ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 8, Issue, 03, pp. 28554-28557, March, 2016

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

VARIATIONS IN MORPHOLOGY OF CEREBRAL HEMISPHERES AND THEIR CLINICAL IMPLICATIONS WITH SPECIAL REFERENCE TO POLYGYRIA

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ARTICLE INFO

Article History:
Received 17th December, 2015
Received in revised form
05th January, 2016
Accepted 22ed February, 2016
Published online 31st March, 2016

Key words:

Polygyria,
Cerebral hemisphere,
Asymmetry,
Mental retardation.

ABSTRACT

Polygyria is a developmental anomaly of the brain characterized by development of numerous small gyri. It is a neuronal migration cortical organization disorder which is often sporadic or genetic but is also seen secondary to vascular compromise. In the present study, 100 brain specimens fixed in 10% formalin were studied extensively in the department of Anatomy, Lady Hardinge Medical College, New Delhi and the pattern of sulci and gyri of the two cerebral hemispheres with their variations were identified and photographed. We observed an abnormal pattern of sulci and gyri in the form of polygyria on the medial surface of the cerebral hemisphere in the occipital and frontal lobes in 2% cases. The length of the corpus callosum and frontal-occipital pole diameter of one hemisphere was more than that of the other in 1% cases. The association of polygyria with unequal size of cerebral hemispheres is a rare presentation. These presentations are associated with numerous neurological deficits like mental retardation, seizures, spastic hemiparesis or quadriparesis etc. which may be of relevance to physicians, neurologists, neurosurgeons and radiologists.

Citation: Athira, P. A., Mangala Kohli, Reeha Mahajan, Anita Tuli and Mukta Rani, 2016. "Variations in morphology of cerebral hemispheres and their clinical implications with special reference to Polygyria", *International Journal of Current Research*, 8, (03), 28554-28557.

INTRODUCTION

Normal brain consists of two cerebral hemispheres of equal sizes separated by median longitudinal fissure. Brain may be associated with asymmetry in size, abnormal structural features and malformations which may lead to specific neurological symptoms. Malformations of cortical development have been of interest to clinicians and neuroscientists for many decades (Friede, 1989; Sarnat, 1992; Norman *et al.,* 1995). Polygyria or polymicrogyria is a developmental anomaly of the brain characterized by development of numerous small gyri. It occurs due to the abnormalities during late neuronal migration and early cortical organization and is characterized by abnormal cortical lamination. It is often sporadic or genetic but is also seen secondary to vascular compromise, intrauterine cytomegalovirus infection, mental retardation syndromes including Adams-Oliver syndrome, Arima syndrome, Delleman syndrome, Zellweger syndrome, multiple sclerosis, Fukuyama congenital muscular dystrophy, etc. It is often associated with schizencephaly.

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Polymicrogyria has heterogenous clinical manifestations which is associated with epilepsy, motor dysfunction and mental retardation. The most common manifestation is seizures which is seen in 50 to 85% patients. The present work endeavours to study the gross features of cerebral hemispheres and to find out the incidence of variations in sulci and gyri in north Indian population.

MATERIALS AND METHODS

The study was piloted on 100 brain specimens (200 cerebral hemispheres) fixed in 10% formalin, obtained from cadavers(50 male and 50 female) within the age group of 20-70 years (belonging to North Indian population), in the department of Anatomy, Lady Hardinge Medical college, New Delhi. The cadavers with history of head injury were excluded from the study. After proper ethical considerations, brain specimens were first collected and studied macroscopically for any gross malformation and later the two hemispheres were separated by dissecting the corpus callosum by a sharp brain knife. The size of the two cerebral hemispheres of each brain specimen along with the distance of anterior end (genu) and posterior end (splenium) of corpus callosum from frontal and occipital poles respectively were measured with the help of vernier caliper

(6″ 150mm Digital LCD Caliper Gauge micrometer metal housed) and compared. The pattern of the sulci and gyri of the two cerebral hemispheres were studied extensively on all the surfaces of each cerebral hemisphere, including the superolateral, medial and inferior surfaces. The variations were noted and photographed (Fig.1). The measurements were taken double-blindedly by two authors and the mean ± S.D was calculated.

hemisphere, an H-shaped sulcus with supplementary gyri were observed in the cuneus region on the left side, in addition to the other sulci, seen normally in the occipital lobe (Fig. 4). Also, similar unnamed gyri were observed in occipital region of another hemisphere. In the same brain, the length of the corpus callosum (CC) and frontal-occipital pole diameter of the left cerebral hemisphere was more than that of the right while

Table 1. Comparison of average measurements of both cerebral hemispheres

Measurements	Left hemisphere	Right hemisphere
Frontal pole- occipital pole distance	18.02 ± 0.6cm	18.04 ± 0.5cm
Frontal pole to anterior end of corpus callosum	3.24 ± 0.5 cm	3.26 ± 0.4cm
Occipital pole to posterior end of corpus callosum	5.24 ± 0.4cm	5.27 ± 0.4cm
Length of corpus callosum	9.60 ± 0.5cm	9.57 ± 0.4cm
Superomedial border to anterior end of corpus callosum	4.46 ± 0.3cm	4.42 ± 0. 3cm
Superomedial border to posterior end of corpus callosum	5.45 ± 0.4cm	5.42 ± 0.3cm
Superomedial border to midpoint of corpus callosum	4.34 ± 0.3cm	4.36 ± 0.3cm

