NeuroGage®

NeuroGage® 4.0 Radar Report

Patient: OOO

Location of MRI: OOO

Date of MRI: OOO

Date of report: OOO

Age at MRI: OOO years

Referring Physician: OOO

Quality control

- *Summary*: The grayscale and segmented DICOM images were high quality and provided a valid basis for the NeuroQuant® results.
- *Details*:
  - MRI scanner:
  - Brand: Siemens, 3T
  - Model: OOO
  - Scanner software version: OOO
- Inspection of the MRI grayscale images showed:
  - The images were high quality and showed good differentiation between gray and white matter.
  - The ears, nose and vertex all were present.
- Visual inspection of the segmented DICOM images showed no segmentation errors.
- Manual comparison of the scanning parameters used versus those recommended by CorTechs Labs showed good compatibility.
- NeuroQuant 4.0 automated Compatibility Assessment (attached) showed good quality but noted the following problems:
  - EchoTime was 4.2 and expected value was 2.9 (not within 10% tolerance). This was a known technical issue that typically did not reduce the quality of the segmented images (Micki Maes, CorTechs Labs Clinical Operations Manager, email communication on 08/05/20).
  - SpecificCharacterSet was noted as “missing, ASCII will be assumed”. But, in fact, it was included in the metadata under a different tag/label and therefore was not missing. More generally, the NeuroQuant® 3.0 software occasionally will not match DICOM parameter tags/labels with scanner tags/labels which could result in a blank parameter; this will not affect the scan quality as it is indicating the amount of noise and quality of contrast. Therefore, the results of the scan may still be reliable (Micki Maes, CorTechs Labs Clinical Operations Manager, email communication on 01/05/21).

- More generally, per email communication on 05/12/23 with Micki Maes, CorTechs Labs Clinical Operations Manager:
  - The Compatibility Assessment report is a useful tool that can help point out problems with scanner parameters but is not always diagnostic of whether the results are accurate.
  - Visual inspection of the segmented DICOM images generally is a better way to determine whether the results are accurate.
  - Reviewing the Compatibility Assessment report and visually inspecting DICOMs is a better approach than either one alone.
- Regarding NQ 4.0 Brain Atrophy report, per email communication on 12/19/23 with Micki Maes, CorTechs Labs Clinical Operations Manager
  - For parenchymal values > 95%tile, they are still valid findings from the perspective of clinical interpretation or research, and the only difference from previous versions of NQ is that they are no longer associated with a blue flag (email communication with Micki Maes, Clinical Operations Manager, CorTechs AI, 12/19/23).

Comparison of NeuroQuant Volumetric Results (left table) with NeuroGage Literature-based Volume Patterns (right table)

NeuroQuant Volumes	Left	Right	Total	Asym	NeuroGage Literature Review										
Region	Normative Percentiles				TBI mild mod	TBI mod sev	ALZ	MCI	SCI	Mold	PTSD	MDD	GAD	SCZ	CB
Whole brain parenchyma	1	75	16	1	✓	✓	✓							✓	
Forebrain parenchyma	1	84	26	1						X					
Cerebral white matter	1	11	2	1	✓	✓								✓	
Cortical gray matter	45	99	91	1	✓	X				✓				X	
Ventricles	99	93	99	99	✓	✓								✓	
• Superior lateral ventricle	99	93	99	99	✓	✓								✓	
• Inferior lateral ventricle	99	99	99	99											
Subcortical structures															
• Cerebellum	22	30	26	16											
• Cerebellar white matter	62	91	81	1	✓										
• Cerebellar gray matter	15	13	14	60											
• Brainstem	-	-	9	-											
• Thalamus	44	64	55	13											
• Ventral diencephalon	48	14	28	97	✓										
Basal ganglia	1	60	18	1	✓	✓									
• Putamen	2	72	27	1		✓	✓								
• Caudate	32	54	44	11											
• Nucleus accumbens	1	35	3	1	X										X
• Pallidum	3	22	9	1		✓		✓	✓	X					
Cingulate	87	75	85	65											
• Anterior cingulate	96	76	93	78	✓	X	X				X	X	X		
▪ Rostral anterior cingulate	68	78	81	38										X	
▪ Caudal anterior cingulate	99	60	96	92	✓								X		
• Posterior cingulate	83	23	55	95											
• Isthmus cingulate	19	92	62	1											
Cortical structures															
Frontal lobe	95	99	97	1		X	X							✓	
• Superior frontal	2	86	73	7	X	✓						✓	✓	X	
• Middle frontal	78	99	99	43	✓	X						X	X		
• Anterior middle frontal	87	99	99	60	✓						✓	X			
• Inferior frontal	85	99	98	1									X	X	
▪ Pars opercularis	69	99	85	1											

