Ultrasonography of Fetal kidney Length and Width As the approach for estimation of gestational age

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فلَوَّاَللهِ أَحْكَمُ ۖ ﻣَلَكَتِهِ ﺎَلَّا ﻳَكُونَ ﻣَلِكُ ﻣَلَكَةِ اللّهِ وَلَمْ يَكُنَّ ﻣَلَكُ ﻣَلَكَةِ أَحَدٍ ۖ سُورَةُ الإِخْلاَصِ
To those who inspired me along the road, my beloved parents,
To the best support in our life ....my families,
To the smiley faces of life ....brothers and sisters,
To the lights of life ....my friends,
To my fiancée and
To those who wished me success.
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Abstract

Background: - A true estimation of gestational age (GA) plays an important role in quality maternity care and scheduling the labor date. The objectives of this study were to evaluate the application of kidney length and width measurement to the determination of gestational age between the 14th and 40th weeks and to compare its accuracy with that of other fetal biometric indices. This study has been designed as a prospective descriptive cross sectional study in Khartoum and Gezira states - Sudan, from June 2013 to May 2014. 389 Sudanese healthy pregnant women, age between 15 – 45 years were examined by ultrasound with normal and well-being fetuses. Linear regression models for estimation of gestational age were derived from the biometric indices and kidney length and width. In addition, stepwise regression models were constructed to detect the best model for determining GA between 14 and 40 weeks. Comparisons were then made between the accuracy of these models in the determination of GA. The results of this study showed the univariate and multivariate linear regression analysis was used to create a predictive equation to estimate gestational age on the kidney length and width and fetal biometry parameters. The equations derived from linear regression analysis when the individual variables were considered separately. Among the variable parameters considered in this study, the most accurate was the kidney width (KW) with a standard error (SE) of 0.02 day, after that the kidney length (KL) (SE=0.04 day), biparietal diameter (BPD) (SE=0.10 day) and femur length(FL) (SE=0.13 day). While the least accurate was the abdominal circumference (AC) with a SE of 1.35 days. A significant correlation was found between GA and KL and KW (r=0.72, P<0.002), (r=0.76, P<0.002), respectively. This study concluded that the Kidney length and width are easy to identify and measure. It is the most accurate parameter for estimating GA than other biometric indices in late second and third trimesters and could be easily incorporated into the models for estimating GA.
ملخص الأطروحة

يلعب التقدير الحقيقي لعمر الحمل دورا هاما في رعاية الأمومة وسلامة الجنين وتقييم الجدول الزمني لتكوين الحمل.

تلتخص هذه الدراسة في تقييم تطبيق قياس طول وعرض الكلى لتحديد عمر الحمل بين الأسبوع الرابع عشر والأسبوع الأربعين ومقارنة دقته مع المعطيات العمرية المتداولة. أجريت هذه الدراسة في ولايتي الخرطوم والجزيرة في الفترة ما بين يوليو 2013 حتى مايو 2014. وقد تم الكشف عن 389 إمرأة حامل في الفئة العمرية من 15 إلى 45 سنة لأمهات صحيات ذوات حمل جنين صحي معافي خال من العيوب والتشوهات الخلقية. وقد استنادت نتيجة الدراسة من نماذج الانحدار الخطي لتقدير عمر حمل الجنين من المؤشرات الحيوية وطول وعرض الكلى بالإضافة إلى ذلك، تم إنشاء نماذج الانحدار التدريجي لتقدير عمر الحمل.

تم نموذج لتحديد عمر الحمل بين الأسبوع الرابع عشر والاسبوع الأربعين من عمر الحمل. ونتيجة هذه الدراسة، استند النموذج إلى تحليل الانحدار الخطي أحادي المتغير والتغيرات المتعددة. تم إنشاء معادلة تنبؤة لتقدير عمر الحمل من قياسات طول وعرض الكلى، وتم استخدام T-Test لتحديد العلاجات المتعددة من خلال المقارنة بين النماذج المستمدة من تحليل الانحدار الخطي للعلاجات كل على حدة.

حالة التقدير: حسب نموذج الانحدار الخطي أحادي المتغير، يمكن تقدير عمر الحمل من قياسات طول وعرض الكلى. وبناءً على النماذج المستمدة، إذا كانت النتائج سنة، فإن أكثر دقة في تقدير عمر الحمل من خلال قياس عرض الكلى مع الخطأ المعياري 0.02 يوم، وقيم طول القد مع الخطأ المعياري 0.04 يوم، وقياس طول القد مع الخطأ المعياري 0.04 يوم. أما قياس عرض الكلى مع الخطأ المعياري 0.13 يوم، وكان الأقل دقة في تقدير عمر الحمل هو قياس عرض الكلي مع الخطأ المعياري 1.35 يوم. مما يعني أن هناك علاقة قوية جداً بين قياس طول وعرض الكلي للجنين وعمر الحمل.

إذا، يمكن إدراجها بسهولة في نماذج تقدير عمر الحمل.
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**List of Abbreviations**

(AC): Abdominal Circumference

(BMP): Bone Morphogenetic Protein

(BPD): Biparital Diameter

(CRL): Crown-Rump Length

(CSP): Cavum Septi Pellucidum

(DFE): Distal Femur Epiphysis

(FL): Femur Length

(GDNF): Glial- Cell-Derived Neurotrophic Factor

(GA): Gestational Age

(HC): Head Circumference

(IVC): Inferior Vena Cava

(KL): Kidney Length

(KW): Kidney Width

(LMP): Last Menstrual Period

(SD): Standard Deviation

(SE): Standard Error

(US): Ultrasound

(UPJ): Ureteropelvic Junction
CHAPTER ONE

INTRODUCTION
1.1. Introduction

Accurate GA estimation is very important to an obstetrician for diagnosis of growth disorders, in assessment of wrong dates or forgotten dates and timing of delivery either by induction or caesarean section. \(^{(1)}\)

Fetal growth assessment, either clinically or by ultrasound evaluation, also relies on accurate assessment of GA. Fetal growth retardation or macrosomia may be missed or incorrectly diagnosed owing to errors in the GA assessment. Interpretation of antenatal biophysical testing (non-stress tests and biophysical profiles) may be subject to variation with gestational age as well. Fetal heart rate reactivity and fetal breathing develop with advancing GA; therefore, the absence of these biophysical parameters may be interpreted as abnormal for fetuses in which the GA has been overestimated. Obstetric management is also dependent on GA. Proper decision regarding presumed preterm labor or postdate pregnancies are only possible when GA is accurately estimated. Likewise, timing of repeat cesarean sections requires accurate assessment of dates. \(^{(1, 2)}\)

Ultrasound is a reliable method for establishing the length of pregnancy and in this way can improve obstetric care. Sonographically measured fetal renal length is accurate and useful tool for assessment of fetal renal growth and well being. \(^{(3)}\)

Ultrasonography of fetal measurements is highly reliable in the first and second trimester of pregnancy but reliability of any ultrasound method greatly diminishes as gestation advances. In third trimester, reliability of any single ultrasound parameter is poor. \(^{(4, 5)}\)
Ultrasound assessment for GA is becoming increasingly important. Many parameters are being used for establishing GA, for example, biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC) and femur length (FL). Recently, the evaluation of the posterior fossa of the fetal cranium has been accepted as part of routine obstetrical estimations. In the past, the BPD had been described as a reliable method of determining GA.\(^{(6,7)}\)

While the BPD was the first fetal parameter to be clinically utilized in the determination of fetal age in the second trimester, more recent studies have evaluated the use of several other biometric parameters including HC, AC, FL, foot length, ear size, orbital diameters, cerebellum diameter and others.\(^{(8-11)}\) However, as GA progresses, they become increasingly unreliable because of the biological variability of size in relation to age,\(^{(15)}\) Accurate dating of pregnancies in the late second trimester or in the third trimester therefore remains a problem, especially in women who consult late for maternity care and are uncertain of the date of their LMP.\(^{(12)}\)

Fetal kidney grows progressively along with GA and, therefore, ultrasonography examination can predict GA at any trimester. Parameters such as BPD etc. are thought to compute GA more correctly when performed at an earlier gestation.\(^{(12)}\)

The fetal kidney is easy to identify and measure,\(^{(13,14)}\) but has not been studied extensively as a biometric index for GA estimation, although ultrasound textbooks often have tables of different dimensions. In a cross-sectional multiple-operator’ study of 397 consecutive pregnancies, Cohen et al,\(^{(16)}\) demonstrated a strong correlation between GA and kidney length. In this
prospective ‘two operator’ longitudinal study we evaluated the accuracy and reproducibility of kidney length measurements in the prediction of gestational age in the second half of pregnancy. In addition, we compared the accuracy of this method with that using BPD, HC, FL.\(^{(16)}\)
Objectives

1.2. General objective:

To perform ultrasonic measurement of fetal kidney length (KL) and width and their correlation with commonly used fetal age estimators.

1.3. Specific objectives:

The specific objectives of this study are to:

1. Establish normative fetal kidney length (KL) and width (KW) ranges in different GA.

2. Prospectively evaluate the accuracy of kidney length (KL) and width (KW) in estimation of gestational age.

3. Evaluate the usefulness of the kidney length (KL) and width (KW) as against the conventional parameters of biparietal diameter and femur length in normal pregnant mothers.

4. Detect variations in the GA by fetal kidney length (KL) and width (KW) in both sexes, in the second and third trimester.

5. Detect the variations of the fetal kidney length (KL) and width (KW) in different ethnic groups.

6. Improve the quality of antenatal care (ANC) through accurate gestational age estimation.

7. Evaluate the usefulness of the kidney length (KL) and width (KW) measurement in antenatal diagnosis of urinary tract anomalies.
CHAPTER TWO

LITERATURE REVIEW
2.1. Gross anatomy of the kidneys:

Grossly, the kidneys are bean-shaped structures and weigh about 150 g in the male and about 135 g in the female. They are typically 10-12 cm in length, 5-7 cm in width, and 2-3 cm in thickness. (1)

The relationship of neighboring organs to the kidneys superiorly, the suprarenal (adrenal) glands sit adjacent to the upper pole of each kidney, on the right side, the second part of the duodenum (descending portion) abuts the medial aspect of the kidney, on the left side, the greater curvature of the stomach can drape over the superomedial aspect of the kidney, and the tail of the pancreas may extend to overlie the renal hilum, the spleen is located anterior to the upper pole and is connected by the splenorenal (lienorenal) ligaments, inferiorly to these organs, the colon typically rests anteriorly to the kidneys on both sides, posteriorly, the diaphragm covers the upper third of each kidney, with the 12th rib most commonly crossing the upper pole, the kidneys sit over the psoas (medially) and the quadratus lumborum muscles (laterally), (1) Fig (2.1).

