INTRODUCTION

Accurate knowledge of gestational age is a keystone in successful management of the antepartum care and is of critical importance in ante-natal tests and successful planning of appropriate therapy or intervention. Failure can result in iatrogenic prematurity which is associated with increased perinatal morbidity and mortality ***(Butt et al., 2014).*** Routine sonographic estimation of gestational age by using biparietal diameter (BPD), femur length (FL), abdominal circumference (AC), head circumference (HC) is considered an important role in management of pregnancy but there are limitations with using such parameters such as BPD and HC after 26 weeks is unreliable in cases of moulding of fetal skull ***(Goel et al., 2010).*** Also, femur length is unreliable as it is shortened in cases of achondroplasia. A new parameter for estimation of gestational age was developed which is transcerebellar diameter (TCD) ***(Reddy et al., 2017; Hashimoto et al., 2001).***

Cerebellum is located in the posterior cranial fossa surrounded by dense petrous ridges and the occipital bone which makes it withstand deformation caused by outer pressure. fetal cerebellum can be seen by ultrasound as early as 10 - 11 weeks and from 2nd trimester it grows with gestational age with progressive linear correlation, it is the least affected parameter by external factors as it is surrounded by dense petrous ridges and the occipital bone ***(Hashimoto et al., 2001),*** in case of growth restriction the cerebellum is the least affected parameter maintaining the size in case of fetal growth restriction hence accurate GA can be predicted with TCD ***(Davies et al., 2001),*** by illustrating the advantages of TCD over other parameters this study will be conducted to evaluate the accuracy of TCD over other parameters of gestational age of 30 - 40 weeks.

AIM OF THE WORK

The study aims to assess the accuracy of use of transcerebellar diameter in singleton gestation as an accurate parameter in determining gestational age in third trimester in comparison with other parameters (biparietal diameter, Femur length and abdominal circumference) according to last menstrual period.

Chapter 1

HISTORY OF ULTRASOUND IN OBSTETRICS

The development of ultrasound as a diagnostic technology started in the late 1940s and 1950s as A-mode, or amplitude-mode, ultrasound. A single high-frequency sound wave was conducted into the body, and the signals from the reflected wave were recorded when they returned to the signal source which is the transducer. The returning signals could be plotted on a graph based on the time starting from transmission to return, and the distance to every reflecting structure could be determined, based on the known speed of the ultrasound wave as it moves through tissue. This technique proved to be accurate for locating the fetal head and for measuring the head size. The first paper on US imaging presented at the Radiological Society of North America annual meeting was the work of Dr Barry Goldberg on fetal head measurements, a study that was published in Radiology in 1966 which showed how A-mode US could be used to measure the fetal head size at the biparietal diameter (Fig 1) and reported this method to be safe and accurate, with good correlation of prenatal head measurements with postnatal head size ***(Goldberg et al., 2000).***

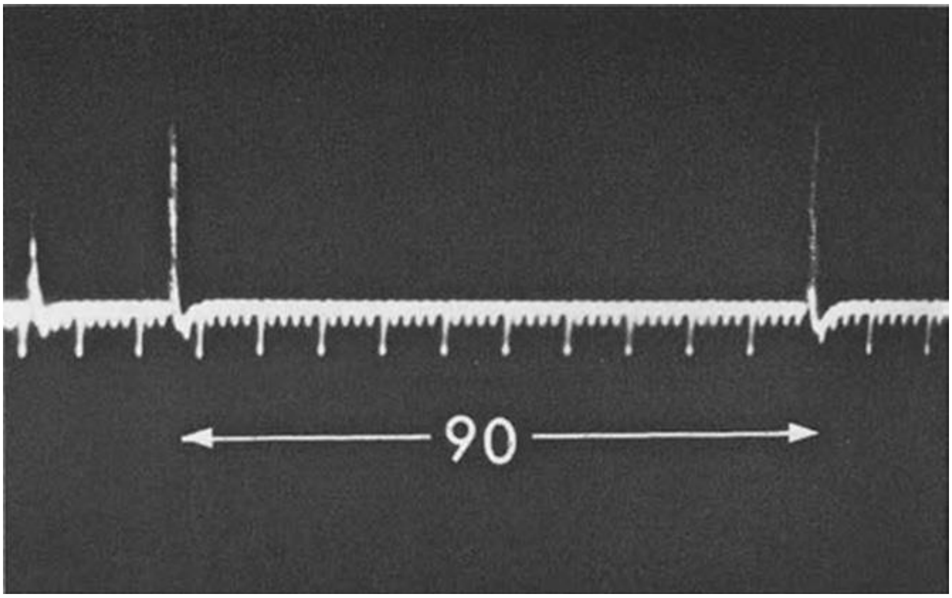

Figure (1): A-mode US scan of fetal head size. Graph of signal returning from ultrasound wave in a pregnant woman shows two peaks 90 mm apart, characterizing the biparietal diameter of the fetal head.

