Altered Cortical Thickness Related to Clinical Severity But Not the Untreated Disease Duration in Schizophrenia

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Although previous studies have reported deficits in the gray matter volume of schizophrenic patients, it remains unclear whether these deficits occur at the onset of the disease, before treatment, and whether they are progressive over the duration of untreated disease. Furthermore, the gray matter volume represents the combinations of cortical thickness and surface area; these features are believed to be influenced by different genetic factors. However, cortical thickness and surface area in antipsychotic-naive first-episode schizophrenic patients have seldom been investigated. Here, the cortical thicknesses and surface areas of 128 antipsychotic-naive first-episode schizophrenic patients were compared with 128 healthy controls. The patients exhibited significantly lower cortical thickness, primarily in the bilateral prefrontal and parietal cortex, and increased thickness in the bilateral anterior temporal lobes, left medial orbitofrontal cortex, and left cuneus. Furthermore, decreased cortical thickness was related to positive schizophrenia symptoms but not to the severity of negative symptoms and the untreated disease duration. No significant difference of surface area was observed between the 2 groups. Thus, without the confounding factors of medication and illness progression, this study provides further evidence to support anatomical deficits in the prefrontal and parietal cortex early in course of the illness. The increased thicknesses of the bilateral anterior temporal lobes may represent a compensatory factor or may be an early-course neuronal pathology caused by preapoptotic osmotic changes or hypertrophy. Furthermore, these anatomical deficits are crucial to the pathogenesis of positive symptoms and relatively stable instead of progressing during the early stages of the disease.

Key words: schizophrenia/cortical thickness/first-episode/antipsychotic-naive/MRI

Introduction

Although schizophrenia is one of the leading worldwide causes of disability, the pathogenesis of the disease remains unclear. One hypothesis states that schizophrenia is caused by neurodevelopmental deficits. This hypothesis is supported by evidence including the early age of onset, some genetic deficits, and premorbid evidence that youth at high risk for schizophrenia are characterized by neurocognitive impairments1,2 and similar but less extensive structural brain abnormalities to those observed in patients with schizophrenia.3,4 In contrast, another hypothesis was put forth by Kraepelin, who described schizophrenia as a neuroprogressive disorder characterized by early-onset (“dementia praecox”) and deteriorating processes.5 This hypothesis is supported by many longitudinal studies that provide evidence of clinical deterioration and cerebral deficits over time, especially recently reported neuroimaging studies.6–8 which have shown progressive changes in brain structure in schizophrenia beyond the effects of age. However, the progressive volume loss that is frequently found in these studies is affected by the use of antipsychotic medications9,10 the small sample size of both patient and healthy control samples,11 as well as comorbidities and other secondary disease factors.12 Specifically, antipsychotic medications may reduce the regional cerebral volume in the frontal, temporal, and parietal lobes in both animals13,14 and humans.10,15 Thus, studying antipsychotic-naive
first-episode schizophrenia is crucial as a starting point for evaluating the progression of disease-related changes in the brain and for assessing brain anatomy and function before they can be influenced by potentially confounding factors. It may also help clarify the brain regions in which functional and anatomical changes are observed at disease onset to provide important, novel information that is relevant to models of pathogenesis.16