NeuroGage®

Comparison of NeuroQuant Volumetric Results (left table) with NeuroGage Literature-based Volume Patterns (right table) (continued)

NeuroQuant Region	Left	Right	Total	Asym	NeuroGage Literature Review										
Frontal lobe (continued)	Normative Percentiles				TBI mild mod	TBI mod sev	ALZ	MCI	SCI	Mold	PTSD	MDD	GAD	SCZ	CB
▪ Pars triangularis	68	**99**	**99**	**1**	X	X									
▪ Pars orbitalis	52	88	77	11											
• Frontal pole	**95**	**96**	**98**	51											
• Lateral orbitofrontal	**2**	57	20	**1**	✓	✓						✓	✓		
• Medial orbitofrontal	78	82	84	53											
• Paracentral	87	74	86	67											
• Primary motor	85	85	87	46											
• Premotor	69	85	81	26											
Parietal lobe	**95**	**99**	**99**	**1**	✓		X								
• Primary sensory	**99**	90	**97**	74	✓	X									
• Medial parietal	**99**	**99**	**99**	90	✓		X						✓		
• Superior parietal	**99**	**99**	**99**	**5**	✓										
• Inferior parietal	31	91	72	**4**	✓										
• Supramarginal	**2**	**99**	60	**1**	✓										
Occipital lobe	80	69	76	72											
• Medial occipital	76	93	87	13											
▪ Cuneus	76	**99**	**98**	**1**			X								
▪ Lingual gyrus	57	69	64	38											
▪ Pericalcarine	89	89	85	82											
• Lateral occipital	77	23	49	**98**	✓										
Temporal lobe	**1**	91	9	**1**		✓	✓							✓	
• Superior temporal	14	**97**	60	**1**		X								X	
• Transverse temporal	20	58	30	20											
• Posterior superior temporal sulcus	60	**96**	87	18	✓										
• Middle temporal	65	65	14	**1**	✓	✓									
• Inferior temporal	**1**	65	**2**	**1**	✓	✓								✓	
• Fusiform	**1**	53	**2**	**1**	X									✓	
• Parahippocampal	**3**	54	14	**1**		✓	✓	✓						✓	✓
• Entorhinal cortex	**1**	81	22	**1**			✓	✓	✓						
• Temporal pole	39	**99**	93	**1**	✓			X							✓
• Amygdala	**1**	22	**3**	**1**	✓	✓	✓	✓	✓	X	✓	✓	X	✓	
• Hippocampus	11	74	40	**1**	✓										

Key for NeuroQuant Volumetric Results table:

--- (strikethrough) indicates that the data were unreliable.

Bold font indicates a normative percentile that was statistically significantly abnormal, defined as ≤5th or ≥95th normative percentile.

Pink background indicates an abnormally small parenchymal volume, or similarly, abnormally large ventricular volume.

Green background indicates an abnormally large parenchymal volume, or similarly, abnormally small ventricular volume.

Asymmetries ≤5th %ile are associated with L<R volumes, and asymmetries ≥95th %ile are associated with R<L volumes.

NeuroGage LLC

(804) 594-7046 (voice)
(866) 586-8977 (fax)
www.VaNeuropsychiatry.org

Patient information

LastName, FirstName
DOB: mm/dd/yy

Yellow background indicates abnormal asymmetry with L<R for parenchymal regions, or similarly, L>R for ventricular regions.

Purple background indicates abnormal asymmetry with R<L for parenchymal regions, or similarly, R>L for ventricular regions.

Key for NeuroGage Differential Diagnoses table:

✓ A green checkmark indicates that an abnormal brain volume finding was consistent with the peer-reviewed literature for a specific diagnosis.

X A red X indicates that an abnormal brain volume finding was opposite the peer-reviewed literature for a specific diagnosis.

