



Role of 3D / 4D Ultrasound in Assessment of Fetal CNS Congenital Anomalies

Thesis

*Submitted for Partial Fulfillment
of Master Degree in **Radiodiagnosis***

Presented by

Ahmed Bassiony Bassiony Elsayed

M.B.B.Ch.

Faculty of Medicine, Ain Shams University

Supervised by

Prof. Fatma Salah El-Dein Mohammed

Professor of Radiodiagnosis

Faculty of Medicine - Ain Shams University

Dr. Wafaa Raafat Abdel Hamid

Lecturer of Radiodiagnosis

Faculty of Medicine - Ain Shams University

*Faculty of Medicine
Ain Shams University*

2019

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

قَالَ

سُبْحَانَكَ لَا عِلْمَ لَنَا
إِلَّا مَا عَلَّمْتَنَا إِنَّكَ أَنْتَ
الْعَلِيمُ الْعَظِيمُ

صدق الله العظيم

سورة البقرة الآية: ٣٢

Acknowledgments

*First and foremost, I feel always indebted to **Allah** the Most Beneficent and Merciful.*

*I'd like to express my respectful thanks and profound gratitude to **Prof. Fatma Salah El-Dein Mohammed**, Professor of Radiodiagnosis, Faculty of Medicine, Faculty of Medicine - Ain Shams University for his keen guidance, kind supervision, valuable advice and continuous encouragement, which made possible the completion of this work.*

*I am also delighted to express my deepest gratitude and thanks to **Dr. Wafaa Raafat Abdel Hamid**, Lecturer of Radiodiagnosis, Faculty of Medicine, Faculty of Medicine – Ain Shams University, for his kind care, continuous supervision, valuable instructions, constant help and great assistance throughout this work.*

I would like to express my hearty thanks to all my family for their support till this work was completed.

Ahmed Bassiony Bassiony Elsayed

List of Contents

Title	Page No.
List of Tables	5
List of Figures	6
List of Abbreviations.....	10
Introduction.....	- 1 -
Aim of the Work	14
Review of Literature	
▪ Embryological Development of the Central Nervous System	15
▪ Physical Principles of 3D/4D Ultrasound	20
▪ Technique of 3D, 4D Ultrasound	34
▪ Ultrasound Assessment of Normal Fetal CNS Anatomy.....	47
▪ 3D/4D Sonoembryology	62
Patients and Methods	65
Results	67
Illustrative Cases	71
Discussion.....	82
Summary	86
Conclusion	88
References	89
Arabic Summary	

List of Tables

Table No.	Title	Page No.
Table 1:	Distribution of cases as per 3D detailed ultrasound diagnosis:	68
Table 2:	Distribution of cases with CNS congenital anomalies.....	68
Table 3:	Trimester wise distribution	69
Table 4:	Detection of CNS anomalies by 3D detailed anomaly scan.....	82

List of Figures

Fig. No.	Title	Page No.
Fig. 1:	Changes in the morphology of the embryo in the embryonic period.....	16
Fig. 2:	Primary vesicles	18
Fig. 3:	3D Scanning by a 3D probe	22
Fig. 4:	Construction of a 3D data set	25
Fig. 5:	Settings for a viewpoint and ROI for a 3D Data set.....	27
Fig. 6:	Surface rendering.....	27
Fig. 7:	Three orthogonal plane display of a fetus.....	28
Fig. 8:	Volume rendering.....	29
Fig. 9:	3D image of fetal skeleton by maximum intensity projection	30
Fig. 10:	3D image of megalocystis and megaureters by minimum intensity projection (left)	30
Fig. 11:	Volume imaging. Slice width (ws) is widened by defocusing lens attached to the surface of a conventional probe	31
Fig. 12:	Relation between three-orthogonal planes and a 3D image (lower right)	32
Fig. 13:	The uterine wall hides a part of a fetus at 10 weeks of gestation (left)	32
Fig. 14:	3D images of a fetus with omphalocele at 35 weeks of gestation	33
Fig. 15:	Coronal and sagittal views of the fetal head the fontanelles and sutures of the upper calvarium	34
Fig. 16:	Schematic representation of acquisition of an ultrasound volume of the fetal brain by an axial approach acquired transabdominally, with corresponding ultrasound image.....	36