Most of the previous neuroimaging studies have examined gray matter volume in schizophrenic patients.17,18 Gray matter volume, however, is a product of cortical thickness and surface area; these features are believed to be influenced by different genetic factors related to sulcal or gyral patterning and the thickness of cortical mantle itself.19 Surface area mainly represents the number of columns within a cortical region,20 whereas cortical thickness reflects the size, density, and arrangement of neurons, neuroglia, and nerve fibres21,22 in the cortical columns. Disturbances in neurogenesis, neuronal migration, differentiation, and synaptogenesis have been found in schizophrenia;33,24 these deficits may affect the arrangement of the cortical laminae and cause morphological changes in the cortical thickness.25 Furthermore, from a methodological perspective, cortical thickness is measured using a surface-based method rather than volumetric techniques; although volume can be directly measured, partial volume effects must be considered.26 Thus, measurements of cortical thickness may be more sensitive than volume to provide important and relatively unique information about disease-specific neuroanatomical changes in schizophrenia. However, unlike gray matter volume, cortical thickness in first-episode antipsychotic-naive schizophrenia has seldom been investigated. Several neuroimaging studies have demonstrated significant cortical thinning, primarily in the frontal and temporal regions in both chronic26 and first-episode schizophrenic patients,22,23 and even in the unaffected first-degree relatives of schizophrenic patients26,29 although the results are inconsistent. Van Haren et al. found decreased cortical thickness to be related to outcome and medication as well as progressive over time.9 However, in a recent study, Wheeler et al. found reduced thickness in the bilateral dorsolateral prefrontal cortex in both chronic and first-episode schizophrenic patients, suggesting a structural impairment in schizophrenia that is independent of illness stage or medication exposure.30 In a recent study of 19 first-episode drug-naive schizophrenic patients, Goghari and her colleagues found an increase in rostral middle frontal thickness in patients after 4- and 8-week atypical antipsychotic treatment.31 Negative results have also been reported in another study of first-episode schizophrenia.32 Other than the effects of antipsychotic medication and disease progression, small effect sizes compared with large interindividual differences in smaller samples may contribute to the discrepancies among studies. Another important factor that may contribute to the inconsistent findings is the different proportion of patients with prominent negative symptoms across studies. This is important because these patients have different clinical manifestations and a diminished treatment response.33,34 Furthermore, different deficits in gray matter volume have been observed between patients with and without prominent negative symptoms.35

Thus, this study aimed to investigate differences of cortical thickness and surface area in a large sample of 128 first-episode drug-naive schizophrenic patients and 128 healthy controls. We hypothesized that (1) regional reductions in cortical thickness and surface area would be observed in the early stages of schizophrenia and (2) changes in cortical thickness and surface area would be related to clinical severity and the duration of untreated disease and may be different between patients with and without prominent negative symptoms.

Methods

Participants

One hundred twenty-eight antipsychotic-naive first-episode schizophrenic patients (78 females, mean age 24.3 ± 8.1 years) and 128 healthy controls (65 females, mean age 26.1 ± 8.3 years) were recruited via the Mental Health Centre of West China Hospital, which is the largest hospital in China. The study was approved by the ethics committee of West China Hospital, and written informed consent was obtained from all subjects before participation. Diagnosis of schizophrenia and the duration of untreated disease were determined by consensus between 2 experienced psychiatrists (W.D. and X.H.) using the Structured Clinical Interview for DSM-IV (SCID)-Patient Version. In addition, diagnoses for all the patients were confirmed after ≥1-year follow-up. The Positive and Negative Syndrome Scale (PANSS) score for 1 patient and the disease courses of 10 patients were unavailable at the time of examination due to the severity of the disease in these patients. Healthy controls were recruited from the local area through poster advertisements and screened using the SCID-Non-Patient Version to confirm the lifetime absence of psychiatric and neurological illness. Additionally, healthy subjects were interviewed to confirm that there was no history of psychiatric illness among their first-degree relatives. Exclusion criteria for both groups were (1) the existence of a neurological disorder or other psychiatric disorders; (2) alcohol or drug abuse (DSM-IV); (3) pregnancy; and (4) any chronic physical illness such as a brain tumor, hepatitis, or epilepsy, as assessed by clinical evaluations and medical records. Magnetic resonance (MR) images were firstly inspected by an experienced neuroradiologist (S.L.) after MR examination to check image quality and exclude possible gross cerebral abnormalities in either group. The psychosocial functioning of patients was assessed using the Global Assessment of Functioning.
The PANSS, which determines positive and negative symptom scores, a total score and general psychopathology symptoms, as well as indices of thought disturbance, activation, paranoid, depression, anergia, and impulsive aggression, was also completed to evaluate the current clinical symptoms of patients. Demographic information of age, gender, handedness, educational years, and clinical data were acquired by 2 experienced clinical psychiatrists (W.D. and X.H.) prior to MR scans. All participants were right-handed as assessed using the Annett Handedness Scale. Demographic and clinical characteristics of all participants are shown in Table 1. No significant differences in age, gender, and educational years were found between the 2 groups at the statistical threshold of \( P < .05 \).

