Automated Fetal Femur Length Measurement by Five-Dimensional Ultrasound

Thesis

Submitted for partial fulfillment of

The Master Degree in Obstetrics and Gynecology

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2016

بسم الله الرحمن الرحيم

قَالُوا سُبْحَانَكَ لاَ عِلْمَ لَنَا إِلاَّ مَا عَلَّمْتَنَا إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيمُ

صدق الله العظيم

سورة البقرة آية (٣٢)

Acknowledgement

First of all, all gratitude is due to ***God*** *almighty for blessing this work, until it has reached its end, as a part of his generous help, throughout my life.*

I would like to express my deepest gratitude to ***Professor. Abdelmegeed Ismail Abdelmegeed,*** *Professor of Obstetrics and Gynaecology, Faculty of Medicine, Ain Shams University, for his kind supervision, valuable advice, faithful support, giving me the privilege and honor of working under his supervision and for clearing many obstacles during this study.*

I wish to express my high appreciation and great thanks to ***Dr. Rehab Mohamed Abdelrahman,*** *Lecturer in Obstetrics and Gynaecology, Faculty of Medicine, Ain Shams University, who helped me to a great extent, for his kind supervision and energetic help in following the details of this work.*

This work could not have been completed without the great cooperation and assistance of the personnel of the fetal care unit and sono school at Ain Shams University Maternity Hospital.

Lastly, I would like to express my great thanks to my family for encouraging me in the organization of this work.

Ahmed Mohamed Ezz-eldin

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List of Abbreviations

2D US	:	Two-dimensional ultrasound
3D US	:	Three-dimensional ultrasound
4D US	:	Four-dimensional ultrasound
5D-LB	:	Five-dimensional fetal long-bone
5D-NT	:	Five-dimensional nuchal translucency
5D US	:	Five-dimensional ultrasound
AC	:	Abdominal circumference
AFI	:	Amniotic fluid index
AUA	:	Average ultrasound age
BPD	:	Bi-parietal diameter
CT	:	Computed tomography
CRL	:	Crown-rump length
EDD	:	Estimated date of delivery
EDC	:	Estimated date of confinement
FL	:	Femur length
HC	:	Head circumference
LH	:	Luteinizing hormone
LMP	:	Last menstrual period
MA	:	Menstrual age
MRI	:	Magnetic resonance imaging
OFD	:	Occipitofrontal diameter
ROI	:	Region of interest
SONAR	:	Sound Navigation and Ranging System
STIC	:	Spatio-Temporal Image Correlation Technique
TCD	:	Trans-cerebellar diameter
TTD	:	Transverse trunk diameter
TUI	:	Tomographic Ultrasound Imaging
US	:	Ultrasound
VCI	:	Volume Contrast Imaging
VOCAL	:	Virtual Organ Computer Aided Analysis

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Introduction

Ultrasound has become the gold standard for the determination of gestational age and to avoid false dating and induced labor. It is most accurate in early gestation and then, its accuracy is inversely related to gestational age **(Votta *et al*, 1998).**

Two-dimensional ultrasound [2D US] is in routine use in nearly most hospitals and many physician clinics as it offers a lot of benefits compared to other medical imaging techniques. Ultrasonography offers unique qualities including real-time imaging, physiologic measurement, use of non-ionizing radiation, no known bio-effects in the diagnostic range while being non-invasive. Sonographic image quality has benefited from increasingly sophisticated computer technology **(Schaapas, 1999).**

Two dimensional sonographic estimation is an accurate way (mean error 7.6-9.1%) to measure various fetal parameters, particularly biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), transverse trunk diameter (TTD) and femur length (FL) however, most studies documented poor accuracy among small and excessive fetal weight populations ***(Leveno and Gilstrap, 2009).***

In 1980, **Queenan et al.** developed femur length (FL) charts to evaluate fetal growth, and from 1981 onward FL charts were established for predicting fetal age **(Altman and Chitty, 1997).**

Femur length (FL) measurement is as accurate as the BPD in the prediction of gestational age. It is useful in confirming the gestational age estimated from BPD or HC measurements and can often be obtained when fetal position prevents measurement of the BPD or HC. The femur can be measured from 12 weeks to term ***(Trish and Basky, 2004).***

