Merging T1w and QSM provides a unique Tissue Contrast

Rakshit Dadarwal, Susann Boretius

Functional Imaging Laboratory, German Primate Center, Göttingen, Germany

Georg-August University Göttingen, Göttingen, Germany

rdadarwal@dpz.eu @RakshitDadarwal

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

DPZ

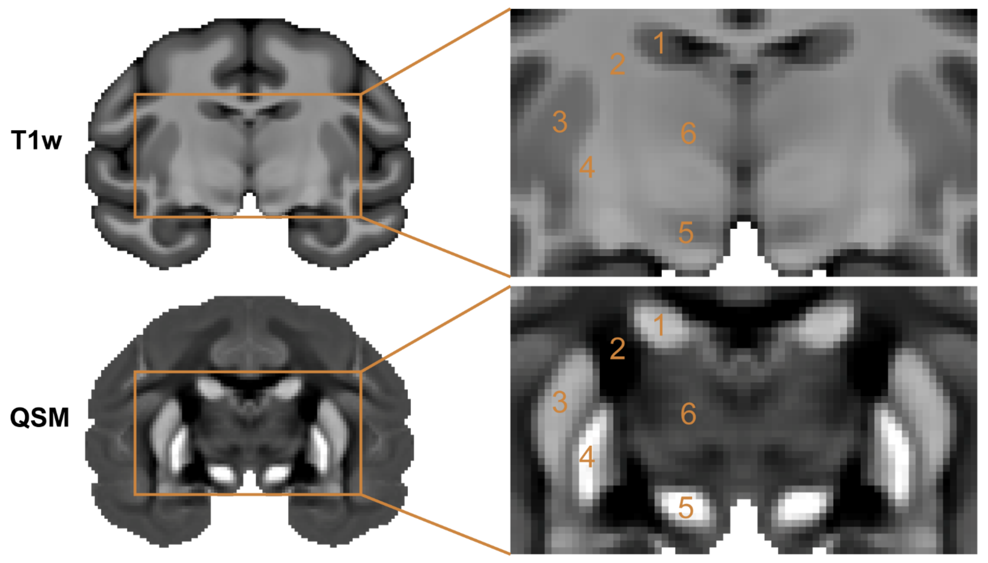
INTRODUCTION

- T1-weighted (T1w) images provide excellent contrast between white and gray matter in the brain but relatively low contrast in subcortical structures except for the caudate and putamen.
- The majority of the automatic brain tissue segmentation methods use T1w images and often misclassifies subcortical gray matter structures as part of white matter.
- Quantitative Susceptibility Mapping (QSM) provides a unique contrast in subcortical structures.
- ***In this work, we combined T1w and QSM contrasts to visualize cortical, subcortical, and white matter contrast that results in an improvement in brain tissue segmentation.***

METHODS

	Human (N = 3)		Monkey (N = 4)	
	T_1w	T_2^*w	T_1w	T_2^*w
sequence	3D MPRAGE	3D ME-GRE	3D MPRAGE	3D ME-GRE
resolution (mm)	0.8x0.8x0.8	0.75x0.75x0.75	0.5x0.5x0.5	0.31x0.31x0.31
repetition time (ms)	2400	41	2700	57
echo time (ms)	2.2	4.5/4.5/36	2.7	3.7/4.9/48
flip angle (deg)	8	20	8	20
acquisition time (min)	6.3	7	17	24
coil	20 channel head		7 cm single loop	

3 T Siemens MAGNETOM Prisma



T1w and QSM images of the monkey brain in the coronal plane. A magnified visualization of the selected subcortical structures such as 1 – caudate, 2 – internal capsule, 3 – putamen, 4 – globus pallidus, 5 – substantia nigra, and 6 – thalamus.