2.1.1. Blood supply of the kidneys:

The kidneys receive approximately 20% of the cardiac output. The blood supply to the kidneys arises from the paired renal arteries at the level of L2. They enter into the renal hilum, the passageway into the kidney, with the renal vein anteriorly; the renal artery; and the renal pelvis posteriorly. (17)
Fig 2.1: Structures related to the posterior surface of each kidney.\(^{(89)}\)

The first branch off of the renal artery is the inferior suprarenal artery. The renal artery then branches off into 5 segmental branches. The posterior segmental artery supplies most of the posterior kidney, with the exception of the lower pole. The anterior branches are the superior segmental artery, anterior superior segmental artery, anterior inferior segmental artery, and inferior segmental artery. These arteries branch into interlobar arteries, which travel in a parallel fashion in between the major calyces and then branch further into arcuate arteries that run within the cortex across the bases of the renal pyramids.\(^{(17)}\)

They then radiate into interlobular arteries, which extend into the cortex of the kidney to finally become afferent arterioles, then peritubular capillaries to efferent arterioles. Some of the terminal branches of the interlobular arteries become perforating radiate arteries, which supply the renal capsule. Renal pelvic and superior ureteric branches also originate from the renal artery and supply the upper portion of the collecting system.\(^{(17)}\) Fig (2.2).
The renal veins drain the kidneys in a similar distribution, and the renal vein is generally anterior to the renal artery at the hilum. The left renal vein is longer than the right as it crosses the midline to reach the inferior vena cava (IVC). Generally, the left gonadal vein drains into the left renal vein inferiorly, while the left suprarenal vein drains into the superior aspect of the renal vein at approximately the same level. Posteriorly, the left second lumbar vein typically drains into the left renal vein as well. The left renal vein then crosses under the origin of the superior mesenteric artery to reach the IVC. On the right side, the renal vein and gonadal vein drain separately and directly into the IVC. \(^{(17)}\)

### 2.1.2. Renal lymphatics:

The lymphatic drainage parallels the venous drainage system. After leaving the renal hilum, the left primary lymphatic drainage is into the left lateral
aortic lymph nodes, including nodes anterior and posterior to the aorta between the inferior mesenteric artery and the diaphragm. On the right, it drains into the right lateral caval lymph nodes. (17)

2.1.3. Collecting system:

Once the filtrate gets to the collecting ducts in the medulla of the kidney, they converge to a renal papilla, which represents the tip or apex of the renal pyramid. Urine then collects in typically 9-12 minor calyces, which then converge into 3-4 major calyces (significant variation is possible).

The major calyces then empty into the renal pelvis, which passes urine through the ureteropelvic junction (UPJ) and into the ureter, which then propels urine distally to the bladder through peristalsis. The ureter may course posterior to the renal artery (or a lower pole branch) at its superior point, cross over the psoas muscle, and then pass posteriorly to the gonadal vessels. As it proceeds further distally, it passes over the iliac vessels and into the pelvis, finally traversing an intramural tunnel into the bladder and ending at the ureteral orifice on the trigone of the bladder, (17) Fig (2.3).

![Coronal section of the kidney shows the collecting system](image)

**Fig 2.3:** Coronal section of the kidney shows the collecting system. (90)
2.1.4. Innervation of the kidneys:

The kidney receives autonomic supply via both the sympathetic and parasympathetic portions of the nervous system. The preganglionic sympathetic nervous innervation to the kidneys arises from the spinal cord at the level of T8-L1. They synapse onto the celiac and aorticorenal ganglia and follow the plexus of nerves that run with the arteries. Activation of the sympathetic system causes vasoconstriction of the renal vessels. Parasympathetic innervation arises from the 10th cranial nerve, the vagus nerve, and causes vasodilation when stimulated. (90)

2.2. Microscopic anatomy of the kidneys:

The kidney is divided into the cortex and medulla. Renal pyramids in the medullary areas are separated by the cortical tissue called renal columns, the functional renal unit is the nephron, which is composed of the renal corpuscle: glomerulus and Bowman capsule, proximal convoluted tubules (PCT), located in the renal cortex, descending loop of Henle (LOH), ascending limb (which resides in the renal medulla, leading to the thick ascending limb), thick ascending limb, distal convoluted tubule, collecting duct (which opens into the renal papilla), blood from the afferent glomerular arteriole passes through the juxtamedullary apparatus to the glomerulus. The glomerulus is a network of capillaries that filters blood across Bowman capsule into the proximal convoluted tubule, the glomerulus contains podocytes and a basement membrane allowing water and certain solutes to be filtered across. This filtrate then reaches the PCT, which reabsorbs glucose and various electrolytes along with water as the filtrate passes through. Meanwhile, after being filtered at the
glomerulus, the blood passes into the efferent glomerular arteriole and then descends into the renal pyramid.\(^{(90)}\)

### 2.2.1. Physiologic considerations in microscopic anatomy:

The renal tubular system is uniquely structured in order to maximize its physiologic function. One of its primary functions is to concentrate urine accordingly to the body’s hydro-osmotic state (either hyperosmotic or hypo-osmotic). A hyperosmotic state results in the excretion of hyperosmotic urine, and the reverse is true for when the body is in a hypo-osmotic state. The kidney is able to carry out this function by 2 mechanisms: the action of antidiuretic hormone on the medullary collecting ducts and the phenomenon termed countercurrent multiplication.\(^{(18)}\)

Countercurrent multiplication is responsible for keeping the medullary interstitial osmotic concentration higher than the renal tubular osmotic concentration. When the iso-osmotic fluid from the proximal tubule enters the descending limb, the osmotic concentration gradient forces water to move out of the descending limb. By the time the tubular fluid reaches the bottom of the loop of Henle, it has a higher osmotic concentration than the interstitial medullary fluid in the ascending limb. Hyperosmolar tubular fluid entering the ascending limb causes NaCl to be reabsorbed back into the medullary interstitium passively. Once the tubular fluid reaches the thick ascending limb, more ions are reabsorbed into the medullary interstitium actively.\(^{(18)}\)

The ion channel responsible for active transport in the thick ascending limb is the Na/K/2Cl transporter. The Na/K/2Cl active ion transporter is responsible for establishing a 200-mOsm/L concentration gradient between
the tubular fluid and the interstitial fluid. The repetitive activity of active
transport in the thick ascending limb, along with the passive reabsorption of
NaCl in the ascending limb, adds more solute to the medulla in excess of
water. This process causes a progressive increase in osmotic concentration
from the corticomedullary junction (approximately 300-mOsm/L) into the
deeper medullary interstitium (approximately 1200-mOsm/L). The elevated
interstitial osmotic concentration helps concentrate urine entering the
collecting tubules and ducts by increasing water reabsorption.\textsuperscript{18}

The vasa recti are a network of capillary vessels that mimic the structure of
the loop of Henle. The main function of the vasa recti is to supply the renal
medulla its metabolic needs while protecting the countercurrent exchange of
the renal tubular system. This is accomplished by low medullary blood flow,
allowing the renal medulla to receive the nutrients it needs while also
preventing significant losses of solute from the medullary interstitium. In
addition, the vasa recti have their own countercurrent exchange mechanism,
preventing the washout of solutes from the medullary interstitium.\textsuperscript{18}

2.3. Development of the kidneys:

The kidneys progress through three developmental stages: the pronephros,
the mesonephros, and the metanephros. The pronephros develops in
gestational week 3 as a condensation of intermediate mesoderm in the lower
cervical and upper thoracic regions extending to the cloaca, and almost
entirely regresses in gestational week 4.\textsuperscript{19}

The pronephric duct, which arises from dorsal and caudal evaginations of
the pronephros, is preserved and ultimately will give rise to the mesonephric
duct. The mesonephros develops more caudally, from intermediate
mesoderm; although the majority of these tubules degenerate, the mesonephric duct persists bilaterally. In both sexes, the ureters, renal pelvis, and bladder trigone are derived from the mesonephric duct; in the male, the mesonephric duct also gives rise to the vasa deferentia, epididymides, and seminal vesicles; the former is part of the duct itself, while the latter two structures arise as a result of ductal dilatation or outpouching.\(^{(19)}\) Fig (2.4).

**Fig 2.4: Embryology of the kidney and ureter.** A, Lateral view of a 5-week embryo shows the three embryologic kidneys. B to E, Successive stages of development of the ureteric bud (fifth to eighth week) into the ureter, pelvis, calices, and collecting tubules.\(^{(91)}\)

Once the mesonephric duct comes in contact with the cloaca at the caudal aspect of the embryo, it then grows cranially as the ureteric bud until it comes in contact with the metanephric mesenchyme, forming the metanephros.\(^{(19)}\)
The ureteric bud and metanephric mesenchyme reciprocally induce growth, forming the kidney. The ureteric bud progressively enlarges and divides to form the renal pelvis, infundibula, collecting ducts, and 8-12 major and minor calyces.\(^{(20)}\) Branching of the ureteric bud is controlled by the glial-cell-derived neurotrophic factor (GDNF).\(^{(21, 22)}\) Bone morphogenetic protein (BMP)-4 acts locally to decrease ureteric bud genesis and branching, and appears to be involved in preventing ureteral bud ectopia and promoting the development of periureteral smooth muscle\(^{(23)}\) gremlin 1 (grem 1), a BMP-4 antagonist, is normally present around the ureteric bud, locally decreasing BMP-4 activity and thus permitting ureteral branching.\(^{(22)}\) Numerous other genes and proteins have been implicated in normal and abnormal renal development.\(^{(24)}\) The collecting tubules invaginate metanephric mesoderm to form metanephric vesicles, which subsequently elongate to form metanephric tubules. As the metanephric tubules are invaginated by capillaries (glomeruli), nephrons are formed. This process continues until the 32\(^{\text{nd}}\) gestational week. At birth, approximately 750,000 to 1 million nephrons are present in each kidney; postnatally, renal size may increase, owing to elongation of the proximal convoluted tubules.\(^{(25)}\)

With differential longitudinal growth of the embryo, the kidney “ascends” from its initial location in the pelvis to its final location in the upper retroperitoneum. During ascent, transient blood vessels serially arise and degenerate; these arteries persist in ectopic kidneys as well as in some orthotopic renal units. Concurrently, the kidneys rotate around their vertical and horizontal axes so that their final orientation is one in which the upper poles are slightly more medial and anterior than the lower poles, Fig 2.4.\(^{(26)}\)
2.3.1. Natural variants:

Anatomic variations in the renal vasculature occur in approximately 25-40% of patients.\(^{(17)}\) Supernumerary, or accessory, renal arteries are the most common arterial variation, with most of these branches supplying the lower pole of the kidney. They may pass anterior to the inferior vena cava (IVC) and over the ureteropelvic junction and be associated with (or cause) obstruction of the ureteropelvic junction (UPJ). Persistence of the right subcardinal vein anterior to the ureter can lead to a retrocaval ureter, which can also cause obstruction.\(^{(27)}\)

Kidney position in the retroperitoneum is subject to variation as well. A kidney may be in an ectopic location, such as the pelvis, when it doesn’t ascend properly, or it can be malrotated or fused (as in horseshoe kidneys, in which the inferior poles are fused, causing a U-shaped configuration).\(^{(17)}\)

In some fusion anomalies, such as crossed-fused ectopia, the 2 kidneys may be located on the same side. Although some of these variations may be associated with pathological conditions, such as hydronephrosis and UPJ obstruction, they can also remain completely asymptomatic and undiscovered until a diagnosis is made by radiographic study.\(^{(17)}\)

Importantly, in an ectopic kidney, the adrenals should still be in the superior portion of the posterior peritoneum, since their embryologic origin is different from that of the kidneys.\(^{(17)}\)

Variants may also exist in the collecting system drainage. Duplication anomalies may develop, wherein more than a single collecting system may form and drain separately into the bladder (complete duplication) or join at
some point proximally before draining into a single orifice into the urinary bladder (partial duplication). In a complete duplicated system, the upper pole moiety drains inferomedially into the bladder, and the lower pole moiety drains superolaterally, as described by the Weigert-Meyer rule.\(^{17}\) Fig (2.5).

