The Accuracy of Multiple Sonographic Parameters in Estimation of Fetal Weight in Pregnant Sudanese Women Presenting to the Ribat University Hospital, Khartoum (December 2003 – May 2004).

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A Thesis Submitted In Partial Fulfillment For The Degree Of
Clinical MD In Radiology
December 2004

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Dedication

To my wife Mary,
To our children Max, Madleine and Marina
who mean everything to me.
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I would very much like to express my thanks and gratitude to my supervisor professor Abdel latief Ashmaig for his keen and tireless efforts in supervising this study through out all its stages. I greatly appreciate his patience in revising and discussing all the aspects of the study. His guidance, advice and continuous encouragement was crucial for the successful completion of this work.

I am also very thankful to Dr. Salah Mohammed Abdel Raheem Karjaweel who carried out the ultrasonographic examinations and the measurements of the fetal biometric parameters. Dr. Salah has used all his knowledge, skills and experience for obtaining as accurate measurements as possible. I really admire his unlimited energy and his skillful handling of the ultrasound probe.

My thanks also go to sister Tawheeda Salih Ahmed, the manager of the Ribat university hospital labor rooms and her assistants, health visitor Hawa Mohammed Adam and health visitor Khadija Ismail Fadlalla together with the team of midwives serving under their direct supervision. Without their cooperation the data collection could not have been achieved in a such a short time.

Sister Salma Abdel Nur Suleiman, the supervisor of the antenatal ward did an excellent service to me by properly preparing her patients for the ultrasonographic examinations.

My special thanks go to Mr. Adil Amin and Miss Mona Mohamed EL Mostafa who analyzed the data and organized the chapters of this thesis.
Finally, I would like to express my profound thanks for my family members and friends for the continual support and encouragement that they showed for me while doing this research work.
ABSTRACT

Ultrasonography has proved to be an accurate, safe, fast, reliable and cost effective imaging modality for the estimation of fetal weight at term. This study was carried out at the Ribat university hospital at Burri, Khartoum from December 6, 2003 to May 3, 2004 to evaluate the relative accuracy of three ultrasonographic formulas in estimating fetal weight in term Sudanese ladies.

200 pregnant ladies, aged between 18 and 42 years, were examined sonologically by a senior radiologist using an Aloka SSD- 650 real time scanner and the fetal weights were calculated using the Aloka formula A, Aoki’s formula and Shephard’s formula.

36.5 % of the study population were primigravidas and the rest were parous women. The mean gestational age at delivery was 39.5 ± 1.4 weeks while 11.5 % of the deliveries occurred after more than 40 weeks of gestation (post term)

41.0 % of the ladies delivered on the same day of sonological examination, 45.0 % delivered one day after examination while 14.0 % delivered two days after examination.

The study found that the birth weights of 93.0 % of the newborn babies were within the reference weight of 2500 – 4000 grams. Only 4.0 % of the newborns have low birth weights (below the 10th percentile) while 3.0 % were macrosomic (above 90th percentile).

54.5 % of the newborn babies were of male gender compared with 45.5 % female babies.

The mean birth weight for the study population was found to be 3196.70 ± 454.16 grams. Male newborns had a higher mean birth weight (3281 ±
664.308 grams) compared to newborn girls whose mean birth weight was 3107 ± 635.077 grams.

Two of the evaluated formulas, Aoki’s and Shephard’s formula, tended to underestimate fetal weights while the third formula, the Aloka formula, gave estimates higher than the mean actual birth weight. However, all three evaluated formulas were found to be accurate for estimation of fetal birth weight in Sudanese ladies. The Aoki formula had the highest degree of accuracy with 77.0% of its estimates falling within 10.0% of actual birth weights. The Shephard equation was next with 76.0% of its estimates within 10.0% of actual birth weights while Aloka’s equation predicted 75.5% of the fetal weights within 10.0% of actual birth weights. The Aoki formula also had the smallest mean error among the three evaluated formulas and has been recommended for use by the Sudanese obstetricians.
ABSTRACT (ARABIC)
ملخص الأطروحة

اجربت هذه الدراسة مستشفى الرباط الجامعي ببري، الخروطوم في الفترة الممتدة من السادس من ديسمبر 2003 إلى الثالث من مايو 2004 وذلك لتقييم الدقة النسبية لثلاثة معدلات إلكترونية مضمونة في الموجات الصوتية في تقدير أوزان أجنة الأمهات السودانيات عند نهاية فترة الحمل.

تم الكشف على 200 حامل في الحد العمري 18-42 سنة بواسطة أخصائي الموجات الصوتية الذي قام بحساب الأوزان حسب معايير أوكا، أووكو و شيبارد المضمنة في جهاز الموجات الصوتية ماركة أوكا س 650. 36.5% من الحوامل كن بكرات والبقية كانت لديهن ولادات سابقة وقد استمرت الحمل في المتوسط لمدة 39.5 أسبوع.

11.5% من الحوامل تجاوزت فترة ال 40 أسبوع المعدة للحمل.

41.0% من الحوامل وضع حملهم في نفس يوم الكشف بالموجات الصوتية فيما وضعت 45.0% و 14.0% من الحوامل بعد 24 ساعة و 48 ساعة على التوالي.

وجدت الدراسة أن أوزان 93.0% من المواليد الجدد كانت في المدى الطبيعي (2500-4000 جرام). 4.0% فقط من المواليد الجدد كانت أوزانهم أقل من 2500 جرام بينما تعدي أوزان 3.0% من المواليد الجدد ال 4000 جرام.

54.5% من المولود الجدد كانوا من الذكور يقابلها 45.5% من الإناث. وقد كانت أوزان المواليد الذكور أكبر في المتوسط من أوزان المواليد الإناث.

وجدت الدراسة أن تقديرات الأوزان بواسطة معايير أوكا، أووكو و شيبارد كانت في المتوسط أقل من الأوزان الحقيقية للمواليد الجدد بينما كانت تقديرات معايير أوكا أكبر في المتوسط من الأوزان الحقيقية.

أكدت الدراسة بأن كل المعادلات الثلاثة تحت التقديم كانت دقيقة في تقديراتها لأوزان الأجنة عند نهاية فترة الحمل، إلا أن معايرة أوكا كانت هي الأكثر دقة حيث أن 77.0% من الأوزان المقدرة باستعمال تلك المعادلة كانت في حدود 10.0% من الأوزان الحقيقية للمواليد الجدد.

كانت معايرة شيبارد هي الثانية من حيث الدقة حيث أن 76.0% من الأوزان المقدرة باستعمال تلك المعادلة كانت في حدود 10.0% من الأوزان الحقيقية للمواليد بينما أنت معايرة أوكا في المرتبة الثالثة بنسبة دقة بلغت 75.5%.
أيضا تميزت معادلة أوروكي بأنها كانت الأقل من ناحية الخطأ النسبية وقد أوصت الدراسة باستخدام هذه المعادلة بواسطة اختصاصي أمراض النساء والولادة السودانيين.
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<td>Antepartal Haemorrhage</td>
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<td>APTD</td>
<td>Anteroposterior Trunk Diameter</td>
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<td>BPD</td>
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Chapter One

INTRODUCTION AND JUSTIFICATION

Ultrasound is a non invasive, fast, accurate, easily performed, and cost effective imaging modality which has been in use in this country for the diagnosis of different causes of pathological and physiological conditions. The above-mentioned characteristics of this modality make it an advantageous modality for a developing country such as ours, where trained personnel are few and economic power for purchasing good quality and sophisticated imaging machines are limited.

One of the medical branches in which ultrasonography is widely used is the field of obstetrics and gynecology where it has become firmly established as an indispensable and highly developed technology that is capable of detecting many fetal structural and functional abnormalities, assessing fetal weight and life and guiding obstetricians as they make effort to manage the pregnant ladies. It is now recognized that the use of diagnostic ultrasound for the care of pregnant ladies improves patient management and pregnancy outcome when there is an acceptable medical indication.

Although there is yet no consensus that routine ultrasound examinations of all pregnancies improved perinatal outcome or decreased morbidity or mortality, nevertheless, the advent of ultrasonography has overcome many of the diagnostic limitations of x-ray during pregnancy and has virtually eliminated the need for fetal exposure to ionizing radiation.

