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Research Article

Quantitative Evaluation of the Parietal Lobes Abnormalities in Sudanese Patients with Schizophrenia: A Comparative Brain Segmentation Study

Meltem Acar Gudek[1], Amani Elfaki[2], Mert Nahir[3], Amira Muhammed Osman Haroun[4], Sahar Shareef[5], Bunyamin Sahin[6]

[1]Samsun University, Faculty of Medicine, Department of Anatomy, Samsun, Türkiye
[2]Imam Abdulrahman Bin Faisal University, Faculty of Medicine, Department of Anatomy, Dammam, Saudi Arabia
[3]Gaziosmanpaşa University, Faculty of Medicine, Department of Anatomy, Tokat, Türkiye
[4]King Salman Bn Abdalaziz Medical City, Department of Psychiatry, Medina, Saudi Arabia
[5]King Saud University, Faculty of Medicine, Department of Anatomy, Riyadh, Saudi Arabia
[6]Ondokuz Mayıs University, Faculty of Medicine, Deapartment of Anatomy, Samsun, Türkiye

Abstract

Aim: Schizophrenia is a long-standing psychiatric condition marked by a gradual deterioration in cognitive functioning, personality organization, and affective responsiveness. This study represents the first magnetic resonance imaging (MRI) investigation to explore morphological similarities and differences of the parietal lobes in Sudanese individuals diagnosed with schizophrenia.
Material and Method: The study cohort comprised 54 patients and 82 healthy participants who met the inclusion criteria. All participants underwent a structured socio demographic assessment and comprehensive physical examination. Brain MRI scans were acquired and subsequently analyzed using automated brain segmentation software applied to DICOM format images.
Results: The mean volume of the parietal lobe was significantly lower in patients (114.97±10.86 cm^3) compared to controls (127.85±10.65 cm^3). Similarly, volume reductions were seen in both gray and white matter compartments in patients (72.49±7.54 cm^3 and 42.47±4.51 cm^3) compared to controls (79.40±6.77 cm^3 and 48.46±5.94 cm^3). However, no significant difference was observed in the cortical pial surface area of the parietal lobe between groups. Parietal cortical thickness was notably diminished in patients ($p \leq 0.05$).
Conclusion: The reductions observed in total parietal lobe volume, along with diminished gray and white matter volumes in individuals with schizophrenia, indicate a widespread atrophic process affecting this cerebral region. These structural abnormalities may underlie specific cognitive deficits commonly associated with schizophrenia.

Keywords: Parietal lobe; chronic schizophrenia, magnetic resonance images, automatic brain segmentations

INTRODUCTION

Schizophrenia, a chronic and heterogeneous mental illness, manifests through a range of symptoms, including perceptual disturbances, distorted beliefs, disorganized thinking, and cognitive impairments (1). It affects nearly 1% of the global population and is frequently associated with significant impairments in both social interaction and occupational functioning (2). Although its exact etiology remains unclear, compelling evidence suggests that underlying neurodevelopmental disturbances begin during the prenatal phase and extend into adolescence (3,4). Diagnosis is based on comprehensive history-taking, physical and mental status examinations, and supportive laboratory tests. In addition to clinical rating scales, researchers are actively investigating neuroimaging biomarkers to improve diagnosis, prognosis, and treatment stratification (5).

Brain volumetric assessments using magnetic resonance imaging (MRI) have proven to be effective tools for monitoring the progression of neurodegenerative diseases and evaluating responses to therapeutic interventions. Observing brain volumetric changes in

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Corresponding Author: Meltem Acar Gudek, Samsun University, Faculty of Medicine, Department of Anatomy, Samsun, Türkiye
E-mail: meltem.gudek@samsun.edu.tr

schizophrenia can aid in establishing the diagnosis and guiding treatment decisions (6). Neuroimaging research has consistently revealed structural brain alterations in individuals with schizophrenia, encompassing not only those experiencing their first episode or in the prodromal phase but also individuals with a genetic vulnerability to the disorder (7). Gray matter volume and cortical thickness are among the most frequently examined neuroanatomical parameters, both showing widespread alterations, particularly in the frontal, temporal, and parietal lobes (8). Advanced neuroimaging modalities, such as CT and MRI, have highlighted notable structural alterations in individuals with schizophrenia, including an approximate 3% reduction in overall brain volume. This reduction appears to be more pronounced in gray matter (2%) than in white matter (1%) and is often accompanied by enlargement of cerebrospinal fluid compartments, particularly the lateral and third ventricles (9). Consistent decreases in gray matter volume have been documented in several key brain regions, including the anterior cingulate cortex, frontal lobe, superior temporal gyrus, hippocampal–amygdala complex, and the left medial temporal lobe (10,11). These anatomical abnormalities are strongly associated with corresponding functional disturbances (12).