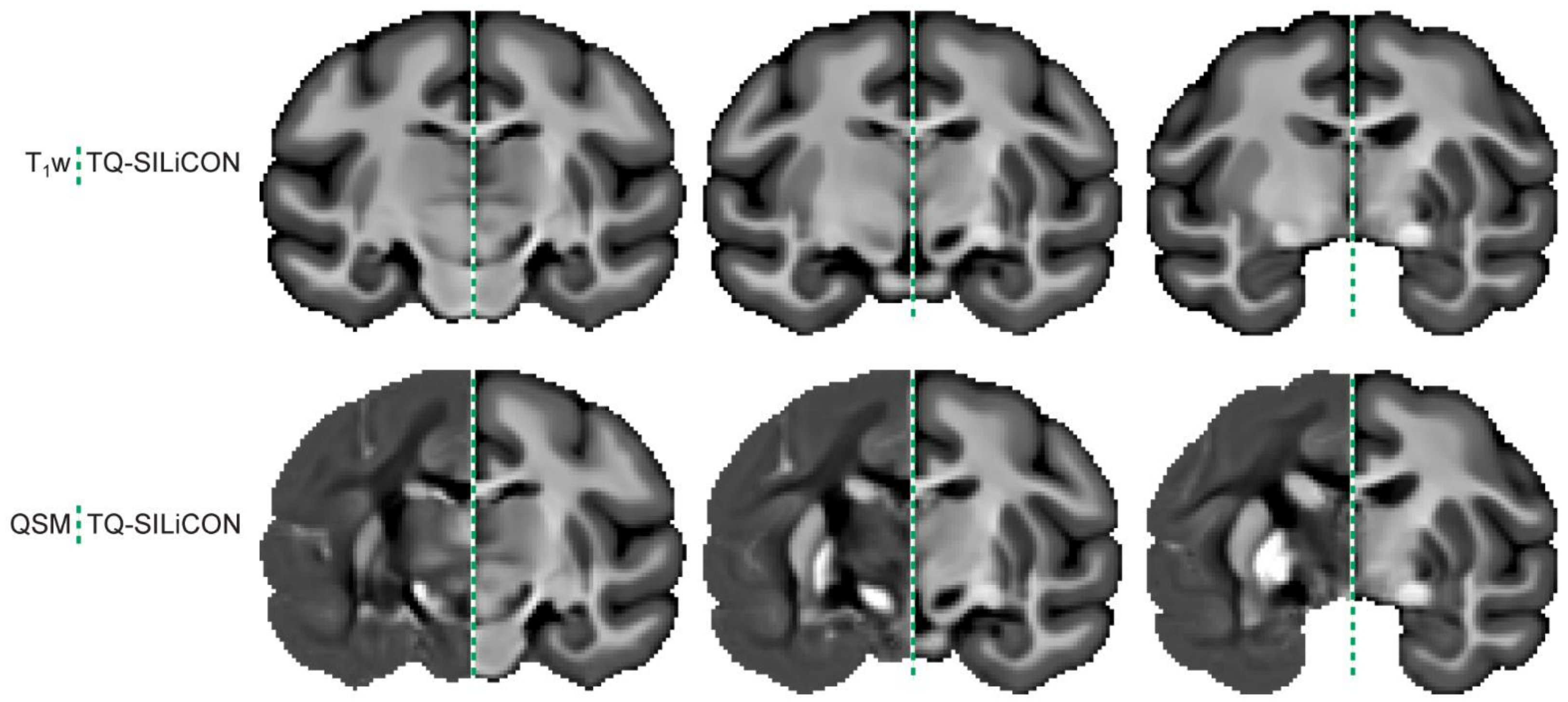
- Human and monkey brain T1w images were denoised and corrected for bias field using ANTs[1]. The skull stripping was performed manually for the T1w, and gradient echo (GRE) scans using the ITK-SNAP tool.
- The mean of GRE brain images over echo times was linearly registered to T1w brain images using the ANTs registration.
- **QSM** reconstruction was carried out using a multi-scale dipole inversion approach[2].
- T1w and QSM contrasts were fused by a weighted linear combination, which we termed TQ-SILiCON (**T**1-**Q**SM **S**ynthetic **I**mages via a **Li**nearly weighted combination of **CON**trasts).

