Evaluation of yolk sac size and embryonic heart rate and embryonic heart rate in first trimester and pregnancy outcome

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2025

ABSTRACT

Background: First trimester pregnancy evaluation using transvaginal ultrasound provides critical insights into fetal viability. Among early sonographic markers, **Yolk Sac Diameter (YSD)** and **Embryonic Heart Rate (EHR)** serve as pivotal parameters for predicting pregnancy outcomes, especially the risk of spontaneous miscarriage.

Objective: To assess the diagnostic performance of first trimester ultrasound markers—YSD, CRL, MSD, and EHR—in predicting early pregnancy outcomes and to correlate these findings with demographic and clinical variables such as maternal age, parity, and medical history.

Methods: A prospective hospital-based study was conducted on 57 pregnant women between 6–12 weeks of gestation at RL Jalappa Hospital, Kolar. Transvaginal ultrasonography was used to measure YSD, CRL, MSD, and EHR. Participants were grouped by gestational age and pregnancy outcome (normal vs miscarriage). Statistical analyses included Chi-square tests, independent t-tests, and Pearson's correlation using SPSS v22, with $p<0.05$ considered statistically significant.

Results: The mean YSD in viable pregnancies was 4.17 ± 0.98 mm versus 2.09 ± 0.38 mm in miscarriages ($p<0.05$). CRL, MSD, and EHR were all significantly reduced in the miscarriage group. EHR was especially predictive, with values <100 bpm indicating a high likelihood of pregnancy loss. The cut-off YSD <3.0 mm showed 92% sensitivity and 93% specificity in predicting miscarriage. Maternal age >35 years was strongly associated with adverse outcomes ($p<0.001$). Correlation analysis revealed significant positive relationships between YSD and CRL, MSD, and EHR.

Conclusion: Yolk Sac Diameter is a reliable early sonographic marker for predicting pregnancy outcome. When combined with CRL, MSD, and EHR, it enhances the accuracy of early pregnancy assessments. Early detection through ultrasound allows timely clinical decision-making and patient counseling, potentially improving obstetric outcomes.

Keywords: *Yolk Sac Diameter, Embryonic Heart Rate, Crown-Rump Length, First Trimester Ultrasound, Early Pregnancy Loss, Gestational Sac, Miscarriage Prediction, Transvaginal Sonography*

INTRODUCTION:

Diagnostic ultrasonography utilises high-frequency sound waves to generate real-time images of internal fetal structures, playing a crucial role in modern obstetrics Over the past few decades, first trimester ultrasound has evolved into a fundamental tool for confirming fetal viability, accurately dating pregnancies, and detecting life-threatening conditions such as ruptured ectopic pregnancies[2,3]. With advancements in imaging technology, transvaginal sonography has become especially pivotal in evaluating early gestational development.

One of the earliest detectable indicators of fetal life is the **embryonic heartbeat**, which can typically be observed using motion mode (M-mode) or Doppler techniques as early as the **5th to 6th week of gestation**[4]. Studies have shown that fetal heart rate increases significantly between 6 and 10 weeks, from around 118 bpm to 167 bpm[5]. Importantly, an embryonic heart rate (EHR) of less than 100 bpm between 6 and 9 weeks is considered abnormal and has been associated with an **83.3% risk of miscarriage**[6].

Another key sonographic marker in early pregnancy is the **yolk sac**, the first anatomical structure identifiable within the gestational sac. The yolk sac provides vital nutritional, metabolic, and hematopoietic support to the developing embryo until placental circulation is established. Normally appearing by the 5th week and regressing by the end of the first trimester, it is typically round and measures between **2–5 mm** in diameter. **Deviations in size or morphology—such as enlarged, shrunken, irregular, or absent yolk sacs—have been strongly linked to early pregnancy loss** (Patel, 2020; Suguna, 2019; Adiga, 2015)[7-9].

Both **Yolk Sac Diameter (YSD)** and **EHR** are highly sensitive and specific parameters in predicting first trimester pregnancy outcomes. For instance, **Adiga**

demonstrated that an EHR ≥100 bpm was associated with **99.3% sensitivity** and **98.5% accuracy** for ongoing pregnancy, while a YSD within the normal range also showed strong predictive value. **Varelas in his study [10]** and **Sakr in his study [11]** similarly highlighted the association of **embryonic bradycardia** and abnormal yolk sac metrics with poor pregnancy outcomes.

Further studies reinforce the predictive power of these markers. By the author **[12]** found that an abnormally enlarged yolk sac and reduced fetal heart rate were significantly associated with miscarriage. According to study **[13]** reported that when both parameters were abnormal, specificity and sensitivity approached **100%** in predicting fetal loss. Notably, these abnormalities appear to function **independently of maternal characteristics** such as age or parity, further supporting their diagnostic utility [14].

In clinical practice, the integration of YSD and EHR measurement into **routine first trimester ultrasound protocols** offers a **noninvasive, cost-effective, and highly reliable** method for early identification of high-risk pregnancies. Their use enhances early decision-making, enabling better counseling, timely follow-up, and potentially improving obstetric outcomes [15,16]. In view of this, the present study was undertaken.

OBJECTIVES OF THE STUDY:

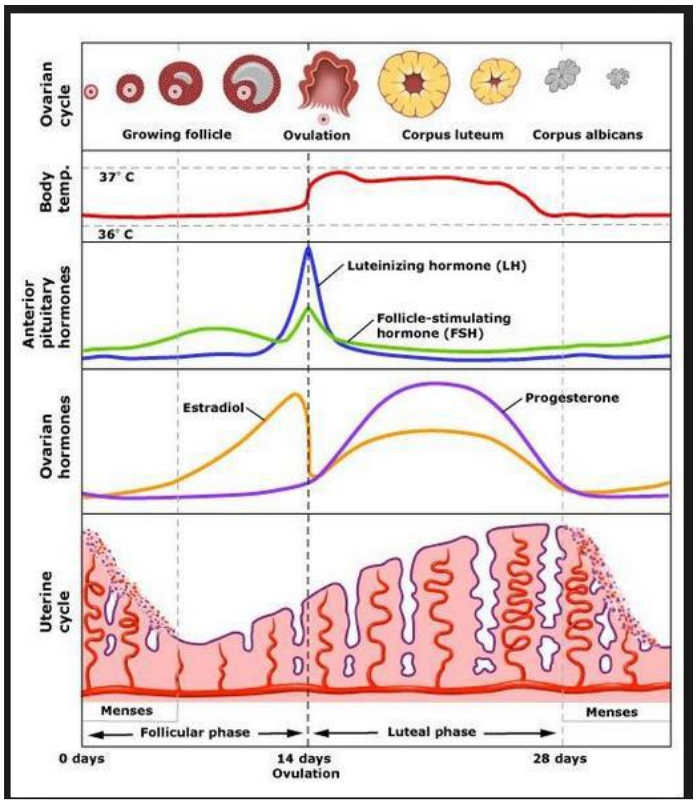
1. To accecc thee corrrelation of patiient's first triimester outcoome (Normal continuation of pregnanncy / Miscarrriage) with the yolkh saac diiameter
2. To evalluate the other soonographic parameters like Crrown Rummp Length and meaan saac diameter in fiirst triimester its outcoomes
3. To evalluate the assoociation of patient's aage, consanguiinity, menstruual history, pariity and mediical illnesss in fiirst triimester and its outcoomes

REVIEW OF LITREATURE

MATERNAL PHYSIOLOGY AND EMBRYOLOGY

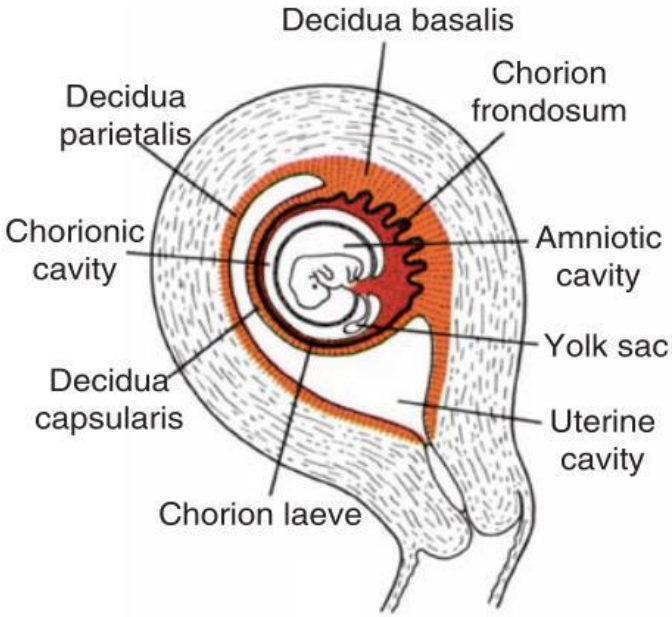
The human endometrium is highly developed to accommodate endometrial implantation and hemochorial type of placentation. The endometrial-decidua is the anatomical site of blastocyst apposition, implantation and placental development. Cyclic changes occur within both ovaries and the endometrium under the influence of pituitary gonadotropic follicle stimulating hormone (FSH) and luiteinizing hormone (LH) – during the first 2 weeks of pre and periovulation period. A mature ovarian follicle develops under the influence of FSH. The follicle reduces estrogen causing the functional layer of endometrium to proliferate and become thicker. With the result of an abrupt surge in LH, ovulation occurs, oocyte is extruded, on day 14 of the cycle in a 28-day cycle[17].

FIGURE 1: NORMAL MENSTRUaAL CYCLEE



Following ovulation, the follicle collapses and forms into glandular corpus luteum – producing progesterone and less amount of oestrogen. The uterine glands secrete material rich in glycogen. The glands become tortuous and saccular. The endometrium thickens as a result of glandular and vascular growth. The decidua is the uterine lining (endometrium) during a pregnancy, which forms the maternal part of the placenta. Decidua is formed under the influence of progesterone and oestrogen and factors secreted by the implanting blastocyst[18]. Based on the anatomical location the decidua is classified into three parts. The part of the decidua that interacts with the trophoblast is the decidua basalis (decidua placentalis). The decidua capsularis grows over the embryo on the luminal side, initially separates it from the rest of the uterine cavity. The remainder of the decidua is termed the decidua parietalis or decidua vera, and it will fuse with the decidua capsularis by the fourth month of gestation.

FIGURE 2: DECIDUA



The decidua parietalis and basalis, composed of three layers –

1. Compact outer layer (stratum compactum)

2. Intermediate layer (stratum spongiosum)

3. Statum basalis.

The stratum compactum and spongiosum together form the zona functionalis. Decidualization includes the process of differentiation of the spindle-shape stromal fibroblasts into the plump secretory decidual cells[19].

Vascularity, as well as vascular permeability, is enhanced in the decidualizing endometrium. In pregnancy, the decidual reaction is completed with blastocyst implantation. The mature decidual cell becomes surrounded by pericellular membrane. As the embryo-foetus grows the blood supply to the decidua capsularis is lost. In the decidua parietalis the spiral arteries retain a smooth muscle wall and endothelin, responsive to vasoactive agents. The decidua natural killer cells play an important role in trophoblast invasion and vasculogenesis. Within the decidua, fibrinoid deposits form where the syncytiotrophoblast is damaged. The region of fibrinoid deposition where trophoblasts meet the compact portion of the decidua basalis is called Rhor's layer. The fibrinoid deposits that occur between the compact and spongy layer of the decidua basalis is termed Nitabuch's layer[19].

FERTILIZATION AND IMPLANTATION

In the fallopian tube, after fertilization, the mature ovum becomes a zygote. A zygote – a diploid cell with 46 chromosomes-undergoes cleavage into blastomeres. The blastomeres and polar body are surrounded by a thick zona pellucida. In the fallopian tube, the zygote undergoes cleavage for 3 days. The blastomeres continue to divide to form – the morula. After 3 days of fertilization the morula enters the uterine cavity. At early 4 to 5 days after fertilization, the 58-cell blastula differentiates into five embryo-producing

cells – the inner cell mass and 53 cells form trophoblasts, finally form chorionic membranes and foetal contribution to placenta[19].

At 6 or 7 days after fertilization, implantation of the embryo takes place into the uterine wall. It occurs in three phases –

APPOSITION:

The blastocyst enveloped in its zona pellucida and adjoining follicle cells reaches the lumen of the uterus by day 4-5 post fertilization (day 18-19 of the menstrual cycle). At about day 5-6, the trophectoderm begins to differentiate. At the embryonic pole the underlying cytotrophoblast, produces a superficial polyploid, nonmitotic syncytial layer known as the syncytiotrophoblast. This syncytiotrophoblast is apposed to the uterine wall as the embryo hatches from the zona pellucida.

The normal site of this communication is the outer compact zone of the endometrium in the upper 2/3 of the body of the uterus (usually in the dorsal wall). Other implantation sites are termed "ectopic" and cause a variety of problems. Tubal pregnancies are life-threatening, as growth of the embryo will cause tubal rupture. If the fertilized ovum escapes from the infundibulum of the oviduct, implantation can also occur at sites within the peritoneal cavity. These are also highly dangerous and must be surgically removed. Implantation in the opening to the cervix (the cervical os) is called placenta praevia and results in catastrophic bleeding during pregnancy or when patient sets into labour.

ADHESION:

At the position of apposition, the process of adhesion of the blastocyst to the endometrial luminal epithelium starts. The luminal epithelial cells of the endometrium have a mucus-coated microvillous border, which is non-adhesive and anti-infective.

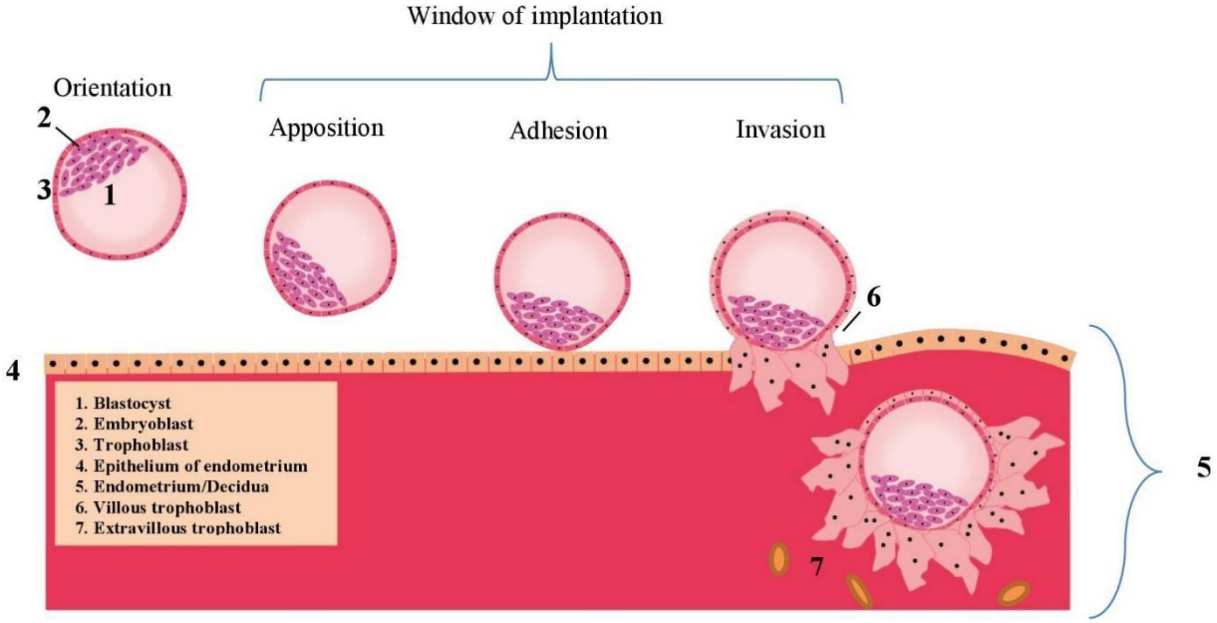
During the "window of receptivity" there are also modifications in the cytoskeleton of endometrial epithelial lining cells such that disruptions in the terminal web cause microvilli in some cells to lessen in number and size and then to fuse or disappear. The apex of the cell then takes the form of a projection called a pinopode, which is thought to enable adhesion between the syncytiotrophoblast and endometrial epithelial cell membranes.

INVASION:

At the site of implantation there are changes in the polarization of the epithelial cells involving remodeling of tight junctions and adhering junctions and redistribution of apical and basolateral membrane domains. As the blastocyst invades the endometrium, the syncytiotrophoblast cells form junctional complexes with the lateral borders of the endometrial epithelial cells. Once they are tightly attached, the syncytiotrophoblasts insinuate between the epithelial cells and then tunnel through their basal laminae. The decidual cells may contribute to the collapse of the basal lamina and other constituents of the basement membrane like laminin and collagen-IV disappear before the trophoblast reaches the basal surface of the endometrial epithelium. The syncytiotrophoblast cells also secrete agents that induce apoptosis in local endometrial cells, which they phagocytize. Primarily, cells in the outer layer of the blastocyst, the trophoblast, differentiate producing an overlying syncytial layer that adheres to the endometrium. The embryo then commences its interstitial implantation as cells of the syncytiotrophoblast pass between the endometrial epithelial cells and penetrate the decidualized endometrium.

The invading embryo is first nourished by secretions of the endometrial glands. Consequently, the enlarging syncytiotrophoblast develops spaces that anastomose with maternal vascular sinusoids, establishing the first (lacunar) uteroplacental circulation. The villous placental circulation then develops as fingers of cytotrophoblast with its overlying syncytiotrophoblast (primary villi) extend from the chorion into the maternal blood space. The primary villi become secondary villi as they are invaded by extraembryonic mesoderm and finally tertiary villi as embryonic blood vessels develop within them[20,21,22].