![Image](image.png)

**Fig 2.5:** photomicrograph, of horseshoe kidneys. \(^{(90)}\)

### 2.4. Fetal ultrasound scan:

Ultrasonography is widely used for the prenatal evaluation of growth and anatomy as well as for the management of multiple gestations. The procedure provides diagnostic findings that often facilitate the management of problems arising in later pregnancy. For example, abnormal fetal growth is a leading cause of perinatal morbidity and mortality in both industrialized and developing countries. In 2005, the World Health Organization (WHO) concluded. That impaired fetal growth had many causes related to: genetic factors, maternal characteristics such as nutrition, lifestyle including smoking, age and disease; complications of pregnancy; and the physical, social and economic environment.\(^{(28, 29)}\) A mid-trimester fetal ultrasound scan serves as
an important baseline against which later scans may be compared for the evaluation of growth and health. Ultrasonography can also be used to detect congenital anomalies.\(^{(30, 31, \text{and } 32)}\)

2.4.1. Fetal movement:

Normal fetuses typically have a relaxed position and show regular movements. There are no specific movement patterns at this stage of pregnancy. Temporary absence or reduction of fetal movements during the scan should not be considered as a risk factor.\(^{(33)}\) Abnormal positioning or unusually restricted or persistently absent fetal movements may suggest abnormal fetal conditions such as arthrogryposis.\(^{(34)}\)

2.4.2. Doppler ultrasonography:

The application of Doppler techniques is not currently recommended as part of the routine second-trimester ultrasound examination. There is insufficient evidence to support universal use of uterine or umbilical artery Doppler evaluation for the screening of low-risk pregnancies.\(^{(35, 36)}\)

2.4.3. Multiple gestation:

The evaluation of multiple pregnancies should include the visualization of the placental cord insertion, distinguishing features (gender, unique markers, position in uterus), determination of chorionicity is sometimes feasible in the second trimester if there are clearly two separate placental masses and discordant genders. Chorionicity is much better evaluated before 14–15 weeks (lambda sign or T-sign).\(^{(37)}\)
Abnormalities of umbilical cord insertion into the placenta, such as velamentous cord insertion, are more common in multiple gestations and can be associated with several pregnancy complications, such as fetal growth restriction, vasa previa and abnormal fetal heart rate patterns.\(^{(37, 38)}\) Unfortunately, many cases of vasa previa may not be recognized during pregnancy.\(^{(39)}\)

### 2.5. Fetal biometry:

Fetal biometry is the sonographic measurement of fetal structures. There are three primary objectives for measuring fetal parts: to assign fetal (gestational) age, to diagnose fetal growth disorders by assessing if measured fetal parts are appropriate size for GA or by estimating fetal weight and to determine the appropriateness of the dimension of fetal structures against each other (ratio) and/or against GA. First trimester ultrasound is a useful and reliable modality for assessment of GA. The gestational sac mean diameter, Yolk Sac and Crown-Rump Length are useful because each measures a different aspect of the first-trimester pregnancy and may be used at different times during the first trimester. The following sonographic parameters can be used to estimate GA and for fetal size assessment:\(^{(40, 41, 42)}\) biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC) or femur length (FL).

Measurements should be performed in a standardized manner on the basis of strict quality criteria. An audit of results can help to ensure accuracy of techniques with regard to specific reference tables. The images should be taken to document the measurements examples of still images appropriate for fetal biometrics are demonstrated in.\(^{(43)}\) Fig (2.6).
Fig 2.6: Standard fetal biometry: sonographic measurements of the biparietal diameter and head circumference (a), the abdominal circumference (b) and the femur diaphysis length (c). In this example, calipers are placed on the outer and inner edges of the skull for BPD measurement (large white dots in (a)); some reference charts have been developed using different caliper placement for this measurement (e.g. outer edge to outer edge of the skull).^{(92)}

If GA has not already been established at a dating or first-trimester scan, it should be determined at the mid-trimester scan on the basis of fetal head size (BPD and/or HC) or FDL. The chosen reference standards should be indicated in the report.^{(44)} Subsequent scans should not be used to calculate a new estimated date of confinement if age has already been established by a highquality scan earlier in the pregnancy. Additional measurements, optimally at least 3 weeks from a preceding scan, are usually reported as deviations from mean values with their expected ranges for a given age. This information can be expressed as Z-scores, percentile reference ranges or on a graph, although the degree of deviation from normal at this early stage of pregnancy that would justify action (e.g. a follow-up scan to assess fetal growth or fetal chromosomal analysis) has not been firmly established. Combining measurements significantly improves accuracy compared with prediction
based on HC alone. However, the clinical significance of this improvement is marginal because the improved accuracy represents less than 1 day.

2.5.1. Gestational sac diameter:

The gestational sac is the first evidence in pregnancy. It can often be recognized in the uterus after five weeks of amenorrhea and can be located asymmetrically. It can be found as a double echogenic ring in the uterus and can be distinguishable from 5 to 6 weeks with uniform echogenicity. A small gestational sac is usually due to a blighted ovum and is fairly a common finding. Fig (2.7).

![Image of gestational sac](CORUT.png)

**Fig 2.7: Gestational sac.** At 5.0 weeks’ gestation gestational sac (arrow) appears as a small, intrauterine fluid collection with an echogenic rim; COR UT, coronal uterus.

2.5.2. Crown-rump length (CRL):
The Robinson and Hadlock crown–rump length (CRL) curves are commonly used to estimate (GA) based on the CRL of an embryo or fetus. However, the Robinson curve was derived from a small population using transabdominal sonography and the Hadlock curve was generated using early transvaginal ultrasound equipment. In total 3710 normal singleton pregnancies with a known LMP were included in the study, corresponding to 4387 scans. Their data differed significantly from both the Robinson and the Hadlock curves (paired t-test, P < 0.0001). A mixed-effects model for CRL as a function of GA was developed on 70% of the data and internally validated with z-scores on their meaning 30%. The new curve extended from 5.5 to 14 weeks’ gestation. Compared to Pexsters CRL curve and Robinson curve, the Robinson curve gave a 4-day underestimation of GA at 6 weeks with a difference in CRL of 3.7 mm and a 1 day overestimation from 11 to 14 weeks with a difference in CRL of (0.9–1) mm. A comparison between the Pexsters and Robinson curves and the Hadlock curve showed a difference in CRL of 2.7 mm at 6 weeks, equivalent to an underestimation of 3 days, and a difference in CRL of 4.8 mm at 14 weeks, equivalent to an overestimation of 2 days. At 9 weeks all three curves were similar. The new CRL curve suggests differences in the range of CRL measurements compared with the Robinson and Hadlock curves. These differences are most significant at the beginning and the end of the first trimester, and may lead to more accurate estimations of GA.\textsuperscript{(47)} Fig (2.8).
Fig 2.8: Crown-rump length (CRL) measurement. Cursors delineate the length of the fetus from the top of its head to the bottom of its torso. The yolk sac (arrow) should not be included in the fetal CRL measurements.\(^{(92)}\)

### 2.5.3. Biparietal diameter (BPD):

Cross-sectional view of the fetal head at the level of the thalami, ideal angle of insonation is 90° to the midline echoes, symmetrical appearance of both hemispheres, continuous midline echo (falx cerebri) broken in middle by the cavum septi pellucidi and thalamus, no cerebellum visualized.\(^{(48)}\)

Both calipers should be placed according to a specific methodology, because more than one technique has been described (e.g. outer edge to inner edge or ‘leading edge’ technique vs. outer edge to outer edge), at the widest part of the skull, using an angle that is perpendicular to the midline falx, Fig (2.9).\(^{(48)}\) The same technique as that used to establish the reference chart should be used. The cephalic index is a ratio of the maximum head width to its maximum length and this value can be used to characterize fetal head shape.
Abnormal head shape (e.g. brachycephaly and dolichocephaly) can be associated with syndromes. This finding can also lead to inaccurate estimates of fetal age. When the BPD is used; in these cases, HC measurements are more reliable.\(^{(49)}\) Fig (2.9).

**Fig 2.9: Biparietal diameter (BPD) and occipitofrontal diameter (OFD) measurements.** Transaxial sonogram of the fetal head at the level of the paired thalami (arrow), with BPD (calipers 1) and OFD (calipers 2). Note how the calipers for the BPD are placed from the outer aspect of the skull to the inner aspect of the skull.\(^{(92)}\)

### 2.5.4. Head circumference (HC):

As described for the BPD, ensuring that the circumference placement markers correspond to the technique described on the reference chart. If the ultrasound equipment has ellipse measurement capacity, then the HC can be measured directly by placing the ellipse around the outside of the skull bone echoes, Fig (3.10). Alternatively, the HC can be calculated from the BPD and occipitofrontal diameter (OFD) as follows: the BPD is measured using a leading edge technique as described in the previous section whereas the OFD
is obtained by placing the calipers in the middle of the bone echo at both the frontal and occipital skull bones. HC is then calculated using the equation: $HC = 1.62 \times (BPD + OFD)$.\(^{(50)}\)

![Head circumference (HC) measurement](image)

**Fig 2.10: Head circumference (HC) measurement.** HC measurement (*calipers and tracing dots*) on transaxial sonogram of the fetal head at the same level as for the BPD measurement. Note how the HC measurement is obtained from around the bone.\(^{(92)}\)

**2.5.5. Abdominal circumference (AC):**

AC can be determined at the skin line on a transverse view at the level of the junction of umbilical vein, portal sinus and fetal stomach. The abdominal imaging plane should be a true transverse cut at the level of the fetal liver and stomach, including the left portal vein at the umbilical region and ensuring that the aorta and IVC are circular. In the third trimester it may be difficult to achieve this plane due to fetal size and position. Hence dating using AC should be made as early as possible.\(^{(51)}\)
Transverse section of the fetal abdomen (as circular as possible), umbilical vein at the level of the portal sinus, stomach bubble visualized, kidneys should not be visible.\(^{(51)}\)

The AC is measured at the outer surface of the skin line, either directly with ellipse calipers or calculated from linear measurements made perpendicular to each other, usually the anteroposterior abdominal diameter (APAD) and transverse abdominal diameter (TAD), Fig (2.11). To measure the APAD, the calipers are placed on the outer borders of the body outline, from the posterior aspect (skin covering the spine) to the anterior abdominal wall. To measure the TAD, the calipers are placed on the outer borders of the body outline, across the abdomen at the widest point. The AC is then calculated using the formula: \( AC = \pi \frac{APAD + TAD}{2} = 1.57 \times (APAD + TAD) \).\(^{(51)}\)

**Fig 2.11: Abdominal diameter and circumference measurements.** A and B, Axial views of the fetal abdomen at the level of the stomach (\(S\)) and intrahepatic portion of the umbilical vein (arrow). On A the transverse (calipers 1) and anteroposterior (calipers 2) diameters have been measured with electronic calipers. On B the circumference of the abdomen has been traced electronically (calipers and tracing dots).\(^{(92)}\)
2.5.6. Femur diaphysis length (FDL):

The FDL is imaged optimally with both ends of the ossified metaphysis clearly visible.\(^{(52, 53)}\) The longest axis of the ossified diaphysis is measured. The same technique as that used to establish the reference chart should be used with regard to the angle between the femur and the insonating ultrasound beams. An angle of insonation between 45° and 90° is typical.

Each caliper is placed at the ends of the ossified diaphysis without including the distal femoral epiphysis if it is visible, Fig (2.12). This measurement should exclude triangular spur artifacts that can falsely extend the diaphysis length.\(^{(52, 53)}\)

Fig 2.12: Femur length (FL) measurement. Electronic calipers measure the ossified diaphysis of the femur.\(^{(92)}\)

2.5.7. Fetal weight (FW):

Mid-trimester sonographic measurements can be used to identify abnormalities of fetal size.\(^{(54, 55)}\) Some countries also use this information to
estimate fetal weight as a baseline parameter for the detection of subsequent growth problems. Many ‘size discrepancies’ are explained by incorrect GA estimates, even in women with ‘certain dates’. If GA is determined at an earlier scan, EFW can be compared to dedicated normal, preferably local, reference ranges for this parameter. However, the degree of deviation from normal at this early stage of pregnancy that would justify action (e.g. follow-up scan to assess fetal growth or fetal chromosomal analysis) has not been firmly established.