JUSTIFICATION
In the past, fetal weight was assessed clinically by external palpation of fetal parts. However, since mid 1960s, fetal biometric prediction algorithms for calculating estimated fetal weight were started and developed by many researchers in the United States of America and Europe beginning in the year 1965 when the Horace Thompson group in Denver, Colorado reported the estimation of fetal weight based on the measurements of the biparietal diameter (BPD) and thoracic circumference (TC). Later, in England in 1975, Campbell and Wilkins published the first formula for fetal weight estimation using the abdominal circumference (AC) \(^{(1)}\). Subsequently, many other researchers in America, Europe and Japan added additional indices and generated new equations for predicting fetal weight. The equations of Hadlock, Rose, Shephard, Warsof, Aoki, and Sabbagha are among the most commonly used in obstetrics practice \(^{(2-7)}\). These equations have varying ranges of accuracy but are generally comparable in terms of overall accuracy in predicting birth weight with no single equation being clearly superior.

It has been claimed by Benson et al \(^{(8)}\) that the use of multiple fetal anatomic parameters for fetal weight estimation provides a more reliable results in estimating fetal weight. However, Chauhan et al showed that the most accurate birth estimates are based on sonographic measurements utilizing only two parameters (abdominal circumference and femur length) and that when three or four fetal parameters were used to predict birth weight, the accuracy decreased.\(^{(9)}\)

With such conflicting reports, it becomes necessary to do research in this area to determine the most accurate formulas that suits the racial, environmental, and socioeconomic characteristics of Sudanese pregnant ladies. So, comes this study.
The evolution of diagnostic ultrasonography has been the combined efforts of physicists, mechanical, electrical, and biomedical engineers, computer technologists, clinicians, researchers as well as commercial enterprises. Developments in echocardiography, neurosonography, ophthalmology and breast echography have all supplemented the advancement in ultrasound instrumentations and methodologies in obstetrical and gynecological sonography. The first linear-array probes used in obstetric ultrasonography for example, were invented for the purpose of ophthalmologic and cardiac investigations.

Historically, diagnostic medical ultrasound has evolved from technology used in mapping waves through liquid (the SONAR), through air (the RADAR) and through solids (the metal flaw detector). The first generation of scanners, the A-scans, did not provide sufficiently accurate, reproducible and interpretable information to allow firm diagnosis to be made. B-scanners, which had its origins in the military radar, followed and became respectable diagnostic tools after the development of scan converter and gray scaling. By the late 1970s, the gray scale compound static scanner, with the incorporation of progressive electronic and computer available at that time, had established itself as a genuine clinical diagnostic tool providing hitherto unavailable information to clinicians regarding disease conditions.

The currently used equipments, which appeared in the early 1980s, are known as real-time scanners. With these scanners, a continuous picture of the moving fetus can be depicted on a monitor screen. Very high frequency sound waves of between 3.5 to 7.0 mega hertzs (ie 3.5 to 7.0 million cycles per second) are generally used. The real time scanner was the innovation which completely changed the practice of ultrasound scanning and added
further impetus to obstetrics ultrasound techniques and its arrival has established ultrasonography as the most important imaging modality in obstetrics and gynecology.

Obstetric ultrasound is the use of ultrasound scans in pregnancy. Its application was started in the year 1958 in Glasgow, Scotland, in the university department of midwifery under professor Ian Donald who carried out some experiments with industrial ultrasound metal flaw detectors on some tumors. After some disappointing early results, a dramatic case when ultrasound saved a patient’s life by diagnosing a huge, easily removable, ovarian cyst in a woman who had been diagnosed as having inoperable cancer of the stomach, made people take the technique seriously. By October 1969, the time the first world congress of ultrasound in medicine was held in Vienna, all essential concepts underlying modern diagnostic ultrasound has been demonstrated and within the following few years, varieties of commercial ultrasound equipments were made available.

Developments in obstetrical ultrasonography lead to the creation of the new speciality of prenatal diagnosis which became concerned with the study of fetal congenital anomalies. Another important development in the 1980s was fetal biometry. Every single measurable part of the fetus has been measured and their changes throughout gestation was documented. At least two dozens measurements were developed to assess gestational age and fetal size. Nevertheless, by the late 1980s only a few basic fetal measurements ‘stood the test of time’ and remained in wide use. The measurements that are still widely used today for fetal biometry are the crown-rump length (CRL), the biparietal diameter (BPD), the abdominal circumference (AC), the femur length (FL), the head circumference (HC), the anteroposterior trunk diameter
(APTĐ), the transverse trunk diameter (TTD) and the fetal trunk cross-sectional area (FTA).

HOW DOES ULTRASOUND WORK?

Basically, the ultrasound machine sends out a beam of sound for a very short period of time and then it listens for the returning echoes. Every time it hears an echo from the sound beam it sent out, it places a dot (usually a shade of gray, ranging from black to white) on the monitor. The location of each dot depends on how long it takes the echo to reach the machine. The shade of gray is determined by how strong (loud) the machine perceives the echo to be. The sound beam is emitted by a transducer which is placed on the maternal abdomen and is moved to scan the contents of the abdomen. A transducer can also be placed inside the mother’s vagina for the same purpose. The ultrasound beams scan the fetus in thin slices and reflect the echoes back to the same transducer. The information obtained from the different reflections are then recomposed back into a picture on the monitor screen.

Ultrasound is now routinely used in a variety of clinical situations to aid in managing pregnancy.\(^{(10)}\) The commonest medical indications for which ultrasound examinations are performed during pregnancy include the following:

- Diagnosis and confirmation of early pregnancy. Ultrasound demonstrates the existence of gestational sac as early as four and a half weeks. It can also very importantly confirm that the site of the pregnancy is within the cavity of the uterus.
• Diagnosis of ectopic pregnancy. Ultrasound is a valuable diagnostic aid for this complication.

• Determination of the viability of the fetus. The viability of the fetus can be documented in the presence of vaginal bleeding in early pregnancy. A visible heartbeat could be seen and is usually clearly depicted by the seventh week.

• Estimation of gestational age for patients with uncertain clinical dates, or verification of dates for patients who are to undergo scheduled elective repeat cesarean delivery, induction of labor, or other elective termination of pregnancy. Ultrasonographic confirmation of these permits proper timing of cesarean delivery or labor induction to avoid premature delivery.

• Follow up evaluation of placenta location for identified placenta previa.

• Evaluation of fetal growth, size and weight (e.g., when the patient has an identified etiology for uteroplacental insufficiency, such as severe pre-eclampsia, chronic hypertension, chronic renal disease, severe diabetes mellitus, or for other medical complications of pregnancy where fetal malnutrition, i.e., intrauterine growth restriction (IUGR) or macrosomia, is suspected). Following fetal growth permits assessment of the impact of a complicating condition on the fetus and guides pregnancy management.

• Determination of fetal presentation when the presenting part cannot be adequately determined in labor or the fetal presentation is variable
in late pregnancy. Accurate knowledge of presentation guides management of delivery.

- Vaginal bleeding in pregnancy. Ultrasound often allows determination of the source of bleeding and status of the fetus.

- Abruptio placentae. Confirmation of diagnosis and extent assists in clinical management.

- Diagnosis of multiple gestation based upon detection of more than one fetal heartbeat pattern, or fundal height more than expected for dates.

- Adjunct to amniocentesis. Ultrasound permits guidance of the needle to avoid the placenta and fetus, to increase the chance of obtaining amniotic fluid, and to decrease the chance of fetal loss.

- Hydatidiform mole on the basis of clinical signs of hypertension, proteinuria, and/or the presence of ovarian cysts felt on pelvic examination.

- Adjunct to cervical cerclage placement. Ultrasound aids in timing and diagnosis of patients with incompetent cervix.

- Adjunct to special procedures, such as fetoscopy, intrauterine transfusion, shunt placement, *in vitro* fertilization (IVF), embryo transfer, or chorionic villi sampling. Ultrasound aids instrument guidance, which increases safety of these procedures.

- Biophysical evaluation for fetal well-being after 28 weeks of gestation. Assessment of amniotic fluid, fetal tone, body movements
and breathing movements, assists in the management of high-risk pregnancies.


- Polyhydramnios or oligohydramnios: Confirmation of the diagnosis is permitted, as well as identification of the cause of the condition in certain pregnancies.