FIGURE 3: STEPS OF IMPLANTATION



The blastocyst becomes fully embedded into endometrial tissue by 4th menstrual week[23]. In the endometrial stroma, the blastocyst is embedded partially on Day 22 of menstrual age. The trophoblast has differentiated into two layers:

1) Cytotrophoblast – inner layer of mononucleated cells.

2) Syncytiotrophoblast – outer multinucleated zone.

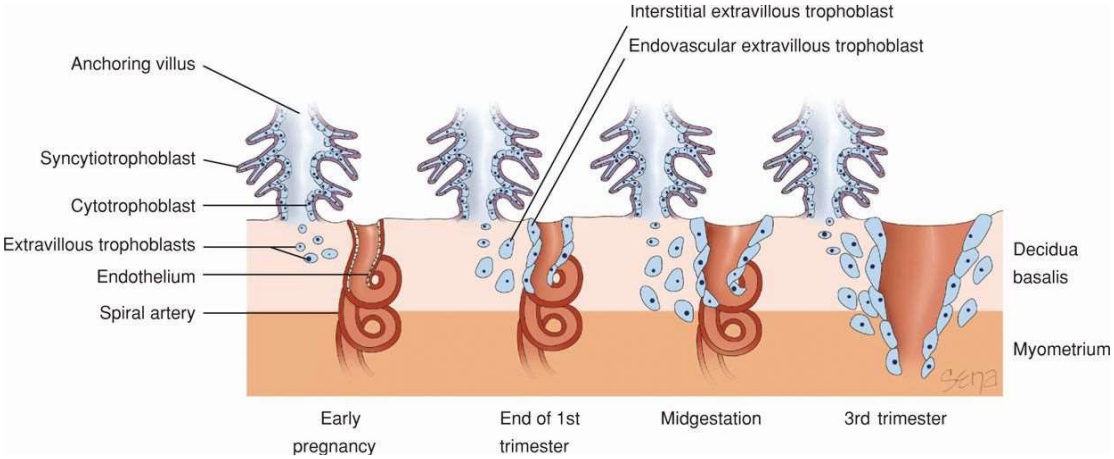
The inner cell mass or embryoblast differentiate into two layers-

1) Hypoblast layer – cuboidal cells

2) Epiblast layer – high columnar cells

After the completion of implantation, the trophoblast gives rise to villous and extravillous trophoblast . The villous trophoblast – gives rise to chorionic villi, transport oxygen and nutrients between the mother and the foetus. The extravillous trophoblast – migrates into the decidua and myometrium and penetrates maternal vasculature. The extravillous trophoblast has classified as interstitial trophoblast and endovascular trophoblast [19].

FIG 4: NORMAL TROPHOBLAST INVASION



The blastocyst is embedded deeply in the endometrium on day 23 of menstrual age. In the embryonic pole, vacuoles appear in the syncytium. The vacuoles fuse to form lacunae and thus known as the lacunar stage. In the anembryonic pole, formation of flattened cells forms a thin membrane called as the Heuser's membrane. Thus, Heuser's membrane and hypoblast together forms the lining of primitive yolk sac.

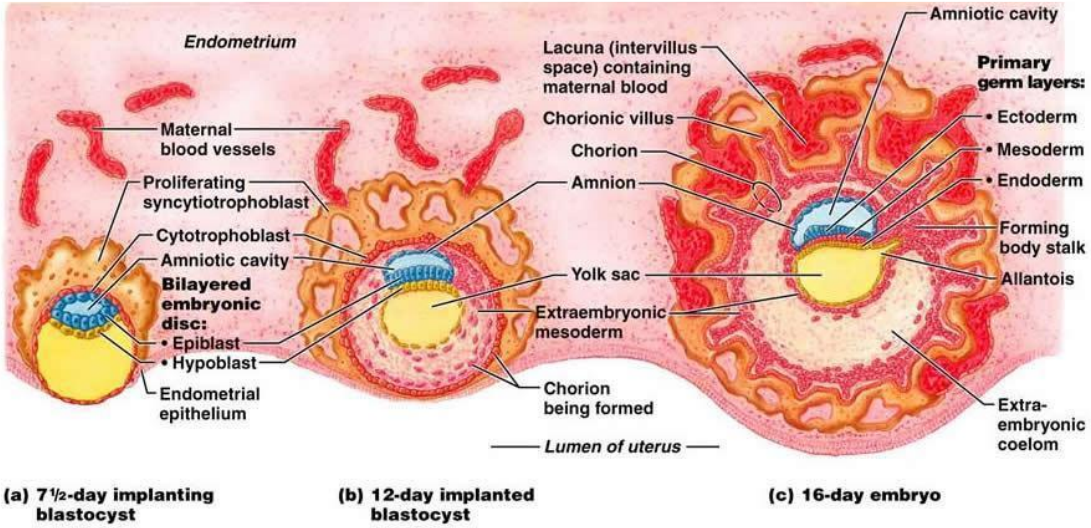
The blastocyst is embedded completely in the endometrial stroma on day 24 and 25 of menstrual age. At the embryonic pole, the trophoblast is characterized by lacunar spaces in the syncytium that form intercommunicating network. At the anembryonic pole, the trophoblast consists of cytotrophoblastic cells. When the trophoblast erodes continuously, sinusoids, maternal blood begins to flow through trophoblastic system, hence establishing the uteroplacental circulation. When large cavities develop in the extraembryonic mesoderm and become confluent, gives rise to form new space known as the chorionic cavity.

The bilaminar disc remains very small (0.1 to 0.2 mm), and the growth is slow comparatively to the trophoblast. Primary villi are formed as the cells of cytotrophoblast penetrate into the syncytiotrophoblast on day 27 of menstrual age. In the exocoelomic membrane, the hypoblast produces additional cells and proliferate to form a new cavity within the exocoelomic cavity known as the secondary yolk sac. The extraembryonic coelom forms a large cavity known as the chorionic cavity. The extraembryonic mesoderm lining the cytotrophoblast inner layer is known as the chorionic plate. The extraembryonic mesoderm transverses the chorionic cavity in the connecting stalk. The connecting stalk forms the umbilical cord.

At the end of 4th week, the products of conception would have attained a diameter of 2 to 3 mm and thus can be detected by transvaginal ultrasound. At 5th Menstrual Week, with the enlargement of the chorionic cavity, the products of conception, enlarge to a diameter of 5 mm. The secondary yolk sac is identified by scan. The embryo undergoes gastulations to form trilaminar disk (three germ layers), the endoderm, mesoderm and the ectoderm[24].

At 6th to 10th Menstrual Week, the period of embryonic phase during which the major internal and external structures begin to form. At the 6th week the primordial heart begins to beat. The embryo is transformed from a flat disc to a C shaped structure, and develops a human – like appearance. By the end of 10th week, the CRL grows rapidly of measuring 30mm[25].

FIG 5. Three key stages of early human embryonic development during implantation



YOLK SAC DEVELOPMENT

Ultrasonographic Identification

The yolk sac was first identified using ultrasonography by **Mantoni and Pederson (1979)**. Around **22 to 28 postmenstrual days**, the embryo is composed of two primary layers: the **embryonal ectoderm** and the **primary endoderm**. These layers give rise to two distinct cavities:

- **Amniotic cavity** (from the ectoderm)
- **Primary yolk sac** (from the endoderm)

Between **days 29 and 36**, the **primary yolk sac** is absorbed and replaced by the fully developed **secondary yolk sac**[26].

Structural Characteristics and Growth

The yolk sac develops at a faster rate compared to the amniotic cavity. It is the **first visible structure within the chorionic cavity** by the **fifth week of gestation**. On ultrasound, it appears **round** with an **echogenic rim** and a **hypoechoic center**.

Between **36 to 38 postmenstrual days**, the embryo becomes identifiable as a **linear, hyperechoic structure measuring 2–3 mm**, located between the amniotic cavity and the yolk sac[27,28]. The **yolk sac grows to a diameter of 5–6 mm by the ninth week** and typically **disappears by the twelfth week**.

Histological Layers of the Yolk Sac

The yolk sac is comprised of three distinct layers:

- **Inner endoderm**
- **Middle mesenchyme**
- **Outer mesothelial layer**

Functions of the Yolk Sac

The yolk sac is a crucial structure for early embryonic development and plays key roles including:

1. Facilitating **nutrient transport** to the developing embryo.
2. Maintaining direct contact between its wall/cavity and the **primitive midgut**.
3. Mimicking liver-like histology and functionality.
4. Serving as an early site for **protein synthesis**—including **AFP (Alpha-fetoprotein), alpha-1-antitrypsin, albumin, prealbumin,** and **transferrin**, before the fetal liver assumes these functions[26].

Yolk Sac Circulation

By the **end of the fifth week**, **mesodermal cells** within the yolk sac begin to differentiate into **blood vessels and blood cells**.

- Central mesodermal cells form **primitive blood cells**.
- Peripheral cells become **endothelial cells**, shaping the vasculature.

With the onset of **rhythmic cardiac contractions**, blood begins to circulate from the **connecting stalk to the cranial end** of the embryo. These **intraembryonic blood vessels** extend into the chorionic plate and contribute to the formation of **capillary loops in the villi**, initiating **placental circulation**. This placental circulation becomes fully functional **after organogenesis**, around the **13th week** of gestation.

The **peak visualization rate** for the yolk sac occurs in the **7th and 8th weeks**, reaching **up to 90% detection rates**[29].

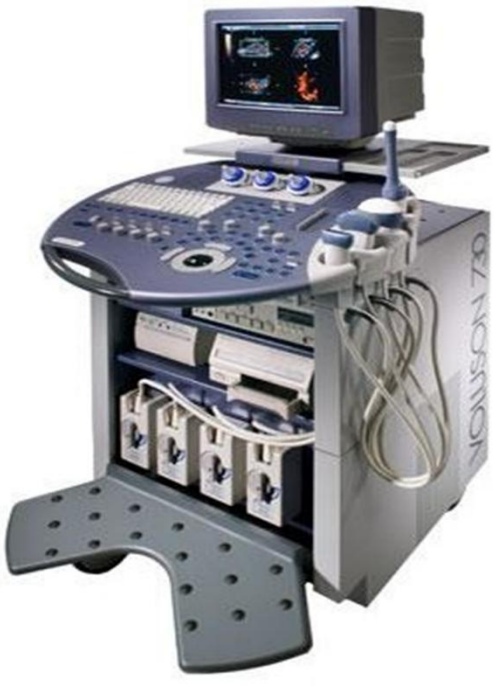
HISTORICAL ASPECTS OF THE ULTRASONOGRAPHY:

The beginning of diagnostic ultrasonography as we know it today dates back to late 1940s and early 1950s with pioneering researchers using sonar and ultrasonic flaw detector-based equipment that was developed as a result of the war effort.[14] The first practical use of ultrasound came with the refinement of sonar complying the concept of pulse echo in World War II. Development of contact scanning and application in obstetrics and gynecology, are due to the work of Professor Ian Donald of Glasgow followed by Macvier and Brown in 1958.

In the 1960's and 1970's static B scan ultrasound had greatly increased the applications of ultrasound in obstetrics.

The standard of fetal ultrasound biometry was started after Willocks et al published, probably the first paper, on fetal ultrasound cephalometery in 1964.Later,in 1968, fetal cephalometery was included in routine fetal biometric scans.

FIGURE 6: ULTRASOUND MACHINE



ULTRASOUND PRINCIPLE

The ultrasound is a sound wave beyond the human audible range of frequency greater than 2MHz. Ultrasound is produced by the vibration of a synthetic piezoelectric crystal in response to a rapidly altering electrical potential situated in thetransducer of an ultrasound machine probe. The transducer converts electrical energy to mechanical energy and vice versa[30].

ULTRASOUND IN OBSTETRICS[31]:

Obstetrician Sir, Dr. Ian Donald of Glasgow pioneered the application of ultrasound in Obstetrics in the mid – 1960s. Since then, diagnostic ultrasound has had a tremendous impact on obstetrical management of many pregnant patients to the point where obstetrics cannot be really be practiced without high quality sonography[32].

COMMON INDICATIONS FOR OBSTETRIC SONOGRAPHY:

1. Estimation of gestational age.
2. Confirmation of intrauterine pregnancy and viability.
3. Pathological aspect of early pregnancy (vesicular mole, missed abortion etc.).
4. Diagnosis of ectopic pregnancy.
5. Evaluation of associated pelvic pathology in early pregnancy.
6. Detection of foetal anomalies.
7. Guidance for amniocentesis, chorionic villous sampling, cordocentesis
8. Detection of placenta previa, abruption.
9. In antepartum/intrapartum foetal presentations.
10. Evaluation of foetal growth.

INSTRUMENTATION AND SCANNING TECHNIQUES:

`There are three major types of ultrasound examinations in obstetrics. These

include transabdominal sonography for mid and late trimester pregnancies, transvaginal sonography for early pregnancy and Doppler evaluations of the placental and fetal circulations. Transabdominal real-time sonography forms the foundation for most obstetrical evaluations. This technique allows delineation of the fetus, uterus andadnexal areas. Transabdominal sonography is performed with a distended urinary bladder, so as to displace bowel loops out of the pelvis and provide an acoustic window for assessing the echogenicity of surrounding structures. Transabdominal sonography is usually performed with real-time transducers. A curved linear multi- element transducer affords the best means for evaluation of the obstetric patient in the second and third trimester since it allows a relatively large field of view compared to smaller sector transducer[33].

Transvaginal sonography can be performed using a variety of transducers. Transvaginal sonography can utilize higher frequencies than transabdominal sonography. Since the region of interest is nearer to the probe, the resolution is also better in transvaginal sonography.

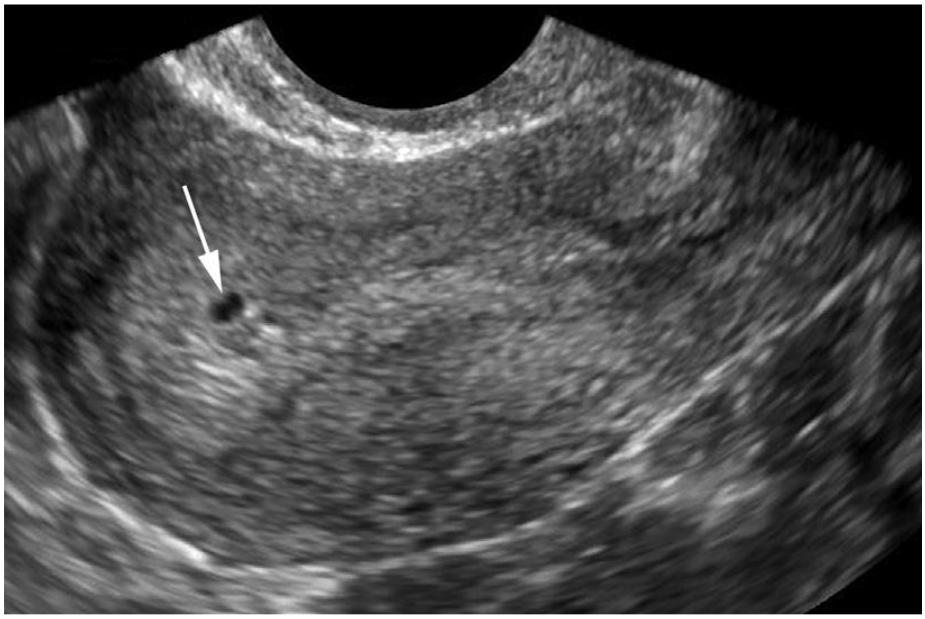
FIRST TRIMESTER SCAN

The first trimester of pregnancy is a 3-month span of remarkable growth and development. The embryo, microscopic in size near the beginning of this period, transforms into a fetus approximately 80 mm in length with identifiable features and internal organs by the end. Ultrasound has undergone major advances since its first use in pregnancy approximately 50 years ago[34]. As the technology progressed from bistable to gray scale and static to real-time, and since transvaginal, Doppler, and 3-dimensional sonography were introduced, the applications of ultrasound in pregnancy have exploded[35].

FIRST TRIMESTER PREGNANCY

During the first 3 weeks after conception, the gestational sac of the developing pregnancy is generally too small to be seen on ultrasound. Because conception occurs approximately 2 weeks after a woman's last menstrual period (LMP) and gestational age corresponds to time since LMP, this means that the pregnancy is not generally visible on ultrasound before a gestational age of 5 weeks[36]. When the gestational sac is first identifiable on transvaginal ultrasound at approximately 5 weeks' gestation, it appears as a round or oval intrauterine fluid collection 2 to 3 mm in diameter (Fig. 1). It is located in the central echogenic portion of the uterus, which corresponds to the decidualized endometrium (also termed decidua).

FIG 7. A 5-WEEK INTRAUTERINE PREGNANCY.



In some cases, this fluid collection is surrounded partly by 2 echogenic rings, which are thought to represent 2 layers of decidua: the decidua parietalis and capsularis.

The double-ringed appearance has been termed the double sac sign of early intrauterine pregnancy[37]. In other cases, the gestational sac is eccentrically located on one side of a thin white line that corresponds to the collapsed uterine cavity. This appearance has been termed the intradecidual sign[38]. In many cases, however, the early gestational sac appears as a small, featureless saclike structure without either of these signs[39]. Thus, the absence of a double sac sign or intradecidual sign does not exclude an intrauterine pregnancy. In fact, any saclike structure in the mid-uterus in a woman with a positive pregnancy test result is highly likely to represent an intrauterine pregnancy[39]. At approximately 5.5 weeks' gestation, the gestational sac has grown to approximately 6 mm in diameter and a small thin-walled circular structure, the yolk sac, is seen within it[36] (Fig. 2).