**MRI Data Acquisition**

High-resolution T1-weighted images were acquired using a 3T MR imaging system (EXCITE, General Electric, Milwaukee) with a volumetric 3D Spoiled Gradient Recall (SPGR) sequence (TR = 8.5 ms, TE = 3.4 ms, Flip angle = 12°, slice thickness = 1 mm) using an 8-channel phase-array head coil. A field of view of \( 240 \times 240 \text{mm}^2 \) was used with an acquisition matrix comprising 256 readings of 128 phase-encoding steps, producing 156 contiguous coronal slices with slice thickness of 1.0 mm. The final matrix of T1-weighted images was automatically interpolated in plane to \( 512 \times 512 \), which yields an in-plane resolution of \( 0.47 \times 0.47 \text{mm}^2 \).

**Image Processing**

We used the CIVET software (version 1.1.9, Montreal Neurological Institute at McGill University, Montreal, Quebec, Canada) to extract cortical thickness and surface area measurements from T1-weighted MR images. The original images were first registered to stereotaxic space using linear transformation, whereas nonuniformity artefacts were corrected using the N3 algorithm. The registered and corrected images were then automatically segmented into gray matter, white matter, cerebrospinal fluid, and background using an advanced neural net classifier. The inner and outer gray matter surfaces, totaling 81924 polygons (40962 vertices in each hemisphere), were then automatically extracted from each MR volume using the constrained Laplacian-based automated segmentation with proximities algorithm. Cortical thickness was thus defined as the distance between linked vertices of the inner and outer surfaces. Finally, a

| Table 1. Demographic and Clinical Characteristics of Antipsychotic-Naive First-Episode Schizophrenic Patients and Healthy Comparison Subjects |
|-----------------|-----------------|-----------------|-----------------|
| Characteristic   | SCZ (\( N = 128 \)) | HC (\( N = 128 \)) |
| Age (years)      | 24.26 ± 8.07    | 26.13 ± 8.35    | .07             |
| Education (years)| 12.14 ± 2.91    | 12.92 ± 3.42    | .06             |
| Duration of illness (months) | 11.49 ± 22.01 | 12.92 ± 3.42 | .06             |
| GAF scores       | 29.42 ± 11.07   |                  |                 |
| PANSS scores     |                  |                  |                 |
| Total            | 96.39 ± 19.15   | 12.92 ± 3.42    | .06             |
| Positive symptoms| 25.34 ± 6.14    |                  |                 |
| Negative symptoms| 18.44 ± 8.19    |                  |                 |
| General psychopathology symptoms | 46.32 ± 10.11 |                  |                 |
| Thought disturbance| 14.11 ± 3.88  |                  |                 |
| Activation       | 9.2 ± 3.41      |                  |                 |
| Paranoid         | 10.37 ± 2.87    |                  |                 |
| Depression       | 8.58 ± 4.1      |                  |                 |
| Anergia          | 8.46 ± 4.3      |                  |                 |
| Impulsive aggression | 16.31 ± 5.33 |                  |                 |
| Gender           |                  |                  |                 |
| Female           | 78              | 60.9            | 65              | 50.8            | .102
| Male             | 50              | 39.1            | 63              | 49.2            | .102

**Note:** GAF, Global Assessment of Functioning Scale; HC, healthy control participants; PANSS, Positive and Negative Syndrome Scale; SCZ, schizophrenic patients; SD, standard deviation.
20-mm smoothing kernel was applied to improve sensitivity.\(^{46}\) These cortical thickness extracting approaches have been validated using both manual measurements\(^ {47}\) and simulation approaches.\(^ {45,48}\) Surface area was measured at the middle cortical surface, which lies at the geometric center between the inner and outer cortical surfaces and thus provides a relatively unbiased representation of sulcal versus gyral regions.\(^ {49,50}\) This gives the surface area of every vertex in the surface mesh, which can be summed to give the lobar surface areas.

**Statistical Analysis**

Differences in age and education levels between the 2 groups were assessed using 2-sample \(t\) tests, whereas gender differences were compared using the chi-squared test. A vertex-based 2-sample \(t\) test was used to investigate cortical thickness and surface area differences between the patient group and the healthy control group, with age and sex as covariates. Significance was set to \(P < .05\) corrected for multiple comparisons using false discovery rate correction.