Although numerous studies have investigated various brain regions in schizophrenia, the parietal lobe has received comparatively less attention. Existing evidence indicates structural changes particularly affecting the inferior parietal lobule and its subcomponents, the angular and supramarginal gyri (13,14). These areas are critically involved in language comprehension (15), spatial working memory (16), and attentional processes, all of which are frequently impaired in patients with schizophrenia.

Impairments in cognitive functioning, particularly in domains related to social cognition, are prevalent in schizophrenia and have been associated with morphological changes in key brain regions, including the amygdala, prefrontal cortex, and the temporal and parietal lobes. These alterations frequently involve reductions in both gray and white matter volumes (17). The fronto-parietal network (FPN), comprising interconnected regions within the prefrontal and parietal cortices, plays a critical role in modulating attentional processes (18). Disruptions in white matter integrity within the FPN have been linked to deficits in sustained attention in individuals with schizophrenia (19).

Accordingly, the present study aims to evaluate the total brain volume, as well as gray and white matter volumes, cortical pial surface area, and cortical thickness of the parietal lobes in individuals with schizophrenia. MRI and BrainSuite software were employed for automated brain segmentation and regional parcellation, with particular attention to hemispheric laterality and sex-related differences.

MATERIAL AND METHOD

Subjects

The present hospital-based case-control study employed a cross-sectional design and was conducted in Sudan at Professor Abdelaal Alidresi and Tigani Almahi Psychiatric Hospitals, as well as in several private psychiatric facilities. The sample included 136 participants: 82 healthy controls (47 males, 35 females) and 54 patients diagnosed with schizophrenia (28 males, 26 females). Patients were selected as a convenience sample during the study period, while controls were healthy volunteers with no history of psychiatric illness or psychotropic medication use (Table 1).

Table 1. Comparison of mean age and body mass index (BMI) values between groups

	n (%)	Age (Years±SD)	BMI (kg/m²±SD)
Male			
Control	47 (34.56)	28.98±5.90	24.65±4.03
Schizophrenic	28 (20.59)	31.11±6.14	22.75±3.39
Female			
Control	35 (25.73)	29.69±6.27	25.51±4.85
Schizophrenic	26 (19.12)	31.69±6.24	24.88±6.06
Total			
Control	82 (60.30)	29.28±6.03	25.02±4.39
Schizophrenic	54 (39.70)	31.39±6.40	23.77±4.93

All participants underwent a semi-structured psychiatric interview, standard mental state examination, physical assessment, and relevant investigations. Diagnoses were made by psychiatric specialists based on the International Classification of Diseases, 10th Revision (ICD-10), as defined by the World Health Organization (WHO). Patients were on regular antipsychotic treatment, including:

1. Typical antipsychotics (Haloperidol, 2–20 mg/day),
2. Atypical antipsychotics (Olanzapine, 5–20 mg/day) (Table 2).

Table 2. Duration of illness, duration of treatment, and types of treatment in patients with schizophrenia

	Sex n (%)		Total
	Male	Female	
Duration of the illness			
1-2 years	0 (0.00%)	2 (7.69%)	2 (3.70%)
2-3 years	5 (17.86%)	2 (7.69%)	7 (12.96%)
3-4 years	1 (3.57%)	3 (11.54%)	4 (7.41%)
4-5 years	1 (3.57%)	5 (19.23%)	6 (11.11%)
More than 5 years	21 (75.00%)	14 (53.85%)	35 (64.81%)
Total	28 (100.00%)	26 (100.00%)	54 (100.00%)
Duration of treatment			
1-2 years	0 (0.00%)	3 (11.54%)	3 (5.56%)
2-3 years	5 (17.86%)	5 (19.23%)	10 (18.52%)
3-4 years	1 (3.57%)	3 (11.54%)	4 (7.41%)
4-5 years	1 (3.57%)	4 (15.38%)	5 (9.26%)
More than 5 years	21 (75.00%)	11 (42.31%)	32 (59.26%)
Total	28 (100.00%)	26 (100.00%)	54 (100.00%)
Treatment used			
Typical antipsychotic (Haloperidol)	8 (28.57%)	8 (30.77%)	16 (29.63%)
Atypical antipsychotic (Olanzapine)	20 (71.43%)	18 (69.23%)	38 (70.37%)
Total	28 (100.00%)	26 (100.00%)	54 (100.00%)