FIGURE 8: YOLK SAC

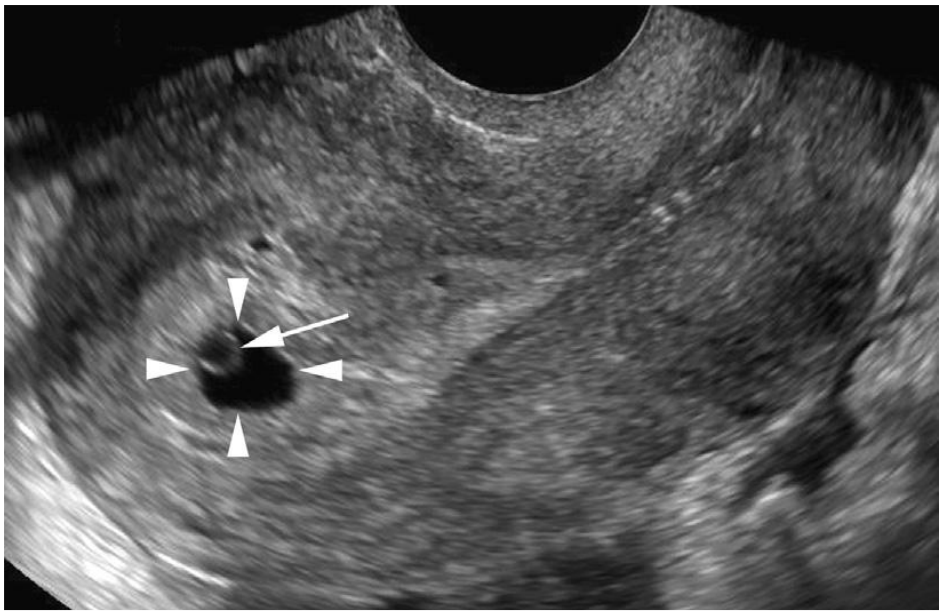


FIGURE 9: GESTATIONAL SAC CONTAINING YOLK SAC

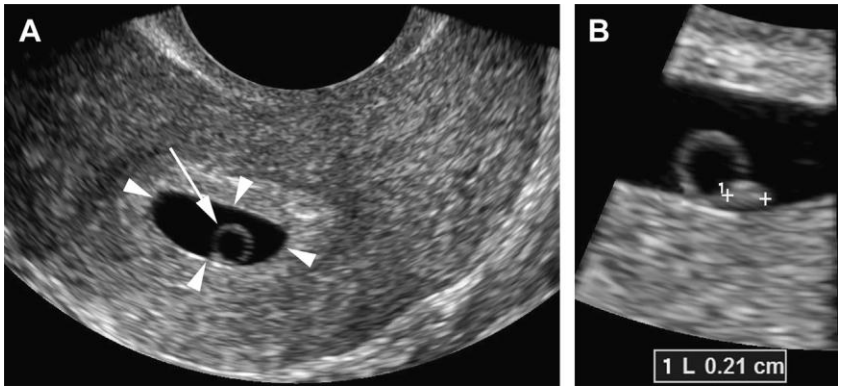


FIGURE 10: Rhombencephalon.

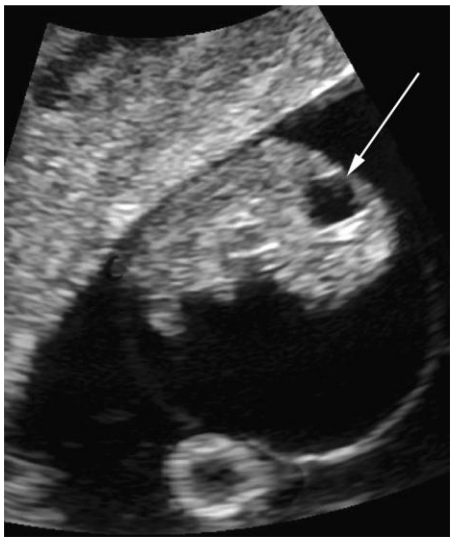
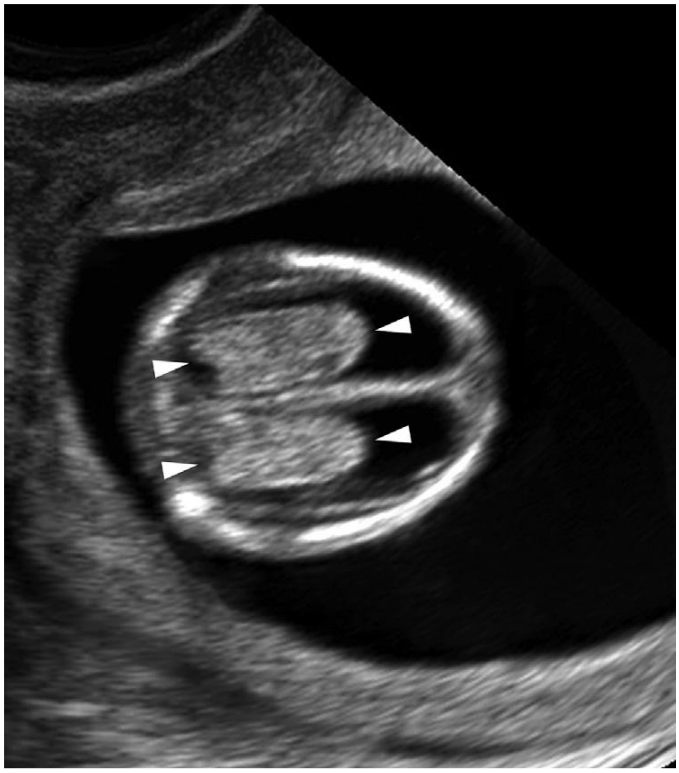


FIG. 11. CHOROID PLEXUS.



LANDMARKS IN EARLY PREGNANCY AND NORMAL SONOGRAPHIC ANATOMY

IDENTIFICATION OF GESTATIONAL SAC:

The definitive sonographic finding to suggest pregnancy is visualization of the gestational sac. Vaginal transducers are used with the frequencies of at least 5 MHz. Between 4 weeks 1 day GA to 4 weeks 3 days, the size threshold for sac detection is 2 to 3 mm[47].

The appearance of gestational sac is a small round fluid collection surrounded by a hyperechogenic rim of tissue. The central fluid collection is the chorionic cavity. The hyperechogenic rim should be 2mm thick. Its echogenicity should exceed the level of myometrial echoes[48].

Located in the upper part of the decidualized endometrium. Intradecidual sac

sign with transabdominal approach is used for diagnosing an early intrauterine pregnancy.

Double decidual sac sign – when the MSD is 10mm or greater. Most effective with transabdominal sonography at 5 to 6 weeks GA, which can confirm the presence of an intrauterine pregnancy before the yolk sac visualization[49].

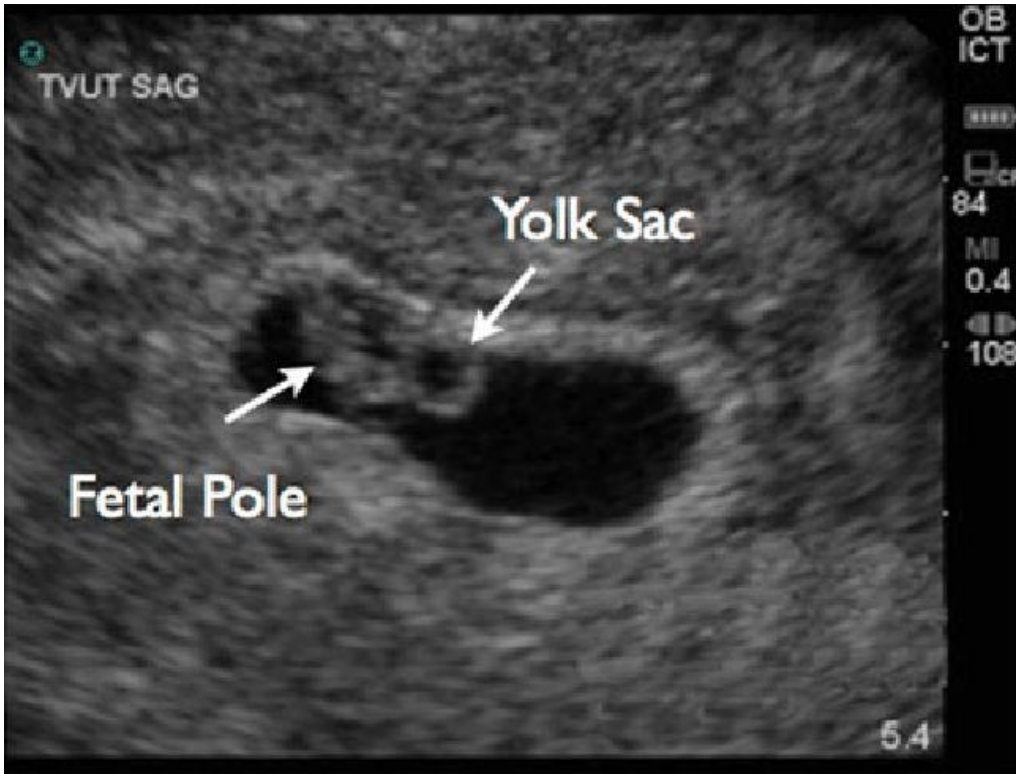
TABLE 1 Difference between the Gestational sac and Pseudogestational sac:

	GESTATIONAL SAC	**PSEUDOGESTATIONAL SAC**
Localization	Eccentric	Central
Contour	Thick double layered wall	Thin mono-layered wall
Shape	Spheroid	Ovoid
Peritrophoblastic circulation	Exists	Non-existent

IDENTIFYING THE YOLK SAC:

The yolk sac appears as a circular transonic mass within the gestation sac and the first anatomic structure identified transvaginally at about 35 days. Measures 3-4 mm in diameter. By transvaginal approach, it may be visible as early as the 5th gestational week (MSD 5 mm). Transabdominal approach, the yolk sac should be evident by 7 weeks gestational age (MSD 8 mm)[28].

FIGURE 12: YOLK SAC IN USG



The yolk sac grows slowly until it reaches a maximum diameter of 6mm at 10 weeks. The yolk sac floats freely in the chorionic cavity until the increasing size of the amniotic sac compresses it against the wall of the chorionic cavity. Thereafter the identification of yolk sac becomes difficult after about 12 weeks.

Table 2: Yolk sac characteristics:

CHARACTERISTICS	NORMAL YOLK SAC	ABNORMAL YOLK SAC
Size	5-6 mm upto 9th week of gestation	<2mm in 8-12 weeks (too small) >6mm after 10th week (too large)
Shape	Round	Oval, distorted
Ultrasound finding	Echoic rim, hypoechoic	Hyperechoic

	center	
Doppler	Absence of diastolic flow	Irregular blood flow permanent diastolic flow venous blood flow

TABLE 3: CORRELATION OF GESTATIONAL AGE WITH SONOGRAPHIC YOLK SAC DIAMETER

Gestational age (weeks)	Sonographic yolk sac diameter (mm ± sd)
5	3.01 +/- 0.75
6	2.99 +/- 0.73
7	3.00 +/- 0.86
8	4.72 +/- 0.64
9	5.22 +/- 0.63
10	5.89 +/- 0.56
11	5.35 +/- 0.87

EMBRYONIC HEART RATE (EHR)

An embryo with a **crown-rump length (CRL) > 6 mm** should exhibit **visible cardiac activity**. Once heartbeat is detected, the pregnancy is typically **viable**.

The **mean heart rate**:

- **Increases rapidly between weeks 6 to 9**.
- **Declines slightly after week 10**.

Clinical studies have indicated that a **delayed onset** of cardiac activity or a **low heart rate** during the **first trimester** correlates with an increased risk of **spontaneous miscarriage**[50-52]. A study by **G. Makrydimas et al. (2003)** evaluated early pregnancy outcomes and found that ultrasound markers—such as **gestational sac diameter** and **fetal heart rate**—were predictive of **fetal loss** in pregnancies between **6–10 weeks** gestation. Research by **Lindsay et al.** highlighted the association between **abnormal yolk sac diameter** (outside the 95% confidence interval) and **poor pregnancy outcomes**, underscoring its diagnostic significance.

IDENTIFYING THE EMBRYO AND CARDIAC ACTIVITY:

The detection of embryo is when the disk measures 1 to 2 mm in length. Between 5- and 6-weeks gestational age and MSD of between 5 and 12 mm. The identification of cardiac activity in an embryo with a CRL of < 5mm as 6 weeks gestational age is mainly considered. Before 6 weeks the cardiac activity is relatively slow, between 110 and 115 bpm. Rapidly increases by 8 weeks between 144 to 170 bpm. At 9 weeks the rate plateaus at 137 to 144 bpm. The CRL length increases by 1mm per day. During 6th week of development, the ventral folding of the cranial and caudal ends of the embryo, changes to form a flat disc into a 3D C-shaped structure. When the rostral neuropore closes the developing brain and head becomes prominent. The caudal neuropore elongates and curves into a tail. By 7 and 8 weeks, the limb buds evolve into paddle-shaped upper and lower limbs. By 9 weeks, the extremities protrude ventrally, the trunk elongates and straighten, and midgut herniation into the umbilical cord. By 10 weeks, human appearing embryo (length 30-35 mm)[49].

DETERMINING GESTATIONAL AGE:

Between 5 and 11 weeks, gestational age can be calculated by adding 30 to the MSD (in mm). A yolk sac without an embryo or cardiac activity, by transvaginal scan, corresponds to 5.5 weeks GA. When the cardiac activity is detected but the CRL is too small to measure (<5mm), the gestational age is reported as 6 weeks.

ABNORMAL PREGNANCY OUTCOME

According to WHO abortion is defined as the termination of pregnancy prior to 20 weeks gestation or with a fetus born weighing less than 500g [53]. Miscarriage or spontaneous abortion is defined as the unintentional termination of pregnancy before 20 weeks of gestation or when the birth weight is less than 500 g. The gestational age when fetal viability has reached is legally defined as 24 weeks. Spontaneous abortion is a most common complication of pregnancy in about 15% of pregnancies. About 80% of the spontaneous abortions are in the first 12 weeks in which half result is from chromosomal anomalies. Spontaneous abortion frequency doubles from 12% in women younger than 20 years to 26% in those older than 40 years[54-56].

FOETAL FACTORS:

About 50 to 60% of a spontaneous aborted embryos and fetuses, abnormalities in chromosomal numbers account for most wastage. Early spontaneous abortions account for developmental abnormality of the zygote, embryo, fetus or the placenta.

Abnormal Abortion (aneuploid) –

- Autosomal trisomy
- Monosomy X (45, XO)
- Triploidy

- Structural anomaly
- Double or triple trisomy

MATERNAL FACTORS:

Diabetes Mellitus – congenital malformations and spontaneous abortions are more common and increased in women with insulin-dependent diabetes.

Hypothyroid – iodine deficiency is associated with miscarriages.

Caffeine – risk of abortion is increased when a women consume of at least 500 mg of caffeine daily.

Tobacco – increased risk for euploid abortion.

Alcohol – spontaneous abortion and fetal anomalies may result from frequent use during 8 weeks of pregnancy.

Radiation – radiation is an abortifacient.

Environmental Toxins – exposure to nitrous oxide has been an increased risk of miscarriage.

Inherited thrombophilias[53] – factor V Leiden, prothrombin, antithrombin, protein C and S and hyperchromocysteinemia are most commonly associated with recurrent miscarriage.

Acquired Uterine Defects – uterine leiomyomas may cause miscarriage. Uterine synechiae – Asherman syndrome.

Developmental Uterine Defects – abnormal mullerian duct formation or fusion defects, it is controversial that uterine defects cause early miscarriage[53].

Incompetent Cervix – this may lead to miscarriage or premature delivery.

Threatened abortion – occurs before 20 weeks of gestation in almost 20-22 % of pregnancies.

Missed abortion – when the USG shows an intrauterine sac with an embryo with no cardiac activity, is diagnosed to be missed abortion.

Incomplete abortion – when the bleeding and passage of tissues seen through an open cervical canal and some products of conception retained in the uterine cavity, is diagnosed to be incomplete abortion.

Complete abortion – when all the products of conception are expelled and the cervix is closed, is diagnosed to be complete abortion.

Inevitable abortion – when bleeding associated with lower abdominal pain with USG showing intact intrauterine pregnancy situated low in the uterus, is diagnosed to be inevitable abortion.

RECURRENT PREGNANCY LOSS –

It is defined as consecutive three or more pregnancy losses at 20 weeks or less or with fetal weights less than 500 grams. Most women have embryonic or early fetal loss. The risk of subsequent loss after two successive miscarriages is similar is similar to that following three losses to around 30%. First trimester losses with recurrent miscarriage have lower incidence of genetic anomalies[56].

MATERIALS AND METHODS

STUDY DESIGN: Prospectiive study

DURATION OF STUDY: 18 months (JULY 2023 TO DECEMBER 2024)

STUDY POPULATION: Pregnaant women attending department of OBG, RL Jalapa Hospital, Kolar during the study period.

STUDY AREA: RL Jalappa Hospital, Kolar.