Amniotic fluid volume can be estimated subjectively or using sonographic measurements. Subjective estimation is not inferior to the quantitative measurement techniques (e.g. deepest pocket, amniotic fluid index) when performed by experienced examiners. Patients with deviations from normal should have more detailed anatomical evaluation and clinical follow-up.

2.5.8. Fetal kidney length (FKL):

A true estimation of gestational age (GA) plays an important role in quality maternity care and scheduling the labor date. The study aimed to evaluate the normal fetal (KL) and its correlation with GA. A cross-sectional study on 92 pregnant women between 8th and 10th week of gestation with normal singleton pregnancy underwent standard ultrasound fetal biometry and KL measurement. univariate and multivariate linear regression analysis was used to create a predictive equation to estimate GA on the KL and fetobiometry parameters. A significant correlation was found between GA and KL (r=0.83, P<0.002). The best GA predictor was obtained by combining HC, fetal BPD, FL and KL with a standard error (SE) about 14.2 days. Seilanian, et al showed
the KL measurements combination with other fetal biometric parameters could predict age of pregnancy with a better precision.\(^{(62)}\)

Early prenatal diagnostics and the importance of genetic counseling are of great interest for echosonographic evaluation of normal fetus anatomy. Serial measurements of kidney dimensions (length, width, thickness) were performed in 110 fetuses. Photomicrographs of kidneys from the 4th, 6th, 8th and 10th lunar months are also presented. On the basis of the results obtained by Vlajkovic et al examination, concluded that the period from the 14\(^{th}\) to 16\(^{th}\) week of intrauterine life is the fastest period of kidney growth during fetal development. Using the ellipsoid formula for calculating the fetal renal volume offers an underestimation of about 32-33\% on average. The importance of this study lies in determining the average fetal kidney dimensions, which could be used as standard values in obstetrics.\(^{(63)}\)

The normal range of fetal kidney length from early stages of gestation that may allow intrauterine assessment of its development. It may also be helpful in the early prenatal diagnosis of renal abnormalities, adequate kidney length measurements were obtained in all 275 normal fetuses as well as in six fetuses with urinary tract anomalies. Kidney length as a function of GA was expressed by the regression equation: (square root) kidney length (mm) = -11.66 + 1.52 x gestational age (weeks). The correlation coefficient, \(r = 0.983\) was found to be highly statistically significant (\(p < 0.0001\)). The normal mean and the 90\% prediction limits were defined. Four cases with single kidney and two cases with posterior urethral valve had kidney length above the 95\% upper limit.\(^{(64)}\)
Among 100 women, 45% were primigravidae and 55% were multigravidae. The mean GA calculated using LMP was 35.39 weeks by using LMP. The mean GA estimated from the standard parameters and using kidney length & circumference was 32.50 weeks and 34.53 weeks respectively. The prediction error in calculating gestational age after 30 weeks by using standard parameters was 1.79 weeks and with kidney circumference and kidney length was 0.72 weeks.\(^{(65)}\)

The result obtained confirmed that measurement of fetal kidney length and circumference can be used as an additional parameter for documentation of GA in 3\(^{rd}\) trimester.\(^{(65)}\)

The best model for estimating GA in late pregnancy included the variables KL, BPD, HC, FL and AC. This model accurately predicted GA with a standard error of ± 8.48 days. A model including KL, BPD, HC and FL accurately predicted GA with a standard error of ± 8.57 days. These models were slightly more accurate than models derived from the biometric indices of BPD, HC and FL (± 9.87 days), BPD, HC, FL and AC (± 9.45 days) and BPD and FL (± 9.9 days). KL and FL were accurate parameters for predicting GA using simple linear regression models (± 10.29 and 10.96 days, respectively); the AC was the least accurate (± 14.54 days).\(^{(13)}\)

KL is a more accurate method of determining GA than the fetal biometric indices of BPD, HC, FL and AC between 24 and 38 weeks’ gestation. When combined with BPD, HC and FL, the precision of dating is improved by 2 days. This measurement is easy to make and could therefore be easily incorporated into the model for dating pregnancies after 24 weeks of
gestation, in particular when measurements of the BPD and HC are difficult.\(^{13}\)

Accurate estimation of normal antenatal fetal kidneys size is of great importance in quality care, thus determination of normal measurements was helpful in early diagnosis and to optimization fetal safety then reduce the high prenatal morbidity and mortality.\(^{88}\)
CHAPTER THREE

MATERIALS AND METHODS
Materials and Methods

3.1. Study design and area:

This study has been designed as a prospective cross sectional (observational) study in Khartoum and Gezira states – Sudan.

The fetal kidneys of 389 pregnant women examined at various stages of pregnancy at Al Saudi Maternity Teaching Hospital, Wad- Medani Military Hospital (Department of Radiology and Imaging) in the duration between June 2013 and May 2014.

3.2. Study population:

The study population were 389 pregnant Sudanese women referred to obstetric clinic in gestation age in the range between (14 to 40) weeks. Aged between (15 – 45) years, all women who satisfied the inclusion criteria were included in study population. The study population representing different Sudanese tribes were confined to Khartoum and Gezira states.

3.3. Inclusion criteria:

The chosen study population of women selected for this study met the following criteria:

1. Regular menstrual cycle with certainty about the time of the last menstrual period.
2. Normal pregnancy.
3. Viable singleton.
3.4. **Exclusion criteria:**

The study excluded those who met the following criteria:

1. Uncertainty to accurately last menstrual period.
2. Fetal congenital abnormalities.
3. Failure to clearly visualized/measures the fetal kidney.
4. Pregnancy associates hypertension.
5. Diabetes mellitus.
6. Cardiac diseases.
7. Thyroid disease.
8. Repeated cesarean section.
10. Chronic renal disease.

3.5. **The equipment:**

All the examinations and ultrasonographic measurement were performed by the authorized person in the department of the ultrasound in the hospitals using standardized Trans abdominal techniques. Using a Pro-sound 5000 scanner (Aloka, Tokyo, Japan) with a 3.5 – MHz curved-array transducer.

3.6. **Techniques:**

Prior to the examination, pregnant women were instructed to drink three or four glasses of water to achieve maximum bladder distention during the procedure. Cases were examined in the supine position. Multiple cross sections of the uterus made in longitudinal and transverse directions. In the course of ultrasonography the fetal position and BPD were determined.
These lengths and widths of kidneys were analyzed in relation to GA
determined on the basis of BPD, FL, AC, and an average of those three GA in
weeks, which we termed average weeks. These measurements were
correlated with gestational ages determined on the basis of LMP and, in a few
cases, CRL and HC. The longest renal lengths and widths also were assessed
in relationship to maternal heights, weights, BMI and age.

3.7. Measurements of the kidneys:

The measurement of kidney is obtained by placing the electronic calipers at
the outer margins of kidney. On sonography, fetal renal structures cannot be
reliably imaged during the early embryologic events of the first trimester.
However in the majority of pregnancies, the developing kidney can be seen
by the early second trimester. Using articulated arm and water – path
scanners, fetal kidneys can be seen by the 15th postmenstrual week in 50% of
gestations and can be reliably imaged in 90% between 17 and 22 weeks. using
higher resolution real time equipment, suggests that normal fetal kidneys are
often visualized as early as 14 weeks’ gestation and routinely seen by the 16
weeks’ gestation. Initially, the kidneys are visualized on transverse scans of
fetal abdomen as paired hypoechoic structures adjacent to fetal spine. The
measurement of kidney is obtained by placing the electronic calipers at the
outer margins of kidney.

Only those kidneys which complete outline could be imaged. Unclear
adrenal or renal borders, abnormal renal morphology, and renal pelvic
dilatation greater than 4 mm in anteroposterior diameter were grounds for
excluding the measurement. We used the last criteria, despite the fact that
dilatations as great as 1 cm may be found in fetuses who at birth have no
evidence of renal obstruction or vesicoureteral reflux, because we wished to avoid any suggestion of falsely long kidney measurements due to dilatation.

The measurement of the BPD is made in transverse axial plane. Intracranial landmark utilized for the BPD include visualization of falx cerebri posteriorly, the cavum septi pellucidi anteriorly and paired thalami in the midline with a sylvian fissure laterally.

The FL was measured with the bone across the beam axis. The strong acoustic shadow behind the femoral shaft and the visualization of both cartilaginous ends indicated the image plane is on the longest axis.

3.8. Sampling and sample size:

Determining sample size is a very important issue, because samples that are too large may be tedious and time consuming with cost in resources and money. While samples that are too small may lead to inaccurate result. In many cases we can easily determine the minimum sample size needed to estimate a process parameter. A total number of 384 pregnant women are eligible for the present study. Sample size in this study was chosen according to Steven K. Thompson equation.

\[
n = \frac{NP(1-P)}{(N-1)(d^2/z^2)+P(1-P)}
\]

Where:

n= Sample size

N= population size

Z= standard deviation when significant level is 95% (1.96).

P= Previous prevalence (0.5)

d= 1- p (0.5)
3.9. Methods of data analysis:

All statistical analyses were done using SPSS, version 16 Statistical Package for the Social Sciences (SPSS, Chicago, Illinois). Pearson correlation was used to determine the association between continuous quantitative variables. Univariate and multivariate linear regression analysis was used to create a predictive equation to estimate GA on the (KL and KW) and fetobiometry parameters. For each model, the standard error of the prediction in days was calculated for subjects with mean values of the anthropometric measurements included. All hypotheses tests were 2-tailed with P<0.05 considered significant. Data are presented as mean ± standard deviation (SD) for quantitative variables and frequency and percent for qualitative variables.

An analysis of variance was used to compare mean renal length and width for each week of gestational age.

3.10. Ethical consideration:

Healthy pregnant women with known gestational age based on the last normal menstrual period (LNMP) and confirmed by first the trimester, second-trimester and third-trimester ultrasound examination will be recruited into the study with written informed consent. The present study will be approved by the Ethics Committee of Ministry of Health, Khartoum States Sudan. A prospective study would be performed from the 14th to the 40th weeks of gestation. These low-risk patients have no medical complications of pregnancy and undergo routine ultrasonography. All birth information and neonatal outcomes would be reviewed for fetal growth and structural abnormalities.
CHAPTER FOUR

RESULTS
5.1. Results

Out of 389 eligible women completed the study. 12 were excluded because of failure to clearly visualized / measures the fetal kidney, pregnancy associated hypertension, diabetes mellitus, cardiac diseases, thyroid disease, repeated cesarean sections or intrauterine fetal death.

In 377 fetuses, both the right and left kidney were imaged adequately and measured. The range of age (15–45) years, parity of the women (range, 0 – 9), and mean, weight, height and BMI of the women were, 70.4 (range, 52 –100) kg, 1.64 (range, 82.00 –195.00) cm and 28.86 (range, 18.52–87.00), respectively, (Tables 4.1 - 4.2, Fig 4.1).

Maternal age and parity of cases taken in this study are shown in Tables 4.2- 4.4 and Figs 4.1- 4.3.

Occupation and socioeconomic status distribution of cases are shown in Tables 4.5, 4.6 and Figs 4.4, 4.5.

Past medical history, bleeding during this pregnancy, chronic illness, and caesarian section distribution are shown in Tables 4.7- 4.9 and Figs 4.6- 4.8

Table 4.1: Maternal weight, height and BMI of pregnant women.

