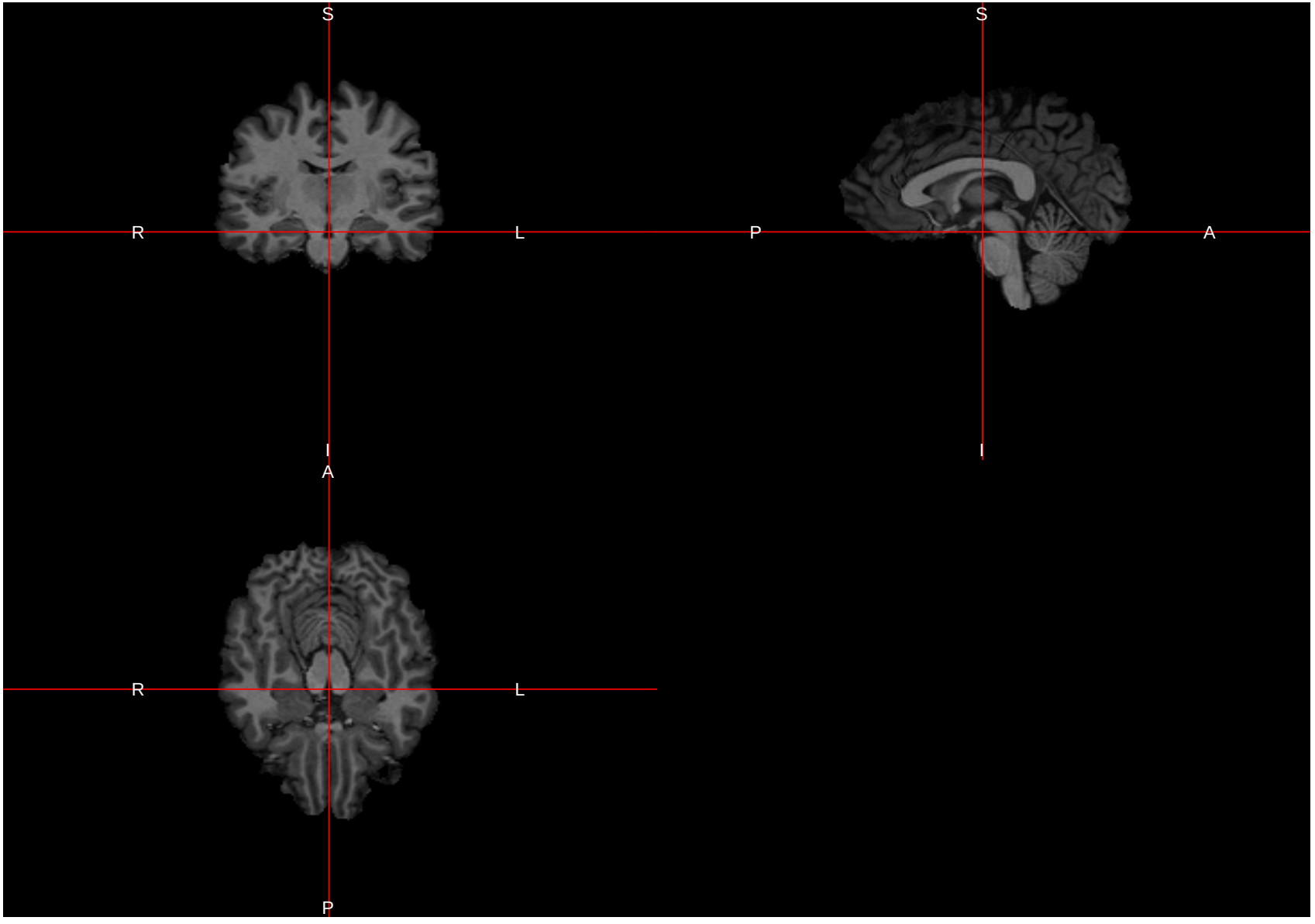
- bias correct image
- remove neck (`double_remove_neck` performs 2 registration steps, more robust than one (which is the default).)
- run BET
- estimate center of gravity (COG)
- run BET again with new COG

fslbet_robust syntax

```
ss = extrantsr::fslbet_robust(
  t1,
  remover = "double_remove_neck",
  correct = TRUE,
  correction = "N4",
  recog = TRUE)
```

BET with neck removal - works well!

```
ortho2(ss)
```



Conclusions

- Brain extraction allows you to analyze the brain only
- Important for tissue segmentation/registration
- BET can work well (look at your data!)
- Should bias correct first
- May need to remove neck
- High values may affect results - may need to remove/Winsorize them

References

Avants, B. B., C. L. Epstein, M. Grossman, and J. C. Gee. 2008. "Symmetric Diffeomorphic Image Registration with Cross-Correlation: Evaluating Automated Labeling of Elderly and Neurodegenerative Brain." *Medical Image Analysis*, Special issue on the third international workshop on biomedical image registration - WBIR 2006, 12 (1): 26–41. doi:10.1016/j.media.2007.06.004.

Jenkinson, Mark, Christian F. Beckmann, Timothy E. J. Behrens, Mark W. Woolrich, and Stephen M. Smith. 2012. "FSL." *NeuroImage* 62 (2): 782–90. doi:10.1016/j.neuroimage.2011.09.015.

Landman, Bennett A, Alan J Huang, Aliya Gifford, Deepti S Vikram, Issel Anne L Lim, Jonathan AD Farrell, John A Bogovic, et al. 2011. "Multi-Parametric Neuroimaging Reproducibility: A 3-T Resource Study." *Neuroimage* 54 (4). Elsevier: 2854–66. `https://www.nitrc.org/projects/multimodal/`.

Landman, Bennett Allan, Annemie Ribbens, Blake Lucas, Christos Davatzikos, Brian Avants, Christian Ledig, Da Ma, et al. 2012. *MICCAI 2012 Workshop on Multi-Atlas Labeling*. CreateSpace