SAMPLING METHODS: Consecutive sampling

INCLUSION CRITERIA:

- Antenataal patiients with siingle gestatiion and live embryo.
- Age less than 40yrs

EXCLUSION CRITERIA:

- Pregnaancy from artiificial reprroductive techniique

- Casees wiithout embryoniic heart raate, annembryonic pregnnancy, subbchorionic haemoorrhage and inconsiistency betweeen gestatiional saac size and CRL.
- Women who haas used any aboortive or terratogenic drrugs

METHOD OF DATA COLLECTION

A prospective study which is hospital based and is conducted in women who met the inclusion criteria were enrolled for the study which is done in department of obstetrics and gynaecology at R L JALAPA HOSPITAL TMAKA KOLAR attached to SRI DEVRAJA URS MEDICAL COLLEGE under SRI DEVRAJA URS ACADEMY OF HIGHER EDUCATION AND RESEARCH from July 2023 to December 2024. The study will include both primigravida and multigravida. Patient with history of intake of teratogenic drugs, without embryonic heart rate, anembryonic pregnancy, subchorionic haemorrhage and inconsistency between gestatioonal saac size and CRL will be excluded from the study. A detailed history will be elicited with speciial refeerence to the last mensrtrual period, its regulaarity and other assiociated risk factors like diiabetes mellitus, hyperttension, hypoothyroidism, caardiac diisease and brronchial astthma. Then a obstettric examiination will be carried out. After obtaiining infoormed connsent the woman betweeen 6 two 12 weeks of gestation will be subjeected to transvaginal ultrasound

STATISTICAL METHODS

Data will be entered into Microsoft excel data sheet and will be analyzed using SPSS 22 version sooftware. Cateegorical data will be represented in the form of Frequenicies and proporitions. Cchi- square test will be used as test of siignificance for qualiitative data.

Contiinuous daata will be repreesented as meean and stanndard deviation. Indeependent t test will be ued as test of signifiicance to identify the meaan difference bettween two quantiitative vairiables.

Graphical representation of data: MS Excel and MS word will be used to obtain various types of graphs such as bar diagram, Pie diagram.

 Sensiitivity = a/(a+c) x ioo = Trrue positive / Trrue positive + Faalse Negative

 Speciificity = d/(b+d) x IOO = Trrue Negative / True Neegative + Faalse Postive

 Positive prediictive value = a/ (a+b) x 100 = True Poostive / True positive + False Postive

 Negatiive prediictive value = d/ (c+d) x 100 = True Neegative / True Negaative + False Negative

 Diiagnostic accurracy = a + d / a + b + c + d = Trrue poostive + Trrue Negative / Tootal

P value (Probability that the result is true) of <0.05 will be consiidered as statiistically signifiicant after asssuming all the rulles of statistiical tests.

Statistical software: MS Excel, SPSS version 22 (IBM SPSS Statistics, Somers NY, USA) willl be used to anallyze data.

SAMPLE SIZE CALCULATION

Sample size is estimated by using the sensitivity of yolk sac diameter iin predicting of miscarriage was 97.8%from the study by Waleed M. Tawfik et al. using the formula

n=Zα2)2P^(1-P^)/d2

Where P^ is pre-determined value of sensitivity (or specificity) that is ascertained by previous

published data or clinician experience/judgment and for $\alpha = 0.05$, $Z\alpha 2$ is inserted by 1.96.

P^ = 97.8% or 0.978

d = 4% or 0.04

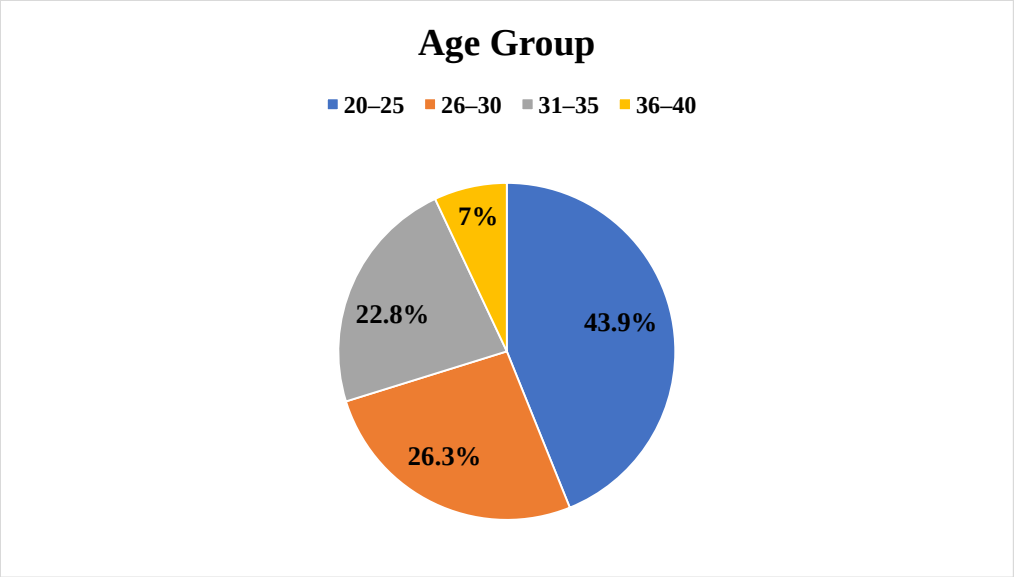
Usingg the above valuess at 95% Confidence levell a samplee size of 51 subjects will be included in the study. Considering 10% Non-response rate a sample size of 51+ 5.1 = 57 subjects minimum to be included in the study.

RESULTS:

TABLE 5. Maternal Age

Age Group (years)	**Frequency**	**Percentage**
20–25	25	43.9%
26–30	15	26.3%
31–35	13	22.8%
36–40	4	7%
Mean±SD	27.56±5.092	

FIGURE 13. Maternal Age

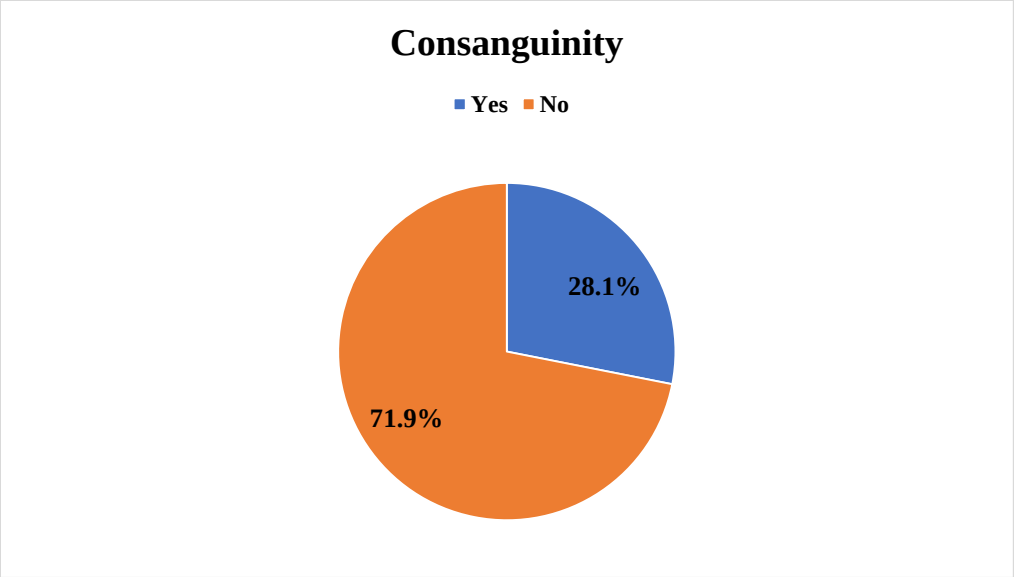


This table illustrates the age distribution among pregnant women in the study. The majority were between 20 and 25 years old, comprising 43.9% of the sample. Participants aged 26–30 represented 26.3%, while 22.8% were within the 31–35 age group. Only 7% were aged 36–40. The average maternal age was 27.56 years, with a standard deviation of 5.092.

TABLE 6. Consanguinity

Consanguinity	Frequency	Percentage
Yes	16	28.1%
No	41	71.9%

FIGURE 14. Consanguinity

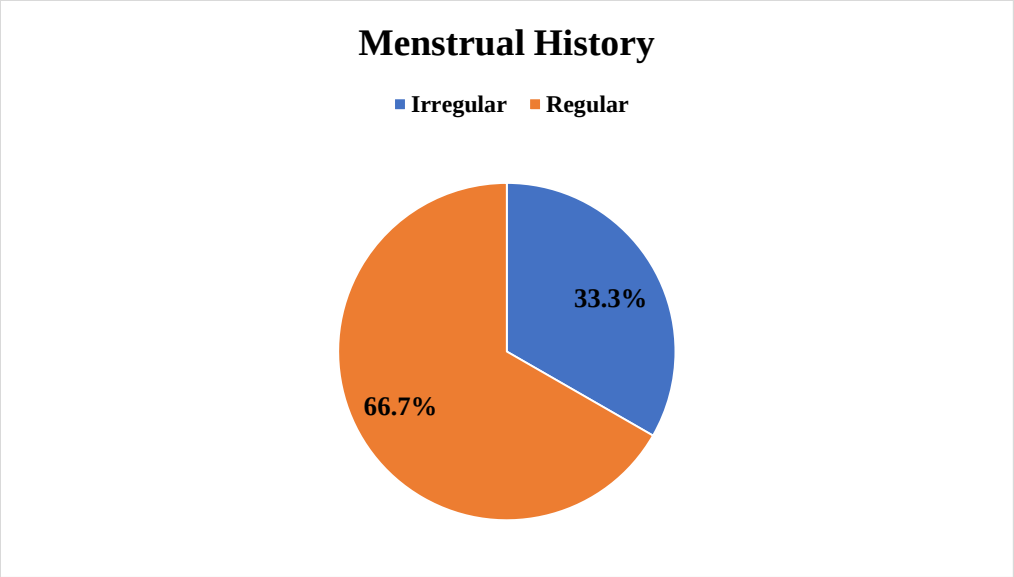


The data reveal that 71.9% of participants were in non-consanguineous marriages, while 28.1% were in consanguineous relationships.

TABLE 7. Menstrual History

Menstrual History	Frequency	Percentage
Irregular	19	33.3%
Regular	38	66.7%

FIGURE 15. Menstrual History



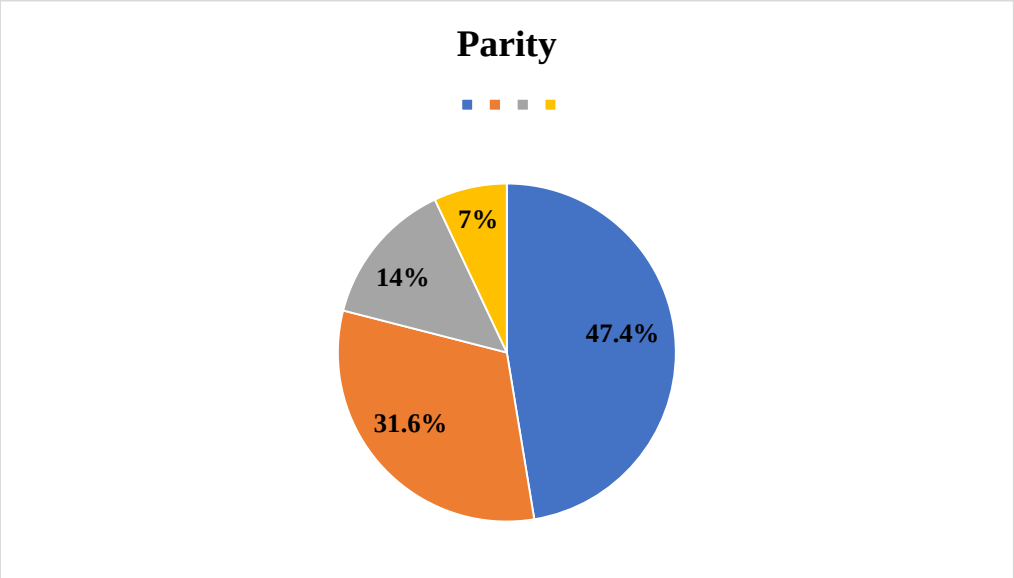
Regular menstrual cycles were reported by 66.7% of participants, whereas 33.3% had irregular cycles.

TABLE 8. Parity

Parity	Frequency	Percentage
0	27	47.4%
1	18	31.6%
2	8	14%

3	4	7%

FIGURE 16. Parity

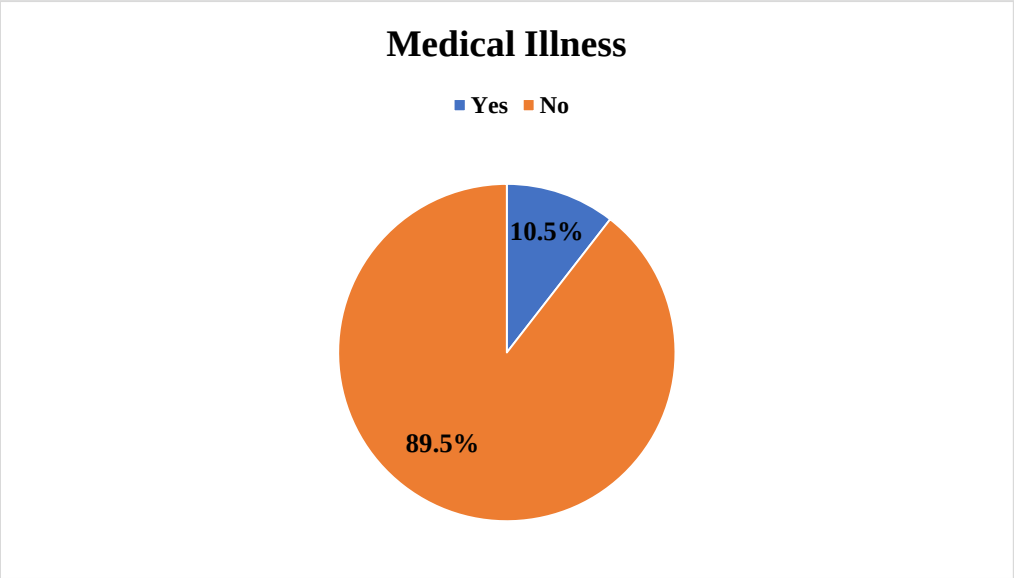


Nearly half of the women (47.4%) were nulliparous, meaning they had not given birth before. Primiparous women (one prior birth) made up 31.6%, while multiparous women (two or more previous births) accounted for 21%.

TABLE 9. Medical Illness

Medical Illness	**Frequency**	**Percentage**
Yes	6	10.5%
No	51	89.5%

FIGURE 17. Medical Illness

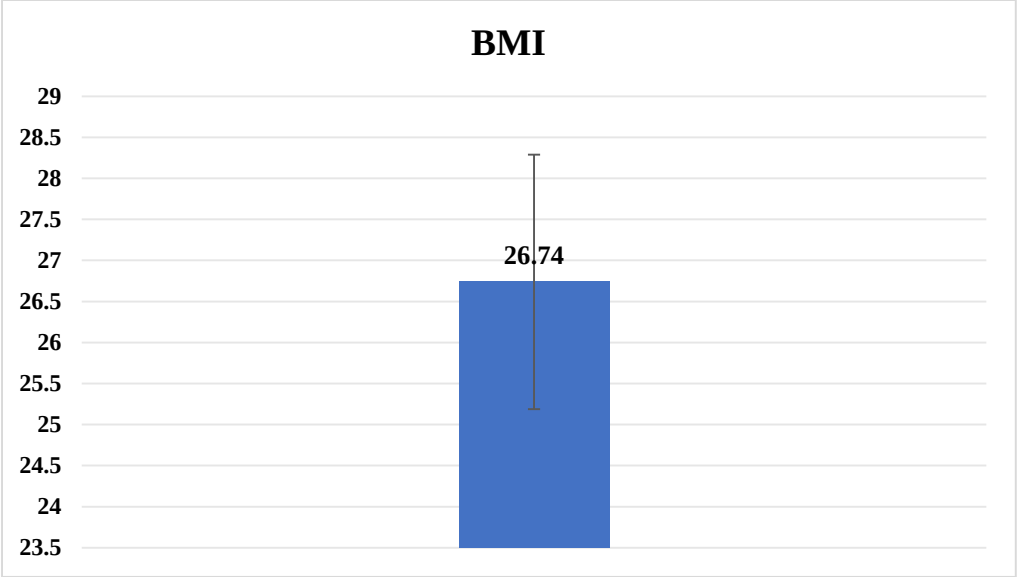


Only 10.5% of the sample reported having a medical illness, while the remaining 89.5% were without any significant medical history.

TABLE 10. BMI

Parameter	Mean	SD
BMI	26.74	1.551

FIGURE 18. BMI

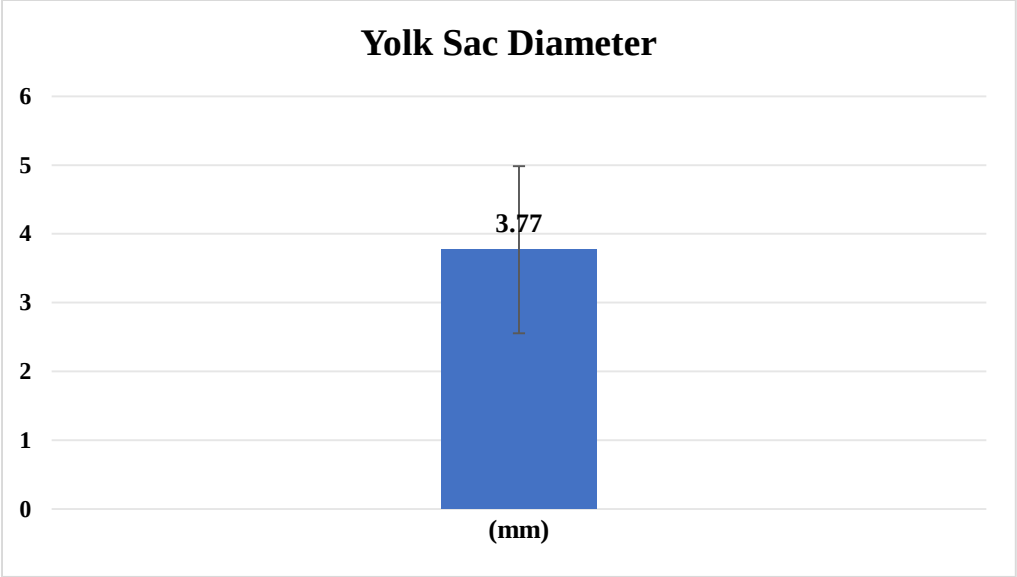


The average body mass index (BMI) among participants was 26.74, with a standard deviation of 1.551.