<table>
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<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
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<tbody>
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<td>Weight</td>
<td>52.0</td>
<td>100.0</td>
<td>70.4</td>
<td>8.0</td>
</tr>
<tr>
<td>Height</td>
<td>82.0</td>
<td>1.95</td>
<td>1.64</td>
<td>25.6</td>
</tr>
<tr>
<td>BMI</td>
<td>18.5</td>
<td>87.0</td>
<td>28.8</td>
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</table>
Table 4.2: Maternal ages of pregnant women between 15 -45 years.

<table>
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<th>Maternal age</th>
<th>Frequency</th>
<th>Percent</th>
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<tr>
<td>25 - 35</td>
<td>224</td>
<td>59.4</td>
</tr>
<tr>
<td>35 - 45</td>
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</tr>
<tr>
<td>Total</td>
<td>377</td>
<td>100.0</td>
</tr>
</tbody>
</table>

As could be seen in Table 4.2 and Fig 4.1 majority of pregnant women fell in the age range between 25-35.

Fig 4.1: Age distribution percentage of pregnant women.
As far as number of parities is concerned, major number of pregnant women had given two births before the one under the current study. As where only two women had nine parities before (Table 4.3 and Fig 4.2).

**Table 4.3:** Parity distribution of cases.

<table>
<thead>
<tr>
<th>Parity</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
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<td>Zero</td>
<td>35</td>
<td>9.3</td>
</tr>
<tr>
<td>one</td>
<td>79</td>
<td>21.0</td>
</tr>
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<td>24.4</td>
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<td>.5</td>
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<tr>
<td>Total</td>
<td>377</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Fig 4.2:** parity distribution of cases taken in this study.
When the residence distribution of the women under the study was taken into consideration almost 60% of total incidence were from urban areas where the rest were from rural localities Table 4.4 Fig 4.3.

**Table 4.4:** Residence distribution of cases taken in this study.

<table>
<thead>
<tr>
<th>Residence</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td>142</td>
<td>37.7</td>
</tr>
<tr>
<td>Urban</td>
<td>235</td>
<td>62.3</td>
</tr>
<tr>
<td>Total</td>
<td>377</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Fig 4.3:** Residence distribution of cases.
When occupations of the pregnant women was considered, majority of women were housewives followed by worker and finally students Table 4.5, fig 4.4.

**Table 4.5:** Occupation distribution of cases.

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>24</td>
<td>6.4</td>
</tr>
<tr>
<td>Housewife</td>
<td>298</td>
<td>79.0</td>
</tr>
<tr>
<td>Worker</td>
<td>55</td>
<td>14.6</td>
</tr>
<tr>
<td>Total</td>
<td>377</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Fig 4.4:** Occupation distribution.

The socioeconomical situation of the cases undertaken in this study is shown in Table 4.6 and Fig 4.5, in which about 80% of the studied cases were fell into medium class, followed by low and very few 3% were of high class.

**Table 4.6:** Socioeconomic status distribution.

<table>
<thead>
<tr>
<th>Socioeconomic status</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>91</td>
<td>24.1</td>
</tr>
<tr>
<td>Medium</td>
<td>274</td>
<td>72.7</td>
</tr>
<tr>
<td>High</td>
<td>12</td>
<td>3.2</td>
</tr>
<tr>
<td>Total</td>
<td>377</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Fig 4.5: Socioeconomic status distribution.

Table 4.7: Bleeding frequency during the pregnancy.

<table>
<thead>
<tr>
<th>Bleeding during this pregnancy</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>20</td>
<td>5.3</td>
</tr>
<tr>
<td>No</td>
<td>357</td>
<td>94.7</td>
</tr>
<tr>
<td>Total</td>
<td>377</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Fig 4.6: Bleeding frequency during the pregnancy.
Out 377 pregnant women considered in this study only around 2% were reported to suffer from chronic illness Table 4.8, fig 4.7.

**Table 4.8:** Chronic illness distribution.

<table>
<thead>
<tr>
<th>Chronic illness</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>9</td>
<td>2.4</td>
</tr>
<tr>
<td>No</td>
<td>368</td>
<td>97.6</td>
</tr>
<tr>
<td>Total</td>
<td>377</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Fig 4.7:** chronic illness distribution of cases taken in this study.

**Table 4.9:** Caesarian section distribution of cases taken in this study.

<table>
<thead>
<tr>
<th>Caesarian Section</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>71</td>
<td>18.8</td>
</tr>
<tr>
<td>No</td>
<td>306</td>
<td>81.2</td>
</tr>
<tr>
<td>Total</td>
<td>377</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Fig 4.8: Caesarian section distribution of cases taken in this study.
4.2. Correlation of the fetal kidney length with different parameters:

No correlation was found between right fetal KL and mother's Height, Weight, BMI, Parity, Residence, Occupation, Socioeconomic status, Bleeding during pregnancy and Chronic illness with 'p' value being not significant for all of them, But there was correlation between right fetal KL and mother's age and Caesarian section group (P < 0.002), table 4.10.

Table 4.10: Pearson correlation coefficient for relation between right fetal kidney length with mother's age, height, weight, BMI, parity, residence, occupation, socioeconomic status, bleeding during pregnancy, chronic illness, and caesarian section.

<table>
<thead>
<tr>
<th>Right fetal kidney length</th>
<th>Pearson Correlation</th>
<th>'p' value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mother's age</td>
<td>.107</td>
<td>.038</td>
</tr>
<tr>
<td>Height</td>
<td>.008-</td>
<td>.870</td>
</tr>
<tr>
<td>Weight</td>
<td>.080-</td>
<td>.119</td>
</tr>
<tr>
<td>BMI</td>
<td>.004</td>
<td>.940</td>
</tr>
<tr>
<td>Parity</td>
<td>.063-</td>
<td>.225</td>
</tr>
<tr>
<td>Residence</td>
<td>.004</td>
<td>.935</td>
</tr>
<tr>
<td>Occupation</td>
<td>.058</td>
<td>.260</td>
</tr>
<tr>
<td>Socioeconomic status</td>
<td>.044-</td>
<td>.397</td>
</tr>
<tr>
<td>Bleeding during pregnancy</td>
<td>.035-</td>
<td>.504</td>
</tr>
<tr>
<td>Chronic illness</td>
<td>.020-</td>
<td>.704</td>
</tr>
<tr>
<td>Caesarian section</td>
<td>.170-</td>
<td>.001</td>
</tr>
</tbody>
</table>

*. Correlation is significant at the 0.05 level (2-tailed).
No correlation was found between left KL and mother's Height, BMI, Parity, Residence, Occupation, Socioeconomic status, Bleeding during pregnancy and Chronic illness with 'p' value being not significant for all of them, But there was correlation between left fetal KL and mother's age, weight and Caesarian section group (P < 0.002), table 4.11.

**Table 4.11**: Pearson correlation coefficient for relation between left fetal kidney length with mother's Age, Height, Weight, BMI, Parity, Residence, Occupation, Socioeconomic status, Bleeding during pregnancy, Chronic illness, and Caesarian section.

<table>
<thead>
<tr>
<th>Left fetal kidney length</th>
<th>Pearson Correlation</th>
<th>'p' value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mother's age</td>
<td>.113</td>
<td>.029</td>
</tr>
<tr>
<td>Height</td>
<td>.093-</td>
<td>.072</td>
</tr>
<tr>
<td>Weight</td>
<td>.102-</td>
<td>.048</td>
</tr>
<tr>
<td>BMI</td>
<td>.074</td>
<td>.154</td>
</tr>
<tr>
<td>Parity</td>
<td>.052-</td>
<td>.314</td>
</tr>
<tr>
<td>Residence</td>
<td>.029</td>
<td>.572</td>
</tr>
<tr>
<td>Occupation</td>
<td>.013</td>
<td>.801</td>
</tr>
<tr>
<td>Socioeconomic status</td>
<td>.098-</td>
<td>.058</td>
</tr>
<tr>
<td>Bleeding during pregnancy</td>
<td>.058-</td>
<td>.258</td>
</tr>
<tr>
<td>Chronic illness</td>
<td>.006-</td>
<td>.909</td>
</tr>
<tr>
<td>Caesarian section</td>
<td>.173</td>
<td>.001</td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level (2-tailed).
4.3. Correlation of the fetal kidney width with different parameters:

No correlation was found between right fetal kidney width and mother's Age, Parity, Residence, Occupation, Bleeding during pregnancy and Chronic illness with 'p' value being not significant for all of them, But there was correlation between right fetal kidney width and mother's Height, Weight, BMI, Socioeconomic status and Caesarian section group (P < 0.002), table 4.12.

**Table 4.12:** Pearson correlation coefficient for relation between right fetal kidney width with mother's Age, Height, Weight, BMI, Parity, Residence, Occupation, Socioeconomic status, Bleeding during pregnancy, Chronic illness, and Caesarian section.

<table>
<thead>
<tr>
<th>Right fetal kidney width</th>
<th>Pearson Correlation</th>
<th>'p' value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mother's age</td>
<td>.081</td>
<td>.116</td>
</tr>
<tr>
<td>Height</td>
<td>.285-</td>
<td>.000</td>
</tr>
<tr>
<td>Weight</td>
<td>.160-</td>
<td>.002</td>
</tr>
<tr>
<td>BMI</td>
<td>.245-</td>
<td>.000</td>
</tr>
<tr>
<td>Parity</td>
<td>.104-</td>
<td>.430</td>
</tr>
<tr>
<td>Residence</td>
<td>.053</td>
<td>.307</td>
</tr>
<tr>
<td>Occupation</td>
<td>.037</td>
<td>.468</td>
</tr>
<tr>
<td>Socioeconomic status</td>
<td>.241-</td>
<td>.000</td>
</tr>
<tr>
<td>Bleeding during pregnancy</td>
<td>.121-</td>
<td>.019</td>
</tr>
<tr>
<td>Chronic illness</td>
<td>.034-</td>
<td>.513</td>
</tr>
<tr>
<td>Caesarian section</td>
<td>.179-</td>
<td>.000</td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level (2-tailed).
No correlation was found between left fetal kidney width and mother's Age, Parity, Residence, Occupation, Bleeding during pregnancy and Chronic illness with 'p' value being not significant for all of them. But there was correlation between left fetal kidney width and mother's Height, Weight, BMI, Socioeconomic status and Caesarian section group (P < 0.002), table 4.13.

**Table 4.13:** Pearson correlation coefficient for relation between left fetal kidney width with mother's age, height, weight, BMI, parity, residence, occupation, socioeconomic status, bleeding during pregnancy, chronic illness, and caesarian section.

<table>
<thead>
<tr>
<th>Left fetal kidney width</th>
<th>Pearson Correlation</th>
<th>'p' value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mother's age</td>
<td>.095</td>
<td>.065</td>
</tr>
<tr>
<td>Height</td>
<td>.345-</td>
<td>.000</td>
</tr>
<tr>
<td>Weight</td>
<td>.131-</td>
<td>.011</td>
</tr>
<tr>
<td>BMI</td>
<td>.309-</td>
<td>.000</td>
</tr>
<tr>
<td>Parity</td>
<td>.080-</td>
<td>.121</td>
</tr>
<tr>
<td>Residence</td>
<td>.061</td>
<td>.237</td>
</tr>
<tr>
<td>Occupation</td>
<td>.007</td>
<td>.889</td>
</tr>
<tr>
<td>Socioeconomic status</td>
<td>.277-</td>
<td>.000</td>
</tr>
<tr>
<td>Bleeding during pregnancy</td>
<td>.166-</td>
<td>.040</td>
</tr>
<tr>
<td>Chronic illness</td>
<td>.030-</td>
<td>.560</td>
</tr>
<tr>
<td>Caesarian section</td>
<td>.212-</td>
<td>.000</td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level (2-tailed).
4.4. Results and analysis of the fetal kidney length in 2\textsuperscript{nd} trimester:

In the 2\textsuperscript{nd} trimester there was no statistically significant difference between the measurements of the left and right kidneys between gestational age (weeks) and kidney length (mm), $r = 0.86$ (P < 0.002), table 4.14.