$$Yi = \sum_{c=0}^{1} WicXc$$

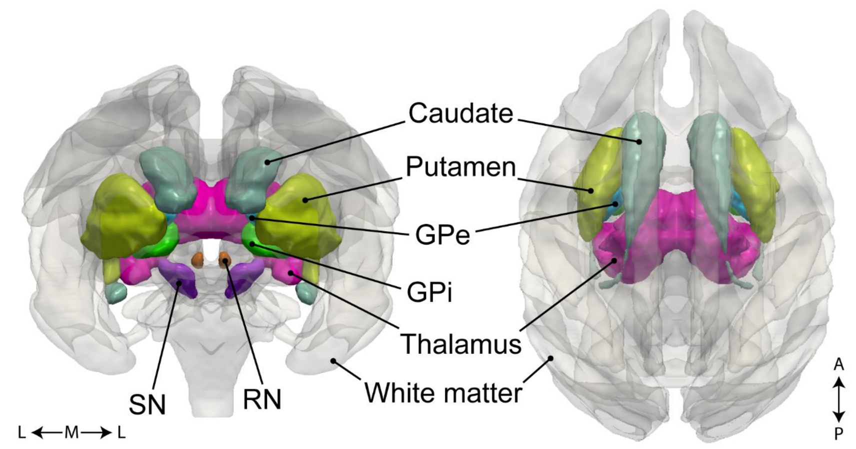
- The weights for T1w were generated at random between 0 and 1, while QSM weights were between -1 and 0.
- Four tissue classes (cerebrospinal fluid, gray matter, subcortical gray matter, and white matter) were segmented on an average macaque brain template.
- The generated synthetic images (Yi) were evaluated based on the contrast-to-noise ratio (CNR) between different tissue classes and the linear discriminant analysis accuracy score.
- Finally, we selected the TQ-SILiCON image having weights with sufficient CNR and a high LDA accuracy score.