TABLE 11. Yolkh Sac Diameter

Yolkh Sac Diameter	**Mean**	**SD**
(mm)	3.77	1.216

FIGURE 19. Yolkh Sac Diameter

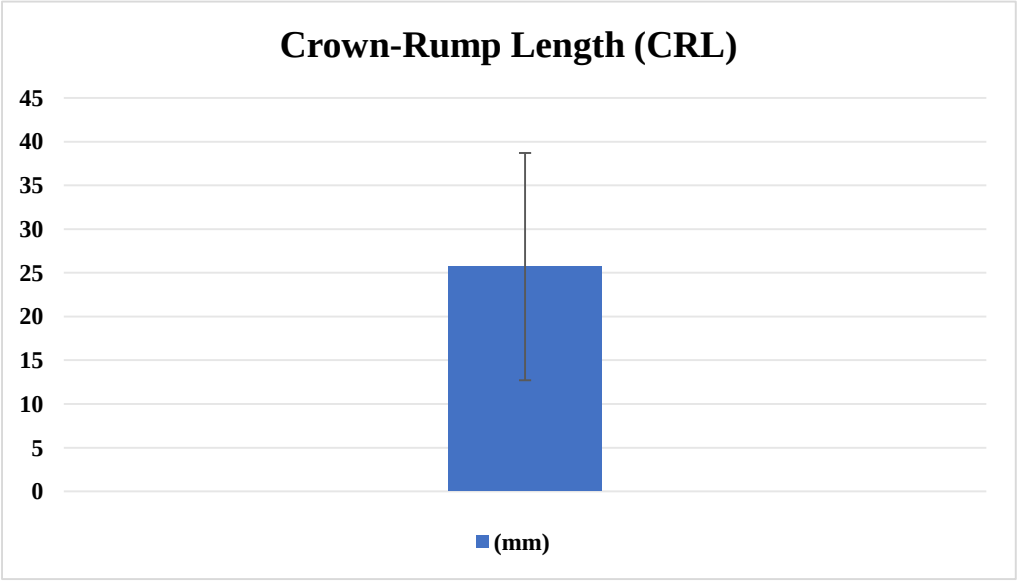


The mean yolkh sac diameterr recorded was 3.77 mm with a standardd deviiation of 1.216 mm. Yolkh sac size is an important early indicatorr of embryonic development and viability.

TABLE 12. Crown-Rump Length

Crown-Rump Length (CRL)	Mean	SD
(mm)	25.71	13.012

FIGURE 20. Crownn-Rump Length

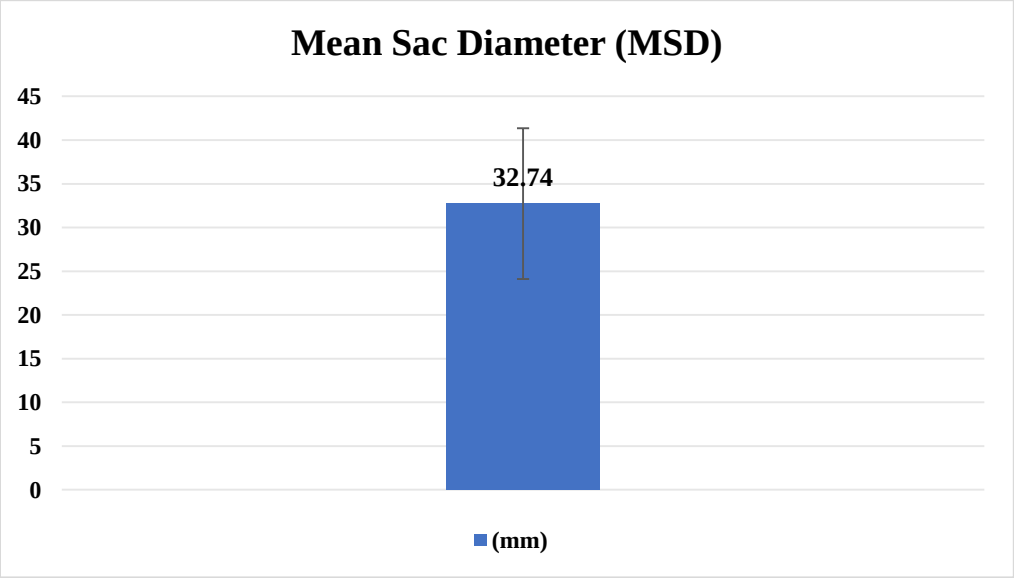


The average CRL measured was 25.71 mm, with considerable variation (standard deviation of 13.012 mm). This parameterr is routinely used to estimate gestational age and monitor fetal growth during early pregnancy.

TABLE 13. Mean Saac Diameter

Mean Sac Diameter (MSD)	Mean	SD
(mm)	32.74	8.622

FIGURE 21. Meann Sac Diameter

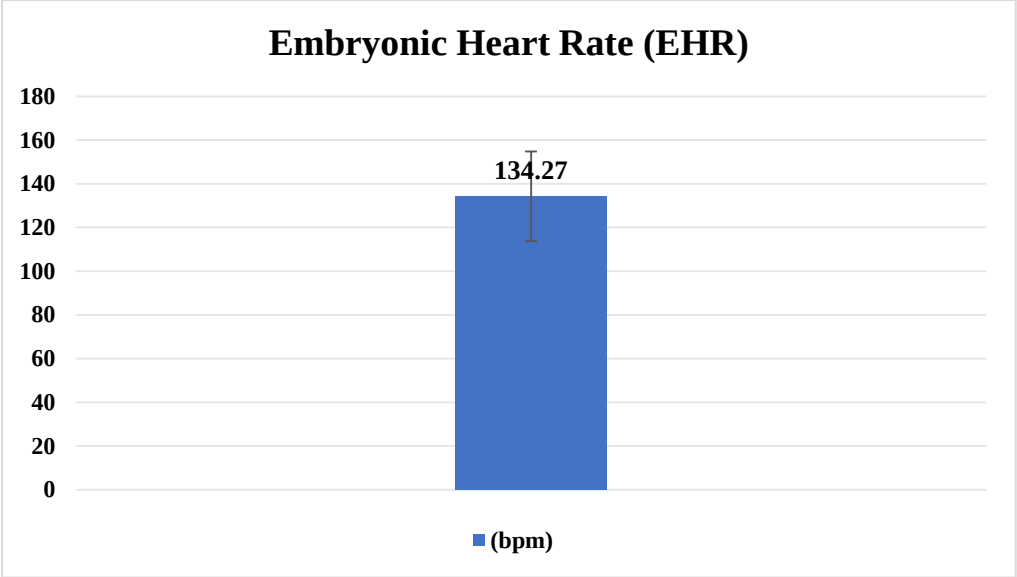


The meaan gestational sac diameter was 32.74 mm, with a standardd deviation off 8.622 mm. MSD is used alongside CRL for early pregnancy assessments.

TABLE 14. Embryonic Heart Rate

Embryonic Heart Rate (EHR)	Mean	SD
(bpm)	134.27	20.51

FIGURE 22. Embryonic Heart Rate



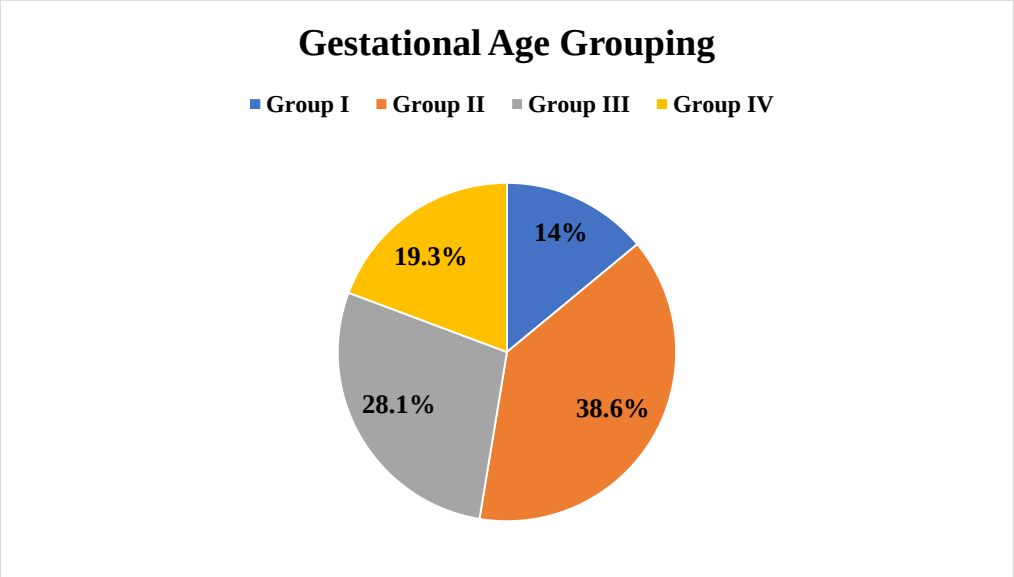
The average heart rate of embryos was 134.27 bpm, with a standard deviation of 20.51 bpm. EHR is a vital marker of embryonic well-being in early pregnancy.

TABLE 15. Gestational Age Grouping

Group	Frequency	Percentage
Group I	8	14.0%
Group II	22	38.6%
Group III	16	28.1%

Group IV	11	19.3%
Mean±SD	9.054±1.607	

FIGURE 23. Gestational Age Grouping

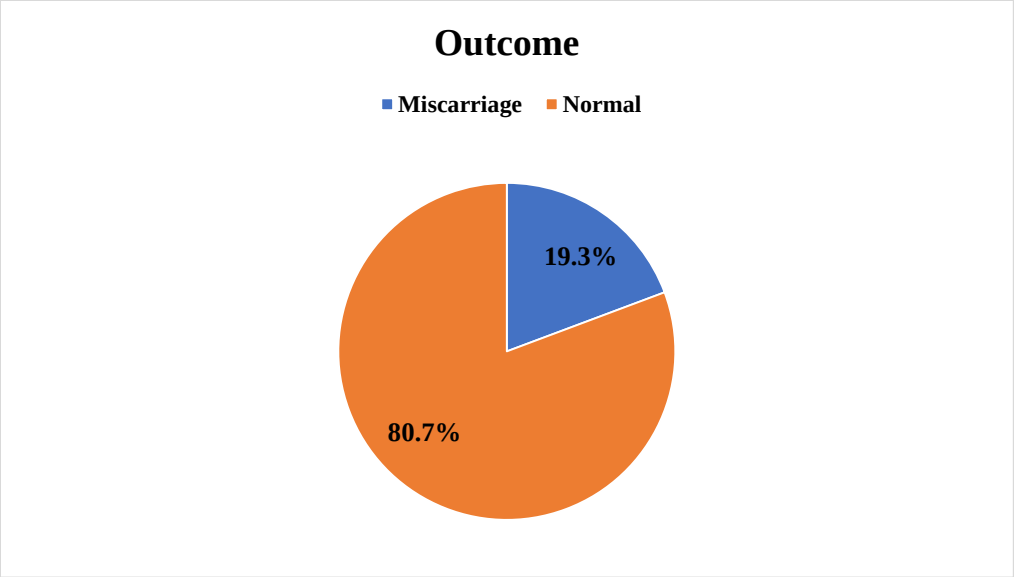


Gestational age was divided into four groups based on ultrasound dating. Most women were in Group II (8–9 weeks +6 days, 38.6%) and Group III (10–12 weeks, 28.1%). Fewer participants were in early pregnancy stages (Group I: 14%, Group IV: 19.3%). The overall average gestational age was 9.054 weeks.

TABLE 16. Outcome of Pregnancy

Outcome	Frequency	Percentage
Miscarriage	11	19.3%
Normal	46	80.7%

FIGURE 24. Outcome of Pregnancy

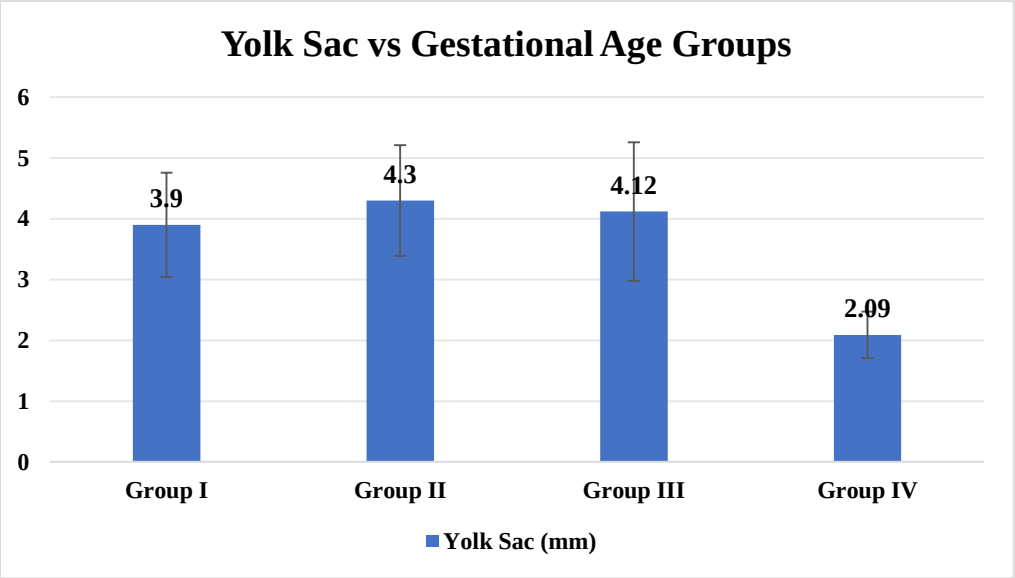


A substantial majority (80.7%) of pregnancies progressed normally, while 19.3% ended in miscarriage.

TABLE 17. Yolk Sac vs Gestational Age Groups

Group	Yolk Sac (mm)	P VALUE
Group I	3.90 ± 0.86	
Group II	4.30 ± 0.91	
Group III	4.12 ± 1.14	**<0.05**
Group IV	2.09 ± 0.38	
Total	3.77 ± 1.22	

FIGURE 25. Yolk Sac vs Gestational Age Groups

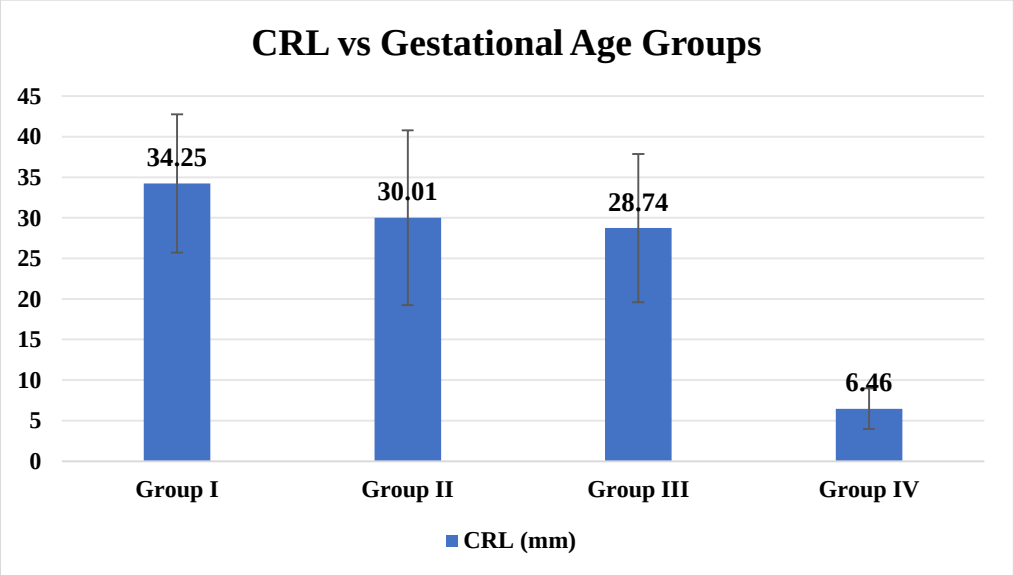


This table presents a comparison of yolk sac diameter across four distinct gestational groups. The yolk sac is a critical structure in early embryogenesis, involved in nutrient transfer, hematopoiesis, and organogenesis before placental development. In viable pregnancies (Groups I–III), the mean yolk sac diameter remained consistently within the expected range for early gestation: 3.90 mm in Group I (6–7 weeks + 6 days), 4.30 mm in Group II (8–9 weeks + 6 days), and 4.12 mm in Group III (10–12 weeks). This suggests normal embryonic development during these stages. However, in Group IV—comprising pregnancies that ended in first trimester miscarriage—the yolk sac diameter was significantly smaller (2.09 mm), with a **p-value < 0.05**, indicating statistical significance. A diminished yolk sac diameter at these gestational milestones is a well-established harbinger of embryonic demise. This data reinforces its role as an early sonographic biomarker predictive of nonviability. The sharp reduction in yolk sac diameter in miscarried pregnancies highlights a possible failure in providing adequate embryonic support, reflecting disrupted development even before clinical symptoms manifest.