- Estimation of fetal weight and/or presentation in premature rupture of membranes and/or premature labor. Information provided by ultrasound guides management decisions on timing and method of delivery.

- Follow up observation of identified fetal anomaly. Ultrasound assessment of progression or lack of change assists in clinical decision making.

- Observation of intrapartum events (e.g., version/extraction of second twin, manual removal of placenta, etc.). These procedures may be done more safely with the visualization provided by ultrasound.

- Diagnosis of uterine abnormality (e.g., clinically significant leiomyomata, or congenital structural abnormalities, such as bicornuate uterus or uterus didelphys, etc.). Serial surveillance of fetal growth and state enhances fetal outcome.

- Pelvic mass detected clinically. Ultrasound can detect the location and nature of the mass and aid in diagnosis.
• Intrauterine contraceptive device (IUCD) localization. Ultrasound guidance facilitates removal, reducing chances of IUCD-related complications.

• Ovarian follicle development surveillance. This facilitates treatment of infertility.

Ultrasound is a safe imaging modality. So far, no clinically perceived risk or adverse effects could be demonstrated clearly in human beings from the use of ultrasound. However, other evidence in experimental systems dictates that a hypothetical risk must be presumed. Biological effects have been observed following ultrasound exposure in various experimental systems. These include reduction in immune response, change in cell membrane functions, cell death, degradation of macromolecules, free radical formation and reduced reproductive potential.\(^{(11)}\)

For these reasons, ultrasound examinations should be performed only for valid and specific medical indications. Examinations performed solely to satisfy the family’s desire to know the fetal sex, to view the fetus or to obtain a picture of the fetus should be discouraged.

One of the important components of obstetrics care in our country is fetal growth and well being monitoring. As the period of intrauterine growth and development is one of the most vulnerable in the human lifecycle, the weight of an infant at birth is a powerful predictor of infant growth and survival and an important indicator of maternal health and nutrition prior to and during pregnancy. Birth weight is thus, the final expression of gestational age and rate of intrauterine growth\(^{(12)}\) and its determination during the management of pregnancy by the use of ultrasound, both antepartum and intrapartum, is
one of the tasks routinely required by obstetricians especially in the investigation of high risk pregnancies such as those complicated by maternal hypertension, diabetes mellitus (DM), antepartal hemorrhage (APH) or breech presentation. Estimation of fetal weight is by far the most important use of ultrasonic measurements in obstetrics as it is the most logical way of interpreting fetal growth basing on ultrasound parameters.\(^{13}\)

Ultrasonographic examination is usually requested by clinicians to confirm their suspicion when palpation of fetal parts suggests excessive fetal weight or growth retardation. By estimating the fetal weight before the birth of the baby, it is possible to anticipate the potential problems that are associated with intrauterine growth retardation, (defined as birth weight below the 10\(^{th}\) percentile) or macrosomia, (defined as birth weight above 90\(^{th}\) percentile). Thus, an accurate assessment of fetal weight is very important in triaging patients in labor.\(^{14}\)

Obstetric ultrasonographic assessment for the purpose of obtaining fetal biometric measurements to predict fetal weight has been integrated into the mainstream of obstetric practice during the past quarter century. From its inception, this method has been presumed to be more accurate than clinical and manual methods for estimating fetal weight especially if multiple fetal biometric parameters are used to derive the birth weight estimate.\(^{9}\) The reasons for this assumption vary, but the fundamental underlying presumption is that the ultrasonographic measurements of multiple linear and planar dimensions of the fetus provide sufficient parametric information to allow for accurate algorithmic reconstruction of the three-dimensional fetal volume of varying tissue density. As such, the ultrasonographic technique represents the newest and most technologically sophisticated
method of obtaining birth weight estimations. Furthermore, because of the absence of clinically perceived risk of ultrasound and its usefulness in many clinical obstetrics situations such as assessing structural anomalies, multiple pregnancy, gestational age and fetal weight to mention a few, many practitioners have now begun to use it routinely as a screening device in all pregnancies. However, the efficacy of many uses of ultrasound in improving the management and outcome of pregnancy has been assumed rather than demonstrated, especially its value as a routine screening procedure. There is, therefore need to investigate the accuracy as well as the safety of ultrasonographic methods in this country so as to enable our pregnant Sudanese women to benefit from this new and sophisticated technology.

**Importance of antenatal fetal weight estimation:**

Accurate assessment of fetal weight by ultrasound examination is critical to obstetric management. Both low birth weight (<2500 grams) and excessive fetal weight at delivery (>4000 grams) are associated with an increased risk of newborn complications during labor and the postpartum. Small-for-gestational-age (SGA) fetuses are vulnerable during the stresses of labor and delivery. For this reason, accurate identification of SGA fetuses allows for close monitoring and more informed decision-making about prolonging the pregnancy or operative delivery. The perinatal complications associated with low birth weight are attributable to pre term delivery, intrauterine growth retardation (IUGR), or both.

As for excessively large fetuses, risks to both newborns and mothers increase significantly as fetal weight climbs beyond 4000 grams. The
potential fetal complications associated with macrosomic delivery include prolonged labor, shoulder dystocia, brachial plexus injuries, bony injuries and intrapartum asphyxia. The maternal risks associated with the delivery of an excessively large fetus include birth canal and pelvic floor injuries, perineal lacerations and postpartum hemorrhage. Other known risks of fetal macrosomia are an increased incidence of operative vaginal delivery and cephalopelvic disproportion with increasing fetal size. This later fact contributes to both an increased rate of forceps delivery and cesarean delivery for macrosomic fetuses compared with fetuses of normal weight.\(^{15}\) To limit the potential complications associated with the birth of both small and excessively large fetuses accurate estimation of fetal weight is required in advance of delivery.

**Fetal development and growth:**

Gestational age is the time elapsed since the first day of the last menstrual period. This starting time, which is usually about two weeks before ovulation and fertilization, has traditionally been used because most women remember when their last period was but do not remember when they last ovulated. The period of gestation is usually divided into three trimesters each trimester lasting for three calendar months. Important obstetrical milestones can be designated conveniently by trimesters. For example, the possibility of spontaneous abortion is linked principally to the first trimester whereas the likelihood of survival of the infants born preterm is increased greatly in pregnancies that reach the third trimester.
During the first two weeks after ovulation and fertilization, the fertilized ovum passes through several successive phases of development eventually, after the development of chorionic villi, becoming an embryo. Eight weeks after fertilization (that is ten weeks after the onset of the last menstrual period), the embryo develops into a fetus and from this stage onwards, development consists of growth and maturation of structures that have already been formed during the embryonic period.

To assess growth of the fetus during the intrauterine period many methods are used. Some of the most important of these methods are:

1. Biparietal diameter (BPD): The BPD is an easily measured parameter that could be made reliably and reproducibly. For it to have any value at all the level of measurement must be carefully defined. The BPD increases steadily throughout gestation, but after about 32 weeks the rate of change decreases. Nevertheless, BPD gives an accurate guide to gestational age up to about 20 weeks.

2. Head circumference (HC): Measurements are made at the same level as the BPD but involve a circumference rather than a diameter assessment. HC is less dependant on head shape than BPD so that a dolicocephalic head, which is narrow but long, has an appropriate circumference for gestation age but a small BPD.

3. Cerebellar growth: Cerebellar growth has been shown to be reasonably linear from 14 to 40 weeks, with the transverse diameter in millimeters being roughly equivalent to gestational age in weeks of pregnancy. It offers an objective assessment of gestational age throughout pregnancy and, more important, the cerebellum does not
seem to be affected by intra uterine growth restriction. However, the measurement is more difficult to make in the latter weeks of pregnancy.

4. Femur Length (FL): FL is primarily a measurement of gestation age, with good accuracy from around 15 – 25 weeks but it can be combined with other measurements to estimate fetal size.

5. Abdominal Circumference (AC): AC is the best index for assessing both fetal size and growth because the measurement is taken at the level of the liver, which constitutes about 4% of total fetal weight and which steadily increases in size with gestational age. For consistency to be achieved, the measurement must at a carefully defined level in the fetal abdomen.