List of Figures *cont...*

Fig. No.	Title	Page No.
Fig. 17:	Schematic representation of multiplanar analysis of ultrasound volumes, with corresponding multiplanar analysis of the fetal face	37
Fig. 18:	Multiplanar analysis of an ultrasound volume of the fetal brain at mid-gestation obtained with a transvaginal approach from the sagittal plane	38
Fig. 19:	Tomographic display mode demonstrating multiple successive sagittal views of the fetal brain.....	39
Fig. 20:	Tomographic display mode, demonstrating multiple successive axial views of the fetal brain.....	40
Fig. 21:	3D fetal neuroscan	41
Fig. 22:	Three-dimensional fetal neuroscan.	42
Fig. 23:	Three-dimensional fetal neuroscan	43
Fig. 24:	Three-dimensional fetal neuroscan	44
Fig. 25:	Fetal face from four different views	45
Fig. 26:	Postanterior sagittal view by transabdominal scan is favorable for vertebral screening scan	46
Fig. 27:	3D US of the Fetal spine by maximum mode	46
Fig. 28:	These identical images of the “perfect” median plane obtained from a multiplanar display mode demonstrate the anatomic location of several midline brain structures	51
Fig. 29:	Standard axial plane taken at the level of the lateral ventricles and cavum septi pellucidi, demonstrating measurements of the lateral ventricles.....	52

List of Figures *cont...*

Fig. No.	Title	Page No.
Fig. 30:	The three-horn view in this image enables the evaluation of all three components of the lateral ventricles.....	53
Fig. 31:	Fetal head in the sagittal position, demonstrating the anatomic position of the successive coronal planes that are recommended by the ISUOG during the fetal neuroscan	54
Fig. 32:	Fetal head in the sagittal position illustrates the correct anatomic position of the three axial planes.....	56
Fig. 33:	Examples of 3D ultrasound reconstructions of the commonly used axial planes: transventricular (A), transthalamic (B), and transcerebellar (C)	57
Fig. 34:	3D US of the fetal spine using transparent mode.....	59
Fig. 35:	Three-dimensional ultrasound images of the fetal spine	60
Fig. 36:	Fetal vertebral development by 3D US from 9 to 22 weeks of gestation	61
Fig. 37:	Three orthogonal image of normal brain at the end of 8 weeks of gestation	63
Fig. 38:	3D reconstructed image of the yolk sac and 5.5 mm CRL-embryo (6 weeks of gestation)	63
Fig. 39:	3D reconstructed image of the embryo (8 weeks of gestation)	64
Fig. 40:	Distribution anomalies detected by 3D US.....	69
Fig. 41:	Trimester wise distrubtion.	70
Fig. 42:	Distribution anomalies detected by 3D US.....	70

List of Figures cont...

Fig. No.	Title	Page No.
Fig. 43:	Detailed 3D anomaly scan was done showing an anencephalic fetus at 19 weeks	71
Fig. 44:	Detailed 3D anomaly scan was done showing an anencephalic fetus at 22 weeks (Frog eye sign, yellow arrow).	72
Fig. 45:	Detailed 3D anomaly scan was done showing A 22 weeks 3 days fetus with a posterior cranial mass	73
Fig. 46:	Detailed 3D anomaly scan was done demonstrating	74
Fig. 47:	Detailed 3D anomaly scan was done showing 23 weeks 4 days fetus with Alobar holoprosencephaly	75
Fig. 48:	Detailed 3D anomaly scan was done demonstrating this a 37weeks fetus with a case of Alobar Holoprosencephaly	77
Fig. 49:	Detailed 3D anomaly scan was done demonstrating 37 weeks fetus with dandy walker malformation	78
Fig. 50:	Detailed 3D anomaly scan was done demonstrating a 33 weeks fetus with a case of dandy walker variant.....	79
Fig. 51:	Detailed 3D anomaly scan was done demonstrating a fetus with gestational age 21 weeks 5 days (according to LMP of the mother),	80
Fig. 52:	Detailed 3D anomaly scan was done showing a 22weeks 3 days fetus with a case of Hydrocephalus.....	81

