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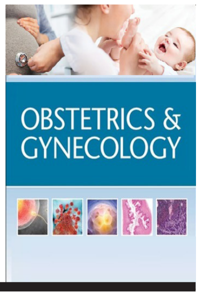

Radiologic Approaches In The Detection And Monitoring of Multiple Pregnancy Complications

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ABSTRACT

Multiple pregnancy, defined as the gestation of two or more fetuses, is a high-risk condition associated with increased maternal and fetal morbidity and mortality. The global incidence varies geographically, with Africa particularly Nigeria recording the highest rates. Twin pregnancies constitute over 98% of multiple gestations, and their risk profile intensifies with the number of fetuses. Complications such as preterm birth, fetal growth restriction, twin-to-twin transfusion syndrome (TTTS), and maternal hypertensive disorders are common. Radiology plays a pivotal role in the diagnosis, monitoring, and management of multiple pregnancies. Ultrasound remains the cornerstone imaging modality due to its safety, accessibility, and real-time imaging capability. It is indispensable in determining chorionicity, detecting congenital anomalies, and assessing fetal growth and wellbeing. Advanced modalities, including high-resolution ultrasound, 3D/4D imaging, Doppler, and fetal MRI, have further enhanced diagnostic accuracy, enabling early detection and guided interventions such as fetoscopic laser ablation and intrauterine transfusion. Although the use of ionizing modalities like CT and X-ray is limited due to teratogenic risks, they remain essential in maternal life-threatening emergencies. The integration of artificial intelligence (AI) into radiologic imaging promises greater precision, automation, and predictive power in future obstetric care.

Introduction

A multiple pregnancy refers to a pregnancy where more than one fetus is carried. These multiple pregnancies could be twins (two fetuses), triplets (three fetuses) or even quintuplets (four fetuses) and could even be more. The rate of occurrence of multiple pregnancy decrease with increasing number of fetus. With an incidence rate of 1:90 for spontaneous twin pregnancy, a 1:8000 incidence of triplets, and a 1:700000 incidence of quadruplets, twin pregnancies are by far the most common type of multiple pregnancy, making up more than 98% of cases, with triplets and higher-order multiples accounting for less than 1.3%. However, since the advent of assisted reproductive procedures, these rates have now increased by almost 300–400% [1,2]. Other factors contributing to the increased incidence of multiple pregnancies include increase in the use of oral contraceptives, obesity, increasing maternal age and higher socioeconomic status [2,3]. Twin pregnancy, which is the commonest from of multiple pregnancy represents just about 2-4% of all births globally. The occurrence of spontaneous multiple pregnancy (particularly twin pregnancy) varies across different parts of the world, with Southeast, East and southern parts of Asia, and India having less than 8 per 1000 births, while countries like United states have between 9-17. Africa has a rate exceeding 17 per 1000 births [3]. Nigeria particularly have the highest rate of twin birth rates with an average of 20.7 per 1000, and Igbo-ora, a community in South-west Nigeria has the highest rate of twin birth rate globally with an average of 45-50 per 1000 births [4,5]. However, the difference in incidence is a reflection of the variation in the occurrence of dizygotic twins, as the rate of monozygotic twins remains relatively constant at 3.5 to 4 per 1000 births worldwide, with Dizygotic twin particularly accounting for over 80% of the twin births in Africa and Asia [3,6].

Twin pregnancies are classified based on their zygosity as either monozygotic (maternal/identical) or dizygotic (fraternal/non-identical). In monozygotic twin, the timing if the division of the fertilized egg determines the chorionicity and amniocity [2]. Multiple pregnancies are considered high risk pregnancies due to the associated increased risks for both mother and child either during intrapartum, postpartum or perinatal period and these risks also increase with the number of fetus [2,3,7. Most of the maternal complications are due to maternal adaptation to twin pregnancy. Risk of maternal death is 2.5 times higher; while that of perinatal mortality is also 2-3 times higher in twin pregnancies which can be up to 7 times higher in LMICs than in singleton pregnancies, which is usually due to complications such as preterm birth, fetal growth restriction (FGR), low birth weight (LBW), and intrapartum asphyxia. The occurrence of preterm births in twin pregnancies is as high as 51%, and up to 60% when other higher multiple pregnancies are considered; with 14% of twin pregnancies being early preterm births (before 32 weeks), with preterm births from twin pregnancies accounting for 20% of all preterm births. Low birth weight is seen in up to 50% of twin pregnancies [3,7,8,9,10,11,12,13]. The occurrence of LBW, and FGR could also be due to the impairment in placental function, which causes a reduction in delivery of enough oxygen and nutrient to fetuses [7].