A white, blank field indicates that peer-reviewed literature was available for the given brain volume, but the brain volume finding was "neutral" because either the volume finding was normal or the literature did not report any volume abnormalities for that region.

A grayed-out field indicates that there were no literature findings available for that brain volume region vis-à-vis a specific diagnosis.

Abbreviations:

ALZ = Alzheimer's disease.
CB = cannabis use disorder.
GAD = generalized anxiety disorder.
MCI = mild cognitive impairment.
MDD = major depressive disorder (also called major depression).
Mold = mold-related illness (also called chronic inflammatory response syndrome [CIRS]).
PTSD = posttraumatic stress disorder.
SCI = subjective cognitive impairment.
SCZ = schizophrenia.
TBI mild mod = mild or moderate traumatic brain injury.
TBI mod sev = moderate or severe traumatic brain injury.

NeuroGage brain volume analyses showed the following:

- The TBI Biomarker test:
  - TBI ✓
  - Normal Ø
- The TBI Biomarker test (a test based on artificial intelligence algorithms) showed that their overall pattern of brain volumes matched that of patients with chronic mild or moderate TBI better than that of normal controls.

NeuroGage®

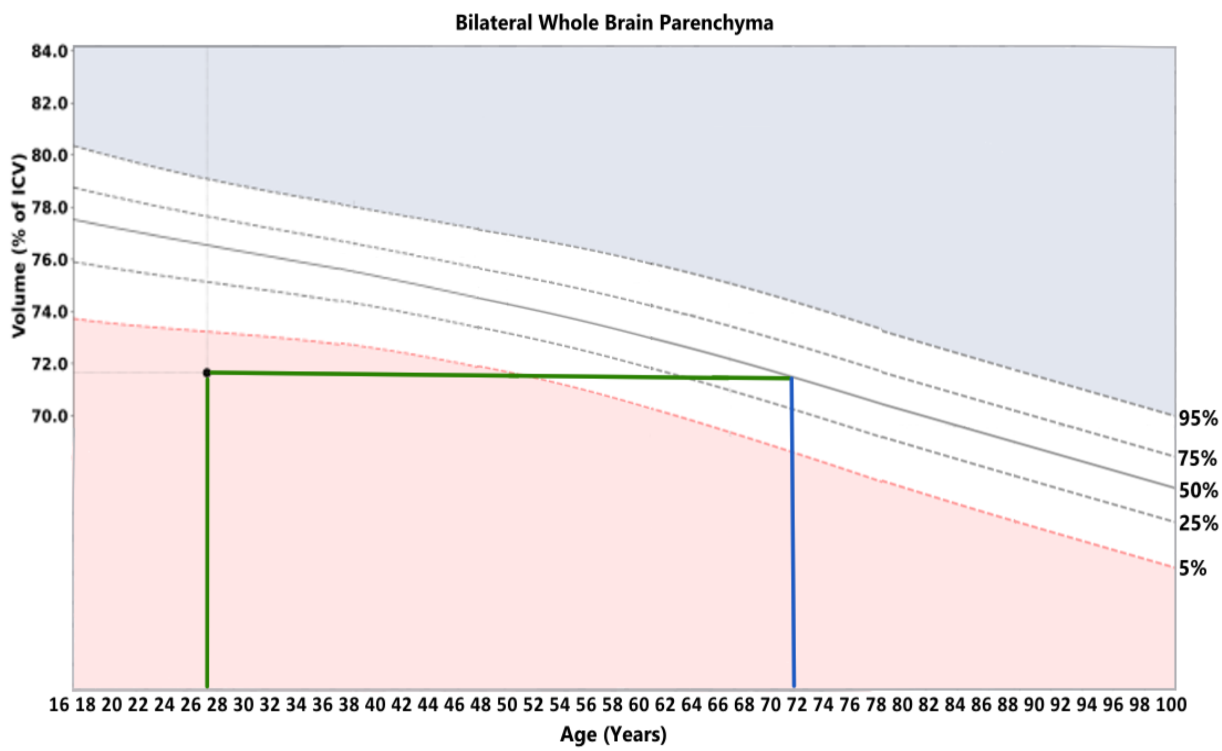

Figure 1: The volume of the patient's bilateral whole brain parenchyma was as small as that of the average 72-year-old person based on NeuroQuant's normal control data.