Soon after the introduction of A-wave US, continuous-wave Doppler was developed then applied to the pregnant patient. Continuous-wave Doppler utilizes continuous emission of a stable frequency wave along a line projected from the transducer, then returning signals are evaluated to identify changes in frequency. These changes, named the Doppler effect, are because of reflection of the sound wave from moving structures, such as blood flowing toward or away from the transducer. The changes in frequency over time can be outlined on a graph, which can be used for monitoring the fetal heart rate (Figure 2), as well as other applications ***(Maulik, 2005)***.

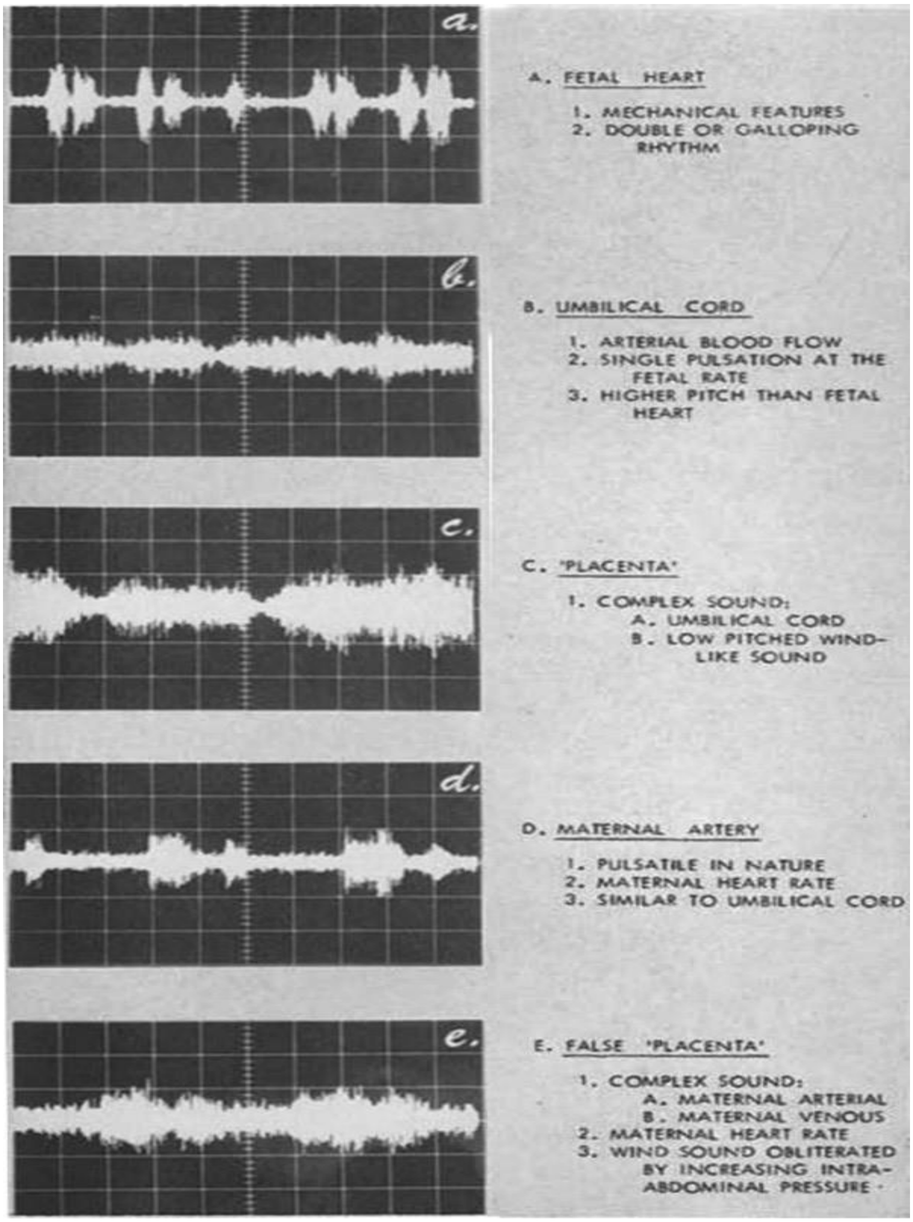

Figure (2): Continuous-wave Doppler from a 1967 publication shows different applications of ultrasonic pulse detector.