RESULTS

Monkey

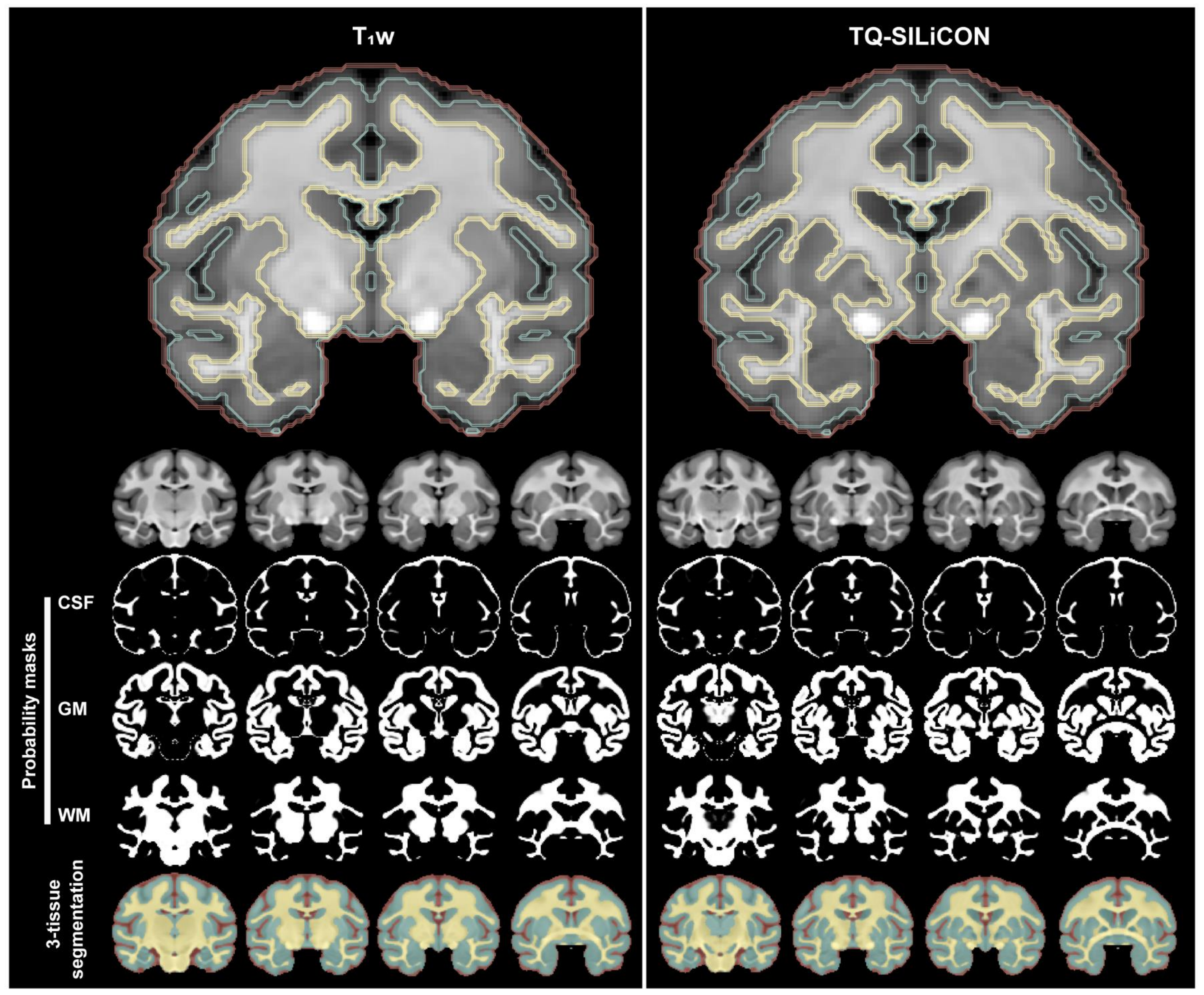


Comparison between the T1w, QSM and TQ-SILiCON images of the average monkey brain template.