Methods

MRI brain segmentation and analyses of volumetry and asymmetry were performed using NeuroQuant 4.0, developed by Cortechs.ai. Tables summarizing brain volume and asymmetry results were generated using NeuroQuant 4.0 additional data output provided by Cortechs.ai. The NeuroQuant csv file provides additional data through Cortechs.ai on a given MRI sequence. It includes 71 regions and subregions, absolute brain volumes, percent of intracranial volume, and 5th and 95 normative percentile references. This additional information expands on the information provided by the NeuroQuant reports which may be utilized for further comparisons and potential research.

The differential diagnoses table was created through an extensive review of brain volume findings of specific diagnoses based on the peer-reviewed literature. The NeuroGage software automatically fills in the differential diagnoses table based on a comparison of the subject's volume results to the data obtained from the literature.

NeuroGage LLC

(804) 594-7046 (voice)
(866) 586-8977 (fax)
www.VaNeuropsychiatry.org

Patient information

LastName, FirstName
DOB: mm/dd/yy

NeuroGage®

The TBI Biomarker test was based on NeuroQuant® 3.0 volume data and NeuroGage 3.0 asymmetry data. 61 patients with chronic mild or moderate TBI, selected using our previously published criteria, were compared to the NeuroQuant normal controls and the NeuroGage normal controls (N=80). Neural network analyses using JMP 16.2 software were used to predict whether each subject belonged to the group of normal controls or patients. Each neural network model was developed using a K-fold method for validation of the results and then a leave-one-out method for testing the results. (The leave-one-out method is a conservative method that minimizes overfitting of the models.) The final method consisted of the average of 3 neural networks for each subject, yielding the following results:

		Diagnosis	
		Normal	TBI
Test result	Normal	76	0
	TBI	4	61
	Sensitivity:	100.0%	
	Specificity:	95.0%	

Since the development of the TBI Biomarker test, we have tested its validity in an additional sample of patients with chronic mild or moderate TBI, many of whom had brain disorders other than TBI. Of that sample (N=47), 93.6% tested positive for a diagnosis of TBI, confirming very good sensitivity of the test. For a subgroup of that sample that included patients with mild TBI but not moderate TBI (N=34), 97.1% tested positive for a diagnosis of TBI, again confirming excellent sensitivity of the test.

TBI BM test results:

NeuroGage 3.0 TBI Biomarker test:

Result: 100% (TBI)

Comparison ranges:

- Normal: 0-50%
- Chronic mild or moderate TBI: >50%

Key: TBI = traumatic brain injury.

Note: The TBI Biomarker test was developed in order to predict whether a given participant is a healthy normal control or a patient with chronic mild or moderate TBI.

For patients with other disorders, the results may or may not be valid and should be interpreted accordingly.

Disclaimer

This NeuroGage Radar software is owned by NeuroGage LLC and the Virginia Institute of Neuropsychiatry and falls under the FDA Clinical Decision Support (CDS) guidelines. As such, it is intended to provide information to healthcare professionals to support their clinical decision-making. It is not intended to replace the healthcare professional's clinical judgment or to be used as a diagnostic tool. The healthcare professional is responsible for independently reviewing the basis of the recommendations and applying their own expertise to the individual patient's needs and circumstances. NeuroGage Radar does not acquire, process, or analyze medical images, signals, or patterns; instead, it relies on the imaging and volumetric results of NeuroQuant, which is FDA-cleared medical software owned by CorTechs.ai. NeuroGage Radar software does not provide specific diagnoses or treatments. The information presented is based on established medical knowledge and clinical guidelines, but it may not be entirely inclusive or exclusive of all reasonable courses of care. Deviations from the recommendations may be justified by individual patient factors. Users should seek the advice of a qualified healthcare professional for the application of NeuroGage Radar software to specific patient cases.

David E. Ross, M.D.
Neuropsychiatrist
Board-certified in:

- General psychiatry
- Neuropsychiatry
- Brain injury medicine

References

Ahmed-Leitao, F., G. Spies, L. Van_den_Heuvel and S. Seedat (2016). "Hippocampal and amygdala volumes in adults with posttraumatic stress disorder secondary to childhood abuse or maltreatment: A systematic review." Psychiatry Res Neuroimaging **256**: 33-43.