The averaged cortical thickness in regions with altered thickness was extracted and input into SPSS Statistics 17.0 software along with other clinical characteristics. Then, a Pearson correlation analysis was performed considering the averaged cortical thickness in regions with altered thickness, the scaled scores obtained on the PANSS and GAF, and the duration of untreated disease to reveal potential associations between anatomical deficits and clinical symptoms, psychosocial function, and the duration of untreated disease. The level of significance was set to \(P < .05\). The averaged duration of untreated disease was 11.5 months (SD = 22.0; range from 0.03 to 144 months). For analysis of the effect of untreated disease duration, we divided the patients into 2 subgroups in terms of the disease course, ie, the shorter course subgroup (with untreated disease duration < 12 months: 81 cases) and the longer course subgroup (with untreated disease duration ≥ 12 months: 37 cases; 12–24 months: 13 cases; 24–36 months: 12 cases; 36–144 months: 12 cases). For analysis of the associations between cortical thickness and negative symptom severity, patients were divided into 2 subgroups: 44 patients with prominent negative symptoms (a score ≥ 20 on the negative symptom subscale of the PANSS\(^ {37,51}\); 26 females, mean age 24.9 years) and 83 patients without prominent negative symptoms (a score < 20 on the negative symptom subscale of the PANSS; 51 females, mean age 24.0 years). Two-sample \(t\) tests were performed to explore the differences in cortical thickness between the patient subgroups.

**Results**

**Changes in Patient Cortical Thickness and Surface Area**

Compared with controls, patients exhibited significantly reduced cortical thickness, primarily in the right dorsolateral prefrontal cortex (DLPFC), left precentral gyrus, left orbitofrontal cortex (OFC), left inferior frontal gyrus pars triangularis, and right precentral and postcentral gyri (\(P < .05\), corrected for multiple comparisons; figure 1, supplementary table 1). In addition, significant cortical thickening was found in the bilateral anterior temporal lobes, the left medial orbitofrontal cortex (med-OFC), and the left cuneus in patients compared with controls (\(P < .05\), corrected for multiple comparisons; figure 1, supplementary table 1). No significant difference of surface area was found between the 2 groups.

**Correlations Between Changes in Cortical Thickness and Clinical Symptoms**

Within the patient group, the average cortical thickness of the regions with reduced cortical thickness, ie, the right DLPFC, bilateral precentral gyri, left OFC, and left inferior frontal gyrus pars triangularis, was negatively correlated with symptom severity, as identified by the PANSS scores. This was especially true for positive symptoms (figure 2), whereas the average cortical thickness within the regions with increased cortical thickness and the right postcentral gyrus was not correlated to the scale scores of PANSS or GAF. Subgroup analysis demonstrated that there was no significant difference in cortical thickness between patients with and without prominent negative symptoms (\(P > .05\)).

**Relationship Between Cortical Thickness and the Duration of Untreated Disease**

To investigate the potential effects of duration of untreated disease on cortical thickness, we used a Pearson correlation analysis to quantify the relationship between the duration of untreated disease and changes in cortical thickness. However, no significant correlation was observed between the cortical thickness in each region with altered thickness and the duration of untreated disease (\(P > .05\), supplementary table 2). Furthermore, patients with shorter duration of untreated disease (<12 months, 81 cases) exhibited no significant differences compared with patients with longer duration of untreated disease (≥12 months, 37 cases) (\(P > .05\)).