However, a big limitation of continuous-wave Doppler is that the location of the flow signals cannot be determined since transmission is continuous, thus the time it takes for the reflected pulse to go back to the transducer cannot be determined.

In the 1960s, M-mode (motion-mode) ultrasound was developed. This method utilizes transmission of repetitive A-mode ultrasound waves, with subsequent detection of the reflected waves along the line of transmission. Reflections could be graphed over time, demonstrating changes happening at different depths from the transducer. The value of M-mode US for measuring fetal heart rate was rapidly recognized ***(Carol and Peter, 2014)***. In addition, fetal movement could be documented.

In the 1970s, a major breakthrough in US imaging occurred early when B-mode (brightness-mode) static imaging was developed. This technology offered the first two-dimensional images of the pregnant uterus and the developing fetus. As the transducer was moved across the body, the ultrasound waves were transmitted along a series of lines. The reflected signals were mapped next to each other to create an image on a television monitor. With the ability to visualize the fetal head, it was possible to improve the plane of measurement of the biparietal diameter to increase accuracy (Figure 3). ultrasound measurements of the fetal head could now be made more safely and reliably, without exposing the fetus to ionizing radiation ***(Woo, 2002).***

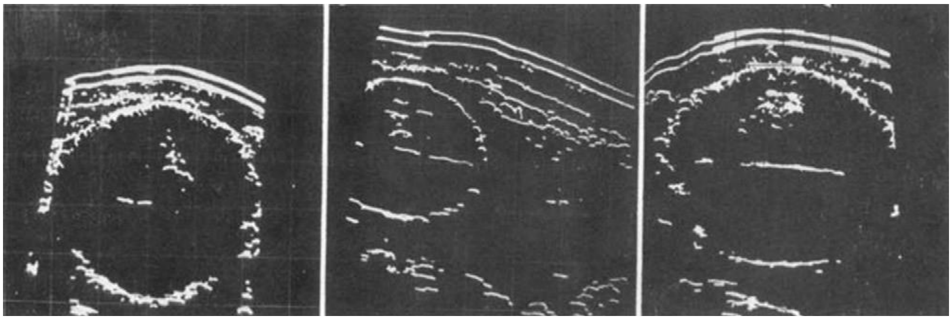

Figure (3): Cross-section B-mode US scans of fetal skulls shows an echo from the midline structures of the fetal brain, making sure that the cross section is at or near a biparietal plane.

Originally, B-mode US generated bi-stable images consisting of white dots on a black background or vice versa. By the 1970s, B-mode images became more sophisticated as the amplitude of the returning signals was altered to a scale of grey, with higher amplitude signals appearing whiter on the US monitor than lower amplitude signals. It became possible to differentiate different types of tissue, with white bony structures different from grey solid tissue and black fluid ***(Arger et al., 1976; Cohen and Moore, 2004).***

The next important development was real-time sonography ***(Campbell, 2013; McLeary et al., 1980).*** ultrasound transducers were developed that could obtain many images per second, updating the US image on the monitor fast enough to seem to be in continuous motion. By the late 1970s and early 1980s, real-time imaging substituted static B-scans. Real-time US imaging was extremely valuable for the obstetric patient. Many more fetal anatomic structures could be evaluated without alteration by fetal movement. Fetal intracranial structures could be visualized, as could the spine, kidneys, stomach, and bladder. Measurements other than the biparietal diameter, such as the fetal abdominal circumference and femur length, could be acquired to assess fetal growth.

