MEG Resting-State Network Changes are Linked to Cognitive Deterioration in Type 1 Diabetic Patients

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Abstract

Objective: For proper cognitive function, the integrity of resting-state functional brain networks (RSNs) is crucial. Cognitive decline is common in type 1 diabetes mellitus (T1DM), possibly as a result of changes in RSNs, which may vary depending on microvascular complication status. Using an impartial method and a high spatio-temporal resolution functional network, we therefore tested the hypothesis that functional connectivity in RSNs differs according to clinical status and correlates with cognition in T1DM patients.

Methods: We collected resting-state magnetoencephalographic (MEG) data from 33 healthy participants and 42 T1DM patients with and without microvascular complications. A new atlas-based beamformer was used to reconstruct MEG time series at the source level. The phase lag index (PLI) was used to estimate functional connectivity within classical frequency bands within eight commonly observed RSNs. Cognitive performance was evaluated using neuropsychological tests, and the connection to RSNs was examined.

Results: The default-mode (DMN), executive control (ECN), and sensorimotor (SMN) RSN functional connectivity between the three groups was significantly different in the lower alpha band. In comparison to the other groups, T1DM patients with microvascular complications had the lowest functional connectivity in these networks. Functional connectivity for DMN was greater in patients who did not have microangiopathy than in controls (all p 0.05). When compared to healthy controls, the general cognitive performance of both patient groups was lower. In patients with microvascular complications, lower DMN alpha band functional connectivity was associated with lower general cognitive ability.

Discussion: Depending on their clinical status, T1DM patients had altered RSN functional connectivity. Cognitive impairment was linked to lower DMN functional connectivity. Based on these findings, functional connectivity may play a significant role in cognitive dysfunction caused by T1DM.

Keywords: Resting-state networks; Magnetoencephalography; Functional connectivity; Phase Lag Index (PLI); Oscillations; Type 1 diabetes mellitus

Introduction

A chronic condition known as type 1 diabetes mellitus (T1DM) is characterized by the inability to produce insulin due to the destruction of beta cells in the pancreas, necessitating the administration of exogenous insulin. Patients with type 1 diabetes are exposed to high (hyperglycemia) and low (hypoglycemia) blood glucose levels, and cumulative hyperglycemia exposure can result in damage to microvascular end organs like retinopathy and nephropathy [1, 2].

The potential effects of dysglycemia on the central nervous system are attracting more and more attention. White matter tract integrity, functional connectivity, and functional networks have been found to be altered in adult T1DM patients in comparison to non-diabetic controls, despite the fact that cortical grey matter appears to be relatively spared [3]. Additionally, cognitive decrements related to speed that range from mild to moderate are frequently observed. It is hypothesized that T1DM-related cerebral compromise may be related to cumulative hyperglycemia. Proliferative retinopathy, a result of long-term hyperglycemia, is hypothesized to be a marker of cumulative hyperglycemia on the brain because the retina and brain share developmental and physiological characteristics [4].

Methods

Participants

In this study, 42 people with type 1 diabetes who have proliferative retinopathy (T1DM+), 41 people with type 1 diabetes who don't have microvascular complications (T1DM), and 33 healthy control people who were matched for sex, BMI, and education were recruited. Age range models were 18-56 years and members were barred in the event that they had a BMI over 35 kg/m2, utilization of medications influencing cerebral working, current or history of liquor (men > 21 and ladies > 14 units per week) or current medication use, mental problems, weakness, thyroid brokenness, utilization of glucocorticoids, hepatitis, stroke, extreme head injury, epilepsy, pregnancy, or poor visual sharpness. A disease duration of at least ten years was required for T1DM patients.

The Centre for Epidemiological Studies scale for depression (CES-D) was used to measure depressive symptoms in order to control for the confounding effects of depression on cognitive performance and functional connectivity. Before the MEG recording, T1DM patients had their current blood glucose levels measured to avoid confounding [5]. The appropriate blood glucose levels were thought to be between 4 and 15 mmol/l (72 and 270 mg/dl). Our prior work provides a comprehensive description of the inclusion and exclusion criteria for patients and control subjects. 2009), in which sensor-level analysis of MEG data was performed on a subset of these participants (n = 15, 29, and 26 for T1DM+, T1DM, and healthy controls, respectively). There were 148 subjects in the original dataset, but 32 of them were eliminated due to poor MEG recordings (n = 24) or issues with MRI co-registration (n = 8).