Ethical approval for the study was obtained from the Sudan Gezira University the Research Ethics Committe (Approval Referans Number C.C/K.T.D.A/T.L.A.B dated September 17, 2009).

MRI Acquisition

Structural magnetic resonance imaging was conducted using a 1.5 Tesla SIEMENS scanner (Production city) at the National Ribat University, Sudan. T1 weighted sequences were acquired through a three-dimensional Magnetization Prepared Rapid Acquisition Gradient Echo (MP-RAGE) protocol, which enables high contrast between gray and white matter within a relatively short scan duration. Imaging parameters included a slice thickness of 1.0 mm, a field of view of 250 mm (read) × 192 mm (phase), repetition time (TR) of 1657 ms, echo time (TE) of 2.95 ms, and a bandwidth of 180 Hz/pixel. The flip angle was set to 15°, echo spacing was 7.5 ms, with 100% phase resolution and 50% slice resolution. The total acquisition time was approximately 5 minutes and 18 seconds.

Analysis of MRI

All participants' DICOM images were subjected to blinded analysis through a series of dedicated software applications.

1. ImageJ software (Figure 1); following re-slicing and re-orientation, all images were converted to the standardized Analyze 7.5 format for further analysis.
2. Brain Suite software (Figure 2); was utilized to process the images, which had been previously converted into Analyze format and imported into the structural brain analysis environment. The processing involved the following sequential steps:
   - The skull stripping phase was manually inspected and, when necessary, adjusted to ensure accurate demarcation of brain tissue boundaries.
   - The subsequent procedures including hemispheric separation, surface generation, and volume registration were executed automatically by the software.
   - After completing visual quality control, the software computed the volumetric values for the regions of interest (ROIs).

The volumes of the parietal lobes, gray and white matter, cortical pial surface area, and cortical thickness of both the frontal and parietal lobes were automatically extracted. All measurements were recorded in a central datasheet specifically designed for this study, and volumetric calculations were subsequently performed.

Figure 1. ImageJ software program

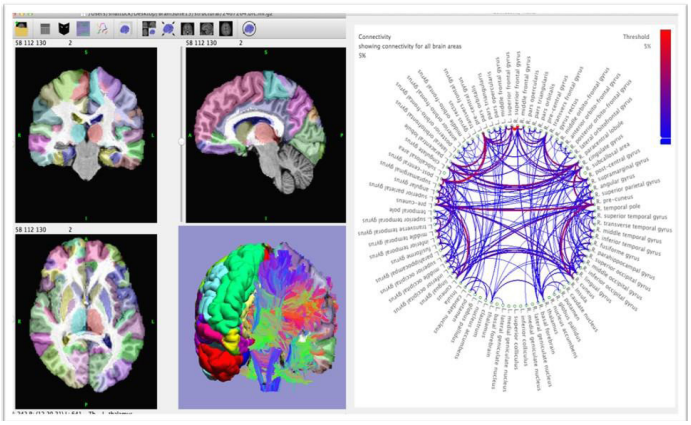

Figure 2. BrainSuite software program

RESULTS

Analysis of Demographic Differences Between Individuals with Schizophrenia and Healthy Controls

The one-way analysis of variance (ANOVA) revealed no statistically significant differences in age or body mass index (BMI) between male and female participants across both control and schizophrenia groups ($p>0.050$). Similarly, chi-square analysis indicated no significant variation in gender distribution between the groups ($p>0.050$).

Assessment of Intracranial Volume (ICV)

Intracranial volume was found to be significantly higher in males compared to females in both patient and control groups ($p\leq0.050$). Furthermore, participants with schizophrenia exhibited reduced ICV in comparison to healthy controls ($p\leq0.050$). The mean difference in ICV between the schizophrenia and control groups was calculated as 88.78 cm^3.