Avants, B., J. Duda, J. Kim, H. Zhang, J. Pluta, J. Gee and J. Whyte (2008). "Multivariate analysis of structural and diffusion imaging in traumatic brain injury." Acad Radiol **15**: 1360-1375.

Bendlin, B. B., M. L. Ries, M. Lazar, A. L. Alexander, R. J. Dempsey, H. A. Rowley, J. E. Sherman and S. C. Johnson (2008). "Longitudinal changes in patients with traumatic brain injury assessed with diffusion-tensor and volumetric imaging." Neuroimage **42**(2): 503-514.

Bigler, E. D. (2005). Structural imaging. Textbook of traumatic brain injury. J. M. Silver, T. W. McAllister and S. C. Yudofsky. Washington, DC, American Psychiatric Publishing, Inc.**:** 79-105.

Bigler, E. D. (2011). Structural imaging. Textbook of Traumatic Brain Injury. J. M. Silver, T. W. McAllister and S. C. Yudofsky. Washington, DC, American Psychiatric Publishing, Inc.**:** 73-90.

Blithikioti, C., L. Miquel, A. Batalla, B. Rubio, G. Maffei, I. Herreros, A. Gual, P. Verschure and M. Balcells-Olivero (2019). "Cerebellar alterations in cannabis users: A systematic review." **24**(6): 1121-1137.

Bottino, C. M. C., C. C. Castro, R. L. E. Gomes, C. A. Buchpiguel, R. L. Marchetti and M. R. L. Neto (2002). "Volumetric MRI Measurements Can Differentiate Alzheimer's Disease, Mild Cognitive Impairment, and Normal Aging." International Psychogeriatrics **14**(1): 59-72.

Brennan, D., J. Duda, J. Ware, J. Whyte, J. Choi, J. Gugger, K. Focht, A. Walter, T. Bushnik, J. Gee, R. Diaz-Arrastia and J. Kim (2023). "Spatiotemporal profile of atrophy in the first year following moderate-severe traumatic brain injury." Hum Brain Mapp **44**: 4692-4709.

Busatto, G., B. S. Diniz and M. V. Zanetti (2008). "Voxel-based morphometry in Alzheimer's disease." Review Expert Rev Neurother **8**(11): 1691-1702.

Cole, J., A. Jolly, S. d. Simoni, N. Bourke, M. Patel, G. Scott and D. Sharp (2018). "Spatial patterns of progressive brain volume loss after moderate-severe traumatic brain injury." Brain **141**(3): 822–836.

Dabiri, M., F. Firouzabadi, K. Yang, P. Barker, R. Lee and D. Yousem (2022). "Neuroimaging in schizophrenia: a review article." Front Neurosci **15**(16).

Farbota, K., A. Sodhi, B. Bendlin, D. McLaren, G. Xu, H. Rowley and S. Johnson (2012). "Longitudinal volumetric changes following traumatic brain injury: a tensor-based morphometry study." Journal of the International Neuropsychological Society **18**(6): 1006–1018.

Govindarajan, K. A., P. A. Narayana, K. M. Hasan, E. A. Wilde, H. S. Levin, J. V. Hunter, E. R. Miller, V. K. Patel, C. S. Robertson and J. J. McCarthy (2016). "Cortical thickness in mild traumatic brain injury." J Neurotrauma **33**(20): 1809-1817.

Harris, T., R. de_Rooij and E. Kuhl (2019). "The shrinking brain: Cerebral atrophy following traumatic brain injury." Ann Biomed Eng **47**: 1941-1959.

Howes, O., C. Cummings, G. Chapman and K. Shatalina (2023). "Neuroimaging in schizophrenia: an overview of findings and their implications for synaptic changes." Neuropsychopharmacology **48**(1): 151-167.

Kolesar, T., E. Bilevicius, A. Wilson and J. Kornelsen (2019). "Systematic review and meta-analyses of neural structural and functional differences in generalized anxiety disorder and healthy controls using magnetic resonance imaging." Neuroimage Clin **24**: 102016.

Lener, M. and D. Losifescu (2015). "In pursuit of neuroimaging biomarkers to guide treatment selection in major depressive disorder: a review of the literature." Ann N Y Acad Sci **1344**: 50-65.

Maller, J. J., R. H. Thomson, K. Pannek, N. Bailey, P. M. Lewis and P. B. Fitzgeral (2014). "Volumetrics relate to the development of depression after traumatic brain injury." Behav Brain Res **271**: 147-153.