One of the advantages of ultrasound is that it allows repeated examinations of the fetus: both head and abdominal measurements have been used to plot fetal growth and normal patterns have been established. The terms ‘symmetrical’ and ‘asymmetrical’ are used to describe patterns of growth in utero in relationship to head and abdominal circumference measurements. Head size increases because of progressive growth of the fetal brain and this may be maintained for some time despite intrauterine starvation. Fetal liver size, which is the main contributor to the abdominal girth, normally increases steadily during pregnancy owing to the accumulation of glycogen and storage substances. However, in contrast to the brain, liver growth is sensitive to reduction of the supply of nutrients and so, provides a potentially useful marker of intra uterine starvation.
Thus, an asymmetrical pattern of growth restriction develops because of continuing head growth with little or no increase in abdominal girth, leading to a high head/abdominal circumference ratio. These changes are observed when intrauterine growth restriction (IUGR) has a vascular or uteroplacental basis. On the other hand, symmetrical growth restriction, when both head and abdominal size are proportionally small, may be found either with a normal small-for-gestational-age fetus or when there has been some serious early insult to the developing embryo, fetus or the placenta. This may include intrauterine infections, congenital syndromes and genetic abnormalities. However, gestational age at delivery is the most significant determinant of newborn weight as preterm delivery constitutes the largest cause for low birth weight in newborns worldwide \(^{(15)}\).

**Fetal Weight Categories:**

Fetal weight may be characterized as falling into one of the following three categories:

1. Reference range (generally defined as between 10\(^{th}\) and 90\(^{th}\) percentile for gestation age).
2. Small for gestational age (<10\(^{th}\) percentile).
3. Large for gestation age (> 90\(^{th}\) percentile).
The diagnosis of deviations in fetal weight presupposes that the reference range for fetal weight at each gestational age is established. Before a reference range for human birth weight can be established properly, the gestational age at which human births occur must first be defined. This issue is of primary importance because fetal weight increases rapidly once the second trimester of pregnancy is reached. The reference range of gestational age for spontaneous delivery in human pregnancies is well accepted as 280 days (40 weeks) from the first day of the last normal menstrual period (ie, 266 days after fertilization). Because fewer than 3% of births occur precisely at 40 weeks’ gestation and the standard deviation (SD) for term pregnancies is 1 week, the normal range of term birth weight is typically referenced to the mean birth weight for pregnancies delivered at 38-42 weeks' gestation (ie, mean term gestational age ±2 SD). During this four-week period, the average fetus gains approximately 25 grams/day, depending on the sex of the fetus.\(^{(16)}\) The average birth weight during this period varies significantly, depending on maternal race and ambient elevation.

**Factors that influence fetal weight:**

The average term infant in the United States of America at birth ranges between 3000 and 3600 grams depending upon many factors, both endogenous and extrinsic.\(^{(17)}\) These factors include maternal, environmental, physiologic, socioeconomic and pathologic factors in addition to some complications of pregnancy:
a. Maternal factors (eg, race, stature). Black and Asian women have smaller fetuses compared to white women when appropriately matched for gestational age. Not surprisingly, white gravidas show a significantly higher prevalence of fetal macrosomia compared with black and Asian gravidas, and nonwhite gravidas have a significantly higher prevalence of small-for-gestational-age newborns compared to white women.

b. Environmental factors: Several major environmental factors can have an adverse effect on fetal size, the two chief among these being high altitude and cigarette smoking.\(^{(17)}\)

c. Physiologic factors (eg, altered glucose metabolism, microvascular integrity)

d. Pathologic factors: Several maternal illnesses and complications of pregnancy are associated with decreased birth weight. The most common associated illnesses are chronic maternal hypertension and pre-eclampsia. Some intrauterine infections (eg, viral, parasitic, bacterial) are also associated with small-for-gestational-age fetuses.

e. Socioeconomic factors: The greater the socioeconomic deprivation of the mother, the lower is the fetal weight.

f. Complications of pregnancy (eg, gestational diabetes mellitus, pre-eclampsia)

After the above-mentioned factors, six other major maternal and pregnancy-specific determinants of birth weight are relevant in influencing birth weight. These are:

- Maternal height
• Obesity
• Pregnancy weight gain
• Age
• Parity
• Fetal sex

Taken together, these measurable demographic factors can help explain more than one third of the variance in term birth weight. By comparison, paternal factors are only minimally important in determining fetal weight\(^{(18)}\). Paternal height is the only routinely measured paternal demographic variable that has significant influence on fetal weight, but it accounts independently for less than 2% of the variance. Fetal sex is associated significantly with birth weight; female fetuses are known to be smaller than male fetuses when matched for gestational age. Although fetal sex is a significant predictor of fetal weight, it accounts independently for less than 2% of the variance.

The term fetal macrosomia denotes a fetal size that is too large. Ideally, this designation should be referenced to the mean of fetal and maternal dimensions within a given population, but, rather arbitrarily, it has been defined as a birth weight greater than 4000 grams and it affects 2-15% of all gravidas, depending on the racial, ethnic, and socioeconomic composition of the population under study. Uncontrolled maternal diabetes mellitus is one of the condition commonly associated with excessive fetal weight as glucose is the primary substrate used by fetuses for growth. When maternal glucose levels are excessive, abnormally high rates of fetal growth can be expected. Even in women without frank diabetes mellitus, the elevated glucose screening test values in pregnancy predisposes to increasing birth weight.\(^{(19)}\)
Methods of Fetal weight estimation:

Estimation of fetal weight is a complicated and imprecise science. There are three main approaches for obtaining fetal weight: Clinical (tactile) examination, ultrasonographic fetal biometry and the use of magnetic resonance imaging (MRI). The first two approaches are currently the most commonly used methods of predicting fetal weight.

1. Clinical assessment of fetal size: The oldest technique for assessing fetal weight involves the manual assessment of fetal size by the obstetrician. Worldwide, this method is used extensively because it is both convenient and virtually costless; however, it has long been known to be a subjective method that is associated with significant predictive errors. It is also patient and clinician-dependant for its success (i.e., less accurate for obese than non-obese gravidas, and is subject to interobserver variation in birth weight predictions even among experienced clinicians). It is not unusual to have larger (macrosomic) babies that are mistaken for average-sized babies. Several factors, including the volume of the amniotic fluid, the size and the configuration of the uterus, mother's size and body habitus make this method difficult. To give accurate results, clinical assessment method for obtaining fetal weight must be employed at or near the date of delivery.\(^{(20)}\)

2. Obstetric Ultrasonography: Ultrasound estimates using formulas developed by Campbell, Hadlock, Rose, Shepherd, Warsof, Aoki, Sabbagha and other researchers can be obtained \(^{(1-7)}\). The calculations use several fetal anatomic measurements based on various combinations of the biparietal...
diameter of the fetal head, head circumference, abdominal circumference, anteroposterior fetal trunk diameter, transverse fetal trunk diameter, fetal trunk cross-sectional area, spine length, and femur length both singly and in combination. These calculations can give an average weight consistent with these measurements. The advantage of this technique is that it relies on linear and/or planar measurements of in utero fetal dimensions that are definable objectively and should be reproducible. However, there appears to be several technical limitations to every ultrasonographic technique for estimating fetal weight, among which are maternal obesity, anterior placental position and oligohydramnios.\(^{(21)}\) The ultrasonographic technique is also complicated, labor-intensive and requires expensive equipments and specially trained personnel which is generally a problem for a developing nation such as our country, where medical resources are often scarce. The ultrasonic method of fetal weight estimation is regarded by most clinicians to be more objective and therefore, a more accurate way to obtain an estimated fetal weight.\(^{(22)}\)

3. Recently, magnetic resonance imaging (MRI) became the latest imaging modality to be used in estimation of fetal weight using fast spin echo sequence. This method was found to have an accuracy that is superior to that of ultrasound especially in term fetuses.\(^{(23)}\) The prospective MR calculation was based on the following equation:

\[
\text{MR weight (g)} = 0.12 + 1.031 \ g/\text{mL} \times \text{fetal volume (mL)}
\]

(Where MR is magnetic resonance; g is gram; mL is milliliter)

**Fetal weight estimation equations:**
There are many equations for fetal weight estimation that were developed by researchers in Europe, United States and Japan during the last 25 years. The first and simplest of these equations use only one fetal biometric parameter. Other equations were derived from the measurement of multiple fetal biometric parameters.