List of Abbreviations

Abb.	Full term
<i>3D US</i>	<i>Three-dimensional ultrasound</i>
<i>3D</i>	<i>Three dimension</i>
<i>4D</i>	<i>Four dimension</i>
<i>3HV</i>	<i>Three-horn view</i>
<i>3V</i>	<i>Third ventricle</i>
<i>4V</i>	<i>Fourth ventricle</i>
<i>AH</i>	<i>Anterior horn</i>
<i>BPD</i>	<i>Biparietal diameter</i>
<i>BS</i>	<i>Brain stem</i>
<i>CC</i>	<i>Corpus callosum</i>
<i>CM</i>	<i>Cisterna magna</i>
<i>CNS</i>	<i>Central nervous system</i>
<i>CRL</i>	<i>Crown-rump length</i>
<i>CSP</i>	<i>Cavum septi pellucidi</i>
<i>CT</i>	<i>Computed tomography</i>
<i>CV</i>	<i>Cavum vergae</i>
<i>HC</i>	<i>Head circumference</i>
<i>HTN</i>	<i>Hypertension</i>
<i>IH</i>	<i>Inferior horn</i>
<i>ISUOG</i>	<i>The International Society of Ultrasound in Obstetrics and Gynecology</i>
<i>MRI</i>	<i>Magnetic resonance imaging</i>
<i>NTDs</i>	<i>Neural tube defects</i>
<i>OFD</i>	<i>Occipitofrontal diameter</i>

List of Abbreviations cont...

Abb.	Full term
<i>PH</i>	<i>Posterior horn</i>
<i>PNS</i>	<i>Peripheral nervous system</i>
<i>QC</i>	<i>Quadrigeminal cistern</i>
<i>QP</i>	<i>Quadrigeminal plate</i>
<i>ROI</i>	<i>Region of interest</i>
<i>STIC</i>	<i>Spatiotemporal image correlation</i>
<i>TC</i>	<i>Tela choroidea</i>
<i>US</i>	<i>Ultrasound</i>
<i>V</i>	<i>Cerebellar vermis</i>

INTRODUCTION

Congenital abnormalities account for 20-25% of perinatal deaths.

Central nervous system anomalies are often severe and are the most common indications for therapeutic abortions (*Bornstein et al., 2014*).

Central nervous system (CNS) malformations are the second most frequent category of congenital anomaly, after congenital heart disease (*Monteagudo et al., 2017*). Approximately 21% of congenital malformations involve the CNS, constituting one of the most common congenital defects and may occur either isolated or in association with other malformations of the CNS itself or other systems (*Alvarengfernandes et al., 2012*).

The CNS develops from 3 to 20 weeks of intrauterine life. Almost all CNS anomalies are a result of the insult in embryogenesis at some point of development. Ultrasound can diagnose many CNS anomalies in first and early second trimester. Some develop or become apparent in late pregnancy. The earlier the detection, the more time available for the clinician and parents to plan the outcome of pregnancy. Lethal and severely life limiting disorders warrant early termination of pregnancy, whereas detection of minor anomalies helps

everybody to be prepared for postnatal management (*Bornstein et al., 2014*).

Prenatal diagnosis uses various noninvasive and invasive techniques to determine the health condition of the fetus or any abnormality in an unborn fetus. Techniques of fetal visualization are:

- a) Non invasive techniques; Ultrasound (US), fetal echocardiography, Magnetic resonance imaging (MRI).
- b) Invasive techniques; Embryoscopy, Fetoscopy.

US examination is an effective modality for prenatal diagnosis of these anomalies. It is a non-invasive technique which is more acceptable by patients. Several studies have shown an accuracy of 92% to 99.7% for US detection of CNS anatomic anomalies (*Monteagudo et al., 2017*).

The current study advocates performing a CNS targeted 3D / 4D ultrasonography after an initial diagnostic 2D ultrasonography.

AIM OF THE WORK

The aim of this study is to verify the role of 3D, 4D ultrasonography in prenatal assessment of anatomical structure of central nervous system and early diagnosis of the CNS congenital anomalies.

EMBRYOLOGICAL DEVELOPMENT OF THE CENTRAL NERVOUS SYSTEM

Neural development is one of the earliest systems to begin and the last to be completed after birth. This development generates the most complex structure within the embryo and the long time period of development means in utero insult during pregnancy may have consequences to development of the nervous system (*Wang et al., 2014*).

The early central nervous system begins as a simple neural plate that folds to form a groove then tube, open initially at each end. Failure of these opening to close contributes in a major class of neural abnormalities (neural tube defects).

Within the neural tube stem cells generate the 2 major classes of cells that make the majority of the nervous system: neurons and glia (*McShane et al., 2015*).