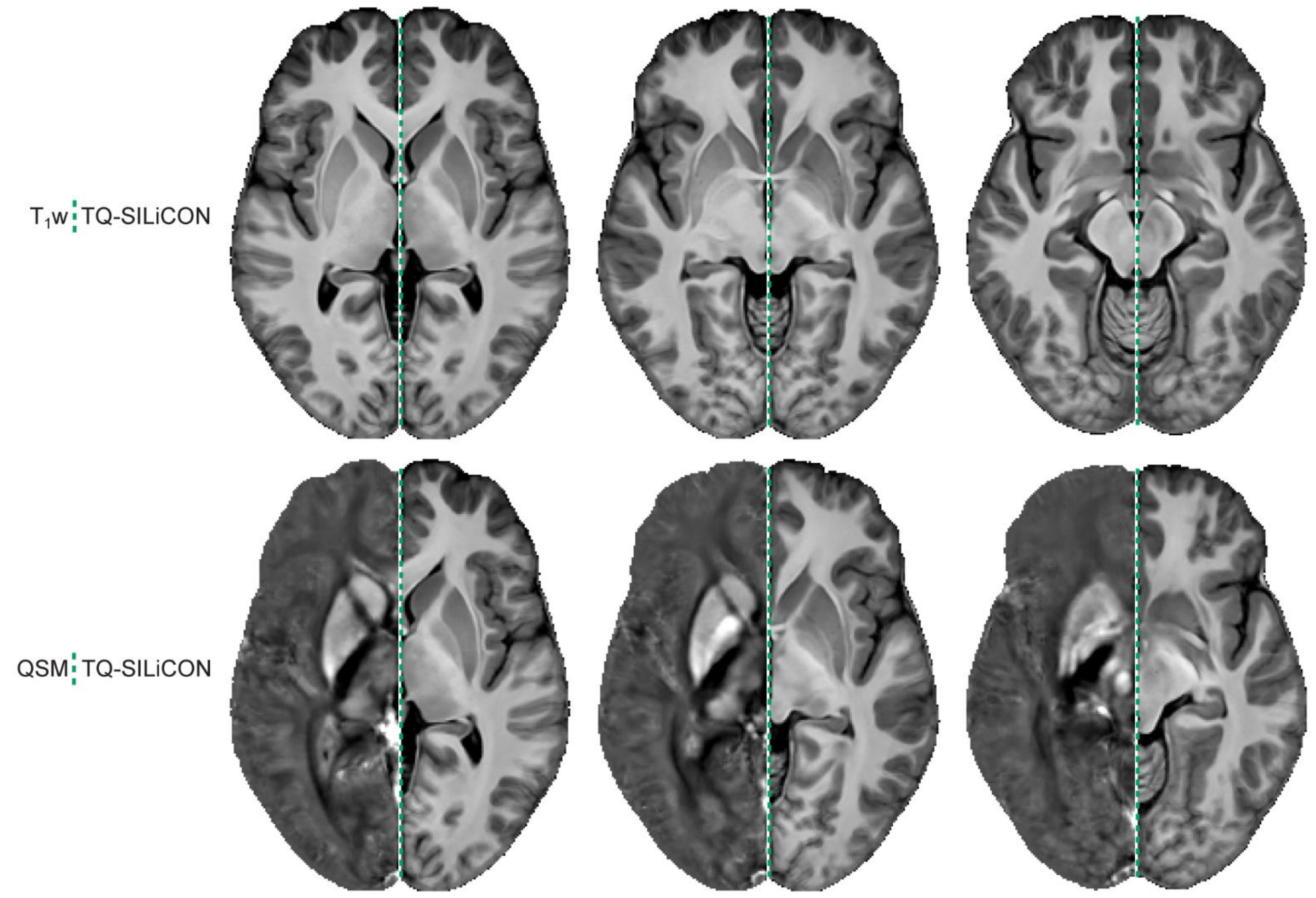
The T1w and QSM images of the monkey brain in the coronal plane. Subcortical nuclei include the caudate, putamen, globus pallidus external (GPe), globus pallidus internal (GPi), substantia nigra (SN), and red nucleus (RN).

- The final weight selected for the T1w was 0.83, while for QSM was -0.87.