Assessment of the structure

Differential white matter hyperintensities, as well as the volume of the entire brain and the total grey matter, were evaluated using structural MRI scans.

An 8-channel phased-array head coil was used for magnetic resonance imaging on a 1.5 T whole body MR scanner from Siemens Sonata, Erlangen, Germany.

SIENAX, a component of the FMRIB Software Library (FSL, 5.0.4; Both the total volume of the grey matter and the whole brain (see http://fsl.fmrib.ox.ac.uk/fsl/fslwiki/) were determined using this method. For this investigation a high goal T1-MPRAGE (redundancy time 2.700 ms, reverberation time 5.17 ms, reversal time 95 ms, flip point 8°, 248 × 330 mm2 field of view, 1.0 × 1.0 × 1.5 mm voxel size) was utilized. All scans

were first corrected for geometric distortion caused by the scanner, and then the Montreal Neurological Institute 152 (MNI152) standard brain was registered with each participant's T1-MPRAGE to remove excess neck tissue. This was done to improve the reliability of the analyses [6].

A neuropsychologist trained to assess structural abnormalities on MRI (EvD) visually rated white matter hyperintensities using the Fazekas score (Fazekas et al., 2002). A 3D-FLAIR sequence with a repetition time of 6500 ms for this rating time to echo: 385 ms; flip angle variable (Mugler et al., was utilized.

Assessment of the neuropsychology

As detailed in van Duinkerken et al. (2009) all members were surveyed utilizing a battery of neuropsychological tests to assess mental execution in six mental spaces: executive functioning, memory, speed of information processing, attention, motor speed, and psychomotor speed. The mean and standard deviation of the controls served as the basis for the creation of z-values for each neuropsychological test. The cognitive domains were then created by grouping these together (see Appendix A). Higher z-scores signify better performance, so z-values were altered whenever necessary. The term "general cognitive ability" was used in this study to refer to the sum of all z-scores across all cognitive domains.

MEG

A 151-channel whole-head MEG system (CTF Systems;) was used to record MEG data. Port Coquitlam, British Columbia, Canada), with participants lying down in a vacuum-shielded room. A software gradient of the third order was utilized with a recording passband of 0.25-125 Hz and an example recurrence of 625 Hz. Magnetic fields were recorded for two minutes with the eyes open, five minutes with the eyes closed, ten minutes for a task, and then three minutes with the eyes closed [7].

Small alternating currents were run through three head position coils attached to the left and right preauricular points and the nose at the beginning and end of each of these recordings to determine the head position in relation to the helmet's coordinate system. Changes in head position of < 0.5 cm during a recording were acknowledged. Here, we only looked at the initial (5 minutes) eyes closed resting state, which we divided into 45 trials of 6.55 seconds (4096 samples). After careful visual inspection (MD, AH), channels and epochs containing artifacts were discarded, with an average rejection of three channels (range: 0–11). For the beamformer analysis, a minimum of 25 epochs were chosen and deemed sufficient [8].

Beamforming

As a first step in beamforming, the structural T1-weighted MRI scan was used for co-registration. For further analysis, only data with an estimated co-registration error of less than 1.0 cm were accepted. The SEG toolbox in SPM8 was then used to spatially normalize MRI data to a template MRI followed by the application of anatomical labels. An approach for a beamformer based on an atlas was utilized to project MEG sensor signs to a physical system comprising of 78 cortical districts. This brought about time-series of neuronal initiation for all voxels inside a return for capital invested, after which a delegate voxel was chosen (the one with greatest power for a given recurrence band. The following frequency bands were used to filter the time series for the 78 ROIs: delta (0.5–4 Hz), theta (4.0–8 Hz), lower alpha (8.5–10 Hz), upper alpha (11–13 Hz), beta (13–30 Hz), and the lower gamma bands (from 30 to 48 Hz). Six sets of 78 time-series, one for each frequency band and one for each AAL region, were produced as a result. Based on careful visual inspection (MD), we selected five artefact-free epochs of 4096 samples (6.55 s) from these time-series in order to obtain stable results, as we had done in previous studies [9].