Table 2. Comparison of various measurements of both cerebral hemispheres in the brain with asymmetry in size

Measurements	Left hemisphere	Right hemisphere
Frontal pole- occipital pole distance	19.08 ± 0.6cm	17.84 ± 0.5cm
Frontal pole to anterior end of corpus callosum	3.48 ± 0.3 cm	3.41 ± 0.2cm
Occipital pole to posterior end of corpus callosum	6.01 ± 0.4cm	5.53 ± 0.4cm
Length of corpus callosum	9.6 ± 0.5cm	8.90 ± 0.4cm
Superomedial border to anterior end of corpus callosum	4.26 ± 0.3cm	4.42 ± 0. 3cm
Superomedial border to posterior end of corpus callosum	5.08 ± 0.4cm	5.42 ± 0.2cm
Superomedial border to midpoint of corpus callosum	4.07 ± 0.2cm	4.36 ± 0.3cm

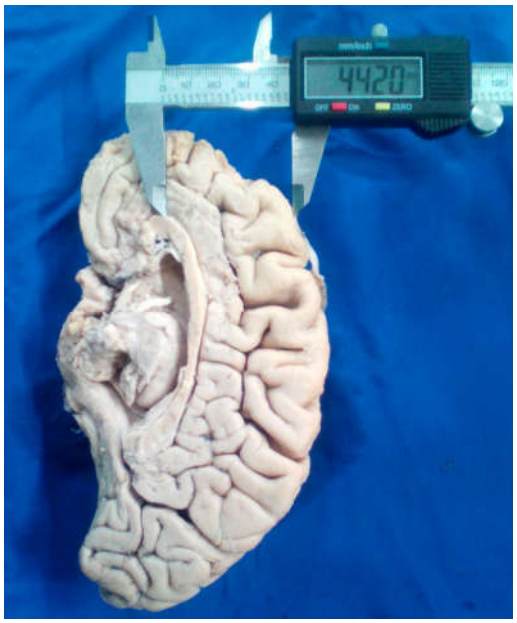

Fig. 1. Measurements taken using digital calipers from the genu to the superomedial border of cerebral hemisphere

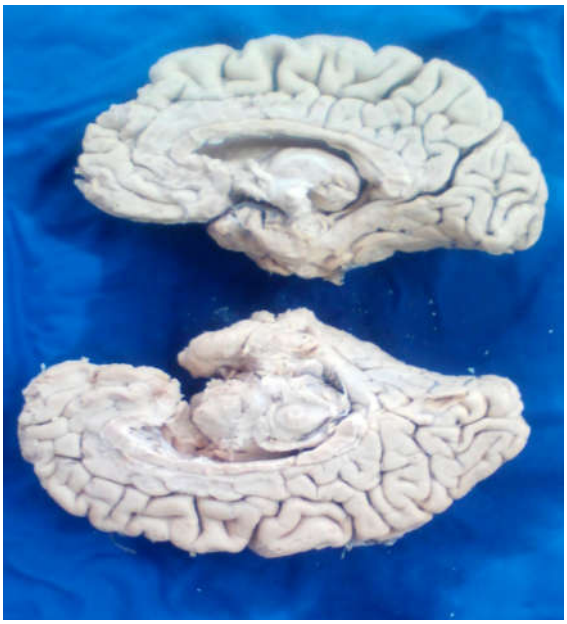

Fig. 2. Unequal cerebral hemispheres

RESULTS

We observed asymmetry in the size of cerebral hemispheres in the form of unequal cerebral symmetry in 1% of brain specimens (Fig.2) and an abnormal pattern of sulci and gyri on the medial surface of the cerebral hemisphere in the occipital and frontal lobes in 2% cases. We observed numerous additional, unnamed sulci and gyri in the frontal lobes of left hemispheres of two (2%) brains (Fig. 3). In one cerebral

vertical dimensions taken from genu, body and splenium of the CC to superomedial border of the LCH were less than that of the right. The gyral pattern of the right cerebral hemisphere of the same brain appeared normal (Table 1). All these findings were seen in brain specimens of male cadavers. Various measurements of the brain with unequal cerebral hemispheres have been compared (Table 2) along with average measurements of the two cerebral hemispheres of the other brains (Table 1).