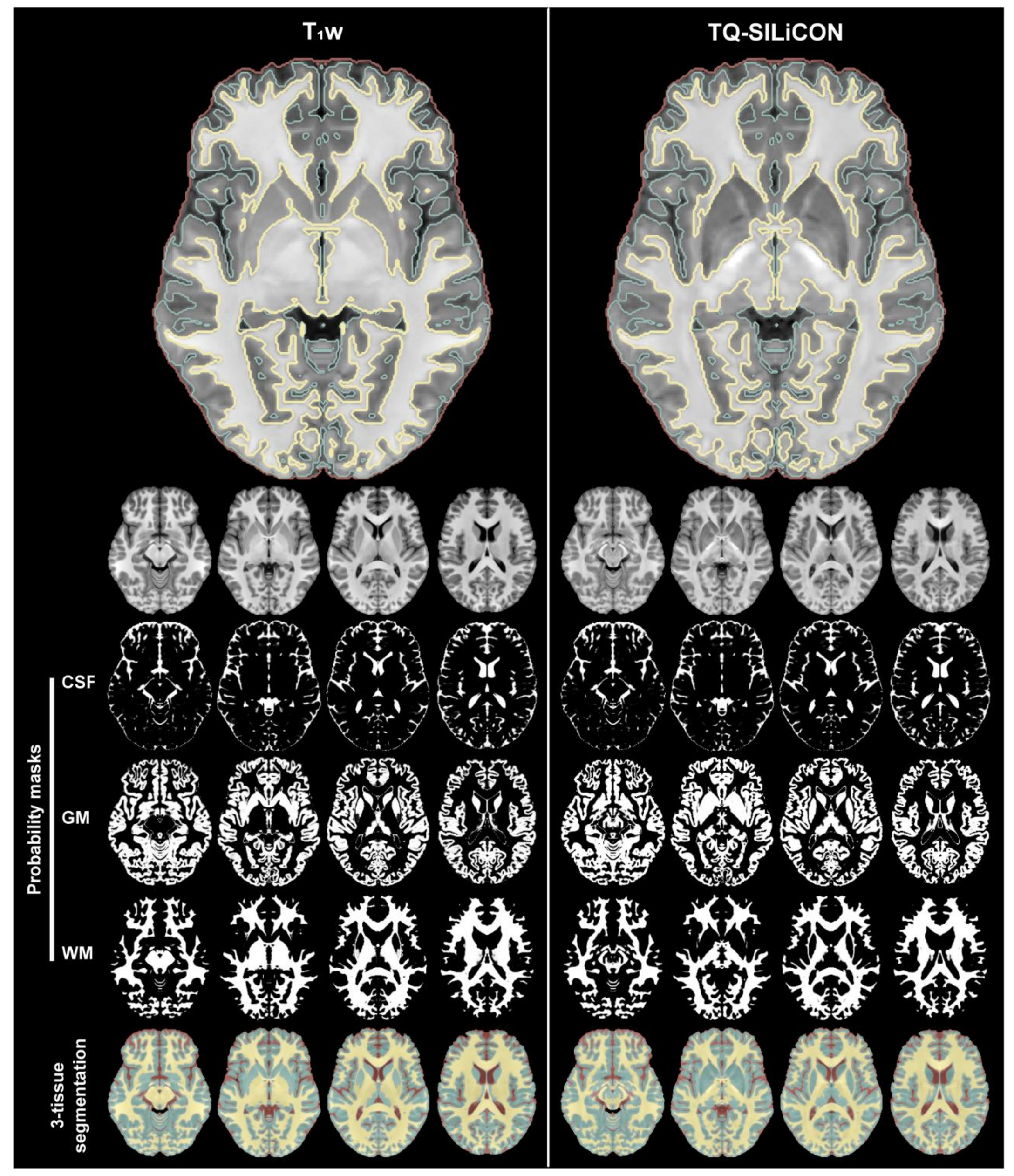
Comparison of monkey brain tissue segmentation using T1w and TQ-SILiCON images, respectively (coronal view). The three-class tissue segmentation derived cerebrospinal fluid (CSF), gray matter (GM), and white matter (WM) probability masks and segmentation images.

Human



The TQ-SILiCON image of an average human brain template is compared to the average T1w and QSM templates.

- The macaque and human TQ-SILiCON images contained excellent gray-white and subcortical contrast.
- In comparison to the T1w image, the TQ-SILiCON revealed enhanced visibility and better delineation of subcortical structures such as the caudate, putamen, globus pallidus external, globus pallidus internal, thalamus, internal capsule, substantia nigra, and red nucleus.
- Using the generated TQ-SILiCON volume, we performed automatic brain tissue segmentation, which resulted in 0.7 % of tissue been classified as gray matter rather than white matter in the monkey brain.
- Human brain TQ-SILiCON image-based automatic brain tissue segmentation classified 0.94 % of tissue as gray matter rather than white matter.



CONCLUSION

- The TQ-SILiCON approach offered a unique brain tissue contrast that worked equally well for both monkeys and humans.
- TQ-SILiCON image-based single-subject gray and white matter automatic brain tissue segmentation outperformed standard T1w image-based segmentation.
- We believe our approach in NHPs has the potential for establishing translational studies aiming at identifying the neuropathophysiological substrates affecting the basal ganglia of humans.

Acknowledgements

We would like to thank Kristin Kötz for her technical assistance.

References

1. Avants, B.B., et al., 2011, Neuroimage. AcostaAcosta-Cabronero, J., et al., 2018, Neuroimage.