

# **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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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا  
عَلَّمْتَنَا إِنَّكَ أَنْتَ الْعَلِيمُ الْحَكِيمُ

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# Contents

<b>List of Abbreviations .....</b>	<b>I</b>
<b>List of Tables .....</b>	<b>II</b>
<b>List of Figures.....</b>	<b>III</b>
<b>Introduction.....</b>	<b>1</b>
<b>Aim of the Work.....</b>	<b>4</b>
<b>Review of Literature</b>	
- Introduction to Ultrasound.....	5
- Gestational Age Assessment .....	14
- Three-Dimentional Ultrasound.....	47
- Four-Dimentional Ultrasound .....	70
- Five-Dimentional Ultrasound.....	70
<b>Patients and Methods .....</b>	<b>73</b>
<b>Results .....</b>	<b>82</b>
<b>Discussion .....</b>	<b>93</b>
<b>Summary and Conclusion .....</b>	<b>102</b>
<b>Recommendations .....</b>	<b>106</b>
<b>References.....</b>	<b>107</b>
<b>Arabic Summary .....</b>	<b>—</b>

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## List of Abbreviations

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

## List of tables

<i><b>Table</b></i>	<i><b>Title</b></i>	<i><b>Page</b></i>
1	Accuracy of prenatal assessment of gestational age by sonographic parameter	25
2	Reassigning EDD based on date ultrasound discrepancy	26
3	Estimation of gestational age (GA) from femur length	44
4	Characteristics of the study population	82
5	Comparison of the accuracy of 2D US and 5D US	85
6	Comparison of the precision of 2D US and 3D US	90
7	Bland-Altman analysis for agreement between 2D and 3D US as regards the estimation of gestational age	91

## List of Figures

<i><b>Fig.</b></i>	<i><b>Title</b></i>	<i><b>Page</b></i>
1	The longitudinal axis of the fetus using the trans-abdominal method. The calipers demonstrate measurement of The crown–rump length	30
2	Transverse section of the fetal head demonstrating the landmarks required to measure the BPD using the lateral ventricles view	33
3	Transverse section of the fetal head demonstrating the landmarks required to measure the BPD using the thalami view	34
4	Transverse section of the fetal head with the callipers placed on the outer border of both the proximal and distal parietal bones	35
5	Measurement of the head circumference using the two diameter method (lateral ventricles view)	38
6	Measurement of head circumference using the ellipse method (lateral ventricles view)	39
7	Measurement of the fetal femur	41
8	Longitudinal sonogram of the fetal femur length	42
9	Fetal thigh volumetry analyzed using the multiplanar method	54
10	Surface-mode rendering of a fetus with a normal face and a fetus with facial dysmorphism (exophthalmia)	55
11	Transparency visualization of fetal skeletal	56

## List of Figures (Cont.)

<i><b>Fig.</b></i>	<i><b>Title</b></i>	<i><b>Page</b></i>
12	three-dimensional volume acquisition of femur longitudinal-90, femur longitudinal-45 and the tibia and fibula	60
13	Fetal thigh volumetry analyzed using the Virtual Organ Computer-aided Analysis (VOCAL) technique	61
14	Long bone measurement by five-dimensional Long Bone	72
15	Femur length measurement by two-dimensional ultrasound	75
16	Femur length measurement by five-dimensional ultrasound	76
17	Samsung-UGEO-WS80A machine	77
18	Entrance of fetal care unit and sono school	77
19	Actual gestational age calculated using the LMP and estimated gestational age by 2D and 3D US	83
20	Standard error of the estimate, SEest, for 2D and 5D US	84
21	Signed error for 2D and 5D US. Markers represent individual observations	86
22	Signed percentage error for 2D and 5D US. Markers represent individual observations	87
23	Absolute (unsigned) error for 2D and 5D US	88
24	Absolute (unsigned) percentage error for 2D and 5D US.	89
25	Bland-Altman plot for agreement between 2D and 3D US as regards the estimation of gestational age	92



## **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*).