The Campbell and Wilkins equation calculated the estimated fetal weight using, the Abdominal circumference (AC). The fetal weight is derived by the following formula:

\[
\ln \text{BW} = -4.564 + 0.0282 (AC) - 0.0000331 (AC)^2
\]

[Where \( \ln \) is the natural logarithm, \( \text{BW} \) is birth weight (in grams) and \( AC \) is the fetal abdominal circumference (in millimeters)]

The Warsof 1 equation, developed in 1986 also uses one fetal anatomic parameter, the femur length (FL). The Warsof 1 equation is derived as follows:

\[
\ln \text{BW} = 4.6914 + 0.00151 (FL)^2 - 0.0000119 (FL)^3
\]

[Where \( \ln \) is the natural logarithm, \( \text{BW} \) is the birth weight (in grams) and \( FL \) is the fetal femur length (in millimeters)]

**Formulas using two parameters:**

In 1982 Shephard developed an equation that employs two fetal anatomic parameters namely BPD and AC for predicting the fetal weight. In this equation the estimated fetal weight in grams is obtained as follows:

\[
\log_{10} \text{BW} = -1.7492 + 0.0166 (BPD) + 0.0046 (AC) - 0.0002646 (AC \times BPD)
\]
Two more equations that use two parameters for calculating estimated fetal were developed by Hadlock in 1985 and Warsof in 1986.

The Hadlock 2 equation employed AC and FL for calculating the estimated birth weight as follows:

\[ \log_{10} BW = 1.304 + 0.005281 (AC) + 0.01938 (FL) - 0.00004 (AC \times FL). \]

The Warsof 2 equation also employ AC and FL but using a different algorithm:

\[ \ln BW = 2.792 + 0.108 (FL) + 0.000036 (AC)^2 - 0.00027 (FL \times AC) \]

**Formulas using three parameters:**

The Hadlock 1 and Hadlock 3 developed in 1985 employ three parameters for calculating the estimated fetal weight. Hadlock 1 uses AC, FL and HC according to the following equation:
Log10 BW = 1.326 – 0.0000326(AC x FL) 0.00107(HC) + 0.00438(AC) + 0.0158(FL)

[Where BW is birth weight (in grams), ac is the fetal abdominal circumference (in millimeters), FL is the fetal femur length (in millimeters) and HC is the fetal head circumference (in millimeters)]

Hadlock 3 equation uses AC, BPD and FL:

Log 10 Birth Weight in grams = 1.335 – 0.000034(AC x FL) + 0.00316(BPD) + 0.00457(AC) + 0.01623(FL)

The Combs formula, developed in 1993, uses AC, HC and FL according to the following formula:

BW = [0.00023718 x (AC)² x (FL)] + 0.00003312 (HC)³

[Where BW is birth weight (in grams), AC is the fetal abdominal circumference (in millimeters) and HC is the fetal head circumference (in millimeters)]

The Aoki equation developed in Japan, (11) also uses three anatomic parameters namely BPD, FTA and FL for the calculation of fetal weight according to the following formula:

FW = .1.25647 x (BPD)³ + 3.50665 x FTA x FL + 6.3

[Where FW is the fetal weight (in grams), BPD is the bi-parietal diameter of the fetal head (in centimeters), FTA is the Fetal trunk cross-sectional area (In squared millimeters) and FL is the fetal femur length (in centimeters)]

**Formulas using four parameters:**
In 1990 the Aloka company LTD developed a formula for calculating estimated fetal weight that uses BPD, APTD, TTD and FL. according to the following formula:

\[ FW = 1.07 \times (BPD)^3 + 3.42 \times APTD \times TTD \times F \]

Where FW is fetal weight (in grams), BPD is the bi-parietal diameter of the fetal head (in centimeters) APTD is the anteroposterior fetal trunk diameter (in centimeters), TTD is the transverse fetal trunk diameter (in centimeters) and F is the fetal femur length (in centimeters)

The formula of Shinozuka et al (24) employs BPD, APTD, TTD and SL according to the following equation:

\[ FW = 1.07 \times (BPD)^3 + 2.91 \times APTD \times TTD \times SL \]

Where FW is fetal weight (in grams), BPD is the biparietal diameter of the fetal head (in centimeters), APTD is the anteroposterior fetal trunk diameter (in centimeters), TTD is the transverse fetal trunk diameter (in centimeters) and SL is the spine length (in centimeters)

**How accurate are the fetal weight estimation methods:**

All the currently available methods for assessing fetal weight in utero are subject to significant predictive errors. These errors are most clinically relevant at the two extremes of birth weight (i.e. those <2500 grams who are also more likely the products of premature deliveries and those >4000 grams who are at risk for the complications associated with fetal macrosomia.
With the advent of three-dimensional fetal imaging, optimism that these new
technologies can provide even better fetal weight estimations may be
justified, but the advantages of estimating fetal weight using these newer
techniques have not yet been demonstrated. In future, it is possible that the
use of magnetic resonance imaging and other recent new approaches, will
result in further improvements in the accuracy of fetal weight prediction
which will hopefully permit prospective obstetric intervention to be
undertaken more confidently by practicing obstetricians in our country, with
the aim of minimizing intrapartum and peripartum risks for both fetuses and
mothers.

OBJECTIVES

The general objective of this study is:
To study the accuracy of some ultrasonicographic formulas in the estimation of the fetal weight in pregnant Sudanese women.

The specific objectives are:

1. To calculate the fetal weight using three different ultrasound formulas:
   a- A formula with two fetal biometric parameters
   b- A formula with three fetal biometric parameters
   c- A formula with four fetal biometric parameters
2. To correlate the ultrasonographically predicted fetal weights above with the actual birth weights immediately after delivery.
3. To determine the relative accuracy of each formula in predicting the birth weights at term.

Chapter Two
PATIENTS AND METHODS

Study design and study area:

This study is a descriptive cross-sectional study conducted at the Ribat University Hospital, departments of obstetrics and gynecology in the labor room, the ante natal ward and the department of radiology and imaging. The study was conducted during the period from December 6, 2003 to May 3, 2004.

Study population:

The study population were selected from the group of term pregnant Sudanese ladies presenting to the labor room in the first stage of labor or admitted to the antenatal ward for elective caesarian section. Two hundred of these ladies aged between 18 and 42 years, who satisfied the inclusion criteria, were included in the study population. The study population, who hailed from sixty one different Sudanese tribes, were all residents of the seven localities of Khartoum State. One hundred women of the study population presented to the labor room for spontaneous vaginal delivery while the other one hundred were admitted for elective caesarian section for various reasons.

The following inclusion and exclusion criteria were used:

Inclusion criteria:

a. Sudanese lady aged between 18 and 45 years.

b. The lady must have a viable singleton pregnancy

c. Gestational age should be between 37 and 42 weeks.
d. Membranes must be intact

e. She should have a booking for delivery in the Ribat University Hospital

**Exclusion criteria:**

a. Non Sudanese women and Sudanese term ladies less than 18 years or more than 45 years of age.

b. Ladies with multiple gestations

c. Ladies with less than 37 weeks of gestation

d. Ladies with ruptured membranes

e. Ladies with known fetal anomalies

**Sampling technique:**

As time allows, all term ladies showing to the labor room in the first stage of labor or to the antenatal ward for elective caesarian section during the availability of the investigator to perform the examinations were included in the study regardless of the amount of amniotic fluid or the ease of obtaining ultrasonographic measurements.

**Data collection technique:**

To avoid non sampling error, which is an error that results solely from the manner in which the observations are made, all examinations and ultrasonographic measurements were performed by one and the same person, a senior radiologist and sonologist in the X-ray department of the Ribat university hospital (Dr. S K) who used standardized trans abdominal
techniques. Meanwhile, the author used a predetermined questionnaire asking about the following variables: age, residence, tribe, parity, membranes status and the gestational age. He also recorded the measurements of the following fetal biometric parameters: BPD, AC, APTD, TTD, FTA, and FL. These parameters were subsequently used in combinations for the calculations of fetal weights.

**Procedure of ultrasonic scanning:**

After informing the subjects about the procedure and obtaining verbal consent from each of them, real-time ultrasonographic examination was performed using a real time Aloka SSD- 650 dynamic image scanner owned by the Ribat University Hospital and a 3.5-MHz convex and linear probes with attached thermal paper printer. The image scanner uses 220- 240 voltage and water soluble, hypoallergenic ultrasound gel from Parker laboratories, New Jersey, USA was used for the examinations.