Analysis of Parietal Lobe Structures

To assess variations in parietal lobe parameters between the groups, a mixed-effects repeated measures ANCOVA was conducted. This model controlled for covariates including intracranial volume, age, and treatment status. Hemisphere side was treated as a within subject factor, while case status (patient/control) and gender were treated as between-subject factors.

Then, we found ICV as significant covariates for volumes of the parietal lobe, parietal gray and white matter and cortical area pial of parietal lobe. We found age as significant covariates for volumes of the parietal gray matter. For thickness of parietal lobe we found no significant covariates. We made our analysis with a correcting of significant covariates.

Volume of parietal lobe: A statistically significant difference was observed between the patient group and the control group ($F (1; 131) =16.756$ $p<0.001$). Moreover, we found no differences between right and left side in patients and controls ($F (1; 131) =0.438$ $p=0.509$) (Table 3).

Table 3. Comparison of mean volumes (cm^3±SD) of parietal lobe between groups

Group	Right	Left	Total
Male control	66.68±5.58	63.93±5.40	130.61±9.80
Male schizophrenic	61.73±6.48 (p=0.039*)	56.71±5.25 (p=0.039*)	118.45±10.72 (p<0.001*)
Female control	63.83±5.94	60.23±5.62	124.06±10.75
Female schizophrenic	57.04±5.59 (p=0.039*)	54.06±4.60 (p=0.039*)	111.10±9.81 (p<0.001*)
Control (All)	65.48±5.88	62.37±5.76	127.85±10.65
Schizophrenic (All)	59.5±6.47 (p<0.001*)	55.46±5.09 (p<0.001*)	114.97±10.86 (p<0.001*)

SD: standard deviation; P-values (p<0.05) are highlighted in*

Volume of gray matter: Statistically significant difference was observed between the patient group and the control group (F (1; 130) =5.952 p=0.016). Moreover, we found no differences between right and left side in patients and controls (F (1; 130) =1.103 p=0.296) (Table4).

Volume of white matter: There was significant difference between patients and controls (F (1; 131) =12.797 p<0.001), also we found significant difference between sex (F (1; 131) =6.794 p=0.010). Then we made pairwise comparisons and found significant differences between male controls and male patients (p=0.039). Additionally, we found no differences between right and left side in patients and controls (F (1; 131) =0.079 p=0.779) (Table 4).

Table 4. Comparison of mean volumes (cm³±SD) of gray and white matter of parietal lobe between groups

Group	Grey matter right	Grey matter left	Grey matter total	White matter right	White matter left	White matter total
Male control	41.82±3.73	39.52±3.15	81.34±6.15	24.86±2.97	24.40±3.30	49.27±5.85
Male schizophrenic	39.69±4.57 (p=0.039*)	35.61±3.35 (p=0.039*)	75.30±7.38 (p=0.016*)	22.04±2.55 (p=0.039*)	21.11±2.50 (p=0.039*)	43.15±4.60 (p<0.001*)
Female control	39.76±4.02	36.95±3.36	76.72±6.73	24.07±2.97	23.28±3.19	47.34±5.97
Female schizophrenic	35.94±3.59 (p=0.039*)	33.43±3.24 (p=0.039*)	69.37±6.50 (p=0.016*)	21.10±2.56 (p=0.039*)	20.63±2.00 (p=0.039*)	41.73±4.37 (p<0.001*)
Control (All)	40.95±3.97	38.44±3.47	79.40±6.77	24.53±2.98	23.93±3.29	48.46±5.94
Schizophrenic (All)	37.92±4.51 (p=0.016*)	34.57±3.45 (p=0.016*)	72.49±7.54 (p=0.016*)	21.59±2.58 (p=0.010*)	20.88±2.27 (p=0.010*)	42.47±4.51 (p=0.010*)

SD: standard deviation; P-values (p<0.05) are highlighted in*

Cortical pial surface area: No statistically significant difference was found between the patient and control groups (F (1; 131) =3.151 p=0.078). Moreover, we found no differences between right and left side in patients and controls (F (1; 131) =0.372 p=0.543) (Table 5).

Thickness of parietal lobe: There was significant difference between patients and controls (F (1; 132) =4.313 p=0.040). Moreover, we found no differences between right and left side in patients and controls (F (1; 132) =0.059 p=0.808) (Table 5).