**Discussion**

This study includes the largest sample of antipsychotic-naive first-episode schizophrenia to date, and the patients exhibited both regional cortical thinning and thickening in widespread areas, including the bilateral prefrontal and temporal cortices. Furthermore, the cortical thinning of the right DLPFC, left OFC, left inferior frontal gyrus pars triangularis, and bilateral precentral gyri was negatively correlated with the severity of clinical symptoms, as identified by PANSS scores (figure 2). This finding suggests that widespread cortical deficits occurring in the early stages of schizophrenia may be crucial to the pathogenesis of the disease. However, the cortical thickening of the bilateral anterior temporal lobes, left med-OFC,
**Fig. 1.** Differences in cortical thickness between untreated first-episode schizophrenic patients and healthy controls. Significant group differences were identified using a vertex-based 2-sample *t* test with age and sex as covariates (*P* < .05, corrected for multiple comparisons with false discovery rate). Reduced cortical thickness was found in the following regions (labeled in blue): the right dorsolateral prefrontal cortex, left precentral gyrus, left orbitofrontal cortex, left inferior frontal gyrus pars triangularis, and right precentral and postcentral gyri. Increased cortical thickness was observed in the following regions (labeled in red): The bilateral anterior temporal lobes, left medial orbitofrontal cortex, and left cuneus in schizophrenic patients compared with healthy controls.

**Fig. 2.** The relationship between cortical thickness and clinical symptoms in antipsychotic-naive first-episode schizophrenic patients. Scatter plots and regression slopes representing the cortical thickness of the right dorsolateral prefrontal cortex, bilateral precentral gyri, left orbitofrontal cortex, and left inferior frontal gyrus pars triangularis. The cortical thickness of these areas was negatively correlated with the severity of clinical symptoms, as identified by Positive and Negative Syndrome Scale scores for positive symptom scores, thought disturbances, or activation (*P* < .05).
and left cuneus was not correlated with the scale scores. Furthermore, these changes in cortical thickness were not related to the duration of untreated disease ($P > .05$, supplementary table 2) or the severity of negative symptoms. These findings were consistent with a recent meta-analysis, suggesting that the longitudinal gray matter volume decreases in schizophrenic patients are associated with higher cumulative exposure to antipsychotic overtime instead of duration of illness. There was no significant difference of surface area between the 2 groups, which was consistent with the findings in a recent study of schizophrenia, suggesting that the alterations in cortical thickness are more pronounced than those in surface area during the early stage of schizophrenia.

The most prominent cortical thinning was observed in the bilateral prefrontal regions, which agrees with the results of previous studies of cortical thickness or volume in medicated first-episode schizophrenia. However, previous volumetric studies of drug-naive first-episode schizophrenia reported no significant differences in frontal volumes between patients and controls. Negative results of frontal thickness have also been reported in another study of first-episode schizophrenia. Thus, it is still unclear whether the observed changes in the bilateral prefrontal regions are disease related or the effect of medication. In fact, a recent study of 19 first-episode drug-naive schizophrenics found an increase in rostral middle frontal thickness in patients after 4- and 8-week atypical antipsychotic treatment. However, Wheeler et al. found reduced thickness in the bilateral DLPFC in both chronic and first-episode schizophrenic patients, suggesting the structural impairment in schizophrenia is independent of disease stage or medication exposure. By studying the largest sample of antipsychotic-naive first-episode schizophrenics to date, this study further confirmed the cortical thinning of the bilateral prefrontal cortex as an early-course characteristic of schizophrenia before treatment. Furthermore, unlike the negative findings from the volumetric studies of drug-naive first-episode schizophrenia, the observed cortical thickness changes of the bilateral prefrontal cortex in these drug-naive first-episode patients provided evidence to support the notion that cortical thickness may be more sensitive than volume to reveal cortical changes, especially early in the duration of the disease. In fact, the gray matter volume of a cortical region represents the combination of its cortical thickness and surface area; these features are believed to be influenced by different genetic factors that are related to gyral and/or sulcal patterning and the thickness of the cortical mantle itself. Conversely, cortical thickness can provide more details reflecting the size, density, and arrangement of neurons, neuroglia, and nerve fibres in cortical columns. Furthermore, cortical volume is measured using volume-based techniques that directly measure cortical volumes, and partial volume effects must therefore be considered, cortical thickness is measured using surface-based techniques that can acquire data at a subvoxel resolution.