The operator sits comfortably by the side of the couch with his fore arm and hand resting gently on the patient and the probe is held with his fingers close to the transducer face and the little finger resting on the lady’s skin so that the transducer is kept in maximum control and maintained steadily on the skin at the correct angle. Enough ultrasound gel is always applied over the scan area to make good contact between the probe and the skin surface and to allow free movement of the transducer face over the skin.

Using a standardized trans abdominal techniques, the operator makes a general survey of the abdomen with the lady in the semi recumbent and slightly tilted position to avoid aorto-caval compression. The fetal
presentation, amniotic fluid volume, placental location were checked and then electronic caliper measurements of the fetal head, fetal femur and abdomen were performed according to established criteria. During the scan, the fetal biparietal diameter (BPD), the fetal abdominal circumference (AC), the fetal femur length (FL), the fetal anteroposterior trunk diameter (APTD), the fetal transverse trunk diameter (TTD) and the fetal trunk cross-sectional area (FTA) were all measured. The fetal head was displayed in an axial plane at the level of the thalami and the cavum septum pellucidum and the BPD was measured from the outer edge of the parietal bone nearer the transducer to the inner edge of the opposite parietal bone i.e. from leading edge to leading edge (25). (See photograph I). The fetal abdominal area and abdominal circumference was measured at the level of the vascular junction of the umbilical vein with left portal vein in the liver where it is equidistant from the lateral walls in a plane perpendicular to the long axis of the fetus measured from outer edge to outer edge of soft tissues. The outline of the abdomen being circular or elliptical (26). (See photograph II).

The femur length was measured with the bone across the beam axis. The strong acoustic shadow behind the femoral shaft and the visualization of both cartilaginous ends indicate that the image plane is on the longest axis and is the optimal measurement plane. The calipers were then placed along the diaphyseal shaft excluding the uncalcified epiphyses (25). (See photograph (III).

**Fetal weight calculation:**

Sonographic estimates of birth weight were derived using the three equations that are incorporated into the Aloka SSD-650 scanner’s software: The equation from Shephard et al (4), the Aoki equation (6) and the Aloka A
equation. In this scanner, the formulas used to calculate the estimated fetal weight (EFW) are as follows:

1. Shephard: \[ \log_{10} EFW = -1.7492 + (0.166 \times BPD) + (0.046 \times AC) - (0.002646 \times AC \times BPD) \]

2. Aoki: \[ EFW = (1.25647 \times BPD^3) + (3.50665 \times FTA \times FL) + 6.3 \]

3. Aloka: \[ EFW = 1.07 \times (BPD)^3 + 3.42 \times APTD \times TTD \times FL \]

[Where EFW is the estimated fetal weight (in grams); BPD is the bi-parietal diameter of the fetal head (in centimeters); AC = fetal abdominal circumference (in centimeters); FTA = fetal trunk cross-sectional area (in squared centimeters); APTD is the anteroposterior fetal trunk diameter (in centimeters), TTD is the transverse fetal trunk diameter (in centimeters) and FL is the fetal femur length (in centimeters)]

**Weighing of the new born babies:**

Immediately after delivery, the babies are weighed by the department’s midwives using a standard seca scale and the birth weights of the newborn babies in kilograms were recorded in the delivery registration book of the labor room. The placenta is also weighed and its weight recorded. The same scale and technique have been used for weighing all the new born babies. The baby is weighed without any clothes and the reading of the scale is registered in the labor room log book under the supervision of one of the two health visitors of the labor room.

**Data Analysis:**

Data was collected from two hundred women at term. One hundred of these women presented in the first stage of spontaneous vaginal delivery while the
other one hundred were admitted for elective caesarian section. Ultrasonographic fetal weight estimations were performed within 48 hours or less of delivery. As previous research has shown that between 37 and 40 weeks’ gestation, the average observed weight gain by a fetus was twenty five grams per day (16), 25 grams was added to the estimated weight for each day between ultrasound scan and delivery of the fetus. The actual birth weights in grams, were obtained from the labor room registration book as recorded by the department midwives immediately after delivery.

Statistical computer analysis was performed by a completely randomized block design with each patient representing a block of repeated measurement. After demonstrating homogeneity of the variance, the error in the three groups of estimations was compared by analysis of the variances and the chi square test was used to analyze categorical data. Analysis also included evaluation of the mean error (in grams) which is the average within estimated age groups of birth weight minus ultrasound estimated weight.

Analysis of the variances and the comparison of mean errors in the three groups of equations used for fetal weight estimation revealed that there was statistically significant difference in the three methods of fetal weight estimation (P < .0005).

**Ethical considerations:**

Permission was obtained from the relevant authorities of the Ribat university hospital for the conduction of this study and prior to any examination, a verbal consent was obtained from each and every pregnant lady and the procedure is then briefly explained to her. All the examinations were
conducted by the same examiner in clinical settings that assured comfort of
the operator as well as privacy and dignity of the patients.

Chapter Three

RESULTS

Results of the background data:

The mean age for the women in the study group was found to be 27.95 years
with a standard deviation of ± 5.53. Tables (1) and (2) showed that the age
group with the largest number of subjects were the (21 – 25) and (26 – 30)
age groups respectively which between them represents 62 % of the study
group. 37% of women who delivered normally and 25% of women who
were delivered by caesarian section fell in the first age group while 25% of
normally delivered women and 37% of those delivered by caesarian section
fell in the second age group.

Table (1): Age distribution of the study population

<table>
<thead>
<tr>
<th>Age groups (Years)</th>
<th>No. of women</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 – 20</td>
<td>18</td>
<td>9.0 %</td>
</tr>
<tr>
<td>21 – 25</td>
<td>62</td>
<td>31.0 %</td>
</tr>
<tr>
<td>26 – 30</td>
<td>62</td>
<td>31.0 %</td>
</tr>
<tr>
<td>31 – 35</td>
<td>35</td>
<td>17.5 %</td>
</tr>
</tbody>
</table>
Figures (1) and (2) explaining the gender distribution of the new born babies shows that overall, 109 (54.5%) of the newborns were male babies while 91 (45.5%) were baby girls. 54 of the normally delivered group of women (54
%) had male babies compared to 55 women (55 %) giving birth to baby boys for those who delivered by caesarian section. However, normally delivered women had slightly more baby girls (46 women or 46 %) than women who delivered by caesarian section (45 women or 45 %).

Figure I: Explains the gender distribution of the newborn babies
Figure II: Explains the gender distribution by mode of delivery
All women of the study population were residents of Khartoum State. Table (3) shows that the original residence of 59 of them (29.5 %) was East Nile locality. 49 women (24.5%) were residents of Khartoum locality, 37 women (18.5) resided in Jebel Aulia locality, while 29 women (14.5 %), 11 women (5.5%), 9 women (4.5%), and 6 women (3.0 %) were residents of Bahry, Omdurman, Um Badda and Kereri localities respectively.
Table (3): Residence of the study population in Khartoum State

<table>
<thead>
<tr>
<th>Locality</th>
<th>No. of women</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease Nile</td>
<td>59</td>
<td>29.5 %</td>
</tr>
<tr>
<td>Khartoum</td>
<td>49</td>
<td>24.5 %</td>
</tr>
<tr>
<td>Jebal Aulia</td>
<td>37</td>
<td>18.5 %</td>
</tr>
<tr>
<td>Bahry</td>
<td>29</td>
<td>14.5 %</td>
</tr>
<tr>
<td>Um Badda</td>
<td>11</td>
<td>5.5 %</td>
</tr>
<tr>
<td>Omdurman</td>
<td>9</td>
<td>4.5 %</td>
</tr>
<tr>
<td>Kereri</td>
<td>6</td>
<td>3.0 %</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>200</strong></td>
<td><strong>100.0 %</strong></td>
</tr>
</tbody>
</table>