Table 5. Comparison of mean cortical pial surface area (cm²±SD) and parietal lobe thickness (mm±SD) between groups

Group	Cortical pial area right	Cortical pial area left	Cortical pial area total	Thickness right	Thickness left	Thickness total
Male control	185.95±14.89	176.12±15.54	362.07±26.77	4.25±0.22	4.27±0.24	4.26±0.21
Male schizophrenic	179.25±14.82 (p=0.078)	162.36±13.73 (p=0.078)	341.60±24.43 (p=0.078)	4.30±0.20 (p=0.040*)	4.32±0.22 (p=0.040*)	4.31±0.20 (p=0.040*)
Female control	177.62±15.32	166.25±14.70	343.87±26.46	4.20±0.18	4.23±0.21	4.21±0.18
Female schizophrenic	165.46±15.48 (p=0.078)	155.50±11.59 (p=0.078)	320.96±25.94 (p=0.078)	4.34±0.19 (p=0.040*)	4.27±0.22 (p=0.040*)	4.31±0.18 (p=0.040*)
Control (All)	182.45±15.55	171.97±15.88	354.42±27.99	4.23±0.21	4.25±0.23	4.24±0.20
Schizophrenic (All)	172.72±16.53 (p=0.078)	159.11±13.11 (p=0.078)	331.83±27.01 (p=0.078)	4.32±0.20 (p=0.040*)	4.30±0.22 (p=0.040*)	4.31±0.19 (p=0.040*)

DISCUSSION

At present, the diagnostic utility of neuroimaging techniques in schizophrenia remains limited, primarily aiding in the detection of structural brain abnormalities in a small subset of individuals with secondary forms of psychosis. Despite this limitation, neuroimaging modalities hold considerable promise for elucidating the potential trajectory of the illness. Moreover, these techniques provide valuable tools for evaluating the effects of therapeutic interventions, including both pharmacological treatments and cognitive-based therapies (20).

The present study demonstrates a significant reduction in parietal lobe volume in patients with schizophrenia compared to healthy individuals (21). Given that the duration of illness and treatment exceeded five years in the majority of our sample (75.92% and 68.52%, respectively), our findings are consistent with those of Olabi et al., who reported a progressive decline in whole-brain volume, gray matter, and parietal white matter volume in patients with schizophrenia relative to healthy controls (22).

Significant differences were observed between patients and controls in parietal lobe volume, as well as in parietal

gray and white matter volumes. Although the parietal lobe has not been investigated as extensively as the temporal lobe (23), our findings are consistent with several-though not all MRI studies (23,24). Moreover, previous research has also reported parietal volume reductions in individuals with schizophrenia, including those experiencing a first episode of the illness (25).

A voxel-based morphometry (VBM) investigation revealed reductions in gray matter volume within the temporal, frontal, occipital, and parietal lobes (26). Another VBM-based study reported that schizophrenia exerts its most prominent structural impact on white matter, suggesting that white matter may represent the primary region affected in the pathophysiology of schizophrenia (27). Additionally, certain studies have noted structural atrophy within the parietal lobe particularly involving the cingulate and supramarginal gyri as well as in the occipital lobe. However, such findings appear to be relatively uncommon and are typically associated with more advanced stages of the disorder (28).

The parietal lobe accounts for approximately one-quarter of the human brain and, with the exception of its somatosensory subregion, forms part of the heteromodal association cortex. This region plays a critical role in integrating visual, auditory, and tactile sensory inputs and coordinating appropriate behavioral responses (29).

Findings from the present study indicate a reduction in total parietal lobe volume, as well as in both gray and white matter volumes, in patients with schizophrenia when compared to healthy controls. We suggest that these structural changes may contribute to the pathophysiologic mechanisms underlying the disorder.

In the present study, no statistically significant differences were identified between the right and left parietal lobes regarding gray and white matter volumes in either the schizophrenia group or the healthy controls. This result may indicate a disruption of the typical left-hemispheric dominance, a neuroanatomical characteristic considered essential for normative language development. These results align with previous research suggesting that individuals with schizophrenia often exhibit either a reversal of hemispheric lateralization toward the right hemisphere or a general reduction in left-lateralized language processing (30-32).