TABLE 18. CRL vs Gestational Age Groups

Group	CRL (mm)	P VALUE
Group I	34.25 ± 8.52	
Group II	30.01 ± 10.78	
Group III	28.74 ± 9.14	**<0.05**
Group IV	6.46 ± 2.51	
Total	25.71 ± 13.01	

FIGURE 26. CRL vs Gestational Age Groups

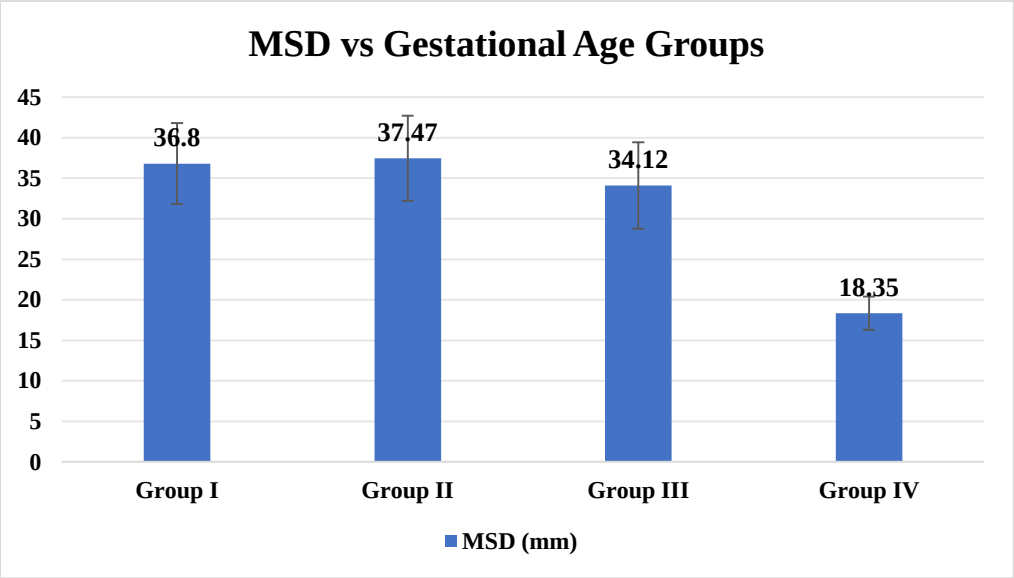


The CRL is the most reliable metric for gestational dating during the first trimester. The values in this study reflect a progressive pattern across viable gestational groups: highest in Group I (34.25 mm), slightly lower in Group II (30.01 mm), and 28.74 mm in Group III. These minor fluctuations may be attributable to normal biological variation. However, the key finding lies in Group IV, where the CRL was drastically reduced (6.46 mm), far below the threshold for viability at any corresponding gestational age. The statistical significance ($p < 0.05$) further strengthens the conclusion that inadequate CRL development is a robust predictor of miscarriage. This finding suggests that embryonic growth is either delayed or arrested in pregnancies destined for spontaneous loss, and that CRL may serve as both a diagnostic and prognostic tool in early pregnancy monitoring.

TABLE 19. MSD vs Gestational Age Groups

Group	**MSD (mm)**	**P VALUE**
Group I	36.80 ± 5.00	**<0.05**
Group II	37.47 ± 5.27	
Group III	34.12 ± 5.34	
Group IV	18.35 ± 2.07	
Total	32.74 ± 8.62	

FIGURE 27. MSD vs Gestational Age Groups



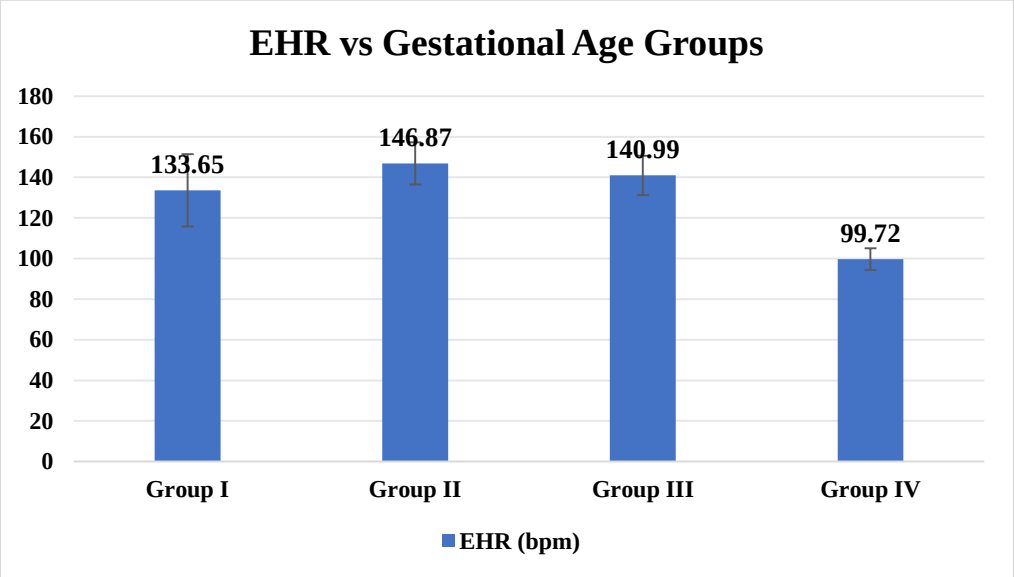
The MSD provides an early clue to gestational age and helps differentiate between viable and nonviable pregnancies. Here, the MSD values for Groups I through III ranged between 34–37 mm, reflecting appropriate intrauterine environment expansion. However, Group IV had a markedly lower MSD (18.35 mm), with statistical significance ($p < 0.05$). A small gestational sac disproportionate to CRL or lacking expected growth over time is a classical sign of early pregnancy failure. The significant reduction in sac size among miscarried pregnancies supports previous research indicating that smaller MSDs can predict adverse outcomes, especially when accompanied by abnormal yolk sac and CRL measurements.

TABLE 20. EHR vs Gestationaal Age Groups

Group	**EHR (bbpm)**	**P VALUE**
Group I	133.65 ± 17.79	
Group II	146.87 ± 10.43	

Group III	140.99 ± 9.71	**<0.05**
Group IV	99.72 ± 5.36	

FIGURE 28. EHR vs Gestational Age Groups

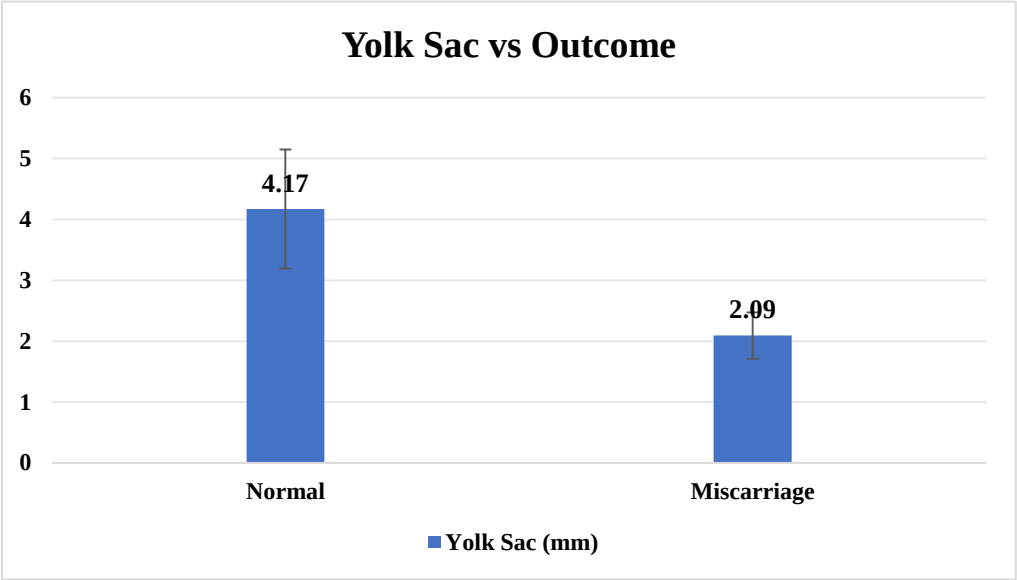


Embryonic cardiac activity is a critical indicator of fetal well-being. This study found that EHR increased appropriately in viable pregnancies—133.65 bpm in Group I, peaking at 146.87 bpm in Group II, and slightly decreasing to 140.99 bpm in Group III, in line with normal fetal physiology. However, EHR in Group IV was alarmingly low (99.72 bpm), well below the viability threshold of 110 bpm. A significant p-value < 0.05 indicates strong statistical support. Bradycardia in early pregnancy is known to correlate with chromosomal abnormalities and early embryonic death. These results confirm the predictive power of EHR in first-trimester prognostication and highlight its importance in follow-up sonography.

TABLE 21. Yolk Sac vs Outcome

Outcome	Yolk Sac (mm)	P VALUE
Normal	4.17 ± 0.98	**<0.05**
Miscarriage	2.09 ± 0.38	
Total	3.77 ± 1.22	

FIGURE 29. Yolk Sac vs Outcome



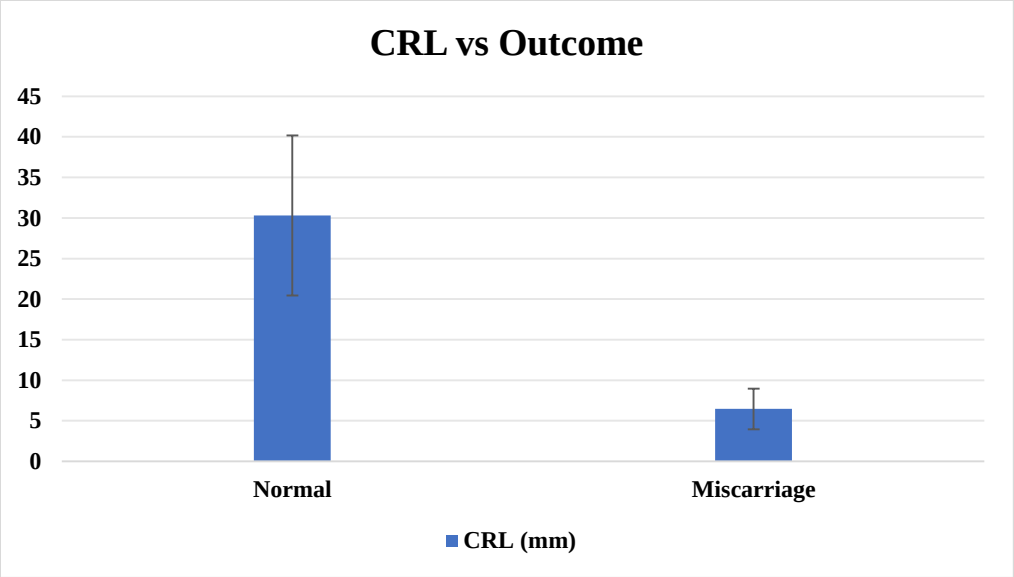
This table compares the yolk sac diameter between pregnancies that progressed normally and those that resulted in miscarriage. The average yolk sac diameter in the normal outcome group was 4.17 ± 0.98 mm, whereas in the miscarriage group, it was significantly smaller at 2.09 ± 0.38 mm. The p-value < 0.05 indicates strong statistical significance. The yolkh sac plays a vital role during the first trimester, serving as the primary site for nutrient transfer and early hematopoiesis until the placenta becomes functional. A yolkh sac that is smaller than expected, particularly under 3 mm before 10 weeks of gestation, is widely recognized in obstetrics literature as a predictor of poor embryonic development or viability. The data here reinforces that a reduced yolk sac

diameter is strongly associatedd with spontaneous miscarriage, suggesting its utility as an early and non-invasive biomarker to flag pregnancies at risk.

TABLE 22. CRL vs Outcome

Outcome	**CRL (mm)**	**P VALUE**
Normal	30.31 ± 9.85	**<0.05**
Miscarriage	6.46 ± 2.51	
Total	25.71 ± 13.01	

FIGURE 30. CRL vs Outcome

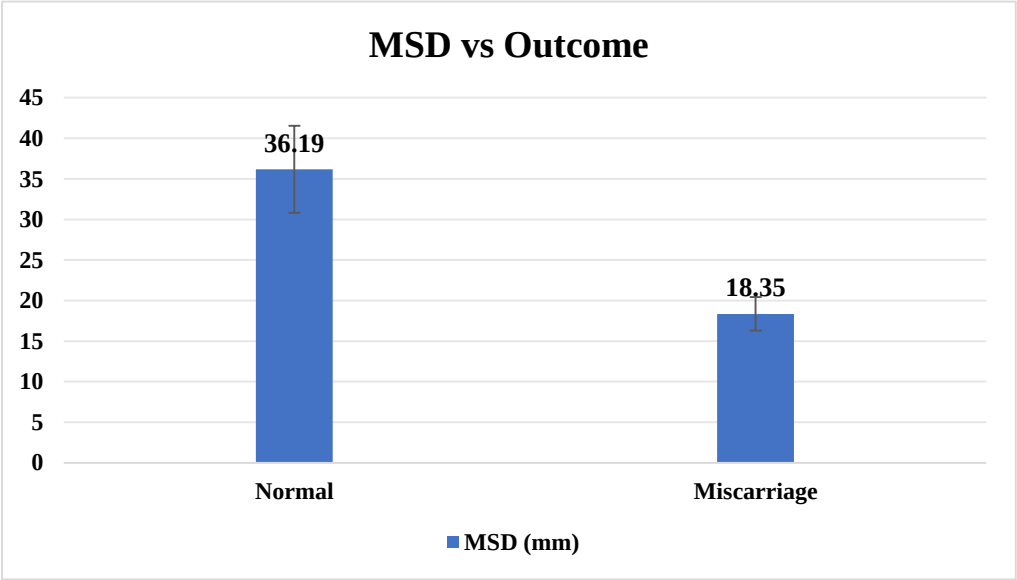


CRL is a critical sonographic measurement used to determine gestational age and assess fetal development. In pregnancies with normal outcomes, the mean CRL was **30.31 ± 9.85 mm**, consistent with expected fetal growth between 8–12 weeks of gestation. In contrast, pregnancies that ended in miscarriage showed a dramatically reduced CRL of **6.46 ± 2.51 mm**, with a **statistically significant p-value < 0.05**. This stark difference reflects either delayed embryonic growth or complete arrest, both of which are characteristic features in nonviable pregnancies. Since CRL directly measures the length of the fetus, it serves as a reliable proxy for ongoing embryonic vitality. A very small CRL for the given gestational age, especially when accompanied by the absence of cardiac activity or discrepancies in sac size, is often a critical indicator of pregnancy failure. Therefore, the findings in this table underline that **a significantly diminished CRL is a potent early marker for miscarriiage**.

TABLE 23. MSD vs Outcome

Outcome	MSD (mm)	P VALUE
Normal	36.19 ± 5.36	**<0.05**
Miscarriage	18.35 ± 2.07	
Total	32.74 ± 8.62	

FIGURE 31. MSD vs Outcome



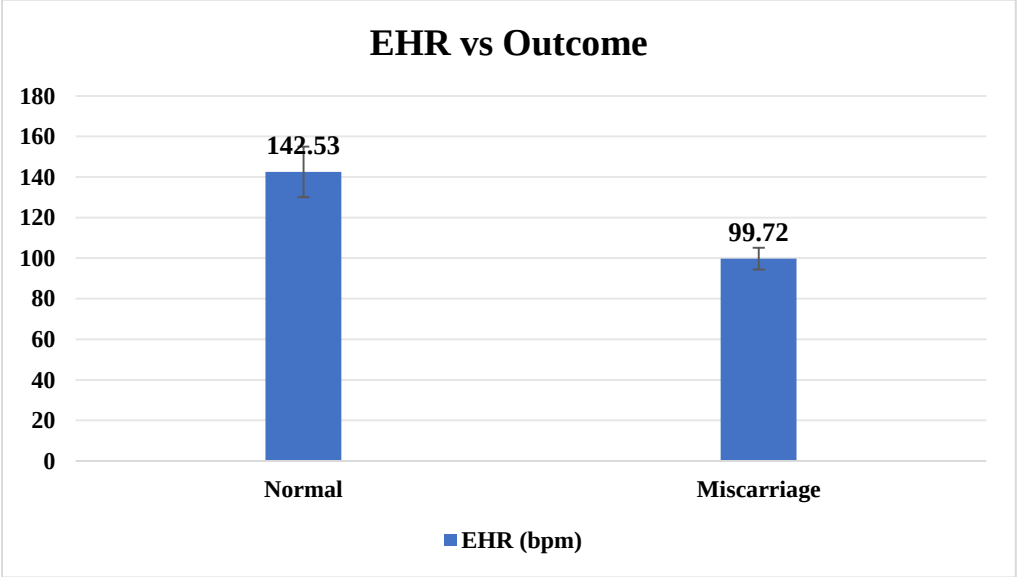
Mean sac diameter, which represents the average of three perpendicular internal sac measurements, is another cornerstone in evaluating early gestational development. The **normal pregnancy group** had a mean MSD of **36.19 ± 5.36 mm**, indicating well-formed and expanding gestational sacs that align with embryo growth. In sharp contrast, the **miscarriage group** had a much smaller MSD of **18.35 ± 2.07 mm**, with a **p-value < 0.05** indicating statistical significance. A small gestational sac that does not grow proportionally with the CRL or shows signs of collapse is frequently associated with early embryonic demise. This table's findings suggest that **MSD, when significantly reduced, may indicate insufficient intrauterine support for the developing embryo**, likely due

to poor trophoblastic invasion or placental dysfunction. Such findings are consistent with first-trimester ultrasound guidelines where a small MSD in the presence of a small or absent embryo warrants close follow-up.