The studied population belonged to 61 different Sudanese tribes hailing from all states of the country. 86 of these women (43 %) belonged to tribes indigenous to the northern region of Sudan comprising the Nile and the Northern States. 52 women (26%) belonged to tribes indigenous to the western region of the country comprising the states of Northern Kordofan, Southern Kordofan, Western Kordofan, Northern Darfur, Southern Darfur and Western Darfur. 50 women (25%) belong to tribes indigenous to the central region of Sudan comprising Khartoum, Gezira, White Nile, Sennar and Blue Nile States. The Southern and Eastern regions had only 10 (5.0 %) and 2 (1.0 %) subjects respectively (See table 4).
Table (4): Ethnic background of the study population

<table>
<thead>
<tr>
<th>Ethnic group</th>
<th>No. of women</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern region tribes</td>
<td>86</td>
<td>43.0 %</td>
</tr>
<tr>
<td>Western region Tribes</td>
<td>52</td>
<td>26.0 %</td>
</tr>
<tr>
<td>Central region Tribes</td>
<td>50</td>
<td>25.0 %</td>
</tr>
<tr>
<td>Southern region Tribes</td>
<td>10.0</td>
<td>5.0 %</td>
</tr>
<tr>
<td>Eastern region Tribes</td>
<td>2</td>
<td>1.0 %</td>
</tr>
<tr>
<td>Total</td>
<td>200</td>
<td>100.0 %</td>
</tr>
</tbody>
</table>

Results of Obstetrical History data:

Figure (III) and (IV) explaining the parity distribution of the study population shows that 73 women (36.5 %) were pregnant for the first time. 44 women (13.0 %) had one previous delivery, 26 women (13.0 %) had two previous deliveries, 20 women (10.0 %) had three previous deliveries, 19 women (9.5 %) had four previous deliveries while 18 (9.0 %) had more than four previous deliveries.
Figure III: Explains parity distribution of the study population

![Bar chart showing parity distribution](chart)

Figure IV: Explains parity of the study population by mode of delivery

![Bar chart showing parity by mode of delivery](chart)
The mean gestational age at delivery was $39.5 \pm 1.4$ weeks while the incidence of post term delivery (gestational age $> 40$ weeks) was $11.5\%$. (Tables 5 and 6).

**Table (5): Gestational age distribution of the study population**

<table>
<thead>
<tr>
<th>Gestational age (Weeks)</th>
<th>No. of women</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>39</td>
<td>19.5%</td>
</tr>
<tr>
<td>38</td>
<td>37</td>
<td>18.5%</td>
</tr>
<tr>
<td>39</td>
<td>53</td>
<td>26.5%</td>
</tr>
<tr>
<td>40</td>
<td>48</td>
<td>24.0%</td>
</tr>
<tr>
<td>&gt; 40</td>
<td>23</td>
<td>11.5%</td>
</tr>
<tr>
<td>Total</td>
<td>200</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

**Table (6): Gestational age distribution by the mode of delivery**
### Mode of delivery

<table>
<thead>
<tr>
<th>Gestational age (Weeks)</th>
<th>Mode of delivery</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal vaginal delivery</td>
<td>Caesarian section</td>
</tr>
<tr>
<td></td>
<td>No. of women</td>
<td>Percentage</td>
</tr>
<tr>
<td>37</td>
<td>18</td>
<td>18.0 %</td>
</tr>
<tr>
<td>38</td>
<td>14</td>
<td>14.0 %</td>
</tr>
<tr>
<td>39</td>
<td>26</td>
<td>26.0 %</td>
</tr>
<tr>
<td>40</td>
<td>27</td>
<td>27.0 %</td>
</tr>
<tr>
<td>&gt;40</td>
<td>15</td>
<td>15.0 %</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100</td>
<td>100.0 %</td>
</tr>
</tbody>
</table>

Tables (7) and (8) showed that overall, 82 women of the study population (41.0 %) delivered on the same day of ultrasonographic examination, 90 of them (45%) delivered one day after the examination while in 28 women (14.0 %) delivery occurred two days after ultrasound examination.

**Table (7): Days between sonogram and delivery**

<table>
<thead>
<tr>
<th>Days until delivery</th>
<th>No. of women</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>82</td>
<td>41.0 %</td>
</tr>
<tr>
<td>1</td>
<td>90</td>
<td>45.0 %</td>
</tr>
<tr>
<td>2</td>
<td>28</td>
<td>14.0 %</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>200</td>
<td>100.0 %</td>
</tr>
</tbody>
</table>
Table (8): Days between sonogram and delivery by mode of delivery.

<table>
<thead>
<tr>
<th>Interval (Days)</th>
<th>Mode of delivery</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal vaginal delivery</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No. of women</td>
<td>Percentage</td>
</tr>
<tr>
<td>0</td>
<td>76</td>
<td>76.0 %</td>
</tr>
<tr>
<td>1</td>
<td>20</td>
<td>20.0 %</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>4.0 %</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100.0 %</td>
</tr>
</tbody>
</table>

Results of data on weight issues:

Figure (V) explaining the birth weight categories of the newborn babies shows that the actual birth of 186 (93.0 %) of the babies born at the end of pregnancies were within the reference birth weight of 2500 – 4000 grams. Only 8 newborn babies (4.0 %) were of low birth weight while 6 (3.0 %) were above 4000 grams (or macrosomc). All the 6 macrosomic babies (100.0 %) and 6 of the small babies (75.0 %) were born to women who had normal vaginal deliveries whereas women delivered by caesarian section had 98.0 % of their babies within the standard birth weight range (See figure VI)

Figure V: Explains the birth weight ranges of the newborn babies
Birth weight ranges

2500 – 4000 grams (93.0%)

< 2500 grams (4.0%)

>4000 grams (3.0%).

Figure VI: Explains the birth weight ranges of the newborn babies by the mode of delivery
The mean and the standard deviation for the birth weight was 3196.70 gram with a standard deviation of ± 454.19. The mean birth weights for male newborns was 3281.009 ± 664.308 grams while that for female babies was 3107.253 ± 635.077 grams. Two equations, the Aoki and the Shephard equations tended to underestimate fetal weights, that is to say, the mean adjusted fetal weights derived by the use of these two formulas were less than the mean actual birth weight. However, the mean adjusted fetal weight as derived by the Aloka equation was higher than the mean actual fetal weight (See Table 9).

**Table (9): Comparison between mean and standard deviation (SD) of estimated weights and the actual birth weights (In grams)**
<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Actual birth weight</strong></td>
<td>3196.70</td>
<td>454.19</td>
<td>2000 – 4400</td>
</tr>
<tr>
<td>Adjusted estimated weight A (Aloka)</td>
<td>3298.89</td>
<td>318.83</td>
<td>2454 – 4285</td>
</tr>
<tr>
<td>Adjusted estimate weight B (Aoki)</td>
<td>3087.51</td>
<td>316.13</td>
<td>2418 – 4204</td>
</tr>
<tr>
<td>Adjusted estimated weight C (Shephard)</td>
<td>3094.60</td>
<td>315.10</td>
<td>2246 – 4094</td>
</tr>
</tbody>
</table>

Table (10) shows that overall, 154 of the fetuses estimated by Aoki formula (77.0 %) were within 10 % of actual birth weight compared with 76.0 % for Shephard’s formula and 75.5 % for Aloka. The sonologically estimated fetal weights were arbitrarily divided into four subgroups and the percentage of estimates within 10 % of actual fetal weight in each subgroup was compared for the three methods of estimation.
Table (10): Percentage of sonographically predicted weights within 10 \% And 5 \% of actual birth weights

<table>
<thead>
<tr>
<th>Sonographic equation</th>
<th>No. of fetuses within 5% of actual birth weight</th>
<th>No. of fetuses within 10% actual birth weight</th>
<th>Percentage of fetuses within 10% actual birth weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aloka’s equation</td>
<td>70</td>
<td>151</td>
<td>75.5%</td>
</tr>
<tr>
<td>Aoki’s equation</td>
<td>79</td>
<td>154</td>
<td>77.0%</td>
</tr>
<tr>
<td>Shephard’s equation</td>
<td>68</td>
<td>152</td>
<td>76.0%</td>
</tr>
</tbody>
</table>

Table (11) shows that six of the newborn babies were macrosomics (Birth weight > 4000 grams) The mean birth weight in this group was found to be 4205 \pm 145.34 grams with a range of 4100 – 4400 grams.

