Chapter 15
Autism Diagnostics by 3D Shape Analysis of the Corpus Callosum

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ABSTRACT

The importance of accurate diagnostics of autism that severely affects personal behavior and communication skills cannot be overstated. Neuropathological studies have revealed an abnormal anatomy of the Corpus Callosum (CC) in autistic brains. This chapter proposes a new approach to quantitative analyses of three-dimensional (3D) Magnetic Resonance Images (MRI) of the brain that ensures a more accurate quantification of the anatomical differences between the CC of autistic and normal subjects. It consists of three main processing steps: (1) segmenting the CC from a given 3D MRI using the learned CC shape and visual appearance; (2) extracting a centerline of the CC; and (3) cylindrical mapping of the CC surface for its comparative analysis. The authors' experiments revealed significant differences (at the 95% confidence level) between 17 normal and 17 autistic subjects in four anatomical divisions (i.e. splenium, rostrum, genu, and body of their CCs). Moreover, the initial classification results suggest that the proposed centerline-based shape analysis of the CC is a promising supplement to the current techniques for diagnosing autism.

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INTRODUCTION

Autistic Spectrum Disorder (ASD), or autism, is a complex neurological disability characterized by qualitative abnormalities in behavior and higher cognitive functions (Brambilla, 2003). It typically appears during the first three years of life and impacts development of social interaction and communication skills. Each individual is affected differently at varying degrees, from milder forms in which intellectual ability is high but social interaction is low, to the most severe cases typified by unusual, self-injurious, and aggressive behaviors. The latter may persist throughout life and inflict a heavy burden on those who interact with autistic persons. Cognitive impairments may also last over time and often result in mental retardation in the majority of autistic individuals (Minshew, 1988).

Autism is not a rare disorder, as once was thought. According to the Centers for Disease Control and Prevention (CDC), about 1 in 110 American children fall somewhere in the autistic spectrum. Although the cause of autism is still largely not clear, researchers have suggested that genetic, developmental, and environmental factors may be the cause or the predisposing effects towards developing autism (Stevens, 2000). No current cure is specifically designed for autism. However, educational, behavioral, or skill-oriented therapies were designed to remedy specific symptoms in each individual. Such therapies can result in substantial improvement, particularly when started at a young age.

Our approach: To identify whether the abnormal neural development of the CC is associated with autism, we compare directly the 3D surfaces of the CC for normal and autistic subjects. To the best of our knowledge, all the previous works (as demonstrated in the background section) have focused on analyzing either the 2D cross section of the midsagittal of the CC or the midsagittal slice along with four adjacent slices on both sides. Unfortunately, this is insufficient for detecting the whole anatomic variability of the CC of autistic subjects. To ensure a complete 3D analysis, the whole CC surface (traced from all the slices in which the CC appears) is mapped onto a cylinder in such a way as to compare more accurately various autistic and normal CCs. Our cylindrical mapping has been inspired by the functional conformal mapping (Schinzinger, 2003). Similar to the conformal mapping, it is a bijective (one-to-one) transformation and preserves angular relationships between the points. For these reasons, the conformal mapping was recently considered an efficient technique for surface matching (Wang, 2007) and visualization of various anatomic structures (Hong, 2006). In addition, in this chapter the CC length was estimated and used as a discriminatory feature between autistic and normal subjects. Moreover, the initial classification results based on the estimated centerline length suggest that the proposed centerline-based shape analysis of the CC is a promising supplement to the current techniques for diagnosing autism.

BACKGROUND

Neuropathological and neuroimaging studies have revealed a great deal concerning the pathogenesis of autism. An overview of these studies as well as the proposed approach for analyzing MRI images of autistic and control subjects is illustrated below.

Neuropathology of Autism

During the past two decades, the study of autism's neuropathology has dramatically intensified. Most studies have reported alterations in some regions of the brains in the autistic individuals compared to typically developing ones. Increased head size was the first observed characteristic in children with autism 60 years ago (Kanner, 1943). Since then, several studies have reported enlarged brain size and Head Circumference (HC) in autistic patients. Postmortem studies have revealed evidence of increased brain weight, while bigger brain volume