The reduced cortical thickness of the right DLPFC, bilateral precentral gyri, left OFC, and left inferior frontal gyrus pars triangularis was negatively correlated with symptom severity, as identified by the PANSS scores. This finding suggests that reduced cortical thickness, especially in the prefrontal regions, may predispose patients to specific symptoms. Thus, the anatomical deficits in the prefrontal and parietal regions may represent core pathology during the early course of schizophrenia. In fact, the prefrontal cortex and, particularly, the DLPFC play an important role in managing many executive functions, such as working memory, response inhibition, and goal-directed behaviors. These cognitive abilities are typically disturbed in schizophrenia. In addition to the DLPFC, the OFC has been proposed to be involved in sensory integration, the representation of affective values of reinforcers, decision making, and expectation. The precentral and postcentral gyri comprise the locations of the primary motor cortex and primary somatosensory cortex, respectively, and have been reported to be inefficient in schizophrenia by fMRI. Furthermore, the left inferior frontal gyrus pars triangularis is part of Broca’s area, which plays a role in language and interpersonal information processing. Reduced volumes of the inferior frontal cortex pars triangularis were observed in subjects with first-episode schizophrenia compared with the healthy controls; additionally, these reduced volumes were suggested to represent a risk factor for schizophrenia. Although the exact mechanism of cortical thinning is not yet well understood, a newly published postmortem study provides convincing evidence to support that reduced pyramidal layer thickness may result in the decreased thickness of the frontal lobe in schizophrenia. Pyramidal neurons are the principal output cells of the cortex, and their functions are associated with advanced cognitive functions; therefore, any alterations in these cells may result in aberrant intra- and intergyral connectivity, resulting in the disordered symptoms of schizophrenia. A pathologically extended pruning processes and sublethal apoptotic activity have been suggested to be involved in the process of gray matter loss in schizophrenia. Reduced blood flow in the prefrontal cortex (ie, bilateral DLPFC, medial frontal cortex, and left OFC) and parietal cortex in neuroleptic-naive schizophrenia may also be considered another contributor to cortical thinning.

Another interesting finding was greater cortical thickness of the bilateral anterior temporal lobes, left medial-OFC, and left cuneus in patients compared with controls, which appeared to contradict the findings of thinner cortices and reduced gray matter volume in the temporal lobes of first-episode schizophrenic patients. A newly published study of a large sample of first-episode schizophrenic patients also found increased gray matter volumes in the left med-OFC. One possible explanation
is that cortical thickening may represent a compensa-
tory factor\textsuperscript{[69]} that is meant to protect against psychosis
related to the early phase of schizophrenia. However, the
increased cortical thickness was not correlated to clinical
symptoms. Another possible explanation may be asso-
ciated with the synaptic pruning neurodevelopmental
model of schizophrenia,\textsuperscript{[67]} which states that schizophrenia
arises from insufficient synaptic pruning.\textsuperscript{[66,68]} Insufficient
synaptic or axonal pruning, which leaves more synapses
or axon branches intact compared with typical neurode-
velopment, may induce cortical thickening in schizophre-
nia. Third, given that the patients in this study were early
in the duration of disease (mean duration of untreated
disease = 11.49 months), possible early-course pathol-
gy, such as preapoptotic osmotic changes or hypertro-
phy, could increase regional tissue.\textsuperscript{[69]} However, the exact
pathological mechanisms underlying cortical thickening
in the early stages of schizophrenia require further study.