Results

Subject characteristics

Characteristics of the subject Both the subject's characteristics and the structural assessment are summarized. There were no distinctions in orientation appropriation between gatherings ($p > 0.05$). Age ($F(2,113) = 6.55$, $p = 0.002$), systolic blood pressure ($F(2,113) = 4.03$, $p = 0.02$), depressive symptoms ($F(2,113) = 5.82$, $p = 0.004$), duration of diabetes ($t(81) = 6.14$, p 0.001), and onset age of diabetes ($t(81) = 3.00$, $p = 0.004$) were all significantly different between the groups Patients with T1DM+ were the oldest, had the highest systolic blood pressure, and scored the highest on the assessment of depressive symptoms. None of these three characteristics was different between the T1DM group and the control group. Ten patients (23.8%) had proliferative retinopathy, eight (19.5%) did not have microvascular complications, and four (12.1%) control subjects had a Fazekas score of 1 (small punctiform lesions). This percentage did not differ between the groups statistically ($2(2,116) = 1.655$, $p = 0.437$). In this sample, there were no Fazekas scores 2 or 3. Total grey matter volume did not differ between the groups ($F(2,113) = 1.75$); $p = 0.178$). Complete cerebrum volume would in general be modified between gatherings, with the most minimal volume in T1DM+ patients ($F(2,113) = 3.02$; $p = 0.053$).

Neuropsychological evaluation

There was no gender effect or interaction effect, but there was a significant group effect on general cognitive ability ($F(2,107) = 6.86$, $p = 0.002$). Post-hoc analysis revealed that T1DM+ patients performed significantly worse than T1DM patients (MD = 0.301; 95% CI = [– 0.512, – 0.090]; $p = 0.006$) and controls (MD = – 0.409; 95% CI = [– 0.636, – 0.182]; $p = 0.001$).

MEG results

A significant group effect in the lower alpha band was found in the MANCOVA model using log-transformed PLI values for the RSNs ($F(16,200) = 1.90$, $p = 0.022$); Wilks' = 0.753, partial 2 = 0.132), whereas there was no significant group effect in the other frequency bands. Gender did not appear to have a main effect or an interaction effect.

DMN ($F(2,107) = 3.45$, $p = 0.035$, partial 2 = 0.061), ECN ($F(2,107) = 5.55$, $p = 0.005$, partial 2 = 0.094), and SMN ($F(2,107) = 4.67$, $p = 0.011$, partial 2 = 0.080) showed significant differences when post-hoc MANCOVA was performed. In particular, T1DM+ patients had the lowest functional connectivity values for each significant sub-network (Fig. 1), whereas T1DM had functional connectivity values that were either comparable to or higher than those of controls.

Discussion

In this study, we demonstrated that functional connectivity in MEG resting-state networks (RSNs) decreased in T1DM+ patients as well as healthy participants when compared to T1DM patients. On the other hand, T1DM patients had more DMN functional connectivity than controls [10]. For the three resting-state networks (DMN, ECN, and SMN), altered functional connectivity was specifically observed in the lower alpha band. In addition, cognitive decline and lower DMN functional connectivity in the lower alpha band were found to be significantly correlated in T1DM+ patients [11].

The findings of this study regarding connectivity are consistent with those of previous EEG studies MEG studies as a whole in terms of the result: Connectivity to functions is affected by T1DM. Critically, our outcomes likewise develop our past MEG and fMRI studies including a similar patient companion; by utilizing the stage slack record and source-level examination we stayed away from false gauges of useful network, and acquired results that were simpler to decipher as far as the specific physical locales that were involved (van Duinkerken et al., 2009). In addition, utilizing MEG examination of RSNs permitted us to use the rich worldly elements of neuronal action [12].

Differences in the methods used, such as a different acquisition technique, different resting-state protocols, and different approaches to source reconstruction (beamforming versus no source reconstruction); grouping of RSN connections) may also help to explain why Cooray et al.'s EEG study used the PLI and found no diabetes-related decreases in functional connectivity.