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The incidence and possible complications of multiple pregnancies also varies based on the chorionicity as monochorionic pregnancies are associated with more complications than dichorionic pregnancies.

Fetal Complications

Twin-to-twin transfusion syndrome (TTTS), seen in 10-20% of monochorionic pregnancies, causes the donor twin to experience severe growth restriction, anemia, and oligohydramnios, while the recipient twin is burdened with circulatory overload, polycythemia, cardiac problems, hydrops, and polyhydramnios. Selective fetal growth restriction (FGR), which occur when the weight difference between the twins exceeds 25%, with one twin falling below the tenth percentile can also occur. There is also high incidence of umbilical cord entanglement in monochorionic monoamniotic pregnancies, which occur in 48-80% of cases and contribute to increased perinatal mortality [3,7,14]. Other fetal complications may include congenital abnormalities, intrauterine growth restriction (IUGR), stillbirth, increase likelihood of NICU admission. Studies have also shown that perinatal outcomes tend to be worse for second twin compared to the first twin [2,7].

Maternal Complications

As stated earlier that most maternal morbidity are usually due to adaptation to physiological changes associated with twin pregnancy; due to higher levels of human chorionic gonadotropin (hCG), the first trimester is associated with more frequent nausea, vomiting, and even hyperemesis gravidarum, hemodilution anemia [2,15]. The occurrence of hypertensive disorders such as preeclampsia, eclampsia and HELLP syndrome is also 2-3 times higher in twin pregnancy. Also, due to the increase in production of human placental lactogen (HPL) in twin pregnancy, there's increase in the occurrence of gestational diabetes which in turn increases the risk of respiratory problems at birth [2,7,16,17]. Other forms of maternal complications include, uterine overdistention leading to urologic symptoms, uterine atony, maternal anemia, venous thromboebplic diseases and postpartum heamorrhage [2,7,15,18].

Despite all of these possible complications highlighted above, it's important to state that most multiple-birth infants survive. Fetal death occurs in around 1.6% of twin pregnancies and 2.7% of triplet pregnancies, showing that the majority of these pregnancies result in healthy outcomes [7].

ROLE OF RADIOLOGY IN OBSTETRIC CARE

Radiology, which simply involves the use of imaging modalities to diagnose and deliver treatment plays an important role in obstetric care. The role of radiology in obstetric care, cut across different stages of pregnancy, beginning from antepartum till postpartum. It encompasses beyond diagnosis, but also very important in delivering timely and effective interventions, as well as for post-intervention assessment. The increasing use and role of obstetric care can be attributed to the improved access to imaging technology, advancements that allow for clearer images and more accurate diagnoses, as well as the growing concern among healthcare providers about potential legal risks and diagnostic uncertainties. Other reasons are due in part to increase in severe conditions such as placenta accreta spectrum disorders, cancer in pregnancy and ectopic pregnancy [19,20]. More so, the similarities in symptoms of obstetrics, gastrointestinal. And urinary conditions together with pregnancy-induced physiological changes can make initial clinical assessment difficult, necessitating the need for rapid and precise imaging.

Ultrasound is regarded as the first-choice imaging modality for pregnant women because it does not use ionizing radiation and is considered safe for both the mother and fetus at any stage of pregnancy although accuracy is dependent on the operator's expertise. It is widely used for fetal screening for congenital anomalies such as down syndrome, neural tube defects, etc.; growth measurements, and routine monitoring of various obstetric and non-obstetric conditions throughout pregnancy. Ultrasound which is the confirmatory diagnostic tool for pregnancy is also used in the diagnosis of multiple pregnancy. It also helps determine chorionicity. This is important because monochorionic twin pregnancy are associated with more complications [7,20-22]. Other diagnostic uses of radiology in obstetrics care also include the diagnosis of ovarian hyperstimulation syndrome (OHSS), hyperreaction luteinalis, ectopic pregnancy, red degeneration of fibroids in pregnancy, placnta accreta spectrum disorder, abruptio placenta, uterine rupture, retained products of conception etc [20,23-27].

For interventional roles of radiology in obstetrics care, its use may involve preprocedural planning, intraoperative guidance and fetal monitoring, and postprocedural assessment. The preprocedural planning is important to document the position of the fetus, location of placenta, delineation of placental edge and identification of "window" for access if necessary. The postprocedural assessment focuses on possible complications of interventions such as hemorrhage, premature rupture of membrane, inadvertent septostomy in multiple pregnancy etc [28-30]. Possible interventions with radiology, most of which are done under ultrasound guide include in-utero transfusion in fetal anemia, fetoscopic laser ablation for TTTS, radiofrequency ablation in selective twin reduction, placement of thoraco-amniotic shunt, fetal endoluminal tracheal occlusion in congenital diaphragmatic hernia, treatment of lower urinary tract obstruction, dilatation of posterior urethral valve, fetal cardiac catheterization and aortic valvuloplasty in severe aortic stenosis etc. [30-35].

In cases where ultrasound results are inconclusive, MRI is typically preferred. However, where non-ionizing imaging is not possible; such as cases of severe trauma or suspected pulmonary embolism; ionizing radiation may be used for rapid evaluation. But this should be done with careful consideration of the risks and benefits, ensuring that the radiation dose to the fetus is minimized as much as possible, following the ALARA (As Low As Reasonably Achievable) principle [30].

Despite the important role played by radiology in obstetrics care, imaging during pregnancy presents certain challenges for both clinicians and radiologists, as the health of both mother and fetus needs to be considered. While there are different imaging modalities, there is often a need to consider the safety of fetal exposure, especially with modalities involving the use of ionizing radiation and this sometimes leads to the unnecessary avoidance of valuable diagnostic tests [20]. This, thus creates the need to answer important questions before proceeding with imaging in a pregnant patient, these include: How likely is the results to change the course of care during pregnancy? Can the imaging be delayed until later in the pregnancy without risking harm to the mother or fetus? Is there a non-ionizing alternative that can provide the necessary information? Finally, is the use of intravenous contrast essential, or can it be avoided without missing critical details? [20]. Thus, all imaging modalities are to be used only when medically necessary.

EVOLUTION OF ULTRASOUND

Nowadays, ultrasound is the safest and most accessible diagnostic technique to assess foetal health and the intrauterine environment, and practically every mother has it done. Ultrasound is the most widely used non-invasive imaging technique that does not utilize ionizing radiation to date. The sound waves released during a particular test are not thought to be harmful to the mother, the foetus, or the individual conducting the examination [36]

However, when its used was first postulated many years ago, it was viewed with great scepticism and seemed like a ridiculous notion. The first used of sonography was in 1912 after the Titanic went down. Soon after, a number of underwater navigation devices that used ultrasound to gauge distances underwater began to take shape. Reginald created the first SONAR (sound navigation and ranging) device in 1914. It quickly gained popularity and was extensively used to monitor German submarines and U-boats during World War I. [36]

Although the scientific technology required to construct the ultrasonic machine has been mentioned in previous years, the first official device was used in the United Kingdom in 1958. Together with a local technical firm, Ian Donald and Tom Brown created the diasonograph, the first 2D ultrasound scanning device.

Although this device was groundbreaking in its day, Americans dubbed it the "dinosaurograph" because to its enormous size—it stood eight feet tall and occupied almost one-third of the scanning area. Despite the delayed generation of static images and the lack of true greyscale, the diasonograph continued to be widely used throughout Europe for the following few years because it had the best image resolution among its rivals [37].

The classic paper "Investigation of abdominal masses by pulsed ultrasound" by Ian Donald and his colleagues in the Lancet in 1958, which is arguably the most significant paper on medical diagnostic ultrasound ever published, is where the use of ultrasound in the field of obstetrics and gynaecology began. Production and research on sonographic devices

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surged in the 1960s. The first real-time ultrasound scanner, called "Vidoson," was created by Siemens® in 1968 and was extensively used in Germany and other European hubs. Doppler applications of obstetrics began in Japan in the early 1950s with Satomura's publications, and because most of the research was first published in Japanese, it was initially mostly unknown to the west [36]. Pioneers of this recently created modality attended the first international congress on ultrasound diagnostics in medicine, which was held in Vienna in 1969. Soon after, there were more and more papers in the diagnostic sonography field. The establishment of routine pregnancy sonography was made possible by the groundbreaking articles that Stuart Campbell and his colleagues from King's College Hospital in London wrote outlining foetal biometry procedures [38]. The first prenatal foetal diagnosis was made by Stuart Campbell in 1970. A instance of anencephaly, in which the foetus lacks sections of the skull and cerebral hemispheres of the brain, was reported by him and his team.

In the ensuing decades, numerous businesses would keep creating various types of ultrasonic devices, competing with one another and constantly advancing. In 1984, Japan began researching three-dimensional ultrasound imaging. In 1990, three-dimensional ultrasonography made a comeback. The development of the 530D Voluson demonstrated the significance of three- and four-dimensional gynaecological imaging in the obstetrics and gynaecological care fields [37].

Real-time scanners with a 3D/4D capability were commonly available and reasonably priced by 2000. The ultrasound machine's most recent advancement is artificial intelligence (AI). Even though many people find AI intimidating, recent technical developments have made it a significant part of daily life.

ULTRASOUND IMAGING AS THE PRIMARY TOOL

The main modality in modern obstetrics is ultrasound imaging because of its accessibility, safety, and diagnostic variety. It uses high-frequency sound waves instead of ionising radiation, which makes it safe for repeated use during pregnancy without endangering the mother or foetus, unlike radiography procedures [39]. In the early stages of pregnancy, it is essential for determining the viability of the pregnancy, detecting multiple pregnancies, calculating gestational age, and verifying intrauterine pregnancy [40].

Ultrasound enables thorough anatomical surveys to identify congenital defects, track foetal growth, and assess placental position and function during the second and third trimesters. By evaluating utero-placental and fetoplacental circulation, Doppler ultrasound further broadens its use and helps guide the treatment of intrauterine growth restriction and pregnancy-related hypertension diseases. Delivery planning is informed by the useful information that ultrasound offers on foetal presentation, amniotic fluid volume, and cervical status during intrapartum care [40].

Ultrasound continues to be the mainstay of obstetric imaging worldwide, despite operator dependence and varied access remaining obstacles. Improved maternal and newborn outcomes are a result of its non-invasiveness, real-time capabilities, and affordability [41].

ADVANCED RADIOLOGICAL TECHNIQUES

High resolution ultrasound

Using a high-frequency transducer and improving image and signal processing techniques like harmonic imaging (HI), spatial compound imaging (SCI), and speckle reduction imaging (SRI) are all part of high-resolution ultrasonography. Although tissue penetration is limited, a transducer with a high-frequency range (5 to 9 MHz) can offer better resolution than one with a low-frequency range (2 to 5 MHz) [42]. HI can create high-resolution images with minimal artifacts by using the principles of non-linear ultrasonic propagation through bodily tissues. Angle-dependent artifacts can be lessened by SCI, which combines several lines of sight to create a single composite image at real-time frame rates. Speckles or other disruptions caused by the echo emitted by an ultrasonic transducer can be minimized by using SRI [42].

Ultrasound with high frequency and high resolution is still the mainstay for multiple pregnancy diagnosis and monitoring [39]. It enables continuous evaluation of fetal growth and health, early detection of structural abnormalities, and accurate measurement of chorionicity and amnionicity. By assessing ductus venosus waveforms, middle cerebral artery flow, and umbilical artery resistance all of which are vital for detecting growth restriction and TTTS. Doppler ultrasound provides value [43].

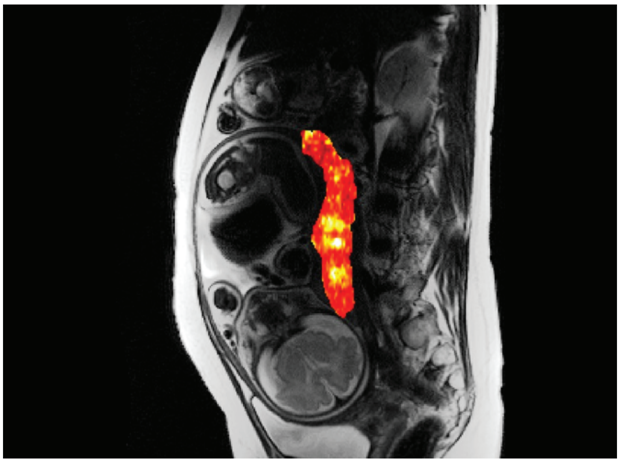

Figure 1: High resonant ultrasound of multiple pregnancy complication.

Three Dimensional and Four Dimensional Ultrasound (3D/4D)

The improved spatial depiction of fetal anatomy offered by 3D/4D ultrasound is especially helpful in identifying congenital abnormalities that can be more difficult to assess in multiple pregnancies because of overlapping fetal positions. 4D imaging helps with neurological and structural examination by providing real-time observation of fetal movement and behavior.

Hata et al. [44] were the first to assess three-dimensional (3D) ultrasound images in order to investigate various forms of intra-pair stimulation and inter-twin contact during all three trimesters of pregnancy. The whole range of twin fetal development and inter-twin interactions may be observed in real time thanks to the later development of four-dimensional (4D) ultrasound [45]. More recently, fetal imaging has been further revolutionized by HDlive, a sophisticated 3D/4D surface-rendering technology. HDlive improves depth perception and delivers incredibly lifelike visuals by employing a changeable light source that produces complex lighting and shadowing effects [46].

Figure 2: 3D image of multiple pregnancy complications.

Magnetic Resonance Imaging (MRI)

For multiple pregnancies, magnetic resonance imaging (MRI) is a helpful, safe, and non-radiating supplementary technique to prenatal ultrasonography, especially in complex situations like monochorionic twins or when fetal anatomy is hard to see [47]. Twin-to-twin transfusion syndrome (TTTS), co-twin demise, and other specific problems can be diagnosed with the help of MRI's superior soft tissue detail. It is frequently used for surgical planning in situations needing in utero intervention and can also assist in evaluating maternal disorders such as placenta accrete [48].

When ultrasound results are unclear, fetal MRI can be used as a supplementary test, particularly when there are possible brain or thoracic abnormalities, placental disease, or growth irregularities. MRI is especially useful in late gestation for assessing ischemia injury or fetal brain maturation in complex twin pregnancies because it offers improved soft tissue contrast without ionizing radiation [49].

Figure 3: 4D image of multiple pregnancy complications.

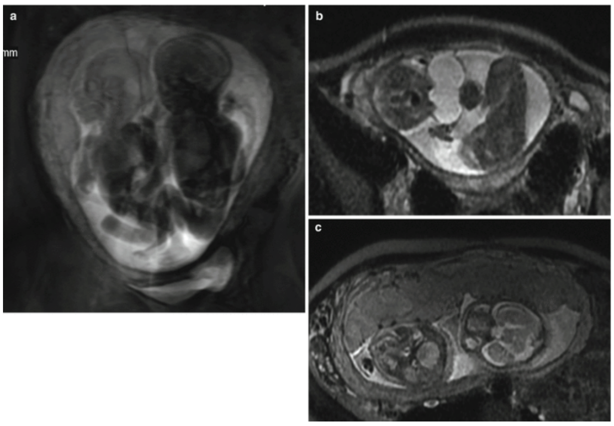

Figure 5: Magnetic resonance imaging showing multiple pregnancy.

Advanced Doppler and Functional Imaging

Many guidelines mention multiple pregnancies as one of the criteria for Doppler ultrasound in obstetrics, particularly when the infants' growth is discordant.

Inspection, palpation, fundal height, belly circumference, and other straightforward monitoring techniques that are effective for single fetuses do not yield information about a single infant in a multiple pregnancy [49]. Therefore, when monitoring multiple pregnancies, ultrasound techniques including cardioto-cogram (CTG), ultrasound, Doppler ultrasound, and color Doppler ultrasound are essential tools [49].

From a relatively early stage, Doppler ultrasonography monitoring of multiple pregnancies was thought to be promising. Since the more straightforward techniques for determining risk in single pregnancies are sometimes useless in multiple pregnancies, selective display of hemodynamic parameters was particularly well received [50].

As a result, research was conducted as early as the 1980s to assess pre-existing hazards and to test for them using Doppler ultrasound examinations. However, at the time those studies were published, diagnostic tests of the fetal membranes to detect chorionicity for the assessment of risk which have recently proven very useful were not as advanced.

Giles et al. [51] looked at whether growth-inhibiting substances were placental or preplacental. They were able to demonstrate that selective placental disease was present in twins with aberrant Doppler results and limited growth. As may be expected in single pregnancies with growth limitation and aberrant Doppler results in the mother's uterus, they did not interpret this as an indication of preplacental disease in these circumstances.

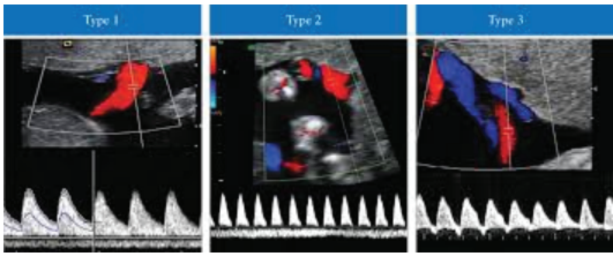

Figure 6: Doppler ultrasound showing multiple pregnancy.

COMPARATIVE EFFECTIVENESS OF IMAGING MODALITIES

The core of a successful obstetric care lies in adequate prenatal assessment and follow-up of each pregnancy [52]. The advancement in technology has offered more precision into the non-invasive monitoring of fetomaternal health status, thereby providing real-time diagnostic and prognostic techniques in prenatal care and assessment [53]. Inarguably, imaging modalities offer various insights into the monitoring of fetal health status, early spotting of danger signs, therapeutic interventions, and prognosis of the index pregnancy [54].

The consideration for modes of radiological imaging to adopt lies on its level of its noninvasinesss and non-ionizing potential [52]. The safety profile of respective imaging methods among pregnant and breastfeeding women is a key concern in the medical field as the number of them have been observed to pose women to more health complications [55]. With the advancement in technology, innovations in medical imaging have progressed from rudimentary sonography to the advanced integration of artificial intelligence, which has profoundly reshaped the field, transforming imaging from a supplementary tool into a cornerstone in clinical practice [56,57].

Globally, the commonly employed Imaging modalities in pregnancy comprise magnetic resonance imaging (MRI), ultrasonography, and nuclear medicine, while Computational Tomography (CT scan) or X-Ray may be employed in absolute maternal indications [58,59]. Specific imaging modality offers unique advantages and limitations that must be critically evaluated in obstetric contexts. However, Ultrasound still remains the corner stone of medical imaging among pregnant women, especially in low and middle income resource countries.

The usage of ionizing radiation based imaging modalities have been low due to the possible teratogenic effects on fetus, especially when done around the period of organogenesis [58]. In recent time, the utilization of X-ray and CT-Scan have been linked to early detection of life threatening maternal complications such as pulmonary embolism or stroke. Potential evidences have indicated that radiation doses above 100 mGy are associated with teratogenesis or miscarriage, while higher exposures, especially during organogenesis (6–16 weeks), increase the risk of growth restriction, microcephaly, intellectual disability, and other malformation [55,60]. Hence, limiting its adoption for routine patient monitoring or fetal care. The potential risks of CT-Scan and X-ray exposure to the fetus depend largely on the gestational age at the time of exposure. The period between 6 and 16 weeks of gestation is considered the most sensitive, during which the likelihood of radiation-induced fetal abnormalities is highest [55, 61,62]. The greatest harm typically results from direct exposure of the maternal abdomen to the primary radiation beam. However, even low-dose radiation has been associated with potential risks, including a slightly increased likelihood of childhood cancers, as supported by both animal experiments and epidemiological studies in humans [63].

Conventionally, non-ionizing radiation imaging techniques are the most preferred for fetal scanning due to its protective effect on fetal growth and low risk of teratogenicity [52]. Magnetic Resonance Imaging and Ultrasound are the commonest non-invasive imaging technique employed in pregnancy due to their safety and absence of radiation induced teratogenesis [55].

MRI employs magnetic field to generate medical images and does not contribute to the ionizing radiations [58]. It is absolutely preferred over CT-Scan and X-ray in pregnancy due to its ability to scan deep and soft tissues without the use of ionizing radiations. Certain studies have reported the potentiality of MRI to cause hear damage, teratogenesis, and tissue destruction, but there are limited evidence to justify its harm to the fetus [64]. The diagnostic importance of MRI is justified by its superiority to Ultrasound in prenatal diagnosis of deep tissues and other brain related

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anomalies and other deep tissues. A study in 2020 showed that Fetal MRI offered accurately diagnosed about 97% of cases (compared to 90.4% of fetal ultrasound; $p < 0.001$), although concordance between fetal ultrasound and fetal MRI was 92.1% [65]. Additionally, Fetal MRI revealed additional information over fetal ultrasound in 23.1% of cases.

From a safety perspective, concerns with fetal MRI especially at 3T center on potential biological effects of strong magnetic fields and the intense acoustic noise generated during scanning. While experimental studies on static magnetic field exposure in embryonic development exist, recent bodies of research has not demonstrated any definitive adverse effects that may hinder its usage, as there was no difference in the outcomes of the studied patients [61]. For several decades, ultrasound has been the most widely acceptable and available imaging technique during pregnancy. It is the primary imaging method for prenatal diagnosis of fetal anomalies for several decades. It supersedes other methods of medical imaging due to its high safety profile across all stages of pregnancy and it has no risk of teratogenic complications [55].

According to the American College of Radiology, MRI in pregnancy is considered a standard of care as no evidence in medical literature suggesting harm to the fetus from the magnetic field. However, the use of gadolinium-based contrast agents is a primary safety concern. While some evidence suggests gadolinium may be safe and is rapidly excreted, many professional guidelines, including those from the American College of Obstetricians and Gynecologists (ACOG), strongly advise against its routine use during pregnancy [66].

Comparing Ultrasonography with CT-Scan, USS procedures can be conducted on pregnant women to confirm whether the women are truly pregnant, to check the fetus's age and growth and figure out the due date, and to check the fetus's heartbeat, muscle tone, movement, and overall development. These advantages also subdue the limitations of the negative ionizing radiation effect posed by X-ray and CT-Scan. Findings have affirmed that every 10 mSv ionizing radiation reduces human lifespan by 240 hours [55]. Therefore, some of the common effects of medical imaging and radiation on pregnant women comprise malignancies, shortened lifespan, genetic line alteration, and fetus-related illnesses among others.

A standard fetal USS involves placing a probe on the abdomen, which can transmit sounds to provide clearer images during early or late gestation. In previous years, the structural quality of ultrasound images and ability to identify structural pathologies were the major concerns Obstetricians. However, Ultrasound image quality has also improved significantly in recent years. High frequency transducers, transvaginal sonography dedicated 3D&4D transducers and increasing processing speed have increased the ability of US to demonstrate structures or pathological conditions which were formerly not available for prenatal diagnosis [53]. Hence, it can easily provide real time structural pathologies at around 18-20 weeks anomaly scan. Behind the structural relevance, the ability to provide real-time doppler scan helps to clinically access fetal circulation especially in high risk pregnancies. Commonly, abnormal uterine artery Doppler studies, especially with bilateral notching, are significant predictors of adverse pregnancy outcomes, including preterm delivery and small-for-gestational-age neonates [67].

RADIOLOGIC MONITORING IN HIGH-RISK PREGNANCY

A high-risk pregnancy is one in which a woman and/or her fetus face a higher-than-normal chance of experiencing complications [68]. High risk pregnancies require adequate monitoring of fetal and maternal profile so as to prompt the early detection of threats and warning signs. The range of conditions that confer this elevated risk comprise maternal medical conditions and some develop as a direct result of the pregnancy. Pre-existing factors include chronic conditions such as chronic hypertension, obesity, bad obstetric history, multiple previous scars, multiple miscarriages or stillbirths [68].

Among the available modalities, ultrasound has emerged as the most critical and versatile tool. Ultrasound provides the crucial link between a known risk factor and its potential impact on the developing fetus [69]. Early ultrasound scan can reveal the number of viable gestational sac and help in the detection of multiple gestation which maybe a high risk especially in those with comorbidities [70]. The chorionicity is effectively determined by an Ultrasound prior to 14 weeks of gestation with an accuracy of 99.0% reported in previous studies [71].

In multiple gestation, Early Ultrasound scan help reveal the positioning of fetus and the amniotic fluid volume which may be a prognostic indicator of feto-maternal well-being [72]. Patients with chronic hypertension have high risks of abnormal placenta location or detachment, this may be easily detectable and monitored during fetal ultrasound scan [73,74].

As evident in dichorionic twins, first-trimester ultrasonography prior to 14 weeks of gestation is required in monochorionic twins to affirm chorionicity, date the pregnancy, and initiate effective counseling and management of the pregnancy [71]. Also, complications of multiple gestation are more observed in monochorionic twins. Further findings have revealed that intrauterine growth restriction is a common finding in multiple gestation, especially in conditions like Twin-Twin transfusion, where one of the twins does not grow proportionately. Interval ultrasound scan may define the fetal growth status based on interventions provided.

Using an ultrasound or MRI, the Prognosis of discordant growth in twins maybe determined by the degree of discordance and presence of abnormal findings during Doppler scan [75]. Additionally, fetal weight assessment using imaging is used to measure the growth discordance overtime in in dichorionic and monochorionic gestations with fetal weight discordance ranging from 18% to 25%, or an estimated fetal weight of less than 10% for one twin [76].

Chronic illnesses like Gestational Diabetes Mellitus have been linked to structural anomalies related fetal outcomes. A Previous study have reported increased thickness of interventricular wall septum which affirms its role in cardiovascular diseases [77]. Also, a global study reported a 4.8% overall malformation rate among the infants of diabetic mothers [78]. This shows that the advent of prenatal diagnosis is a key innovation to reducing birth defects. Hence, a detailed anomaly scan is required in such patient. Anomaly scan comprehensive screening procedure usually conducted between 18 and 22 weeks of gestation is all pregnant women with a significant need in high risk patients [79]. The purpose of this scan is to perform a detailed evaluation of fetal organ development and to screen for a range of structural abnormalities, including neural tube defects like spina bifida and anencephaly, congenital heart defects, and renal agenesis.

In high risk pregnancies, Amniotic fluid volume is an essential indicator of fetal well-being, and it is routinely assessed using the Amniotic Fluid Index (AFI) and the Deepest Vertical Pocket (DVP), also known as the Maximal Vertical Pocket (MVP) [80]. An AFI of less than 5 cm or a DVP of less than 2 cm is indicative of oligohydramnios, a condition associated with placental insufficiency, while an AFI greater than 24 cm or a DVP greater than 8 cm is considered polyhydramnios, a common finding in pregnancies complicated by gestational diabetes [80]. Additionally, patients with placenta insufficiency are required to have Doppler scan which will help determine the viability of the fetus and the perfusion. Also, a finding of a large EFW and/or polyhydramnios provides critical information that guides clinical management, including dietary changes, exercise, or the need for medication like insulin.

EMERGING TRENDS AND FUTURE DIRECTIONS

Multiple pregnancy radiological imaging is developing quickly, with new trends emphasizing improving diagnostic accuracy, identifying problems early, and integrating cutting-edge technology to enhance perinatal outcomes. Although more recent modalities are changing clinical practice, traditional two-dimensional (2D) ultrasound is still the major diagnostic tool.

Foetal structures and intertwine interactions can now be seen much better thanks to the development of three-dimensional (3D) and four-dimensional (4D) ultrasound, especially with HDlive rendering. This near-photorealistic imaging makes it easier to spot abnormalities and aids in parental counseling [25].

Similarly, serial Doppler examinations are used to guide procedures like fetoscopic laser ablation, and Doppler ultrasound remains essential in detecting problems including twin-to-twin transfusion syndrome (TTTS) and twin anemia-polycythemia sequence (TAPS) [30].

When ultrasound results are unclear, magnetic resonance imaging (MRI) is being used more and more as a supplemental technique, especially when assessing anomalies of the central nervous system and complicated structural abnormalities. It is useful in advanced fetal examinations due to its improved soft-tissue contrast and safety profile [36].

The integration of machine learning and artificial intelligence (AI) in picture interpretation is emphasized in future developments. Artificial intelligence (AI)-based systems can improve the identification of minute growth irregularities, automate biometric assessments, and more accurately forecast the likelihood of problems [41]. Additionally, personalized risk classification may be made possible by integrating radiological imaging with maternal biomarkers and genetics, which could result in precision medicine methods for managing multiple pregnancies.

Additionally promising are new telemedicine applications that allow for expert consultations and remote monitoring in environments with limited resources.

GAPS IN LITERTURE AND RESEARCH NEEDS

Due to the rarity of multiple pregnancy, there seem to be a dearth of studies that focuses on the importance of different radiological modalities in the diagnosis of the various complications and possible interventions possible with these modalities as well as the outcomes of each of them. However, with the newer advancements in assisted reproductive technologies (ART), there has been an increase in the incidence and prevalence of multiple pregnancy and consequently more hospitalizations resulting from complications, which further highlights the need for more studies on the importance of radiology in diagnosing and intervening in associated complications of multiple pregnancy. More so, the few studies that exists on multiple pregnancies focus more on twin-pregnancy, reason being that this is the commonest of the multiple pregnancy.

There's also a need for a protocol or a form of algorithm in monitoring multiple pregnancy using certain radiologic modalities especially in higher order multiple pregnancy which are also on the rise with advances in ART. In addition to this, early onset of monitoring and surveillance of multiple -pregnancy particularly higher order- will be essential in predicting outcomes of multiple pregnancy, the fetus with the highest chance of survival and possible early intervention where and when possible.

More studies on the possible long-term effects of some of these radiological methods and outcomes of interventions will be important in the future, as this will further drives advancement in obstetrics care delivery.

In the nearest future the importance of artificial technologies (AI), will also be paramount in radiological diagnosis of complications of multiple pregnancy.

Conclusion

Radiologic imaging has revolutionized the management of multiple pregnancies, transforming clinical care through early diagnosis, targeted intervention, and improved monitoring of both maternal and fetal health. Ultrasound remains the gold standard, providing non-invasive, safe, and dynamic evaluation across all trimesters, while MRI serves as a complementary modality for complex cases. The evolution of advanced imaging technologies—such as high-resolution ultrasound, 3D/4D imaging, and Doppler studies—has significantly improved diagnostic precision and perinatal outcomes. These modalities have not only enhanced visualization of fetal structures but also guided life-saving intrauterine procedures and personalized management of complications like TTTS and fetal growth restriction. Despite these advances, challenges persist in standardizing imaging protocols for higher-order multiple pregnancies and ensuring equitable access in low-resource settings. Furthermore, the long-term safety and outcomes of newer imaging techniques warrant further investigation. Future directions point toward the integration of AI and telemedicine to support remote diagnostics and predictive analytics, offering transformative potential in obstetric imaging. Ultimately, radiology stands as an indispensable pillar of modern obstetric care, ensuring safer pregnancies and healthier outcomes for mothers and their babies.

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