No significant correlations were found between altered
cortical thickness and duration of untreated disease; addi-
tionally, no significant differences in cortical thick-
ness were noted between patients with shorter duration
of untreated disease and those with longer duration of
untreated disease. This appears to contradict the hypoth-
esis that schizophrenia is a progressive disease in which
cerebral structures deteriorate over time.\textsuperscript{[5]} Although
progressive clinical symptoms and further decreases in
brain tissue have been reported in many longitudinal
studies,\textsuperscript{[6,7,9,70]} the results of these investigations were con-
founded by the effects of antipsychotic medication, sub-
stance abuse, prolonged duration of disease and stress,
as well as other factors that were secondary to the dis-
ease. Although some studies have demonstrated that age-
related gray matter reductions occur in schizophrenia,\textsuperscript{[56]}
no evidence of disease progression has been found.\textsuperscript{[56,72,73]}
Especially, a recent meta-analysis of the effect of anti-
psychotics on schizophrenia found that the longitudinal
gray matter volume decreases in schizophrenic patients
were associated with higher cumulative exposure to anti-
psychotic over time, whereas no effects were observed
for duration of illness.\textsuperscript{[52]} Thus, current findings provided the
direct evidence to support that the cortical deficits in
schizophrenia are relatively stable instead of progressing
during the early stages of the disease. In fact, our previ-
ous study of first-episode untreated schizophrenia dem-
onstrated that gray matter volume was not correlated
with the untreated disease duration.\textsuperscript{[35]} Evidence from a
number of clinical studies also contradicts the hypothesis
that schizophrenia is a progressive disease. For example,
cognitive functioning, which is certainly impaired in
schizophrenic patients compared with healthy controls,
does not appear to worsen over time.\textsuperscript{[12,74]} On the contrary,
most patients exhibit the potential to remit and experi-
ence functional recovery. Reports that some schizophrenic
patients experience deterioration may reflect poor access
or adherence to treatment, the effect of comorbidities,
poverty, and a lack of social support.\textsuperscript{12} Our findings fur-
ther suggest that the anatomical changes associated with
schizophrenia may be relatively stable or evolve slowly in
the early stages of schizophrenia\textsuperscript{[35]} and may thus be con-
sidered a relatively objective biomarker for early diagno-
sis. However, it is possible that different neuropathological
mechanisms exist that may be associated with progressive
anatomical changes occurring in the later stages of the ill-
ness. Because a longitudinal study of antipsychotic-naive
schizophrenia is unethical, cross-sectional designs includ-
ing longer duration of untreated disease, up to as many
as 5 or 10 years, may be the optimal way to detect and
confirm the relationship between structural neuroanatomi-
cal changes and the duration of disease and to reveal the
nature of pathophysiological processes in schizophrenia.

No significant correlations were found between altered
cortical thickness and the negative symptom subscale of
the PANSS; additionally, no significant differences in
cortical thickness were noted between patients with and
without prominent negative symptoms. These findings
suggest that these cortical thickness deficits occurring in
the early stages of schizophrenia may be crucial to the
pathogenesis of positive symptoms instead of negative
symptoms. This is consistent with previous findings in
treated and untreated schizophrenia,\textsuperscript{[35,75,76]} which also sug-
gested that negative symptoms have a different mecha-
nism of pathogenesis from positive symptoms. However,
the exact pathological mechanisms underlying the nega-
tive symptoms in schizophrenia require further study.

Two issues must be addressed to explain the current
findings. First, due to the limitations associated with the
research methodology, no subcortical regions, which may
also be affected by aberrant neurodevelopmental mecha-
nisms, were investigated. For example, the thalamus
provides critical inputs to brain regions such as the prefrontal,
cingulate, and temporal cortices, and thalamic deficits
have been reported in schizophrenic patients via both
neuroimaging\textsuperscript{[8,18]} and postmortem studies.\textsuperscript{[77]} Further-
more, although the duration of untreated disease ranged from
0.03 to 144 months, the majority of the durations of
untreated disease in our sample were limited to within
36 months (106 cases). Similarly, the distribution of
the duration of untreated disease was not symmetrical in our
sample. Samples including patients with longer duration of
untreated disease, such as 5–10 years, are relatively small.
Thus, our study mainly revealed anatomical changes that
are specific to the early stages of schizophrenia.

This study provided the first empirical evidence of
widespread differences in cortical thickness, including
both thinning and thickening, in the largest sample of
antipsychotic-naive first-episode schizophrenic patients
to date. Furthermore, these anatomical changes were
related to the positive symptoms observed in schizophre-
nia, but not to the duration of untreated disease or the
severity of negative symptoms. This finding suggests that
these anatomical deficits are crucial to the pathogenesis
of positive symptoms and may be relatively stable in very early stages of the disease. However, it remains unclear whether these deficits are progressive in patients with longer untreated disease duration of schizophrenia. Further study of antipsychotic-naive patients with longer duration of untreated disease may help clarify the effect of disease duration on the brain in the later stages of disease as well as the natural dynamic of disease progression in schizophrenia.

Supplementary Material

Supplementary material is available at http://schizophreniabulletin.oxfordjournals.org.

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