Multiple neuroimaging studies have documented alterations in the typical cerebral torque configuration in individuals with schizophrenia compared to healthy controls (33). This asymmetry, normally reflected in the greater width of the right frontal and left occipital lobes relative to the opposite hemispheres, appears to be disrupted in schizophrenia. In healthy populations, cerebral torque contributes to establishing asymmetrical brain connectivity patterns (34). This structural asymmetry is thought to facilitate information flow within the brain, typically progressing from the left occipito-temporo-parietal region to the right occipito-temporo-parietal region, then to the right dorsolateral prefrontal cortex, and finally to the left dorsolateral prefrontal cortex. Consequently, it has been proposed that core features of schizophrenia may be linked to a disruption in this left-hemisphere-dominant network involved in language processing (34,35). These findings suggest potential neuropathological mechanisms underlying the observed loss of hemispheric lateralization in patients with schizophrenia.

In the present study, individuals with schizophrenia demonstrated no statistically significant differences in cortical pial surface area of the parietal lobes compared to controls ($F(1,131)=3.151$, $p=0.078$), nor any lateral asymmetry in either group ($p=0.543$). In contrast, parietal cortical thickness was significantly reduced in the schizophrenia group relative to controls ($F(1,132)=4.313$, $p=0.040$), again without side differences ($p=0.808$). These observations suggest that whereas the overall surface area of the parietal cortex remains unaffected, the cortex itself is subtly thinner in patients.

This pattern aligns with the broader neuroimaging literature, which shows that cortical thinning is a more robust and widespread feature of schizophrenia than surface area reduction, the latter being more regionally variable or even preserved in some cohorts. Meta analytic data from the ENIGMA consortium report robust reductions in cortical thickness (Cohen's $d\approx-0.53$ bilaterally) and smaller, more globally distributed reductions in surface area ($d\approx-0.25$), with the strongest effects observed in the frontal and temporal regions, and somewhat less pronounced changes in the parietal areas, as reported by van Erp et al. (36).

Similarly, in a large cohort of first episode, antipsychotic naive individuals with schizophrenia, significant cortical thinning was observed across the frontal and temporal cortices, while surface area showed no group differences. This reinforces the pattern of cortical thickness being the principal driver of volumetric change (37,38).

Studies focusing on high-risk or unaffected familial cohorts have shown preserved or even slightly increased cortical thickness alongside reduced surface area in fronto-parietal regions, supporting the idea that surface area alterations may reflect genetic liability, whereas thinning may be more closely tied to illness manifestation or progression (38,39).

By contrast, our findings in a Sudanese sample demonstrate preserved parietal cortical pial surface area despite reduced thickness. The consistency of lateral symmetry in both parameters further underscores the generalized rather than focal nature of these morphological differences.

Strengths of the Study

This study is among the first to investigate parietal lobe morphology in individuals with schizophrenia within a Sudanese population, addressing a major gap in African neuroimaging data. The use of high-resolution MRI and automated brain segmentation software allowed for objective assessment of gray matter, white matter, cortical thickness, and pial surface area. Statistical control for important confounders such as age, intracranial volume, and treatment status through repeated measures ANCOVA enhanced the validity of the results. Including both sexes and analyzing sex differences further strengthened the generalizability. By distinguishing between different parietal tissue components, the study provides a detailed profile of schizophrenia-related structural alterations.

Limitations of the Study

The cross-sectional design prevents conclusions about disease progression or causality. The moderate sample size, while adequate, limits subgroup analyses and statistical power. Minor inaccuracies may arise from automated segmentation tools, particularly in populations underrepresented in their development. The absence of cognitive or neuropsychological assessments restricts the ability to link structural changes to functional outcomes. Finally, the findings may not be generalizable beyond similar demographic and clinical settings, and replication in other populations is encouraged.

CONCLUSION

Patients demonstrated reduced mean parietal lobe volume relative to controls. In addition, average volumes of parietal gray and white matter were lower in the schizophrenia group. While the cortical pial surface area of the parietal cortex did not differ significantly between groups, cortical thickness in this region was notably reduced in patients.

Since large numbers of studies have showed variable results in measurements of the brain volume in schizophrenia, which may reflect effects of age, gender, illness chronicity, and neuroleptic medications as confounding factors in the pathophysiology of schizophrenia, future studies may gain greater insight by focusing on more homogeneous patient populations, incorporating analyses of sex-related differences, and performing detailed parcellation and assessment of specific subregions within the parietal lobes.

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