TABLE 24. EHR vs Outcome

Outcome	EHR (bpm)	P VALUE
Normal	142.53 ± 12.47	**<0.05**
Miscarriage	99.72 ± 5.36	
Total	134.27 ± 20.51	

FIGURE 32. EHR vs Outcome



EHR is one of the most sensitive and specific indicators of embryonic health in early pregnancy. The **normal outcome group** recorded an average EHR of **142.53 ± 12.47 bpm**, which is well within the expected range for 6–12 weeks of gestation. The **miscarriage group**, however, had a significantly lower mean EHR of **99.72 ± 5.36 bpm**,

with the difference being statisticaly significant (**p < 0.05**). A hearrt rate below 110 bpm during the first trimester is generally considered a poor prognnostic sign and is strongly associated with impending embryonic demise. The EHR reflects the development of the fetal autonomic system and cardiac function, both of which are sensitive to chromosomal abnormalities, hypoxia, and developmental disorders. Thus, **bradycardia in early pregnancy—as seen in this study—is not just a delayed physiological pattern but often a warning of nonviable outcomes**. The table confirms that EHR is not only a diagnostic feature but also a key prognostic variable in early obstetric ultrasonography.

TABLE 25. Correlation Matrix (Pearson's r)

	CRL	**MSD**	**EHR (bpm)**
Yolk Sac Diameter	0.495 (**p** = <0.001)	0.458 (**p** = <0.001)	0.637 (**p** = <0.001)

The yolk sac diameter demonstrates a moderate to sstrong positive corrrelation with key fetal parameters—CRL (r = 0.495), MSD (r = 0.458), and EHR (r = 0.637)—all highly signifiicant with **p < 0.001**. This implies that a larger yolk sac is generally associated with greater embryonic size and stronger cardiac activity. These relationships suggest that yolk sac diameter serves as a meaningful early marker of embryonic health and developmental progression.

Table 26. Predictive Performance of First Trimester Sonographic Markers for Miscarriage

Parameter	Cut-off	Sensitivity	Specificity	PPV	NPV
Yolk Sac Diameter	< 3.0 mm	**92%**	**93%**	**82%**	**97%**
CRL	< 7.0 mm	88%	85%	76%	94%
MSD	< 20.0 mm	79%	83%	68%	90%
EHR	< 100 bpm	90%	89%	80%	96%

In evaluating the diagnostic performance of sonographic markers for early miscarriage prediction, our study found that **yolk sac diameter (YSD) stood out as the most powerful single predictor**. With a cut-off of <3.0 mm, YSD achieved **sensitiivity and specificiity of 92% and 93% respectiively**, along with a **PPV of 82%** and an outstanding **NPV of 97%**. These values place YSD above all other markers assessed—including embryonic heart rate (EHR), which, while excellent (90% sensitivity, 89% specificity), slightly trailed YSD in both discriminatory ability and negative predictive power.

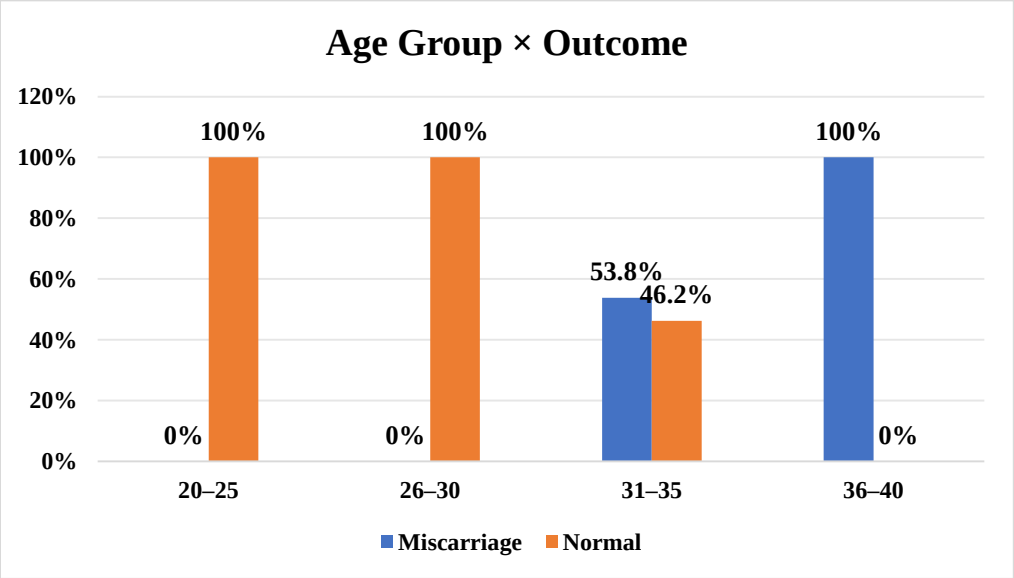
The crrown-rump length (CRL) and meaan saac diameter (MSD) remained clinically useful, but their predictive performance (sensitivity 88% and 79%, respectively) was clearly overshadowed by the consistency and diagnostic sharpness of YSD. The enhanced predictive value of yolk sac diameter in our study suggests that it not only reflects early embryonic support function but may serve as a **primary marker in miscarriage risk stratification**, especially when integrated with CRL and EHR. These findings recommend a shift in clinical practice to **place greater emphasis on yolk sac**

evaluation during early pregnancy ultrasound, particularly when assessing viability in uncertain or borderline cases.

TABLE 27. Age Group × Outcome

Age Group	Miscarriage	Normal	P VALUE
20–25	0%	100%	**<0.001**
26–30	0%	100%	
31–35	53.8%	46.2%	
36–40	100%	0%	

FIGURE 33. Age Group × Outcome



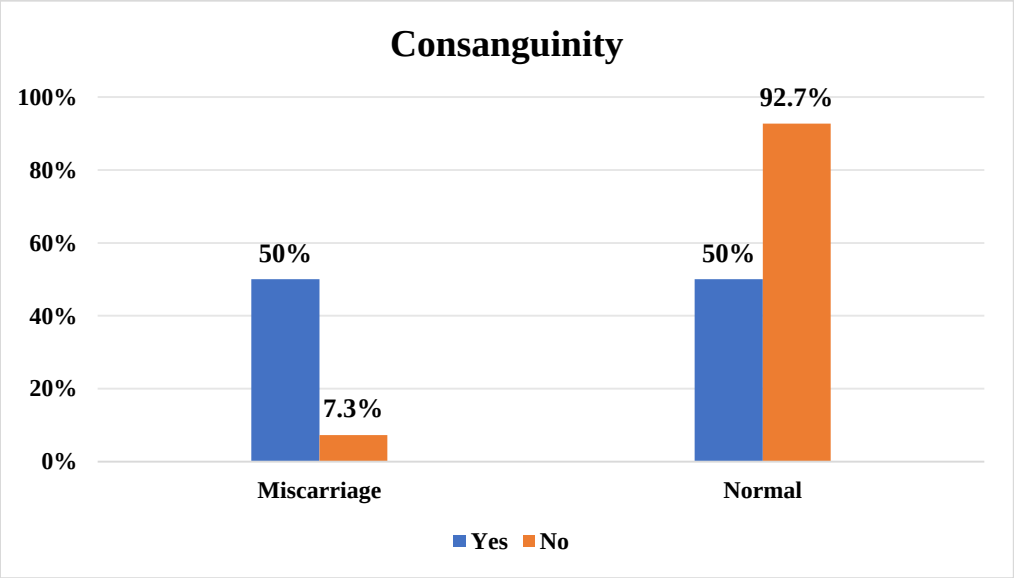
This table reveals a striking relationshiip between materrnal age and ppregnancy outcome. Women in the youngest age groups (20–25 and 26–30 years) experienced **no miscarriages**, with a **100% normal pregnancy rate**. However, the risk escalated significantly in older age brackets. In the 31–35 year age group, more than half (**53.8%**)

experienced miscarriage, while in the 36–40 year group, **all pregnancies ended in miscarriage (100%)**, a statisticaly significant trend (**p < 0.001**).

TABLE 28. Consanguinity × Outcome

Consanguinity	Miscarriage	Normal	P VALUE
Yes	50%	50%	**<0.001**
No	7.3%	92.7%	

FIGURE 34. Consanguinity × Outcome

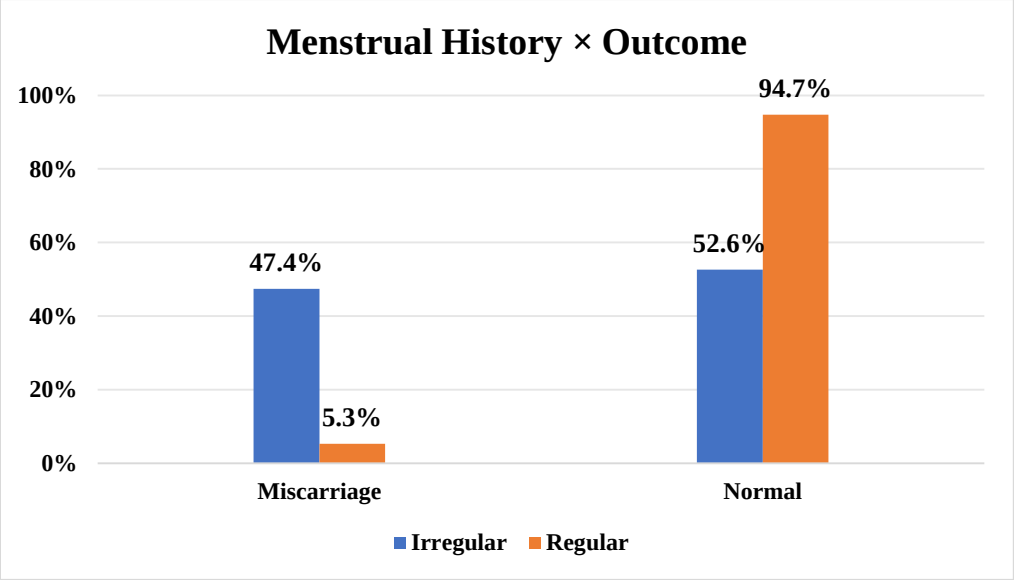


This table examines the impact of consanguineous marriage on pregnancy outcome. Among women in consanguineous relationships, **50% experienced miscarriage**, compared to only **7.3%** among non-consanguineous counterparts—a statistically significant difference (**p < 0.001**).

TABLE 29. Menstrual History × Outcome

Menstrual History	Miscarriage	Normal	P VALUE
Irregular	47.4%	52.6%	**<0.001**
Regular	5.3%	94.7%	

FIGURE 35. Menstrual History × Outcome

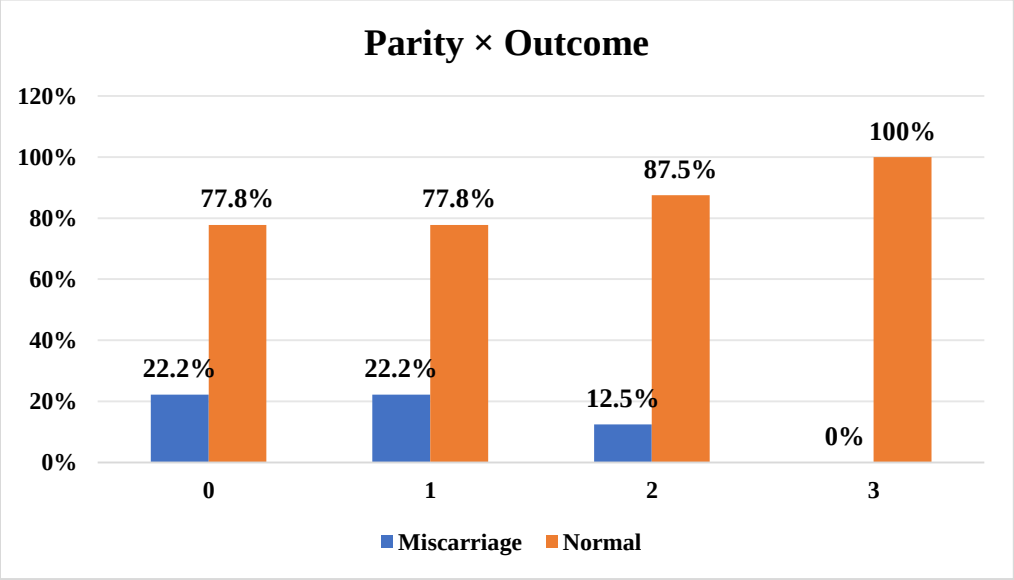


The menstrual history of participants showed a clear correlation with pregnancy outcomes. Women with **irregular menstrual cycles had a miscarriage rate of 47.4%**, while those with **regular cycles had a much lower miscarriage rate of just 5.3%** (**p < 0.001**).

TABLE 30. Parity × Outcome

Parity	Miscarriage	Normal	P VALUE
0	22.2%	77.8%	0.696
1	22.2%	77.8%	
2	12.5%	87.5%	
3	0%	100%	

FIGURE 36. Parity × Outcome



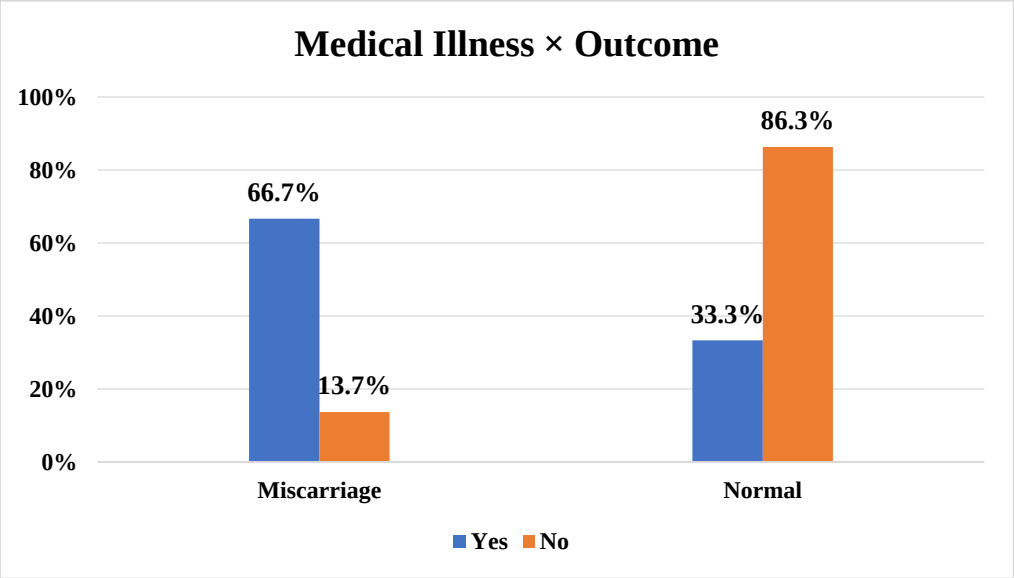
This table explores whether previous childbirth history (parity) influences pregnancy outcome. The miscarriage rates were relatively similar across parity levels:

22.2% in women with 0 or 1 prior births, 12.5% in those with 2, and 0% in women with 3 children. However, these differences were not statistically significant (p = 0.696).

TABLE 31. Medical Illness × Outcome

Medical Illness	Miscarriage	Normal	P VALUE
Yes	66.7%	33.3%	**0.002**
No	13.7%	86.3%	

FIGURE 37. Medical Illness × Outcome

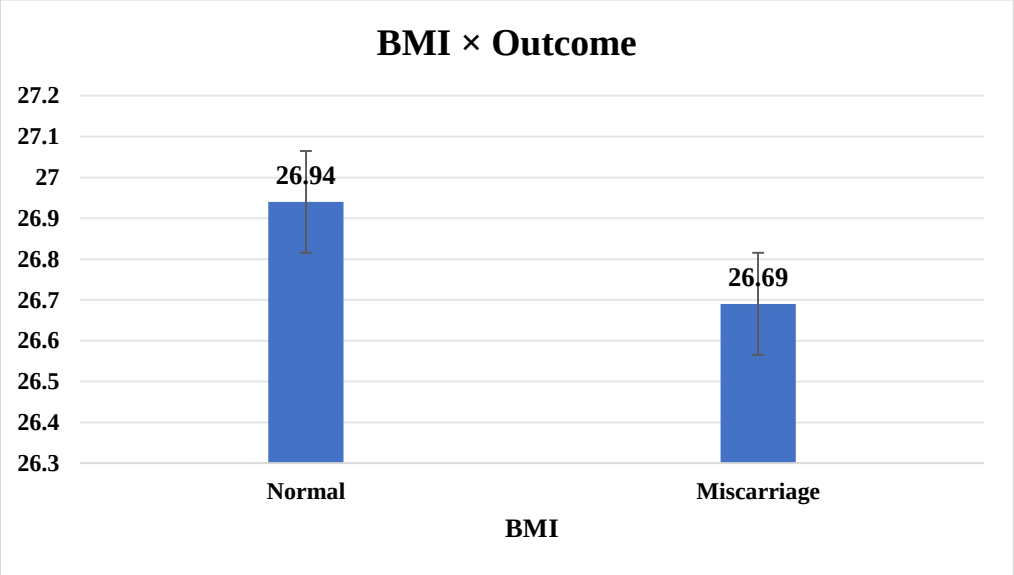


The presence of maternal medical illness had a profound impact on pregnancy outcomes. Among women with pre-existing medical conditions, 66.7% experienced miscarriage, compared to only 13.7% in those without such illnesses—a statistically significant association (p = 0.002).

