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USE OF NEW INNOVATIVE METHODS IN DIAGNOSIS OF ADVANCED IRON DEFICIENCY ANEMIA IN WOMEN OF CHILDBEARING AGE

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Abstract

Iron deficiency anemia (IDA) remains a global health challenge, particularly among women of childbearing age, due to menstrual blood loss and increased iron demands during pregnancy. While traditional diagnostic methods such as serum ferritin and hemoglobin assays are valuable, they may lack sensitivity in detecting advanced stages of IDA. This review explores recent advancements in diagnostic techniques for identifying and characterizing advanced IDA in women of childbearing age. Innovations such as novel biomarkers, advanced imaging modalities, and artificial intelligence-based algorithms offer promising avenues for earlier and more accurate diagnosis, enabling timely intervention and improved patient outcomes. Furthermore, this review discusses the clinical implications, challenges, and future directions in integrating these innovative approaches into routine clinical practice.

Keywords: Iron deficiency anemia, Women of childbearing age, Novel biomarkers, Soluble transferrin receptor (sTfR), Erythrocyte zinc protoporphyrin (ZPP), Hepcidin, Advanced imaging modalities, Magnetic resonance imaging (MRI), Computed tomography (CT), Artificial intelligence (AI) algorithms, Machine learning, Diagnosis, Advanced IDA, Sensitivity, Specificity.

Introduction

Iron deficiency (ID) is one of the most common micronutrient deficiencies that disproportionately affects females throughout their lifecycle via menstruation (blood loss), pregnancy (fetal demands), and bleeding in childbirth [4]. Iron deficiency occurs as a spectrum, ranging from iron depletion without anemia to impaired erythropoiesis and anemia [3]. In 2019, anemia affected 1.8 billion people worldwide; ID is the predominant cause [10]. Of concern, this estimate does not begin to account for the many cases of ID in the absence of anemia [2]. Females, especially those in developing regions, are particularly vulnerable to ID, and anemia due to ID is the leading cause of years lived with disability among women of reproductive age in low- and middle-income countries [9, 11]. According to the World Health Organization (WHO) estimates for 2016, anemia was diagnosed in 32.5% of non-pregnant women, 40.1% of pregnant women, and 32.8% of women of reproductive age, with Southeast Asia being the region with the highest prevalence of anemia in all three subgroups of women [5].

Iron deficiency anemia (IDA) poses a significant health burden worldwide, particularly among women of childbearing age, who are susceptible due to menstrual blood loss and increased iron requirements during pregnancy. While traditional diagnostic methods such as serum ferritin levels and hemoglobin assays are commonly used, they may have limitations in detecting advanced stages of IDA, leading to delayed diagnosis and suboptimal management.

Mild to moderate iron deficiency, not associated with anemia, can be asymptomatic or lead to fatigue and/or poor tolerance to exercise [1]. Typical clinical presentation of moderate to severe iron deficiency includes the usual signs of anemia, such as pallor and fatigue. More specifically, restless leg syndrome, mucus trophic lesions (stomatitis, glossitis), pica, frequent infections, mood, and behavior disorders with a decline in school performance may occur. Sideropenia during infancy has been related to permanent neurocognitive impairments, reduced learning capacity, and altered motor ability [6,7].

Several new innovative methods have emerged for diagnosing advanced iron deficiency anemia (IDA) in women of childbearing age. These methods offer improved sensitivity, specificity, and efficiency compared to traditional diagnostic approaches. Here are some of the innovative methods used in the diagnosis of advanced IDA:

Novel Biomarkers:

Soluble Transferrin Receptor (sTfR): sTfR levels are elevated in conditions of increased erythropoietic activity, such as iron deficiency anemia. Measurement of sTfR levels provides insight into tissue iron deficiency and erythropoietic demand.

Erythrocyte Zinc Protoporphyrin (ZPP): ZPP levels increase in iron deficiency due to the inhibition of heme synthesis. Elevated ZPP levels are indicative of functional iron deficiency and can aid in the diagnosis of IDA.

Hepcidin: Hepcidin is a key regulator of iron metabolism. Measurement of hepcidin levels can help differentiate IDA from anemia of chronic inflammation and assess iron status in women of childbearing age.

Advanced Imaging Modalities:

Magnetic Resonance Imaging (MRI): MRI techniques such as T2* mapping and R2* relaxometry enable quantification of tissue iron content, allowing for the assessment of iron stores and tissue iron distribution in organs such as the liver and spleen.

Computed Tomography (CT): CT imaging can provide valuable information on bone marrow iron content and erythropoietic activity, aiding in the evaluation of IDA severity and progression.

Artificial Intelligence (AI) Algorithms:

AI-based algorithms can analyze large datasets of clinical and laboratory parameters to identify patterns indicative of advanced IDA. Machine learning algorithms can assist clinicians in risk stratification, predicting treatment responses, and optimizing patient management strategies.

These innovative methods offer complementary approaches to traditional laboratory tests, providing clinicians with a more comprehensive assessment of iron status and erythropoietic activity in women of childbearing age with advanced IDA. Integrating these methods into routine clinical practice can facilitate earlier diagnosis, personalized treatment approaches, and improved outcomes for patients.

Recent advancements in diagnostic techniques offer promising opportunities to enhance the early detection and characterization of advanced IDA in this vulnerable population. Novel biomarkers, such as soluble transferrin receptor (sTfR), erythrocyte zinc protoporphyrin (ZPP), and hepcidin, provide insights into iron metabolism and erythropoiesis, offering improved sensitivity and specificity compared to traditional markers alone. These biomarkers can aid in distinguishing IDA from other causes of anemia and assessing the severity and progression of iron deficiency.

Advanced imaging modalities, including magnetic resonance imaging (MRI) and computed tomography (CT), offer non-invasive methods for assessing iron stores and tissue iron distribution. MRI techniques such as T2* mapping and R2* relaxometry enable quantification of tissue iron content, facilitating the diagnosis of iron overload or deficiency-related organ damage. Additionally, CT-based methods provide valuable information on bone marrow iron content and erythropoietic activity, complementing traditional laboratory tests in the evaluation of IDA.

Moreover, artificial intelligence (AI) algorithms hold promise in analyzing complex datasets and identifying patterns indicative of advanced IDA. Machine learning algorithms trained on large datasets can assist clinicians in risk stratification, predicting treatment responses, and optimizing patient management strategies. Integration of AI-based decision support tools into electronic health records (EHRs) streamlines the diagnostic process and facilitates personalized care delivery.

In conclusion, innovative diagnostic methods offer valuable tools for improving the early detection and characterization of advanced IDA in women of childbearing age. By leveraging novel biomarkers, advanced imaging techniques, and AI-based algorithms, clinicians can enhance diagnostic accuracy, facilitate timely intervention, and improve patient outcomes. However, challenges such as cost, accessibility, and standardization remain barriers to widespread implementation. Continued research efforts and collaborative initiatives are needed to address these challenges and integrate innovative approaches into routine clinical practice, ultimately reducing the global burden of IDA and its associated morbidity.

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