McLaren, M., S. Szymkowicz, A. O'Shea, A. Woods, S. Anton and V. Dotson (2016). "Dimensions of depressive symptoms and cingulate volumes in older adults." Transl Psychiatry **6**(4): 788.

McMahon, S. W., R. C. Shoemaker and J. C. Ryan (2016). "Reduction in forebrain parenchymal and cortical grey matter swelling across treatment groups in patients with inflammatory illness acquired following exposure to water-damaged buildings." J Neurosci Clin Res **1**(1).

McPherson, K., D. Tomasi, G. Wang, P. Manza and N. Volkow (2021). "Cannabis affects cerebellar volume and sleep differently in men and women." Front Psychiatry **13**(12): 643193.

Mehta, M. A., N. I. Golembo, C. Nosarti, E. Colvert, A. Mota, S. C. Williams, M. Rutter and E. J. Sonuga-Barke (2009). "Amygdala, hippocampal and corpus callosum size following severe early institutional deprivation: the English and Romanian Adoptees study pilot." J Child Psychol Psychiatry **50**: 943-951.

Meier, M., A. Caspi, A. Knodt, W. Hall, A. Ambler, H. Harrington, S. Hogan, R. Houts, R. Poulton, S. Ramrakha, A. Hariri and T. Moffitt (2022). "Long-term cannabis use and cognitive reserves and hippocampal volume in midlife." **179**(5): 362-374.

Morey, R., A. Gold, K. LaBar, S. Beall, V. Brown, C. Haswell, J. Nasser, H. Wagner and G. McCarthy (2012). "Amygdala volume changes in posttraumatic stress disorder in a large case-controlled veterans group." Arch Gen Psychiatry **69**(11): 1169-1178.

Moyer, A. (2016). "Post-traumatic stress disorder and magnetic resonance imaging." Radiol Technol **87**: 649-667.

Nader, D. and Z. Sanchez (2017). "Effects of regular cannabis use on neurocognition, brain structure, and function: a systematic review of findings in adults." 4-18.

Niu, X., L. Bai, S. Yingxiang, W. Yuan, B. Guanghui, Y. Bo, S. Wang, G. Shuoqiu, J. Xiaoyan and L. Hongjuan (2020). "Mild traumatic brain injury is associated with effect of inflammation on structural changes of default mode network in those developing chronic pain." J Headache Pain **21**(1): 135.

O'Doherty, D. C., K. M. Chitty, S. Saddiqui, M. R. Bennett and J. Lagopoulos (2015). "A systematic review and meta-analysis of magnetic resonance imaging measurement of structural volumes in post traumatic stress disorder." Psychiatry Res. **232**: 1-33.