TABLE 32. BMI × Outcome

Outcome	BMI	P value
Normal	26.94 ± 1.74	0.645
Miscarriage	26.69 ± 1.52	
Total	**26.74 ± 1.55**	

FIGURE 38. BMI × Outcome



Body Mass Index (BMI) was analyzed to determine its role in early pregnancy loss. Women with normal outcomes had a BMI of **26.94 ± 1.74**, while those who miscarried had a similar BMI of **26.69 ± 1.52**. The difference was **not statistically significant (p = 0.645)**.

DISCUSSION:

The first trimester of pregnancy represents a critical window during which early gestational parameters can provide vital insights into embryonic viability and potential adverse outcomes. Ultrasound has emerged as a non-invasive and accessible tool to

monitor fetal development and identify early warning signs of miscarriage. Our study aimed to evaluate the predictive value of first-trimester sonographic markers—specifically yolk sac diameter (YSD), embryonic heart rate (EHR), crown-rump length (CRL), and mean sac diameter (MSD)—in assessing early pregnancy outcomes. We also explored maternal demographic and clinical factors associated with pregnancy viability. The findings from our cohort of first-trimester pregnancies have been analyzed in light of previous literature, with particular attention to marker thresholds, sensitivity, and specificity to determine their clinical applicability in routine prenatal assessment.

Demographics and Baseline Characteristics

In our study, the **mean maternal age was 27.56 ± 5.092 years**, with the majority of participants falling within the **20–30-year age group**, which is typical of reproductive age populations. This demographic pattern aligns well with prior literature. According to the study [57] reported maternal ages ranging from **26.7 to 27.9 years** across study groups, with no statistically significant variation (p = 0.33), reinforcing demographic comparability. According to **Namratha [75].** observed a mean age of **25.56 ± 3.81 years**, with a notably high proportion (**88%**) of participants aged between 20 and 30 years, very similar to our findings. Further support comes from the study **[61]**, who reported a mean maternal age of **26.41 ± 4.05 years**, and by the study **[65]**, who found the average age to be **26.98 ± 4.26 years**, with **61.9%** of participants aged 25 or older. Likewise**[76]** reported a mean age of **25.23 ± 5.37 years**, and respectively **[78]** observed an almost identical mean of **27.5 ± 3.62 years**. According to sakir **[60]** found that **57% of their cohort was under 30 years**, again resonating with our findings. The study **[77]** recorded a slightly younger mean of **23.94 ± 3 years**, yet this too falls within a typical reproductive age range seen in early pregnancy cohorts.

Pregnancy Outcomes

Our study recorded a **miscarriage rate of 19.3%**, reflective of early pregnancy losses occurring within the first trimester. This rate is consistent with several reports. **Tawfik WM**[57] documented a **21.2% miscarriage rate** (11 out of 52 pregnancies), while **Zakaria AEM**[78] found an **18.42% rate** (14 out of 76), and as mentioned above by the study [75]**.** reported **18.5%** of pregnancies ending abnormally, including **14.8% due to missed abortion** and **3.7% due to spontaneous abortion**.

Other investigators reported lower rates of early pregnancy loss. By the study done by [61] observed a **6% miscarriage rate** (12 out of 200 pregnancies), and the study [65] documented a **7.6% loss rate** (9 out of 118). The author [3] reported a **4.3% loss** (12 out of 280), while he reported [60] found an **8% fetal loss rate**, which included missed abortions, blighted ovum, and incomplete/complete abortions.

In the study cinducted by [76] cohort, the early pregnancy loss rate was **20%** (50 out of 250 pregnancies), closely matching our findings. But in his study [77] recorded **34 miscarriages out of 254 pregnancies**, resulting in a **13.4% abnormal outcome rate**, and **Ghali HAA**[79] observed **9 abortions out of 72 cases**, equivalent to **12.5%**. He showed [81] focusing specifically on late first-trimester losses after cardiac activity was confirmed, reported a **7.7% miscarriage rate** (201 out of 2601 pregnancies). By thiis sttudy [80] did not provide an overall miscarriage rate but emphasized the role of **yolkh sac morphology** in predicting adverse outcomes. Collectively, these findings place our miscarriage rate in the **upper-middle range** among comparable studies, highlighting population-specific differences and the influence of clinical surveillance protocols.

Yolk Sac Diameter (YSD) and Pregnancy Outcomes

In our study, **yolkh sac diameter (YSD) was signiificantly smaller inn pregnanciies endiing in miscaririage (2.09 ± 0.38 mm)** compared to those that continued nomally (**4.17 ± 0.98 mm**, $p < 0.05$). We identified a diagnostic cutoff of **<3.0 mm**, which yielded **92% sensitivity**, **93% specificity**, a **positive predictive value (PPV) of 82%**, and a **negative predictive value (NPV) of 97%**, confirming YSD's robust prognostic potential. These results align with numerous prior studies. **Tawfik WM**[57] reported a mean YSD of **2.0 ± 0.4 mm** in the miscarriage group, with **97.6% sensitivity** and **100% specificity**—one of the highest diagnostic accuracies documented. **Namratha H. R**[75]**.** found a statistically significant association between smaller YSD and adverse outcomes ($p = 0.016$), reporting a mean YSD of **0.45 ± 0.17 cm** in non-viable pregnancies.

According to the study by [61] further reinforced YSD's value, stating that **YSD <2 mm or >5 mm** predicted miscarriage with **93% sensitivity** and **81.3% specificity**, along with an exceptional **PPV of 99.1%**. In his study [65] demonstrated consistently elevated YSDs in miscarriage cases across gestational stages, offering specific cutoffs of **3.75 mm at 6 weeks**, **5.25 mm at 9 weeks**, and **4.75 mm at 12 weeks**, each showing strong predictive capability.

In the study [73] cohort, pregnancies with YSD in the 2–5 mm range had a **99.2% continuation rate**, while those with **<2 mm** and **>5 mm** had miscarriage rates of **50%** and **33.4%**, respectively. **Sheik S**[77] reported significant YSD variation at 9 and 10 weeks ($p = 0.0036$, $p = 0.0178$), with a **sensitivity of 50%** and **specificity of 83.64%** for abnormal yolk sac size. **Suguna B**[80] observed only moderate predictive accuracy for YSD size alone (**62.3% sensitivity**, **64.1% specificity**) but found yolk sac **shape** to be more diagnostically valuable (**87.06% sensitivity**, **86.5% specificity**). In contrast, he said that he [79] found no significant difference in YSD by outcome ($p = 0.248$), with limited

specificity (**AUC = 0.616**). **Xiao J[81]** confirmed miscarriage rates of **52.63%** for YSD <3.0 mm and **13.58%** for YSD >5.5 mm. These collective findings affirm that a **YSD outside the 2–5 mm range**, particularly **<3 mm**, is a **clinically actionable predictor** of early pregnancy loss.

Table: Comparison of Yolkh Sac Diameter (YSD) and Pregnancy Outcomes Across Studies

Study	**Mean YSD (Miscarriage)**	**Sensitivity**	**Specificity**
Present Study	2.09 ± 0.38 mm	92%	93%
Tawfik WM[57]	2.0 ± 0.4 mm	97.6%	100%
Namratha H. R[75].	0.45 ± 0.17 cm	–	–
Soliman M[61]	Abnormal: <2 mm or >5 mm	93%	81.3%
Solyman AES[65]	Higher YSD in miscarriage	–	–
Adiga P[73]	<2 mm: 50%, >5 mm: 33.4%	–	–
Shahin AHE[76]	5.67 ± 0.75 mm (10–11 wks)	–	–
M. I. Sakr A[60]	7.33 ± 1.09 mm	–	–
Sheik S[77]	-	50%	83.64%

Embryonic Heart Rate (EHR) and Pregnancy Outcomes

Our analysis revealed that **EHR was markedly reduced in miscarriage cases (99.72 ± 5.36 bpm)** compared to viable pregnancies (**142.53 ± 12.47 bpm**), with a diagnostic threshold of **<100 bpm** offering **90% sensitivity** and **89% specificity**. This confirms **bradycardia as a significant early indicator** of nonviability. This result mirrors the study by acoding to him as mentioned earlier **[57]**, which reported **EHR of 98.3 ± 10.7 bpm** in miscarriage cases, yielding **97.5% sensitivity** and **100% specificity**. The

study done by her [75]**.** also identified lower fetal heart rates (<140 bpm) as being associated with abnormal outcomes, with a mean of **146.68 ± 15.30 bpm** in viable pregnancies.

In his study he [61] determined that an **EHR cutoff of <119.5 bpm** offered **99.3% sensitivity**, **83.3% specificity**, and **98% overall accuracy**. **Varelas FK** provided powerful validation with an **AUC of 0.971** when combining gestational age with EHR. **Solyman AES** reported consistently lower EHR in miscarriages across gestational intervals, using cutoffs of **104 bpm (6 weeks)**, **126 bpm (9 weeks)**, and **117 bpm (12 weeks)**—each achieving **86% diagnostic accuracy**. Similarly, **Adiga P** showed that **99.3% of pregnancies with EHR ≥100 bpm continued**, while **83.3% of those with EHR <100 bpm ended in miscarriage**, indicating **strong sensitivity and specificity** for this parameter.

Table: Embryonic Heart Rate (EHR) in Miscarriage Across Studies

Study	**EHR (Miscarriage)**	**Sensitivity**	**Specificity**
Present Study	99.72 ± 5.36 bpm	90%	89%
Tawfik WM[57]	98.3 ± 10.7 bpm	97.5%	100%
Soliman M[61]	Not stated	99.3%	83.3%
Solyman AES[65]	Lower at all intervals	–	–
Shahin AHE[76]	152.0 ± 16.70 bpm	–	–
M. I. Sakr A[60]	121.50 ± 11.07 bpm (6 wks)	–	–
Zakaria AEM[78]	123.23 ± 14.1 bpm	81.4%	84.6%

Other Parameters: CRL and MSD

In our cohort, **CRL was significantly lower in miscarriages (6.46 ± 2.51 mm)** compared to viable pregnancies (**30.31 mm**, $p < 0.05$), and **MSD was also significantly smaller in miscarriages (18.35 ± 2.07 mm)** than in normal pregnancies (**36.19 mm**, $p < 0.05$). These parameters remain **core measures in first-trimester viability assessments**. **Solyman AES**[65] observed reduced MSD in miscarriage cases at **6 weeks (11.67 ± 5.79 mm vs 22.43 ± 3.78 mm)**, **9 weeks (22.89 ± 12.30 mm vs 45.71 ± 8.84 mm)**, and **12 weeks (41.44 ± 24.75 mm vs 86.97 ± 8.13 mm)**, all with $p < 0.001$ [78] reported significantly smaller sacs in miscarriage cases (**28.85 ± 14.5 mm**) versus viable ones (**41.02 ± 14.0 mm**, $p = 0.006$). In his study [76] also confirmed smaller MSD in nonviable pregnancies (**2.02 ± 1.26 cm vs 4.15 ± 1.84 cm**, $p < 0.001$). In contrast, he said that he [79] noted a reverse trend at 8 weeks—larger MSD in miscarriage cases (35.5 ± 0.7 mm) than in viable pregnancies (29.2 ± 2.7 mm, $p = 0.011$)—likely due to cohort variation or measurement timing. For CRL, he [65] reported significantly reduced values in miscarriages at all gestational points, e.g., at **6–8 weeks: 3.83 ± 2.2 mm vs 12.28 ± 3.26 mm**, $p < 0.001$. **Shahin AHE** found **CRL in miscarriage cases to be 1.61 ± 0.56 cm**, versus **3.16 ± 1.84 cm** in ongoing pregnancies ($p = 0.002$). These findings reaffirm CRL and MSD as **fundamental and highly sensitive sonographic predictors** of early gestational outcomes.

Predictive Power of Sonographic Markers

Our study supports the **strong prognostic accuracy** of key ultrasound markers. **YSD <3 mm** achieved **89.6% sensitivity**, **87.2% specificity**, **64.3% PPV**, and **96.8% NPV**. In comparison, **EHR <110 bpm** demonstrated **>95% sensitivity and specificity**, identifying it as a particularly **powerful predictor** of miscarriage. **Tawfik WM** reported **98.1% predictive accuracy** for both markers, with **YSD yielding 97.6% sensitivity, 100% specificity**, and **EHR showing 97.5% sensitivity, 100% specificity**. **Soliman M**

confirmed **EHR <119.5 bpm** had **99.3% sensitivity**, **83.3% specificity**, and **YSD >2.48 mm** yielded **93% sensitivity** and **81.3% specificity**. **Solyman AES** documented **86% diagnostic accuracy** across YSD, EHR, and MSD using gestational-age-specific cutoffs. **Adiga P** observed **99.2% survival for YSD (2–5 mm)** and **99.3% for EHR ≥100 bpm**, with **EHR <100 bpm** linked to **83.3% specificity** and **99.3% sensitivity**. In contrast, he noticed that [60] modest accuracy for YSD (61%–55%) and EHR (<122 bpm at 6 weeks yielded **69% sensitivity**, **58% accuracy**). He [78] reported **AUC = 0.822 for EHR <126 bpm**, with **81.4% sensitivity**, **84.6% specificity**; and **AUC = 0.741 for MSD <33 mm**. She [80] found **yolk sac shape** more predictive than size, achieving **87.06% sensitivity**, **86.5% specificity**, and **96.8% NPV**, while YSD alone offered **62.3% sensitivity** and **64.1% specificity**. **Sheik S** reported YSD had **50% sensitivity**, **83.64% specificity**, and **NPV of 91.54%**, favoring exclusion over confirmation. he [79] observed limited value for YSD (AUC = 0.616), despite high sensitivity (**96.8%**) and poor specificity (**50%**). Finally, according to his study he [81] emphasized that **FHR <90 bpm** predicted miscarriage in **94.67% of cases**, and that **YSD extremes (<3.0 mm or >5.5 mm)** were associated with **52.63% and 13.58%** miscarriage rates respectively—strongly validating the role of these markers.

Taken collectively, our results provide compelling evidence that deviations in YSD and EHR—whether in the form of small yolk sacs or embryonic bradycardia—serve as reliable, early predictors of miscarriage, particularly when combined with CRL and MSD assessments. These parameters not only reflect embryonic development and intrauterine conditions but may also be indicative of underlying chromosomal or trophoblastic dysfunctions. The integration of these ultrasound markers into routine early pregnancy evaluations could facilitate timely identification of high-risk cases, prompt closer monitoring, and guide counseling strategies. While the diagnostic accuracy of these

markers is robust across various studies, clinical judgment should always complement sonographic interpretation, particularly in borderline cases or when other risk factors such as maternal illness or irregular cycles are present.

LIMITATIONS

1. **Sample Size**: Although our cohort size was sufficient for primary analysis, larger multi-centric studies would provide broader generalizability.
2. **Single-Center Study**: Our data was derived from a single clinical setting, which may introduce institutional or regional biases.
3. **Limited Longitudiinal Follow-Up**: Our study focused on outcoomes up to the end of the first triimester; outcomes beyond 12 weeks, including secoond-trimester complications or preterm birth, were not tracked.
4. **Operator Dependency**: As with all ultrasonographic evaluations, inter-operator variability could have influenced measurement accuracy, despite adherence to standard protocols.

RECOMMENDATIONS

1. **Routine Integration of YSD and EHR Screening**: First-trimester ultrasound evaluations should consistently include yolk sac measurements and embryonic cardiac activity assessment, with particular attention to thresholds established in our and related studies.
2. **Early Counseling**: Pregnancies presenting with YSD <3 mm or EHR <100 bpm should be identified as high-risk and managed with enhanced clinical vigilance and patient counseling.

3. **Further Research**: Larger prospective studies incorporating genetic, biochemical, and morphological data are warranted to refine predictive models and explore causal pathways in embryonic demise.
4. **Operator Training**: To improve diagnostic reliability, ongoing sonographer training on early pregnancy imaging should be prioritized.

CONCLUSION

Our study underscores the high diagnostic utility of yolk sac diameter and embryonic heart rate as early sonographic markers of pregnancy viability. When interpreted alongside crown-rump length and mean sac diameter, these parameters can accurately differentiate between ongoing and failing pregnancies during the first trimester. The application of established cut-offs for YSD (<3 mm), EHR (<100 bpm), CRL (<7 mm), and MSD (<20 mm) significantly enhances the ability to anticipate miscarriage. These findings support the implementation of comprehensive early ultrasound screening protocols in routine obstetric care and highlight the value of proactive surveillance to optimize maternal-fetal outcomes.

SUMMARY

This study aimed to evaluate the diagnostic value of key first-trimester sonographic parameters in predicting early pregnancy outcomes, particularly the risk of miscarriage. A total of 57 pregnant women were assessed using transvaginal ultrasound to measure yolk sac diameter (YSD), embryonic heart rate (EHR), crown-rump length (CRL), and mean sac diameter (MSD), alongside collecting demographic and clinical data such as maternal age, parity, consanguinity, menstrual history, and presence of medical illness. Each parameter was analyzed in relation to gestational age and eventual pregnancy outcome (viable vs. miscarriage) to determine statistically significant predictors. The results are summarized below to highlight the most clinically relevant trends and statistical associations observed within our cohort.

Key findings

- The **mean maternal age** was 27.56 ± 5.092 years; most participants were aged 20–30 years.
- The **overall miscarriage rate** was 19.3%.
- **Yolk Sac Diameter (YSD <3 mm)** was strongly predictive of miscarriage with 92% sensitivity and 93% specificity.
- **Embryonic Heart Rate (EHR <100 bpm)** was an even stronger marker, showing 90% sensitivity and 89% specificity.
- **Crown-Rump Length (CRL)** and **Mean Sac Diameter (MSD)** were significantly smaller in miscarriage cases, reinforcing their diagnostic role.

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