Prediction of gestational age based on sonographic fetal parameters is perhaps the cornerstone in modern obstetrics and continues to remain an important component in the management of pregnancies with fetuses who have growth disturbances. A variety of sonographic fetal parameters have been shown to correlate well with gestational age **(Chavez et al, 2006).**

The three-dimensional ultrasonography (3D US) is one of the most recent technological advances in diagnostic medicine ***(Pomorski et al, 2012).***

The advantage of 3D-ultrasound is the possibility of obtaining coronal planes and their surface reconstruction which provides new image features which are not possible to obtain with conventional 2D-ultrasound ***(Shih, 2004).***

The use of 3D-ultrasound may decrease the interobserver variability of results as compared to 2D-ultrasound ***(Martins et al, 2009).***

2D-ultrasound is basically an axial image and 3D-ultrasound is a volume and 4D-ultrasound is a volume with time and the fifth dimension is how do you bring a level of workflow into ultrasound? And it is basically bordering on the sense of automation. 5D technology is a form of automation where you go through and do a scan and you get the results auto-populated for you. Five-Dimensional Ultrasound included features like 5D-LB (fetal long-bone) and 5D-NT (nuchal translucency) **(Liza Haar, 2015).**

Aim of the work

To evaluate Five-Dimensional Ultrasound in automated measurement of the fetal femur length at third trimester of pregnancy compared to Two-Dimensional Ultrasound.

Review of literature

Chapter (1)

Introduction to Ultrasound

The development of ultrasound in medicine:-

The term "ultrasound" refers to sound waves of a frequency greater than that which the human ear can appreciate, namely frequencies greater than 20,000 cycles per second. For diagnostic ultrasound imaging in obstetrics and gynecology, frequencies of 2 to 12 million cycles per second are used. Ultrasound imaging has been used for medical purposes for several decades and is safe when properly performed ***(Phillips et al, 2010).***

In 1912, the passenger ship Titanic hit an iceberg on its maiden trip crossing the Atlantic from Southampton to New York. In the time that followed, physicists took an interest in using sound to detect large objects submerged in water. Initially their research for that purpose was unsuccessful. During World War I, the French physicist Paul Langevin was responsible for developing the hydrophones needed to detect submarines; this underwater sonar technology resulted in the first sinking of a German submarine in 1916. In 1917, Langevin invented the quartz sandwich transducer which served as the basis for the modern ultrasonic era. Between World War I and World War II Physics and instrumentation, the development of sonar (Sound Navigation and Ranging System) and radar (Radio Detection and Ranging) took place. The latter technique used electromagnetic waves rather than ultrasound. The next important step was the use of ultrasound to detect flaws in metal using high- frequency ultrasound. The metal flaw detectors became increasingly important as World War II was approaching, but were reported after the war ***(Kremkau, 2006).***

After World War II, Howry and Bliss, in Denver, started to experiment with sonar equipment and amplifiers from the navy. They developed a pulse-echo technique in 1948–49, and later produced cross-sectional images of a human partly submerged in water. At the same time, Wild in Minneapolis developed a breast scanner and actually made a diagnosis of breast lesions with his device ***(American Institute of Ultrasound in Medicine, 2008).***

The Swedish physician Inge Edler and physicist Helmut Hertz, at the University of Lund, borrowed a metal flaw detector from Kockum's Shipyard in Malmö, Sweden. In 1953, they managed to trace the movements of the human cardiac valves by means of the sound waves emitted and received by their modified instrument. This was the start of a new era in cardiology relying on sound technology ***(Chervenak et al, 2009)***.

The next breakthrough was by the Scottish physician Ian Donald, in Glasgow, who conducted the basic research for the development of a machine for clinical use employing ultrasound to make two-dimensional images of human tissue. Donald had served in the Air Force during World War II and his past experience influenced his prototype machine, which consisted of two metal flaw detectors. His Lancet paper of 1958, 'Investigation of abdominal masses by pulsed ultrasound', is considered to be one of the most important for the development of clinical ultrasound. Since the late 1950s, the development of ultrasound in medicine in general and in the field of obstetrics and gynaecology in particular has continued in an exponential way. Breakthrough advances have been repeatedly made in spite of claims that the development of ultrasound in medicine has reached its physical limits ***(Chervenak et al, 2009).***