The exact location of the placenta could be verified and the volume of amniotic fluid could be measured ***(Campbell, 2013; McLeary et al., 1980).***

From the 1980s to the present, new transducer technologies and improved computing power enabled fast improvements in grey-scale real-time US and development of new capabilities for the US systems. Transvaginal transducers, which was developed in the mid- to late 1980s, delivered high-resolution imaging of the uterus and ovaries, allowing for better and earlier assessment of pregnancy than was possible before ***(Okeji et al., 2017; Pennell et al., 1987; Levi et al., 1988).***

At about the same time, pulsed-wave Doppler, which shows the Doppler shift from a specific location, was included into ultrasound systems. This Doppler technology allows assessment of blood flow all through the cardiac cycle to assess the waveform configuration from a particular vessel or structure and verify peak velocity. By the early 1990s, color Doppler, which offers a color-encoded display of direction and velocity of blood flow superimposed on the grey-scale image, became widely available and provided real-time information about the presence of blood flow in vessels and organs

(Maulik, 2005). This was particularly useful in obstetric patients to assess blood flow in the umbilical cord, placenta, and fetal heart.

In general, each new development in ultrasound, from A mode to B mode, from static to grey scale, static to real-time scanning to transvaginal scanning to pulsed-wave Doppler to color Doppler, was implemented very quickly into the diagnostic resources in obstetrics.

This has led to more precise and rapid diagnoses of fetal abnormalities and obstetric complications. One exception to this rapid implementation has been 3D ultrasound. 3D ultrasound development and implementation were slow throughout the 1990s, although 3D imaging was developed as early as the 1980s ***(Tonni et al., 2015; Fishman et al., 1987)***, probably because of poor image resolution and slow computer processing speeds.

Studies gradually emerged reviewing static and real-time 3D ultrasound (also known as four-dimensional US) and their value for evaluating the fetus ***(Tonni et al., 2015; Hamper UM et al., 1994; Kelly et al., 1994; Baba et al., 1999)***, but these techniques were lengthy to be implemented into clinical practice. It was not until the 21st century that 3D and four-dimensional US finally became commonly available ***(Garjian et al., 2000).*** With 3D acquisition capabilities, it became achievable to store volumes that could be controlled after the examination was complete and the patient had left. physicians no longer required to depend on selected images of fetal structures, but could inspect the entire fetus by viewing the stored volumes (Fig 4) ***(Benacerraf et al., 2006).***

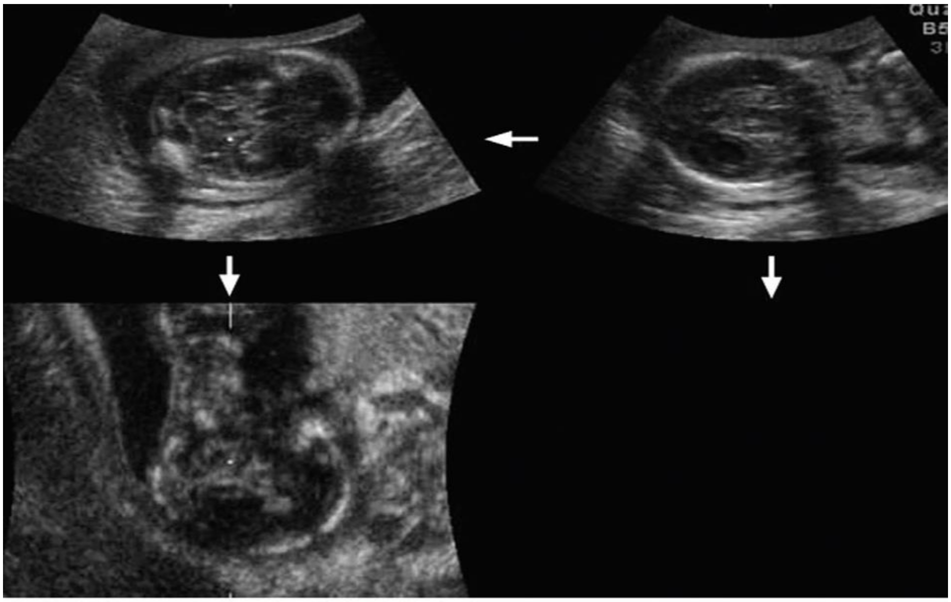

Figure (4): Multiplanar display of 3D ultrasound volume shows fetal head in three orientations perpendicular to each other.

However, despite the extensive availability, the use of post-examination processing of 3D volumes for interpretation is still infrequent. One major factor pushing the use of 3D US in obstetrics is patients' need to view their fetus in 3D.