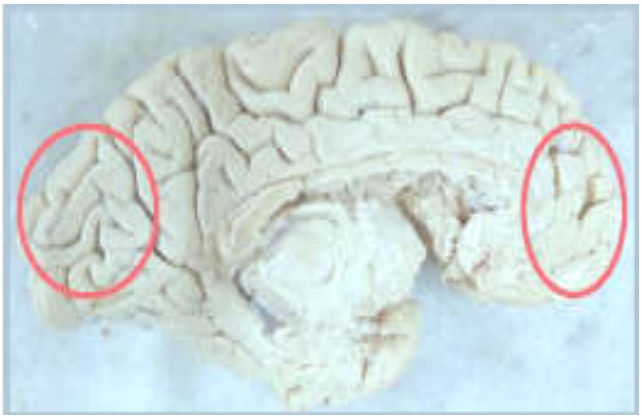

Fig. 3. Polygyria in the frontal (oval area) and cuneus region (circular area) on the medial surface of left cerebral hemisphere

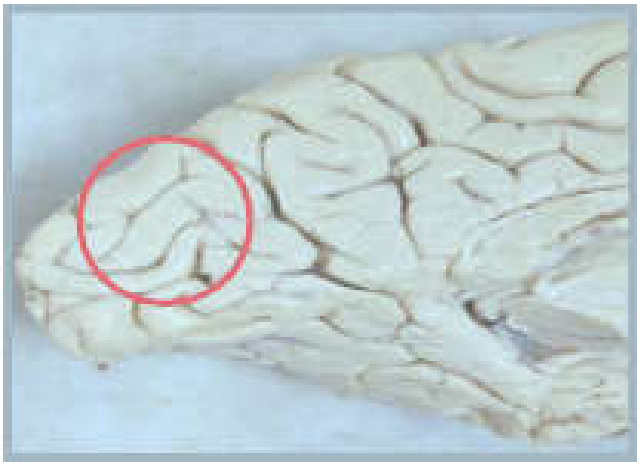

Fig. 4. Polygyria in the form of H-shaped sulcus in the cuneus region on the medial surface of left cerebral hemisphere

DISCUSSION

Most malformations of cortical development do not involve the entire cortex equally, but show regions of maximal severity. In the present study, polygyria was seen in the occipital and frontal region on the medial surface of cerebral hemisphere which is in contrast to findings of another researcher according to whom the perisylvian polymicrogyria is the most common form, second most common form being generalized (Leventer *et al.,* 2010). According to one of the hypothesis proposed for the development of polygyria, it is associated with Sturge Weber syndrome which suggests that hypoperfusion is related to development of multiple gyri. Also, polymicrogyria is seen to develop in areas of ischaemic insults. In keeping with another hypothesis proposed for the manifestation of polymicrogyria, it is considered to be a neuronal migration disorder. Microtubule transport and stabilisation, neuroependymal integrity etc are important in neuronal migration. As a result mutations affecting microtubule proteins TUBA1A, TUBA8, TUBB2B and TUBB3 are associated with abnormal neuronal migration (lissencephaly) and postmigrational development (polymicrogyria or polymicrogyria-like dysplasias) (Poirier *et al.,* 2007; Abdollahi *et al.,* 2009 , Jaglin and Chelly, 2009; Kumar *et al.,* 2010; Poirier *et al.,* 2010). Polymicrogyria can present with a spectrum of clinical signs and manifestations. It can range from no manifestation to severe cognitive impairment and encephalopathy. 50 % to 85 % of the patients have seizures associated with it. The child presents with delay in developmental milestones, spasticity and seizures. In the present study, frontal polygyria was seen in 2% cases which could lead to delayed motor and language milestones, spastic hemiparesis or quadriparesis and mental retardation (mild to moderate). In the current study, the presence of polygyria and unequal cerebral hemispheres was observed in male cadaveric brains which is in accordance with findings of another author who noticed a predilection of polygyria towards males and suggested that the genes responsible for the development of this disorder may be present on the X chromosome (Barkovich *et al.,* 2012).

In the present study, Polygyria was not associated with porencephaly which is in contradiction to findings of Leventer *et al* (2008) who reported it to occur at the periphery of many porencephalic or hydranencephalic defects. Polygyria shows abnormal cortical lamination, excessive folding and fusion of adjacent gyri and may be associated with a variety of brain malformations, including ventriculomegaly and abnormalities of the corpus callosum, brain stem, and cerebellum (Leventer *et al.,* 2008) which is similar to findings of present study where increase in length of corpus callosum is observed on the left cerebral hemisphere along with polygyria. Initial theories of PMG suggested that it was the result of a vascular defect such as arterial ischemia. In the present study, there is a slight variation in various morphometric parameters of cerebral hemispheres bilaterally which may be due to individual variability which is in accordance with results of few researchers who found this attribute, particularly pronounced in certain structures (Fornito *et al.,* 2004; Huster *et al.,* 2007). Furthermore, there is a growing appreciation of sex-linked differences in regional brain morphology (Witelson, 1989; Habib *et al.,* 1991; Crespo-Facorro *et al.,* 2001), including hemispheric asymmetries (Luders *et al.,* 2009; Raz *et al.,* 2004), as well as age-related hemispheric differences (Raz *et al.,* 2004; Shaw *et al.,* 2009).

Conclusion

The rare presentations seen in the present study may be associated with numerous neurological deficits like mental retardation, seizures, spastic hemiparesis or quadriparesis etc. which are of relevance to physicians, neurologists, neurosurgeons and radiologists.

Acknowledgement

The authors express their heartfelt gratitude to the authorities of Lady Hardinge Medical College, New Delhi for their cooperation.

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