The mean kidney length increased from $16.9 \pm 0.28$ mm at 16 weeks’ gestation to $26.9 \pm 6.6$ mm at 26 weeks’ gestation, table 4.15.

We found a strong correlation between kidney length and gestational age as predicted by BPD ($r = .65$), HC ($r = .67$), KW ($r = .69$). Extremely strong correlation was found between each of the three component measurements (BPD weeks, HC weeks, or KW weeks), table 4.16.

**Table 4.14:** Correlation coefficient for relation between right and left fetal kidney length.

<table>
<thead>
<tr>
<th>R</th>
<th>Std. Error of the Estimate</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>.864</td>
<td>3.4</td>
<td>.000</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), left fetal kidney length  
b. Dependent Variable: right fetal kidney length
Table 4.15: Changes in fetal kidney length with gestation. Values (mm) are mean ± standard deviations.

<table>
<thead>
<tr>
<th>Gestational age (weeks)</th>
<th>Mean kidney length ± (SD) (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>16.9 (.28)</td>
</tr>
<tr>
<td>17</td>
<td>8.75 (.78)</td>
</tr>
<tr>
<td>18</td>
<td>17.1 (2.6)</td>
</tr>
<tr>
<td>19</td>
<td>22.0 (2.1)</td>
</tr>
<tr>
<td>20</td>
<td>17.3 (1.8)</td>
</tr>
<tr>
<td>21</td>
<td>22.0 (3.6)</td>
</tr>
<tr>
<td>22</td>
<td>26.5 (2.2)</td>
</tr>
<tr>
<td>23</td>
<td>21.1 (4.6)</td>
</tr>
<tr>
<td>24</td>
<td>28.1 (6.8)</td>
</tr>
<tr>
<td>25</td>
<td>26.3 (2.8)</td>
</tr>
<tr>
<td>26</td>
<td>26.9 (6.6)</td>
</tr>
</tbody>
</table>

Table 4.16: correlation coefficient for relation between fetal kidney length with biparietal diameter, head circumference and fetal kidney width.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>R</th>
<th>Std. Error of the Estimate</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPD</td>
<td>.647</td>
<td>9.12</td>
<td>.000</td>
</tr>
<tr>
<td>HC</td>
<td>.674</td>
<td>32.0</td>
<td>.000</td>
</tr>
<tr>
<td>KW</td>
<td>.686</td>
<td>4.43</td>
<td>.000</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), fetal kidney length  
b. Dependent Variable: BPD: biparietal diameter; HC: head circumference; KW: kidney width.

4.5. Results and analysis of the fetal kidney width in 2\textsuperscript{nd} trimester:

In the 2\textsuperscript{nd} trimester there was no statistically significant difference between the measurements of the left and right kidneys between GA (weeks) and kidney width (mm), \( r = 0.91 \ (P < 0.002) \), table 4.17.
The mean kidney width increased from 9.15 ± 1.5 mm at 16 weeks’ gestation to 16.6 ± 4.6 mm at 26 weeks’ gestation, table 4.18.

Strong correlation was found between kidney width and GA as predicted by BPD (r = .76), HC (r = .74), KL (r = .69). On the other hand, strong correlation was found between each of the three component measurements (BPD weeks, HC weeks, or KL weeks), table 4.19.

**Table 4.17:** Correlation coefficient for relation between right and left fetal kidney width.

<table>
<thead>
<tr>
<th>R</th>
<th>Std. Error of the Estimate</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>.908</td>
<td>1.7</td>
<td>.000</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), left fetal kidney width
b. Dependent Variable: right fetal kidney width

**Table 4.18:** Changes in fetal kidney width with gestation. Values (mm) are mean ± standard deviations.

<table>
<thead>
<tr>
<th>Gestational age (weeks)</th>
<th>Mean kidney width ± (SD) (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>9.15(1.5)</td>
</tr>
<tr>
<td>17</td>
<td>5.45(.07)</td>
</tr>
<tr>
<td>18</td>
<td>9.79(1.3)</td>
</tr>
<tr>
<td>19</td>
<td>11.0(0.97)</td>
</tr>
<tr>
<td>20</td>
<td>10.8(.74)</td>
</tr>
<tr>
<td>21</td>
<td>11.6(2.0)</td>
</tr>
<tr>
<td>22</td>
<td>12.5(1.4)</td>
</tr>
<tr>
<td>23</td>
<td>15.9(4.6)</td>
</tr>
<tr>
<td>24</td>
<td>15.2(3.5)</td>
</tr>
<tr>
<td>25</td>
<td>16.4(1.8)</td>
</tr>
<tr>
<td>26</td>
<td>16.6(4.6)</td>
</tr>
</tbody>
</table>
Table 4.19: Correlation coefficient for relation between fetal kidney width with biparietal diameter, head circumference and fetal kidney length.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>R</th>
<th>Std. Error of the Estimate</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPD</td>
<td>.759</td>
<td>7.79</td>
<td>.000</td>
</tr>
<tr>
<td>HC</td>
<td>.740</td>
<td>29.17</td>
<td>.000</td>
</tr>
<tr>
<td>KL</td>
<td>.686</td>
<td>4.43</td>
<td>.000</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), KW: fetal kidney width

4.6. Results and analysis of the fetal kidney length in 3rd trimester:

In the 3rd trimester there was no statistically significant difference between the measurements of the left and right kidneys in gestational age (weeks) and kidney length (mm), $r = 0.69(P < 0.002)$, table 4.20.

The mean kidney length increased from 29.5± 6.2 mm at 27 weeks’ gestation to 38.8± 3.4mm at 40 weeks’ gestation, table 4.21.

Correlation between kidney length and gestational age was evident as predicted by BPD ($r = .47$), FL ($r = .31$), AC ($r = .11$), KW ($r = .47$), table 4.22.

Table 4.20: Correlation coefficient for relation between right and left fetal kidney length.

<table>
<thead>
<tr>
<th>R</th>
<th>Std. Error of the Estimate</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>.692</td>
<td>4.1</td>
<td>.000</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), left fetal kidney length.
b. Dependent Variable: right fetal kidney length.
Table 4.21: Changes in fetal kidney length with gestation. Values (mm) are mean ± standard deviations.

<table>
<thead>
<tr>
<th>Gestational age (weeks)</th>
<th>Mean kidney length ± (SD) (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>29.5(6.2)</td>
</tr>
<tr>
<td>28</td>
<td>29.9(3.9)</td>
</tr>
<tr>
<td>29</td>
<td>30.3(3.9)</td>
</tr>
<tr>
<td>30</td>
<td>31.5(4.0)</td>
</tr>
<tr>
<td>31</td>
<td>34.3(4.8)</td>
</tr>
<tr>
<td>32</td>
<td>35.1(5.1)</td>
</tr>
<tr>
<td>33</td>
<td>35.2(5.1)</td>
</tr>
<tr>
<td>34</td>
<td>36.3(3.7)</td>
</tr>
<tr>
<td>35</td>
<td>37.1(5.5)</td>
</tr>
<tr>
<td>36</td>
<td>37.6(4.9)</td>
</tr>
<tr>
<td>37</td>
<td>38.0(5.1)</td>
</tr>
<tr>
<td>38</td>
<td>37.8(3.8)</td>
</tr>
<tr>
<td>39</td>
<td>37.6(7.4)</td>
</tr>
<tr>
<td>40</td>
<td>38.8(3.4)</td>
</tr>
</tbody>
</table>

Table 4.22: Correlation coefficient for relation between fetal kidney length with biparietal diameter, femur length, abdominal circumference and fetal kidney width.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>R</th>
<th>Std. Error of the Estimate</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPD</td>
<td>.469</td>
<td>7.35</td>
<td>.000</td>
</tr>
<tr>
<td>FL</td>
<td>.310</td>
<td>14.3</td>
<td>.000</td>
</tr>
<tr>
<td>AC</td>
<td>.111</td>
<td>155.3</td>
<td>.138</td>
</tr>
<tr>
<td>KW</td>
<td>.466</td>
<td>7.34</td>
<td>.000</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), fetal kidney length
4.7. Results and analysis of the fetal kidney width in 3rd trimester:

In the 3rd trimester there was no statistically significant difference between the measurements of the left and right kidneys between gestational age (weeks) and kidney width (mm), $r = 0.69 (P < 0.002)$, table 4.23.

The mean kidney width increased from 19.9± 3.4 mm at 27 weeks’ gestation to 23.9± 2.9mm at 39 weeks’ gestation, table 4.24.

We found correlation between kidney width and gestational age as predicted by BPD ($r = .47$), FL ($r = .31$), AC ($r = .11$), KL ($r = .47$), table 5.27.

Table 4.23: Correlation coefficient for relation between right and left fetal kidney width.

<table>
<thead>
<tr>
<th>R</th>
<th>Std. Error of the Estimate</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>.743</td>
<td>2.4</td>
<td>.000</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), left fetal kidney width
b. Dependent Variable: right fetal kidney width
Table 4.24: Changes in fetal kidney width with gestation. Values (mm) are mean ± standard deviations.

<table>
<thead>
<tr>
<th>Gestational age (weeks)</th>
<th>Mean kidney width ± (SD) (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>16.9(3.4)</td>
</tr>
<tr>
<td>28</td>
<td>17.5(3.0)</td>
</tr>
<tr>
<td>29</td>
<td>18.7(4.6)</td>
</tr>
<tr>
<td>30</td>
<td>19.0(2.9)</td>
</tr>
<tr>
<td>31</td>
<td>20.3(3.5)</td>
</tr>
<tr>
<td>32</td>
<td>20.7(2.3)</td>
</tr>
<tr>
<td>33</td>
<td>21.0(3.3)</td>
</tr>
<tr>
<td>34</td>
<td>22.2(4.0)</td>
</tr>
<tr>
<td>35</td>
<td>21.4(3.4)</td>
</tr>
<tr>
<td>36</td>
<td>23.5(3.2)</td>
</tr>
<tr>
<td>37</td>
<td>22.8(4.2)</td>
</tr>
<tr>
<td>38</td>
<td>21.6(3.5)</td>
</tr>
<tr>
<td>39</td>
<td>23.9(4.1)</td>
</tr>
<tr>
<td>40</td>
<td>20.8(2.9)</td>
</tr>
</tbody>
</table>

Table 4.25: Correlation coefficient for relation between fetal kidney width with biparietal diameter, femur length, abdominal circumference and fetal kidney length.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>R</th>
<th>Std. Error of the Estimate</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPD</td>
<td>.427</td>
<td>7.52</td>
<td>.000</td>
</tr>
<tr>
<td>FL</td>
<td>.229</td>
<td>14.01</td>
<td>.000</td>
</tr>
<tr>
<td>AC</td>
<td>.115</td>
<td>155.3</td>
<td>.119</td>
</tr>
<tr>
<td>KL</td>
<td>.466</td>
<td>7.34</td>
<td>.000</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), fetal kidney width
4.8. Results and analysis of the fetal kidney length:

There was no statistically significant difference between the measurements of the left and right kidneys between gestational age (weeks) and kidney length (mm), \( r = 0.83 \) (\( P < 0.002 \)), table 4.26.

A significant correlation was found between Gestational age (days) and kidney length (mm) \( (r=0.72, \ P<0.000) \), table 4.27.

The changes in mean kidney length in the 377 fetuses at different gestational ages, table 5.30. the mean kidney length increased from 16.9 ± .28 mm at 16 weeks’ gestation to 38.8 ± 3.4 mm at 40 weeks’ gestation.