In this group, our current findings are in part consistent with our previous fMRI RSN analysis. In that study, patients without complications had greater connectivity in the sensorimotor and visual networks than controls, whereas patients with proliferative retinopathy had lower connectivity than patients with uncomplicated T1DM. The DMN and ECN showed a pattern that was similar in the current study. The affected RSNs varied, despite the fact that the pattern of connectivity changes among the groups was

similar in both studies [13]. According to Logothetis (2008), Singh (2012), Tewarie et al., it is still unknown how exactly functional connectivity estimates based on electrophysiological oscillatory activity relate to functional connectivity estimates based on hemodynamic correlations. 2014). This may also account for the reasons our prior fMRI study showed that some RSNs (auditory, frontoparietal, and ventral attention) had a dose-response effect, and that functional connectivity varied depending on the patient's clinical status. However, our current and previous MEG studies, the functional connectivity levels of healthy participants generally fell somewhere in between those of T1DM+ and T1DM patients [14].

According to previous research highlighting the significance of this rhythm in mediating functional processing within and between areas, both in healthy subjects and its deviation in pathology, the lower alpha band was the only frequency band with significant results. 2013).

Conclusion

In conclusion, our findings confirmed that T1DM has an effect on functional sub-networks (resting-state networks like DMN, ECN, and SMN) and that these changes are linked to cognitive performance. Based on these findings, functional connectivity may play a significant role in cognitive dysfunction caused by T1DM.

Acknowledgement

None

Conflict of Interest

None

References

1. Ashburner J, Friston KJ. Unified segmentation. NeuroImage. 2005; 26: 839-851.
2. Bartolomei F, Bosma I, Klein M, Baayen JC, Reijneveld JC. Disturbed functional connectivity in brain tumour patients: evaluation by graph analysis of synchronization matrices. Clin Neurophysiol. 2006; 117: 2039-2049.
3. Bassett DS, Bullmore ET. Human brain networks in health and disease. Curr Opin Neurol. 2009; 22: 340-347.
4. Brands AMA, Biessels GJ, de Haan EHF, Kappelle LJ, Kessels RPC. The effects of type 1 diabetes on cognitive performance: a meta-analysis. Diabetes Care. 2005; 28: 726-735.
5. Brookes MJ, Vrba J, Robinson SE, Stevenson CM. Optimising experimental design for MEG beamformer imaging. NeuroImage. 2008; 39: 1788-1802.
6. Brookes MJ, Woolrich M, Luckhoo H, Price D, Hale JR. Investigating the electrophysiological basis of resting state networks using magnetoencephalography. Proc Natl Acad Sci. 2011; 108: 16783-16788.
7. Brownlee M. The pathobiology of diabetic complications: a unifying mechanism. Diabetes. 2005; 54: 1615-1625.
8. Broyd SJ, Demanuele C, Debener S, Helps SK, James CJ. Default-mode brain dysfunction in mental disorders: a systematic review. Neurosci Biobehav Rev. 2009; 33: 279-296.
9. Cooray GK, Hyllienmark L, Brismar T. Decreased cortical connectivity and information flow in type 1 diabetes. Clin Neurophysiol. 2011; 122: 1943-1950.
10. Damoiseaux JS, Greicius MD. Greater than the sum of its parts: a review of studies combining structural connectivity and resting-state functional connectivity. Brain Struct Funct. 2009; 213: 525-533.
11. Damoiseaux JS, Rombouts SARB, Barkhof F, Scheltens P, Stam CJ. Consistent resting-state networks across healthy subjects. Proc Natl Acad Sci. 2006; 103: 13848-13853.
12. de Pasquale F, Penna Della S, Snyder AZ, Lewis C, Mantini D. Temporal dynamics of spontaneous MEG activity in brain networks. Proc Natl Acad Sci. 2010; 107: 6040-6045.
13. de Pasquale F, Penna Della S, Snyder AZ, Marzetti L, Pizzella V. A cortical core for dynamic integration of functional networks in the resting human brain. Neuron. 2012; 74: 753-764.
14. Douw L, de Groot M, van Dellen E, Aronica E, Heimans JJ. Local MEG networks: the missing link between protein expression and epilepsy in glioma patients?. NeuroImage. 2013; 75: 195-203.

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