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Review Article

Iron deficiency anemia: A global public health concern

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ABSTRACT

Iron deficiency anemia (IDA) remains a significant global public health concern, affecting populations across both developing and developed nations. The World Health Organization (WHO) estimates that in 2019, approximately 1.62 billion people were affected by anemia, with iron deficiency being the most common cause. This condition disproportionately impacts vulnerable groups, including women, children, and populations in low- and middle-income countries. In the United States, the Centers for Disease Control and Prevention (CDC) reports a substantial prevalence of IDA, particularly among certain demographic groups, including pregnant women and young children (CDC, 2020). The impact of IDA is particularly evident in regions like India, where the Indian Council of Medical Research (ICMR) highlights concerning trends and the need for targeted interventions to address iron deficiency, particularly among women and children. Studies suggest that improved iron status in populations is essential for reducing the prevalence of IDA and its associated complications, such as cognitive impairment, fatigue, and weakened immune function. Recent advances in diagnostics, including point-of-care testing, have improved the identification and management of anemia in primary healthcare settings. Addressing IDA involves comprehensive strategies such as iron supplementation, dietary improvements, and public health initiatives like the Weekly Iron and Folic Acid Supplementation Program in India. The global efforts to combat nutritional anemia underscore the importance of multifaceted approaches to prevention and control. Ultimately, tackling IDA in India will require a multi-sectoral approach, with collaboration between government agencies, healthcare providers, research institutions, and local communities to ensure the widespread success of interventions in reducing iron deficiency and improving overall health outcomes.

1. Introduction

Iron deficiency anemia (IDA) is a widespread and significant global health issue, particularly affecting vulnerable populations such as young children, women of reproductive age, and pregnant women. It is characterized by a decrease in the number of red blood cells or hemoglobin levels due to insufficient iron stores, leading to impaired oxygen transport and various systemic manifestations. Iron is a crucial component of hemoglobin, the protein in red blood cells responsible for oxygen binding and delivery throughout the body. As a result, individuals with IDA often experience symptoms such as fatigue, weakness, pallor, and impaired cognitive function, which can adversely affect quality of life and productivity.

IDA remains one of the most common nutritional deficiencies worldwide. According to the World Health Organization (WHO), it is estimated that approximately 1.62 billion people, or 24.8% of the global population, are affected by anemia, with iron deficiency being the leading cause of anemia in most settings.[1] The condition is most prevalent in developing countries, particularly in sub-Saharan Africa and South Asia, where poor dietary intake,

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limited access to healthcare, and high rates of infections contribute to high prevalence rates.

In high-income countries, IDA is also a notable concern, especially among women of reproductive age and certain subpopulations. For instance, a study conducted in the United States found that 5-10% of premenopausal women and 2-5% of men suffer from iron deficiency anemia.[2] Furthermore, IDA in pregnancy is a significant public health issue, as it increases the risk of maternal and neonatal complications, including preterm delivery, low birth weight, and developmental delays in infants.[3]

The causes of iron deficiency anemia are multifactorial, with insufficient dietary intake of iron, malabsorption syndromes, blood loss (e.g., heavy menstruation or gastrointestinal bleeding), and increased iron requirements during pregnancy or childhood being the most common contributing factors. Interventions aimed at improving iron status, such as dietary modifications, iron supplementation, and addressing underlying causes of blood loss or malabsorption, are key to managing and preventing IDA.

Despite global awareness of the problem, IDA remains a pressing challenge in both resource-poor and developed settings, highlighting the need for continued public health efforts and clinical strategies to reduce its prevalence and mitigate its associated health consequences.[4]

2. Current Scenario

The Indian Council of Medical Research (ICMR) and other health organizations report alarmingly high rates of iron deficiency anemia, contributing to the country's overall burden of anemia. According to the National Family Health Survey (NFHS-5, 2019-21), approximately 57.2% of Indian women aged 15-49 years are anemic, with 53.1% of children aged 6-59 months also affected. These numbers underscore the widespread nature of the condition, with iron deficiency being a leading cause of anemia in the country.[5]

IDA in India is primarily driven by factors such as poor dietary intake of iron-rich foods, low bioavailability of iron in the diet (due to high consumption of plant-based foods with low iron absorption), frequent blood loss from menstruation, parasite infestations, and poor maternal nutrition. Furthermore, pregnant women in India are particularly vulnerable, with studies showing that nearly 50-60% of pregnant women are anemic, which increases the risk of maternal complications like preterm delivery, low birth weight, and postpartum hemorrhage.[6]

The socio-economic determinants of IDA in India are also critical. Rural populations, lower socio-economic groups, and communities with limited access to healthcare or education are disproportionately affected by iron deficiency. Additionally, food insecurity, inadequate sanitation, and limited awareness of the importance of iron-rich foods contribute to the high prevalence rates.

In response to this widespread problem, the Indian government has implemented various initiatives aimed at reducing iron deficiency anemia, such as iron supplementation programs for pregnant women, iron-fortified food schemes, and health education campaigns. Despite these efforts, challenges remain, including limited access to iron supplements in remote areas, insufficient dietary diversity, and the persistence of chronic infections that deplete iron stores.

