

Chapter 67

Analysis of 3D Corpus Callosum Images in the Brains of Autistic Individuals

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ABSTRACT

Autism spectrum disorder (ASD) is a complex neurodevelopmental disorder that is characterized by abnormalities in behavior and higher cognitive functions. The corpus callosum (CC) is the largest fiber bundle that connects the left and the right cerebral hemispheres of the human brain. Several studies have revealed an abnormal anatomy of the CC in the brains of autistic individuals that associates this neurodevelopmental condition with impaired communication between the hemispheres. In this chapter, we develop a framework to analyze the CC of autistic individuals in order to provide a diagnostic tool for autism. The key advantage of this approach is the development of a cylindrical mapping that offers simplified coordinates for comparing the brains of autistic individuals and neurotypicals. Experimental results showed 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 centerline-based shape analysis of the CC documented a promising supplement to the current techniques for diagnosing autism.

INTRODUCTION

Developmental brain disorders are among the most interesting and challenging research areas in modern neuroscience. In 2006-2008, about 1 in 6 children in the U.S. had a developmental disability (Boyle, 2011). Autistic Spectrum Disorder (ASD), or autism, is an extremely complicated example of such a disorder that affects the US population and is reported in all racial, ethnic, and socioeconomic groups.

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According to the Centers for Disease Control and Prevention (CDC), about 1 in 88 American children fall somewhere in the autistic spectrum. ASD is 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).

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.

The importance of accurate diagnostics of autism cannot be overstated. Research studies have revealed an abnormal anatomy of the Corpus Callosum (CC) brain structure in autistic brain (Egaas, 1995; Piven, 1997; Manes, 1999; Hardan, 2000; Chung, 2004; He, 2007; He, 2008; Vidal, 2006). In this chapter, our goal is to analyze the CC brain structure in order to provide an accurate diagnosis tools for autism. Unlike the 2D CC analysis methods, 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 will be 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. However, these techniques can't account for 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 (Elnakib, 2010a, Elnakib, 2011; El-Baz, 2011; Casanova, 2011; Elnakib, 2012a). Our cylindrical mapping was engendered by the idea of 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 centerline length is 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

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 and macrocephaly, defined as HC above the 97th percentile (Aylward,

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