We found a strong correlation between KL and GA as predicted by BPD \( (r = .73) \), FL \( (r = .31) \), AC \( (r = .11) \). Extremely strong correlation was found between each of the three component measurements (BPD, FL, or AC). These measurements are not statistically different, and each can be used to correlate renal length, table 4.29, - 4.31.

The equations derived from linear regression analysis when the individual variables were considered separately. The most accurate was the KL with a standard error (SE) of 0.04 day, after that BPD (SE=0.10 day) and FL (SE=0.13 day). While the most inaccurate was the AC with a SE of 1.35 days, table 4.32.

The correlation and Linear equation: derived from the stepwise regression analysis between BPD, HC, AC, FL, GA and KL. It also shows the accuracy of the precision (standard error of the prediction) with which GA was estimated using the various derived models, table 4.33.Figs 4.9 - 4.13.
Table 4.26: Correlation coefficient for relation between right and left fetal kidney length.

<table>
<thead>
<tr>
<th>Paired Samples Statistics</th>
<th>Mean</th>
<th>R</th>
<th>Std. Deviation</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>right kidney length</td>
<td>33.6</td>
<td>.826</td>
<td>7.3</td>
<td>.000</td>
</tr>
<tr>
<td>Left kidney length</td>
<td>33.7</td>
<td>.826</td>
<td>7.1</td>
<td>.000</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), left fetal kidney length
b. Dependent Variable: right fetal kidney length

Table 4.27: Correlation coefficient for relation between fetal kidney length and Gestational age.

<table>
<thead>
<tr>
<th>R</th>
<th>Std. Error of the Estimate</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>.718</td>
<td>.71</td>
<td>.000</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), fetal kidney length
b. Dependent Variable: Gestational age (week)

Table 4.28: Changes in kidney length with gestation. Values (mm) are mean ± standard deviations.

<table>
<thead>
<tr>
<th>Gestational age (weeks)</th>
<th>Mean kidney length ± (SD) (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>16.9(.28)</td>
</tr>
<tr>
<td>18</td>
<td>17.1 (2.6)</td>
</tr>
<tr>
<td>20</td>
<td>17.3 (1.8)</td>
</tr>
<tr>
<td>22</td>
<td>26.5 (2.2)</td>
</tr>
<tr>
<td>24</td>
<td>28.0 (6.8)</td>
</tr>
<tr>
<td>26</td>
<td>26.9 (6.6)</td>
</tr>
<tr>
<td>28</td>
<td>30.0 (3.9)</td>
</tr>
<tr>
<td>30</td>
<td>31.4 (4.0)</td>
</tr>
<tr>
<td>32</td>
<td>35.0 (5.1)</td>
</tr>
<tr>
<td>34</td>
<td>36.3 (3.7)</td>
</tr>
<tr>
<td>36</td>
<td>37.6 (4.9)</td>
</tr>
<tr>
<td>38</td>
<td>37.8 (3.8)</td>
</tr>
<tr>
<td>40</td>
<td>38.8 (3.4)</td>
</tr>
</tbody>
</table>
Table 4.29: correlation coefficient for relation between fetal kidney length and biparietal diameter.

<table>
<thead>
<tr>
<th>R</th>
<th>Std. Error of the Estimate</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>.743</td>
<td>9.3</td>
<td>.000</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), kidney length  
b. Dependent Variable: biparietal diameter

Table 4.30: correlation coefficient for relation between fetal kidney length and femur length.

<table>
<thead>
<tr>
<th>R</th>
<th>Std. Error of the Estimate</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>.310</td>
<td>14.2</td>
<td>.000</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), kidney length  
b. Dependent Variable: femur length

Table 4.31: Correlation coefficient for relation between fetal kidney length and abdominal circumference.

<table>
<thead>
<tr>
<th>R</th>
<th>Std. Error of the Estimate</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>.111</td>
<td>155.3</td>
<td>.000</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), kidney length  
b. Dependent Variable: abdominal circumference

Table 4.32: Linear regression analysis of fetal biometric parameters.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>SE</td>
<td>Beta</td>
</tr>
<tr>
<td>KL</td>
<td>.982</td>
<td>.035</td>
<td>.718</td>
</tr>
<tr>
<td>BPD</td>
<td>1.01</td>
<td>.104</td>
<td>.451</td>
</tr>
<tr>
<td>FL</td>
<td>.095</td>
<td>.130</td>
<td>.041</td>
</tr>
<tr>
<td>AC</td>
<td>.825</td>
<td>1.35</td>
<td>.034</td>
</tr>
</tbody>
</table>

Constant: gestational age  
Dependent Variable: AC: abdominal circumference; BPD: biparietal diameter; FL: femur length; KL: kidney length.
Table 4.33: The correlation and Linear equation between fetal kidney length and fetal biometric parameters.

<table>
<thead>
<tr>
<th>(Constant)</th>
<th>Linear equation:</th>
<th>SE</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA</td>
<td>GA = 2.1+KL 0.982.</td>
<td>.045</td>
<td>.000</td>
</tr>
<tr>
<td>BPD</td>
<td>BPD = 3.858+KL0.370.</td>
<td>.017</td>
<td>.000</td>
</tr>
<tr>
<td>HC</td>
<td>HC= 3.344+KL0.096.</td>
<td>.015</td>
<td>.000</td>
</tr>
<tr>
<td>FL</td>
<td>FL= 28.172+KL0.107.</td>
<td>.018</td>
<td>.000</td>
</tr>
<tr>
<td>AC</td>
<td>AC= 34.653+KL0.003.</td>
<td>.032</td>
<td>.000</td>
</tr>
</tbody>
</table>

Dependent Variable: fetal kidney length mean
Constant: GA: Gestational age; AC: abdominal circumference; BPD: biparietal diameter; FL: femur length; KL: kidney length.

Fig 4.9: Scattergraphs of gestational age with kidney length.
**Fig 4.10:** Sonographic measurements of the Femur length at 30\textsuperscript{th} week of the gestation.

**Fig 4.11:** Sonographic measurements of the biparietal diameter and abdominal circumference at 30\textsuperscript{th} week of the gestation.
**Fig 4.12:** Sonographic measurements of the kidney length at 30th week of the gestation.

**Fig 4.13:** Sonographic measurements of the kidney width at 30th week of the gestation.
4.9. Results and analysis of the fetal kidney width:

There was no statistically significant difference between the measurements of the left and right kidneys, between gestational age (weeks) and kidney width (mm), r = 0.84 (P < 0.002), table 4.33.

A significant correlation was found between Gestational age (days) and kidney width (mm) (r=0.67, P<0.002), table 4.34. The changes in mean kidney width in the 377 fetuses at different gestational ages, table 4.35. The mean kidney width increased from 9.1 ± 1.5 mm at 16 weeks’ gestation to 20.8 ± 2.9 mm at 40 weeks’ gestation.

We found a strong correlation between kidney width and gestational age as predicted by BPD (r = .71), FL (r = .23), AC (r = .12). Extremely strong correlation was found between each of the three component measurements (BPD weeks, FL weeks, or AC weeks). These measurements are not statistically different, and each can be used to correlate renal width, table 4.36, - 4.38.

The equations derived from linear regression analysis when the individual variables were considered separately. The most accurate was the KW with a standard error (SE) of 0.02 day, after that BPD (SE=0.10 day) and FL (SE=0.13 day). While the most inaccurate was the AC with a SE of 1.35 days, table 4.39.

The correlation and Linear equation: derived from the stepwise regression analysis between BPD, HC, AC, FL, GA and kidney width. It also shows the accuracy of the precision (standard error of the prediction) with which GA was estimated using the various derived models, table 4.40. Figs 4.14 - 4.18.
Table 4.33: Correlation coefficient for relation between right and left fetal kidney width

<table>
<thead>
<tr>
<th>Paired Samples Statistics</th>
<th>Mean</th>
<th>R</th>
<th>Std. Deviation</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>right kidney width</td>
<td>19.9</td>
<td>.843</td>
<td>4.5</td>
<td>.000</td>
</tr>
<tr>
<td>left kidney width</td>
<td>20.0</td>
<td>.843</td>
<td>5.0</td>
<td>.000</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), left fetal kidney width  
b. Dependent Variable: right fetal kidney width

Table 4.34: Correlation coefficient for relation between fetal kidney width and GA.

<table>
<thead>
<tr>
<th>R</th>
<th>Std. Error of the Estimate</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>.673</td>
<td>3.9</td>
<td>.000</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), fetal kidney width  
b. Dependent Variable: Gestational age (week)

Table 4.35: Changes in kidney width with gestation. Values (mm) are mean ± standard deviations.

<table>
<thead>
<tr>
<th>Gestational age (weeks)</th>
<th>Mean kidney width ± (SD) (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>9.1 (1.5)</td>
</tr>
<tr>
<td>18</td>
<td>9.8 (1.3)</td>
</tr>
<tr>
<td>20</td>
<td>10.8 (.7)</td>
</tr>
<tr>
<td>22</td>
<td>12.5 (1.4)</td>
</tr>
<tr>
<td>24</td>
<td>15.2 (3.5)</td>
</tr>
<tr>
<td>26</td>
<td>16.6(4.7)</td>
</tr>
<tr>
<td>28</td>
<td>17.5 (3.0)</td>
</tr>
<tr>
<td>30</td>
<td>19.0 (2.9)</td>
</tr>
<tr>
<td>32</td>
<td>20.7 (2.3)</td>
</tr>
<tr>
<td>34</td>
<td>22.2 (4.0)</td>
</tr>
<tr>
<td>36</td>
<td>23.5 (3.2)</td>
</tr>
<tr>
<td>38</td>
<td>21.6 (3.5)</td>
</tr>
<tr>
<td>40</td>
<td>20.8 (2.9)</td>
</tr>
</tbody>
</table>
Table 4.36: Correlation coefficient for relation between fetal kidney width and BPD.

<table>
<thead>
<tr>
<th>R</th>
<th>Std. Error of the Estimate</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>.715</td>
<td>9.7</td>
<td>.000</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), kidney width
b. Dependent Variable: biparietal diameter

Table 4.37: Correlation coefficient for relation between fetal kidney width and femur length.

<table>
<thead>
<tr>
<th>R</th>
<th>Std. Error of the Estimate</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>.229</td>
<td>14.6</td>
<td>.000</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), kidney width
b. Dependent Variable: femur length

Table 4.38: Correlation coefficient for relation between fetal kidney width and abdominal circumference.

<table>
<thead>
<tr>
<th>R</th>
<th>Std. Error of the Estimate</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>.115</td>
<td>155.2</td>
<td>.000</td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), kidney width
b. Dependent Variable: abdominal circumference

Table 4.39: Linear regression analysis of fetal biometric parameters.

<table>
<thead>
<tr>
<th>Dependent Variable:</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>SE</td>
<td>Beta</td>
</tr>
<tr>
<td>KW</td>
<td>.607</td>
<td>.024</td>
<td>.673</td>
</tr>
<tr>
<td>BPD</td>
<td>1.01</td>
<td>.104</td>
<td>.451</td>
</tr>
<tr>
<td>FL</td>
<td>.095</td>
<td>.130</td>
<td>.041</td>
</tr>
<tr>
<td>AC</td>
<td>.825</td>
<td>1.35</td>
<td>.034</td>
</tr>
</tbody>
</table>

Constant: gestational age
Dependent Variable: AC: abdominal circumference; BPD: biparietal diameter; FL: femur length; KW: kidney length
Table 4.40: The correlation and Linear equation between fetal kidney width and fetal biometric parameters.