Surface-rendering techniques deliver strikingly lifelike images, which, on top of delighting the parents, allow presentation of anomalies such as facial clefts. Other techniques for manipulating volumes of the fetus can also be valuable for evaluation of a number of anomalies, mainly those involving the face and the skeletal system. For example, utilizing bone window settings to an acquired volume allows visualization of bone detail of the vertebrae to aid diagnosis of hemivertebrae or to clarify the level of a meningomyelocele ***(Carol and Peter, 2014).***

Two other US technologies have recently become available but have barely penetrated into obstetric imaging. The first involves the use of US contrast agents, which are not widely used in the United States for noncardiac applications partially because of the lack of authorization of such agents by the Food and Drug Administration. At least one study from the United Kingdom has showed that contrast material can aid in establishing chorionicity of a twin gestation ***(Denbow et al., 2000),*** which is an application of limited use and value because ultrasound without contrast material can usually achieve this goal. The second technology in the near future is ultrasound elastography, which provides qualitative and quantitative assessment of tissue stiffness. Recently permitted for use in the United States, there is some evidence that this modality might be valuable for monitoring the cervix in pregnancy ***(Hwang et al., 2013).***

Chapter 2

ULTRASOUND AND FETAL BIOMETRY

Introduction:

A study in 2010 showed that diagnostic ultrasound is extensively used technology, especially in pregnancy for evaluation of fetal growth, verification of clinical complication in order to reduce any possible unfavorable outcome in absence of any risk factors. Routine ultrasound done in all pregnancies give benefits through an earlier detection and sufficient management of complications that could happen during pregnancy, Pregnancy scanning using ultrasound enhance the pregnancy dating accuracy which have a direct effect on the number of pregnancies that could undergo induction ***(Whitworth et al., 2010)***.

A 2006 study, illustrated that the policy concerning induction of labor after 41 gestational week or more in comparison to waiting for spontaneous labor is associated with fewer prenatal death of the fetus ***(Gulmezoglu et al., 2006).***

Quality of ultrasonography:

Pregnancy ultrasound should be always considered a medical procedure and the aim of its use is the assessment of the fetus. Because the efficiency of ultrasound depends on the operator, implementation of quality monitoring programs and application of continual education are essential in all centers offering ultrasound screening. The misinterpretation of the acquired images as well as the possibility of false negative tests should be lowered by sufficient training and having experienced qualified medical personnel ***(Salomon et al., 2009).***

Role of ultrasound parameters is estimation of gestational age:

The accuracy of dating in pregnancy is vitally significant for pregnancy management and antenatal care from first trimester to delivery, in particular for determination of viability in premature labor and in postdate deliveries ***(Kalish & Chervenak, 2005).***

Prior to using ultrasound as a main tool in determining gestational age, obstetricians depended on history and physical examination to clinically determine gestational age. there are variable methods to calculate gestational age the most accurate and common of which is Naegle’s rule, it depends on calculation of expected date of delivery (EDD) by subtraction of three months and adding seven days from the date of onset of LMP.

However sometimes estimation of gestational age based on LMP can be inaccurate or unreliable as some pregnant women are not sure of the date of their LMP, or have irregular cycles, also bleeding in early pregnancy or recent usage of contraception make the speculation of ovulation time and consequently gestational age inaccurate ***(Hoffman et al., 2008).*** Also, clinical examination shows inaccuracy in estimating gestational age because it may be affected by liquor volume and fetal growth disorders ***(Hoffman et al., 2008).***

Ultrasound presented physicians a way to calculate the fetus and hence estimation of gestational age. There is evidence that, if done with precision and quality, using ultrasound to estimate gestational age is more superior than using last menstrual period with or without using ultrasound ***(Hughes et al., 2008; Solomon et al., 2013).***

Fetal biometry

Sonographic fetal biometry is a method to calculate different parts of fetal and their growth. Different circumferences and diameters have been utilized to calculate gestational age. The assessment of gestational age in normal pregnancy in most of the cases is accurately estimated by biparietal and femur length as well as head circumference (HC), abdominal circumference and transcerebellar diameter (TCD) measurements were recommended to be undertaken ***(Azra et al., 2016)***

For assessment of the fetal anatomy, amniotic fluid volume, placental position and gestational age, recommendations were given to accomplish the sequence of scanning as follows ***(Chudleigh & Thilaganathan., 2005)***: