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Use of Doppler Ultrasound in Perinatal Care: Maternal and Neonatal Care

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ABSTRACT

Introduction and purpose

Doppler ultrasound has become a milestone in monitoring maternal and fetal health, offering critical information about blood flow in the placenta, umbilical cord, and fetal organs. Its applications range from assessing placental function to diagnosing complications such as fetal growth restriction, preeclampsia, and fetal anemia.

Material and methods

This review is based on articles from the PubMed database, published between 2015 and 2024, using keywords such as doppler u, doppler ultrasound, doppler USG in perinatal care, doppler USG in neonatal care.

Results

Doppler ultrasound is a very effective and minimally invasive test that detects many pathologies in the perinatal and neonatal period. It allows for early diagnosis of many vascular pathologies, which allows for early treatment

Conclusions

Doppler ultrasound should be a commonly used test in perinatal and neonatal care. This would avoid some of the complications of these periods, improving survival, and financially relieve the health care system.

Key words: doppler, doppler USG, perinatal care.

Introduction

Doppler ultrasound is a non-invasive imaging technique that utilizes the Doppler effect to assess blood flow within vessels and tissues. By measuring changes in the frequency of sound waves reflected by moving red blood cells, this method provides valuable insights into vascular dynamics. In perinatal care, Doppler ultrasound has become a cornerstone in monitoring maternal and fetal health, offering critical information about blood flow in the placenta, umbilical cord, and fetal organs. Its applications range from assessing placental function to diagnosing complications such as fetal growth restriction, preeclampsia, and fetal anemia. Moreover, Doppler ultrasound enables the diagnosis of deep vein thrombosis, a postpartum complication that can lead to life-threatening maternal pulmonary embolism. This review aims to explore the utility of Doppler ultrasound in maternal and neonatal care, highlighting its role in improving outcomes for both mother and child.

The Use of Doppler Ultrasound in the Assessment of Fetal Circulation

Umbilical Artery (UA) Blood Flow

The umbilical arteries (UAs) play a crucial role in the fetoplacental circulation, transporting deoxygenated blood from the fetus to the placenta for nutrient and gas exchange. Their tone depends on locally released vasoactive substances and ions like calcium and potassium, as they lack nerve regulation. Proper fetal development requires functional umbilical cord architecture, adequate placental perfusion, a healthy fetus, and favorable maternal conditions; any disruptions can lead to intrauterine growth restriction (IUGR). Placental insufficiency, the primary cause of IUGR, results from increased resistance in placental blood flow and necessitates strict fetal monitoring. Doppler ultrasound (USG) of the UAs is a key tool for assessing placental function in high-risk pregnancies and has been shown to reduce perinatal mortality by approximately 29%. This method measures blood flow velocities to calculate indices like the pulsatility index (PI), which reflect placental vascular resistance and fetal well-being. Despite its benefits, Doppler USG has limitations, including variability in reference ranges and the potential to increase anxiety and lead to early interventions. [1]

Abnormal UA Doppler findings indicate increased resistance in the umbilical circulation and suggest placental dysfunction. Fetal growth restriction (FGR) is generally diagnosed when both an estimated fetal weight below the 10th percentile and abnormal umbilical Doppler results are present. The timing of diagnosis distinguishes early FGR (before 32 weeks, associated with umbilical artery abnormalities) from late FGR (after 32 weeks, often linked to low middle cerebral artery pulsatility). [2]

Hypertensive disorders during pregnancy (HDP) are linked to higher risks for both the mother and fetus. Doppler ultrasound measurements of the umbilical artery have shown potential in forecasting negative fetal outcomes in women with HDP. Mahajan and co. explored the relationship between abnormal umbilical artery Doppler indices and unfavorable fetal outcomes in patients with HDP. Mahajan et al. included 138 pregnant women with HDP at or after 28 weeks of gestation who had singleton pregnancies. Detailed clinical evaluations, laboratory tests, and Doppler examinations of the umbilical artery were conducted. The Doppler indices analyzed were the systolic/diastolic (S/D) ratio, resistance index (RI), and pulsatility index (PI). Adverse fetal outcomes were determined based on birth weight and the need for neonatal intensive care unit (NICU) admission. The study showed that abnormal Doppler measurements in the umbilical artery, such as an increased S/D ratio, RI, and PI, seem to serve

as significant indicators for adverse fetal outcomes in women with HDP. Tracking these indices may help in assessing risk and enhancing the management of pregnancies affected by HDP. [3] Placental abnormalities are found in over half of FGR and stillbirth cases. The most common placental condition linked to FGR is maternal vascular malperfusion (MVM), which is also a major cause of preventable stillbirth. Although the pathologic features of MVM are well-established, current diagnostic techniques, such as placental imaging, uterine artery Doppler ultrasound, and maternal serum biomarkers, offer only moderate predictive value. A study of 856 low-risk women showed that the combination of ultrasound and angiogenic biomarkers provided only moderate precision in predicting MVM. Fetal vascular malperfusion (FVM) is less frequent but also associated with FGR and serious complications, including stillbirth, perinatal stroke, and vascular injury. FVM is harder to diagnose prenatally and is typically identified only after pathological examination. Improved diagnostic methods are needed, especially in late pregnancy when interpreting Doppler waveforms becomes more challenging due to cardiovascular changes. Cahill and co demonstrated that wave reflections in umbilical artery Doppler signals, isolating the placental component, can help distinguish between healthy and growth-restricted fetuses and detect placental pathologies like MVM and FVM. This study indicates that measuring wave reflections in the umbilical artery (UA) alongside conventional clinical ultrasound parameters may improve the diagnostic accuracy of UA Doppler for identifying placental vascular abnormalities. Detecting fetal vascular malperfusion (FVM) during the prenatal period is especially challenging, and future research will help determine whether women at risk for this specific placental condition could benefit from this novel diagnostic approach. [4, 5]

Blood Flow in the Middle Cerebral Artery (MCA)

The use of peak systolic velocity (PSV) assessment in the fetal middle cerebral artery has provided a non-invasive method for diagnosing fetal anemia. This technique is grounded in the fact that anemia leads to a decrease in fetal hematocrit, which lowers blood viscosity, resulting in an increase in blood flow velocity. By tracking blood flow velocity through ultrasound, it becomes possible to evaluate fetal anemia without the need for invasive diagnostic procedures. [6]

Leizer and co. recruited fifty patients diagnosed with preterm prelabor rupture of membranes (PPROM) from 23 weeks and 0 days to 33 weeks and 6 days of gestation. They conducted weekly measurements of the peak systolic velocity (PSV) in the fetal middle cerebral

artery (MCA) after PPROM, using the value closest to the delivery time for our statistical analysis. The main outcome evaluated was clinical chorioamnionitis, with MCA PSV as the primary variable of interest. Other Doppler measurements of the MCA were also considered as additional independent variables. Secondary outcomes included histological chorioamnionitis and various neonatal health indicators, such as NICU length of stay, sepsis and mortality. This research did not identify any significant differences in the PSV of the MCA in fetuses from pregnancies with PPROM and suspected chorioamnionitis. Nevertheless, a higher PI in the MCA may act as a potential indicator of impending chorioamnionitis in cases of PPROM. Larger studies are needed to further substantiate these findings. [7]

Zhou et al. performed a study in which colour Doppler ultrasound was used to monitor the hemodynamic parameters of the fetal uterine artery (UtA), umbilical artery (UA), and middle cerebral artery (MCA) during pregnancy, particularly in cases of hypertension complicating pregnancy. The study included 120 singleton pregnant women, divided into three groups: mild preeclampsia, severe preeclampsia, and normal control. Parameters such as pulsatility index (PI), resistance index (RI), and systolic/diastolic velocity (S/D) were measured in all groups. In the severe preeclampsia group, the hemodynamic values of UtA and UA were significantly higher compared to the other groups, while the MCA parameters were lower. These measurements showed changes during different stages of pregnancy, with trends of increasing and then decreasing PI, RI, and S/D in the severe group. The combination of hemodynamic measures and pregnancy outcomes demonstrated high sensitivity and specificity in predicting adverse pregnancy outcomes. The findings suggest that Colour Doppler ultrasound can effectively detect changes in these parameters, providing valuable information for assessing fetal well-being and predicting potential complications, especially in later pregnancy. [8]

Blood Flow in the Ductus Venosus (DV)

There is strong evidence supporting the use of ductus venosus Doppler in early suspected fetal growth restriction (FGR) for both prognostic and monitoring purposes. The ductus venosus redirects oxygenated blood from the umbilical vein toward the heart at the point where the inferior vena cava joins the right atrium. The crista dividens directs this oxygen-rich blood preferentially toward the left atrium and cerebral vessels. Typically, the ductus venosus waveform is triphasic, with the a-wave being a sensitive indicator of atrial contraction. An enhanced a-wave occurs due to increased preload, inotropic stimulation from elevated afterload,

hypoxia, or a combination of these factors, often reflecting progressive dilation of the ductus venosus to improve the delivery of oxygenated blood to the systemic circulation. In severe cases, the a-wave may flatten or even reverse, indicating a significantly increased risk of fetal death (40%-70%) and neonatal mortality. These changes signal late stage acidemia, regardless of gestational age, and are often accompanied by spontaneous decelerations on cardiotocography. When such advanced cardiovascular changes are present, fetal death is often anticipated within a week in 40%-70% of cases, following spontaneous heart rate decelerations and an abnormal biophysical profile. [2]

Sekielska-Domanowska and co.' findings align with the theory that the ductus venosus can dilate under moderate chronic hypoxia without indications of elevated central venous pressure caused by increased cardiac stress. Increased venous pulsatility has been observed in cases of fetal heart failure and severe hypoxia, where it reflects elevated central venous pressure. This elevation has been shown to affect the ductus venosus and even the umbilical vein, causing pulsatile flow instead of the usual steady flow because of ductus venosus dilation. Based on this, it was hypothesized that changes in ductus venosus pulsatility index for veins (PIV) represent increased cardiac strain during chronic fetal hypoxia. However, Doppler studies on blood flow in central fetal veins, such as the hepatic veins and inferior vena cava, have not identified changes in venous pulsatility under moderate chronic hypoxia. Similarly, assessments of fetal heart wall motility have failed to demonstrate reduced wall movement—an indicator of cardiac strain—correlated with increased ductus venosus pulsatility. These findings suggest that the ductus venosus might function primarily as a redistribution mechanism, enhancing the flow of oxygenated blood to the left heart, coronaries, and brain during moderate hypoxia, without raising central venous pressure. Currently, ductus venosus Doppler is increasingly used for fetal monitoring in early-onset FGR before 30–32 weeks of gestation. Evidence indicates that ductus venosus PIV measurements are effective predictors of perinatal outcomes and could assist in determining the optimal timing of delivery in cases of early FGR. [9]

Placental function monitoring

The Use of Doppler Ultrasound in the Assessment of Placenta Vascular Resistance

As mentioned earlier, the study by Lees and co. examines the diagnosis, monitoring, and delivery timing of fetuses suspected of being small for gestational age (SGA) or experiencing FGR. Placental dysfunction plays a central role, with an abnormal umbilical artery

Doppler PI serving as a marker for increased resistance in the placental circulation. SGA, often defined as an estimated fetal weight below the 10th percentile, is not synonymous with FGR, which is characterized by slowed growth velocity and may result from placental insufficiency, infections, or genetic abnormalities. Early-onset FGR, diagnosed before 32 weeks, is typically linked to umbilical artery abnormalities, while late-onset FGR often shows a reduced MCA PI. A combination of computerized cardiotocography and ductus venosus Doppler in early FGR has been shown to improve outcomes, with most infants achieving normal neurodevelopment by age two. Late FGR, while associated with adverse perinatal outcomes, lacks definitive evidence for MCA Doppler as a tool for determining delivery timing but remains useful for heightened surveillance. The study emphasizes the importance of integrating fetal size, growth patterns, uteroplacental Doppler metrics, cardiotocography, and maternal conditions like hypertension into management strategies to improve outcomes in suspected FGR. [2]

Preeclampsia is a significant pregnancy complication affecting 2-15% of pregnancies and poses serious risks to both mothers and fetuses. It is characterized by hypertension after 20 weeks of gestation, along with proteinuria, edema, or organ damage, and is linked to high maternal and fetal mortality and morbidity. A core feature of preeclampsia is placental dysfunction, often beginning with impaired uteroplacental perfusion or defective trophoblast invasion, leading to endothelial dysfunction and systemic inflammation. Risk factors include maternal age, obesity, nulliparity, multifetal pregnancies, and pre-existing medical conditions, which highlight the need for careful monitoring. Placental insufficiency plays a critical role, with Doppler ultrasonography and biomarkers like uterine artery pulsatility index (UtA-PI) and pregnancy-associated plasma protein A (PAPP-A) being essential tools for early detection. Preventative measures, such as administering low-dose aspirin to high-risk individuals, can mitigate the onset of preeclampsia. In pregnancies complicated by preeclampsia, advanced monitoring—including Doppler studies and biophysical profiles—is crucial for timely interventions. Delivery of the fetus and placenta remains the definitive treatment for severe cases. Continued research is needed to unravel the detailed mechanisms of preeclampsia, particularly its placental origins, to improve prevention and management strategies. [10]

Dangerous placenta previa involves abnormal placental attachment, including placenta accreta, where the placenta invades the uterine wall, often seen in the lower uterus partially or completely covering the cervix after 28 weeks of pregnancy. It is classified into complete, partial, and marginal types and is more common in women with prior cesarean sections, increasing maternal mortality risk. Early diagnosis is critical for reducing complications and guiding treatment. Ultrasound, particularly color Doppler, is a noninvasive and effective tool

for detecting placenta previa and accreta, allowing visualization of placental thickness, fetal positioning, and uterine scars, with advanced Doppler methods improving diagnostic precision. Transabdominal ultrasound is widely used but has limitations in patients with thicker abdominal fat, while transperineal ultrasound complements it by providing detailed images of the placental-uterine interface. Combining these methods improves accuracy, revealing features like thinned myometrium, abundant blood flow, and disrupted uteroplacental boundaries associated with accreta. Early detection allows timely interventions to minimize complications like hemorrhage and the need for hysterectomy, improving outcomes for both mother and child. Despite its benefits, color Doppler ultrasound is costly and not always accessible, necessitating the use of appropriate methods based on individual cases. Further research is needed to explore complex cases involving combined placenta previa and accreta. Nevertheless, the use of advanced ultrasound techniques significantly enhances the ability to manage these high-risk pregnancies effectively. [11]

Doppler techniques are essential for assessing intraplacental circulation, helping to identify placental abnormalities. These methods can distinguish between maternal and fetal components of the placental blood flow, providing valuable insights into placental function. A decrease in placental functional units, identified through Doppler imaging, can be linked to complications like fetal growth restriction. Additionally, Doppler evaluation reveals details about decidual vessels and blood flow, with abnormal circulation raising the risk of conditions such as placenta accreta. This technology plays a critical role in diagnosing various placental conditions, including placenta accreta, vasa previa, and placental infarcts. However, its use is limited in diagnosing placental abruption, hematomas, and mesenchymal dysplasia, as well as in mapping placental connections in monochorionic twin pregnancies. Despite these limitations, Doppler ultrasound remains a powerful tool for managing high-risk pregnancies related to placental issues. [12]

Benefits of Using Doppler Ultrasound

Doppler ultrasound is a safe and non-invasive method that provides valuable information about the health of the mother and child during pregnancy. It allows for better planning the method and time of delivery if problems with fetal circulation are identified. Early detection of severe circulatory defects can help in preventing serious complications, which allows for a reduction in the costs of treating these complications.

Limitations of Using Doppler Ultrasound

A Doppler ultrasound examination can present many interpretative challenges. The results may vary depending on the physician performing the examination. Moreover, the interpretation of the results also depends on the examiner's experience. The influence of technical and anatomical factors on image quality is a significant limitation of this method.

Conclusion

Doppler ultrasound is a non-invasive diagnostic tool that assesses blood flow dynamics in vessels and tissues, playing a pivotal role in perinatal care. It aids in monitoring maternal and fetal health, detecting complications like fetal growth restriction (FGR), preeclampsia, and fetal anemia by evaluating blood flow in the umbilical artery, middle cerebral artery, and ductus venosus. Doppler techniques also provide insights into placental function, identifying abnormalities such as maternal vascular malperfusion and placenta previa. Despite its benefits in improving pregnancy outcomes, Doppler ultrasound has limitations, including variability in results due to examiner experience and technical factors. Advanced Doppler methods, like wave reflection analysis, offer potential for better diagnostic accuracy, especially for placental issues. While it reduces treatment costs by enabling early detection of severe complications, challenges in image interpretation and accessibility remain. Continued research and innovation are essential to enhance its efficacy and broaden its clinical applications in maternal and neonatal care.

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