Pihlajamäki, M., A. M. Jauhiainen and H. Soininen (2009). "Structural and functional MRI in mild cognitive impairment." Curr Alzheimer Res **6**(2): 179-185.
Rajesh, A., G. E. Cooke, J. M. Monti, A. Jahn, A. M. Daugherty, N. J. Cohen and A. F. Kramer (2017). "Differences in brain archetecture in remote mild traumatic brain injury." J Neurotrauma **34**(23): 3280-3287.
Ross, D., J. Seabaugh, J. Seabaugh, J. Plumley, J. Ha, J. Burton, A. Vandervaart, R. Mischel, A. Blount, D. Seabaugh, K. Shepherd, J. Barcelona and A. Ochs (2021). "Patients with chronic mild or moderate traumatic brain injury have abnormal longitudinal brain volume enlargement more than atrophy." Journal of Concussion **5**: 1-21.
Ross, D. E., A. L. Ochs, J. M. Seabaugh, M. F. DeMark, C. R. Shrader, J. H. Marwitz and M. D. Havranek (2012). "Progressive brain atrophy in patients with chronic neuropsychiatric symptoms after mild traumatic brain injury: A preliminary study." Brain Injury **26**: 1500-1509.
Ross, D. E., A. L. Ochs, M. D. Zannoni and J. M. Seabaugh (2014). "Back to the future: Estimating pre-injury brain volume in patients with traumatic brain injury." NeuroImage **102**: 565-578.
Ross, D. E., J. D. Seabaugh, J. M. Seabaugh, C. Alvarez, L. P. Ellis, C. Powell, C. Hall, C. Reese, L. Cooper and A. L. Ochs (2020). "Patients with chronic mild or moderate traumatic brain injury have abnormal brain enlargement." Brain Injury **34**: 11-19.
Ross, D. E., J. D. Seabaugh, J. M. Seabaugh, C. Alvareza, L. P. Ellis, C. Powell, C. Reese, L. Cooper, K. Shepherd and &_for_the_Alzheimer's_Disease_Neuroimaging_Initiative (2023). "Journey to the other side of the brain: Asymmetry in patients with chronic mild or moderate traumatic brain injury." Concussion **CNC101**: 1-18.
Ruet, A., F. Joyeux, S. Segobin, C. Jokic, B. Desgranges, F. Eustache and A. Pitel (2018). "Severe traumatic brain injury patients without focal lesion but with behavioral disorders: Shrinkage of gray matter nuclei and thalamus revealed in a pilot voxel-based MRI Study." J Neurotrauma **35**: 1552-1556.
Schindler, S., L. Schmidt, M. Stroske, M. Storch, A. Anwander, R. Trampel, M. Straub, U. Hegerl, S. Geyer and P. Schonkknecht (2019). "Hypothalamus enlargement in mood disorders." Acta Psychiatr Scand **139**(1): 56-67.
Shoemaker, R. C., D. House and J. C. Ryan (2014). "Structural brain abnormalities in patients with inflammatory illness acquired following exposure to water-damaged buildings: a volumetric MRI study using NeuroQuant®." Neurotoxicology and Teratology **45**: 18-26.
Starcevic, A., S. Postic, Z. Radojicic, B. Starcevic, S. Milovanovic, A. Ilankovic, I. Dimitrijevic, A. Damjanovic, M. Aksic and V. Radonjic (2014). "Volumetric analysis of amygdala, hippocampus, and prefrontal cortex in therapy-naive PTSD participants." BioMed Research International **2014**(968495): 6.

Tomaiuolo, F., G. Carlesimo, M. Paola, M. Petrides, F. Fera, R. Bonanni, R. Formisano, P. Pasqualetti and C. Caltagirone (2004). "Gross morphology and morphometric sequelae in the hippocampus, fornix, and corpus callosum of patients with severe nonmissile traumatic brain injury without macroscopically detectable lesions: a T1 weighted MRI study." J. Neurol. Neurosurg. Psychiatry **75**: 1314–1322.

Toth, A., N. Kovacs, G. Perlaki, G. Orsi, M. Aradi, H. Komaromy, E. Ezer, P. Bukovics, O. Farkas, J. Janszky, T. Doczi, A. Buki and A. Schwarz (2013). "Multi-modal magnetic resonance imaging in the acute and sub-acute phase of mild traumatic brain injury: can we see the difference?" Journal of Neurotrauma **30**(2): 2-10.

Wang, X., H. Xie, A. Cotton, M. Tamburrino, K. Brickman, T. Lewis, S. McLean and I. Liberzon (2015). "Early cortical thickness change after mild traumatic brain injury following motor vehicle collision." J Neurotrauma **32**(7): 455-463.

Wang, Y., C. Zuo, W. Wang, Q. Xu and L. Hao (2021). "Reduction in hippocampal volumes subsequent to heavy cannabis use: a 3-year longitudinal study." Psychiatry Research **295**.

Wolf, H., A. Hensel, F. Kruggel, S. G. Riedel-Heller, T. Arendt, L.-O. Wahlund and H.-J. Gertz (2004). "Structural correlates of mild cognitive impairment." Neurobiology of aging **25**(7): 913-924.

Zagorchev, L., C. Meyer, T. Stehle, F. Wenzel, S. Young, J. Peters, J. Weese, K. Paulsen, M. Garlinghouse, J. Ford, R. Roth, L. Flashman and T. McAllister (2016). "Differences in regional brain volumes two months and one year after mild traumatic brain injury." Journal of Neurotrauma **33**: 29-34.

Zhou, Y., A. Kierans, D. Kenul, Y. Ge, J. Rath, J. Reaume, R. I. Grossman and Y. W. Lui (2013). "Mild traumatic brain injury: longitudinal regional brain volume changes." Radiology **267**(3): 880-890.