Table (11): Actual birth weight distribution

<table>
<thead>
<tr>
<th>Birth weight range (Grams)</th>
<th>Number of babies</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2500</td>
<td>8</td>
<td>4.0 %</td>
</tr>
<tr>
<td>2500 – 4000</td>
<td>186</td>
<td>93.0 %</td>
</tr>
<tr>
<td>&gt; 4000</td>
<td>6</td>
<td>3.0 %</td>
</tr>
<tr>
<td>Total</td>
<td>200</td>
<td>100.0 %</td>
</tr>
</tbody>
</table>
Table (12) showed that the mean BPD was $9.27 \pm 0.4$ cm, mean AC was $32.41 \pm 2.1$ cm, the mean FL was $7.34 \pm 0.4$ cm and the mean FTA was $83.94 \pm 11.0$ squared cm.

Table (12): the mean, standard deviation and range of measured fetal parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPD (cm)</td>
<td>9.27</td>
<td>± 0.4</td>
<td>8.4 – 9.6</td>
</tr>
<tr>
<td>AC (cm)</td>
<td>32.41</td>
<td>± 2.1</td>
<td>29.1 – 37.3</td>
</tr>
<tr>
<td>APTD (cm)</td>
<td>9.77</td>
<td>± 0.6</td>
<td>8.5 – 11.6</td>
</tr>
<tr>
<td>TTD (cm)</td>
<td>9.86</td>
<td>± 0.6</td>
<td>8.6 – 10.9</td>
</tr>
<tr>
<td>FTA (cm²)</td>
<td>83.94</td>
<td>±11.0</td>
<td>64.0 – 114.5</td>
</tr>
<tr>
<td>FL (cm)</td>
<td>7.34</td>
<td>± 0.4</td>
<td>6.6 – 8.8</td>
</tr>
</tbody>
</table>
Photograph I: Showing the correct position for BPD
Photograph II: Showing the correct position for AC
Photograph III: Showing the correct position for FL
DISCUSSION

Accurate estimation of birth weight is important because it influences obstetrics management and potentially predict peripartum complications. With the development of ultrasonographic fetal measurements, numerous methods of fetal weight estimation have been evaluated. Many of these computer generated equations such as the Campbell & Wilkins(1), Hadlock et al(2), Rose & McCallum (3) and the Sabbagha equation (7) use head and abdominal measurements similar to our formulas in this study. Obese patients, anterior location of the placenta and decreased amniotic fluid levels are factors that can affect the quality of sonographic examination and therefore, its accuracy. However, Ott et al (27) studied the effect of head shape, growth pattern and amniotic fluid volume and clearly showed that placenta location did not significantly affect the error in any of the formulas for estimating fetal weight.
The quality and the accuracy of our study may have been affected by the other factors such as maternal body habitus, maternal obesity and diminished volume of amniotic fluid, which are thought to affect the quality and accuracy of ultrasonographic estimation of fetal weight before delivery and near term, but which have not been investigated in our study.

One way to determine the relative accuracy of two or more ultrasound methods of fetal weight estimation is to perform the estimations concurrently on the same patient and then compare the error for the methods. Another way is to calculate the percentages of the estimated fetal weights that are within 10.0% of the actual birth weight, the formula with more estimates that are within 10.0% being considered more accurate.

The present study was designed to evaluate the relative accuracy and the effect of various fetal parameters on three sonographic methods of estimating fetal weight. The effect of birth weight on accuracy was minimized by selecting a population with an expected narrow birth weight range. All examinations were carried out by a single investigator, thus eliminating inter observer variation as a confounding variable.

The mean error for each of the three methods was comparable to other published reports. The comparison of mean error among the methods and the percentage of fetuses estimated within 10 % of actual birth weight revealed that the Aoki formula was slightly more accurate than either Aloka or Shephard’s formulas. This is in agreement with the findings of Chien et al (22) who estimated fetal weight using the Aoki, Campbell, Shephard and Hadlock formulas. They suggested that the high validity for estimating fetal weight obtained with the Aoki formula might be because it uses three fetal biometric variables (BPD, FTA and FL) rather than two variable (BPD &
AC) as in the Shephard’s formula or one variable (AC) as in the Campbell formula.

Our result is also comparable to other published reports. For example, using BPD and two dimensions of the abdominal diameter (AD) which was averaged, Benacerraf et al stated that 74.0% of their estimates were within ±10% of the actual birth weight in a sample of thirteen hundred pregnant women (21). This is lower than our result which showed that 75.5% - 77.0% of the estimated weights were within 10% of actual birth weight. The large sample size in that study compared with our 200 subjects may have contributed to the difference that existed between the two results.

Our result also agreed with the findings of Shamley et al who evaluated prospectively four published equations by Hadlock et al, Rose and McCallum, Shephard et al, and Sabbagha et al (2,4,3,7) for accuracy in determining fetal weight during labor and found that 70.0 – 79.0% of their weight predictions were within 10% of actual fetal weight (28). This is similar to our finding of 75.5 – 77.0% accuracy rate. However in that study, the Hadlock equation, which does not rely on BPD measurements, was found to be both the most accurate and clinically useful method for predicting fetal weight for patients in labor at term, indicating that formulas with multiple fetal parameters does not necessarily give the most accurate results in fetal weight estimation at term.

As the head is frequently engaged during first stage of labor, BPD could not often be measured accurately in patients in active labor. In our study all three formulas under evaluation use BPD in the estimation of fetal weight. The accuracy of our BPD measurements may have been affected by this limiting factor. In such patients formulas using other standard ultrasound
measurements such as the femur length (eg Hadlock 2 formula) are advised for estimation of fetal weight.

Our study demonstrated that fetal weight can be estimated accurately and reliably by ultrasound at term using any of the three formulas under evaluation. The percentage of estimates within 10% of actual birth weight was significantly higher among those who were estimated by Aoki’s formula followed closely by Shephard’s formula. Furthermore, the Aoki equation presented the smallest mean difference between fetal weight estimated by ultrasound and actual birth weight compared with the two other equations. The study also found that the Aoki and the Shephard equations tended to underestimate fetal weight whereas the Aloka equation tended to overestimate. This finding is in agreement with that of Chien et al (22) who found a high level of validity for fetal weight estimated by the Aoki and Shephard formulas.

**CONCLUSION**

The study concludes that:

1. Sonographic estimation of fetal weight, especially when based on the measurements of multiple fetal parameters and obtained under research conditions during the antepartum period, provides reliable and clinically useful information for most patients in labor.

2. All three formulas evaluated showed similar degree of accuracy in estimating fetal weights during the antepartum period but, that the
Aoki equation was relatively more superior in its accuracy followed by the Shephard equation.

3. The use of three fetal anatomic biometric parameters for predicting fetal weight during the antepartum period was found to give more accurate results than the use of two fetal parameters.

4. When the number of fetal parameters was increased to four, the accuracy of fetal weight estimations tended to decrease.
RECOMMENDATION

Based on the finding that Aoki’s formula showed a superior degree of accuracy compared with either the Shephard or the Aloka formula, we recommend to our Sudanese obstetricians the use of Aoki’s formula followed by the Shephard formulas as the formulas of choice for the sonographic estimation of fetal weights for Sudanese pregnant women.
REFERENCES


Questionnaire

1. Serial Number………………………………
2. Date of examination………………………
3. Name ………………………………………
4. Age………………………………………….
5. Residence…………………………………
6. Parity………………………………………. 
7. Tribe ………………………………………
8. Last Normal Menstrual Period (LMP)…………………….
9. Expected Date of Delivery (EDD)………………………
10. Menstrual Gestation Age (GA)…………………………
11. Membranes: ……………..Intact / Ruptured………………
12. Measurements of fetal anatomic parameters:

<table>
<thead>
<tr>
<th>BPD</th>
<th>AC</th>
<th>APTD</th>
<th>TTD</th>
<th>FTA</th>
<th>FL</th>
<th>Estimated Weight A</th>
<th>Estimated Weight B</th>
<th>Estimated Weight C</th>
</tr>
</thead>
</table>

13. Date of delivery……………………………………

14. Mode of delivery : ……Normal Vaginal delivery / Caesarian section

15. Actual Birth Weight (in grams)…………………………

16. Interval between sonological estimation and delivery (Days) ……

17. Corrected Estimated Weights:
(a) Corrected weight A ......................................
(b) Corrected weight B ......................................
(c) Corrected weight C ......................................

18. Fetal gender ................................. Male / Female