<table>
<thead>
<tr>
<th>(Constant)</th>
<th>Linear equation:</th>
<th>SE</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA</td>
<td>GA = 0.496 + KW0.607.</td>
<td>.032</td>
<td>.000</td>
</tr>
<tr>
<td>BPD</td>
<td>BPD = 1.153 + KW0.234.</td>
<td>.012</td>
<td>.000</td>
</tr>
<tr>
<td>HC</td>
<td>HC = KW0.069 - 0.686.</td>
<td>.009</td>
<td>.000</td>
</tr>
<tr>
<td>FL</td>
<td>FL = 17.322 + KW0.055.</td>
<td>.013</td>
<td>.000</td>
</tr>
<tr>
<td>AC</td>
<td>AC = 20.552 + KW0.002.</td>
<td>.001</td>
<td>.153</td>
</tr>
</tbody>
</table>

Dependent Variable: fetal kidney width mean
Constant: GA: Gestational age; AC: abdominal circumference; BPD: biparietal diameter; FL: femur length; KW: kidney width.

Fig 4.14: Scattergraphs of gestational age with fetal kidney width.
**Fig 4.15**: Sonographic measurements of the Femur length at 36\textsuperscript{th} week of the gestation.

**Fig 4.16**: Sonographic measurements of the biparietal diameter and abdominal circumference at 36\textsuperscript{th} week of the gestation.
**Fig 4.17:** Sonographic measurements of the kidney length at 36th week of the gestation.

**Fig 4.18:** Sonographic measurements of the kidney width at 36th week of the gestation.
CHAPTER FIVE

DISCUSSION
5.1. Discussion:

It is helpful to know normal lengths of fetal kidneys in order to diagnose fetal renal abnormalities. This is particularly true if the echogenicity is apparently normal, which may occur in some early cases of polycystic disease of the kidney. Knowledge of normal renal length can be helpful in early determinations of nephromegaly or hypoplasia.\(^{(69)}\)

Age of pregnancy can be accurately estimated by diameter and volume of gestational sac and measurement the length of fetal crown-rump throughout the early pregnancy. Also, fetal BPD and length of the femur can be used during the later gestational stages. The accuracy of ultrasonic biometry has been calculated and it has been showed that these parameters predicted the age of pregnancy within 4.7 and 6-10 days respectively during the first 10 weeks and up to 24th week of gestation. This method has led to a significant decrease in the number of labor induction for suspected prolonged pregnancy.\(^{(13)}\) Although these biometric indices are inaccurate in late stages of pregnancy, they are continued to be used among women with uncertain LMP in late stages. So, several studies were performed to determine an accurate estimation of GA by ultrasonic investigation during the late second and third trimesters. Ozat et al, carried out a study on 2,184 pregnant women and established a nomogram of fetal sacral length in different fatal ages for assessment of GA.\(^{(70)}\) They found sacral length as an easily acquired and valuable index with a direct and strong correlation with GA as well as other fetal biometry parameters.

Sherer et al in a study on 602 pregnancies and used fetal hard palate width, length and area as indicators of GA with relative ease between 15 and 41 weeks' gestation and showed that hard palate parameters were well correlated
with GA, BPD, AC, FL and ultrasonic estimated fetal weight. Several other studies have been made on this issue, but nevertheless none of their methods are practically used for gestational dating, because the ultrasound dating method should be simple, easy to define and reproducible. Similar to our study, where one investigator performs the dating ultrasound scans (as in this study) an investigation by Konje et al., was performed on 85 pregnant women and used the length of fetal kidney for prediction the age of pregnancy. They indicated that KL between 24 and 38 weeks of pregnancy was a more accurate technique for determining GA than other feta-biometry parameters such as BPD, HC, FL, and AC. Another study in India by Kansaria et al., demonstrated that by measuring KL, pregnancies could be dated within 9.17 days. Studies indicated that only the anterior–posterior and transverse diameters of the fetal kidney are changed in different growth conditions and KL is unchanged in small-for gestational age fetuses. Hence, some attempts by Ismail et al and Duval et al stated that the anterior-posterior diameter of the kidney can be used to identify fetal growth problems.
In present study the kidneys were easily identify in the 2\textsuperscript{nd} and 3\textsuperscript{rd} trimester and both kidneys in all cases were measurable. However, when only one kidney can be measured in difficult cases, the insignificant differences between the left and right KL does not affect the GA estimation.

Our findings showed that KL measurements combination with other fetal biometric parameters could predict age of pregnancy within 0.04 days. A better precision for prediction of GA than other model such as using AC and FL was observed by application of KL measurement. And KW measurements combination with other fetal biometric parameters could predict age of pregnancy within 0.02 days. A better precision for prediction of GA than other model such as using AC and FL was observed by application of KW measurement. The benefit of this method is more significant in the absence of BPD and/or HC measurements due to unfeasibility of ultrasonic evaluation in the correct plane or when the fetal head is too low. In this situation, only KL and KW can be used to estimate the age of pregnancy.

In present study we evaluated the role of FKL measurements in estimation of GA and compared its accuracy with other fetal biometric indices. Cohen et al,\textsuperscript{(17)} stated that unless the fetus was prone with its back facing the transducer, only the borders of near kidney could be measured. Duval et al,\textsuperscript{(75)} encountered difficulty in imaging kidneys in breech presentation and in vertex presentations with back facing laterally or posteriorly However, no such difficulty was experienced in present study. A little manipulation of the transducer position and angle of insonation relative to the kidney plane allowed easy identification of both kidneys which is in agreement with Konje et al.\textsuperscript{(13)} There was no case in which both kidneys were not measurable.
The mean BPD, FL, HC and AC measurements at various gestations observed in our study were similar to measurements obtained by previous authors O'Brien et al and Kaul et al.\(^{(76, 77)}\)

The mean KL and KW measurements at various gestations observed in our study were similar to measurements obtained by Abdelmoneim et al,\(^{(88)}\) and Kaul et al,\(^{(78)}\). The variability of the FKL and other biometric measurements about the mean observed in our study was noticeably less than that observed in previous studies done by Konje et al,\(^{(13)}\) Hohaler et al,\(^{(76)}\) O'Brien et al,\(^{(77)}\) Kaul,\(^{(78)}\) Lyn et al.\(^{(79)}\)

Many authors, Konje et al,\(^{(13)}\) Cannie et al,\(^{(80)}\) Schlesinger et al,\(^{(81)}\) and Shin et al,\(^{(82)}\) reported no significant difference between left and right FKL measurements, Left FKL was slightly, but significantly, longer than the right FKL in the study done by Fitzsimons et al.\(^{(83)}\) Kaul et al,\(^{(78)}\) Duval et al,\(^{(75)}\) and Sampaio et al,\(^{(84)}\) in their study found left FKL to be longer than right FKL at the end of intrauterine life. The left kidney was longer than the right in neonates with body length more than 43 cms and this difference became more significant as the body length increased in a study done by Gonzales.\(^{(85)}\) In present study the mean left FKL was similar to the mean right FKL at each gestational period observed in the study, there was no statistically significant difference between left and right FKL measurements. This finding was consistent with the study of Konje et al,\(^{(13)}\) Cannie et al,\(^{(80)}\) Schlesinger et al,\(^{(81)}\) and Shin et al.\(^{(82)}\)

We found a very strong correlation between FKL and GA as compared to previous studies. The correlation coefficient (r=0.83) observed in present study was higher as compared to Cohen et al (1991) (r=0.82), and less as compared to Schlesinger et al (1987) (r=0.859), Gloor et al (1997) (r=0.90),
Chiara et al (1989) (for RK r=0.84, for LK r=0.87), Konje et al (2002) (r=91), and Kaul et al (2012)(r=0.958). Correlation coefficients between GA and other biometric indices were also less as compared to previous studies. A number of reasons could explain these differences. These include type of study (longitudinal vs. cross-sectional), quality of ultrasonography machine (new vs. old) and characteristics of subjects (only uncomplicated pregnancies vs. all pregnancies).

In present study FKL was the most accurate single parameter for the estimation of GA closely followed by BPD and FL. AC was the most inaccurate parameter for estimation of GA according to present study. These findings were consistent with the findings of Konje et al and Kaul et al.

Many authors reported no correlation was found between FKL and mother's age, height, weight and parity. In present study the observations we found no correlation between fetal kidney length and mother's height, weight, BMI, parity, residence, occupation, socioeconomic status, bleeding during pregnancy and chronic illness with 'p' value being not significant for all of them, But there was correlation between fetal kidney length and mother's age and Caesarian section group (P < 0.002), no correlation was found between fetal kidney width and mother's age, parity, residence, occupation, bleeding during pregnancy and chronic illness with 'p' value being not significant for all of them, But there was correlation between fetal kidney length and mother's height, weight, BMI, socioeconomic status and Caesarian section group (P < 0.002).
CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS
Conclusions & Recommendation

6.1. Conclusions:

Accurate gestational age assessment is of great importance in obstetric practice. Appropriate estimation of gestational age requires good judgment by the obstetrician caring for the patient. Since clinical data such as the menstrual cycle or uterine size often are not reliable, the most precise parameter for pregnancy dating should be determined by the obstetrician early in the pregnancy. Ultrasound is an accurate and useful modality for the assessment of gestational age in the first and second trimester of pregnancy and, as a routine part of prenatal care, can greatly impact obstetric management and improve antepartum care. From this study we could find that the most accurate method for evaluation of GA was the kidney width with a standard error (SE) of 0.02 day, followed by kidney length (SE=0.04 day), followed by biparietal diameter (SE=0.10 day) and finally femur length (SE=0.13 day). While the most inaccurate method for estimation of GA was the abdominal circumference with a standard error of 1.35 days. Kidney length and width are easy to identify and measure. Measuring of kidney length and width can help in determination of gestational age, especially in cases where the date of the mother’s last menstruation is unknown. Moreover, KW and KL are most accurate parameters for estimating GA in comparison to other biometric indices in late 2\textsuperscript{nd} and 3\textsuperscript{rd} trimester and should be therefore be incorporated into the future models for estimating GA. In addition to that it could be more valuable tool in cases where other established biometric indices are difficult to obtain and show gross discrepancies with each other or with GA.
6.2. Recommendation:

- Since classically the GA is still determined, in some places, by LMP, the chances of error increases, therefore the need for use of ultrasound investigation is highly recommended as the only measuring tools for GA determination.

- The present study emphasizes on the use of KW and KL as the most accurate parameter for GA determination; we recommend therefore the use KW and KL as one of the main methods for GA estimation.
References


Appendices

Data collection sheet

A. Basic information

1. Maternal age: 15<25 □ 25<35 □ 35<45 □ 45 and above □
2. Residence: Rural □ Urban □
3. Occupation: student □ housewife □ worker □
4. Parity: ...............................................................
5. Last normal menstrual period: sure □ not sure □
6. Anthropometric measurements: Weight □ Height □ BMI □
7. Socioeconomic status low □ Medium □ High □

B. Past medical history

8. Bleeding during this pregnancy Yes □ No □
9. Chronic illness Yes □ No □
10. Caesarian section: Yes □ No □

C. Ultrasound data

11. First trimester data: First trimester start at (0-13 weeks) but as the kidney develops at 5th week of gestation.

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<thead>
<tr>
<th>Date of visit</th>
<th>Kidney measurement</th>
<th>Common Biometric parameters</th>
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<tr>
<td></td>
<td>Length (mm)</td>
<td>Crown-rump length</td>
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<td>Right Left</td>
<td>Biparietal diameter</td>
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<td>Width (mm)</td>
<td>Head circumference</td>
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13. Second trimester data

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14. Third trimester data:

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15. Sex of fetus at the 2nd and 3rd trimesters: male ☐ female ☐