The ICMR and other health agencies continue to advocate for comprehensive strategies that address the underlying determinants of IDA. These include improving dietary habits, increasing access to healthcare, promoting iron supplementation, and addressing socio-economic disparities in nutrition and health care access.[5,6]

3. Diagnostic Approach

Iron deficiency anemia (IDA) remains a significant public health issue in India, affecting millions, especially in women, children, and pregnant women. The diagnostic approach in India integrates clinical evaluation, laboratory testing, and occasionally more advanced techniques, though access to resources can vary widely across regions. Here is an overview of the current diagnostic approach to IDA in India, with references to guide understanding of the methodology used and challenges encountered.

3.1. Clinical evaluation

3.1.1. Symptoms

Initial diagnosis of IDA typically begins with a clinical evaluation. Common symptoms such as fatigue, pallor, dizziness, weakness, shortness of breath, and cold extremities are looked for, though these can be nonspecific and often occur in other forms of anemia or systemic illnesses.

3.1.2. Physical signs

Pallor, especially of the conjunctiva, tongue, and nail beds, is a key indicator. Angular cheilitis, koilonychia (spoon-shaped nails), and glossitis (inflamed tongue) may also be present. (Figure 1)

3.2. Medical history

The diagnostic process includes reviewing dietary habits (low iron-rich foods), menstrual history (heavy menstruation in women), and pregnancy status, which may increase iron demand. Additionally, a history of blood loss, gastrointestinal disorders, or parasitic infections is important for identifying the underlying causes of IDA.

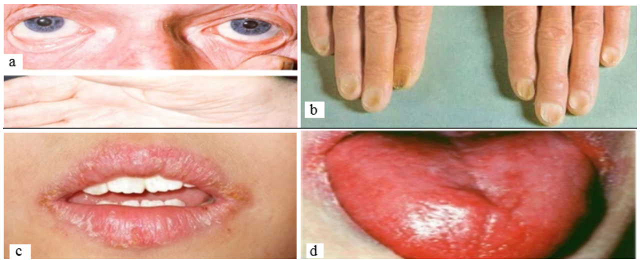

Figure 1: Physical signs of iron deficiency anemia; a: Pallor (Conjunctiva, and palm creases); b: Koilonychia (Spoon-shaped nails); **c:** Angular chelitis; **d:** Glossitis (Inflamed tongue)

3.3. Laboratory investigations

The primary diagnostic tools for IDA in India include Complete Blood Count (CBC) and tests assessing iron metabolism and stores. In resource-limited settings, a combination of these tests is typically used for an accurate diagnosis.

3.3.1. Complete blood count (CBC)

A CBC is often the first test conducted and can show key indicators of IDA:

3.3.2. Low hemoglobin (Hb)

Typically less than 12 g/dL for women and 13 g/dL for men is suggestive of anemia.

3.3.3. Low mean corpuscular Volume (MCV)

Microcytic anemia (MCV < 80 fL) is common in IDA.

3.3.4. Low mean corpuscular hemoglobin (MCH)

Suggests hypochromic red blood cells, a hallmark of IDA.

3.3.5. Low hemoglobin concentration in RBCs (MCHC)

Indicative of reduced hemoglobin in individual RBCs.

3.3.6. Serum ferritin

Ferritin is considered the best marker for iron stores in the body. Serum ferritin levels below 15 ng/mL are strongly indicative of iron deficiency.[7] However, ferritin levels can be elevated in the presence of inflammation, infection, or chronic disease, limiting its reliability in some cases.

3.3.7. Serum Iron and total Iron-binding capacity (TIBC)

TIBC is usually increased/high.

3.3.8. Serum iron

This level is often low in IDA.

3.3.9. Transferrin saturation

This is calculated as (serum iron/TIBC) × 100. A transferrin saturation level below 16% is indicative of iron deficiency.[8]

3.3.10. Soluble transferrin receptor (sTfR)

Elevated levels of sTfR reflect iron deficiency and can be particularly useful in the presence of inflammation or infection, as sTfR levels are less affected by these conditions compared to ferritin.[9]

3.3.11. Reticulocyte hemoglobin content (CHr)

Reticulocyte hemoglobin content is a more recent test used to assess iron supply to the bone marrow. In iron deficiency, the reticulocytes contain less hemoglobin, which can be measured to determine the recent availability of iron.

3.4. Advanced Testing (when needed)

3.4.1. Peripheral blood smear

A blood smear is sometimes examined, showing microcytic, hypochromic red blood cells in IDA. It can also help differentiate between various types of anemia, such as thalassemia or anemia due to chronic disease.

3.4.2. Bone marrow aspiration

This is a rarely used diagnostic tool but may be performed in atypical cases, especially in patients where IDA is suspected but not confirmed by other tests.

3.5. Point-of-care diagnostics in India

In remote areas, where access to advanced diagnostic facilities may be limited, point-of-care tests are increasingly being used:

3.5.1. Hemoglobin color scale

This is a simple, cost-effective tool used by frontline health workers, particularly in rural areas. The hemoglobin color scale can provide a visual approximation of hemoglobin levels to identify anemic individuals, though it is not as precise as laboratory tests.

3.5.2. Portable hemoglobinometers

These handheld devices offer a quick way to measure hemoglobin levels, facilitating rapid screening, particularly in primary healthcare settings.[10]

3.5.3. Iron tests in primary healthcare settings

Basic tests like serum ferritin and iron levels are becoming more accessible at district or primary healthcare centers.

3.6. Challenges in Diagnosis

3.6.1. High prevalence of co-morbidities

India has a high prevalence of infections, malnutrition, and chronic diseases that complicate the diagnosis of IDA. For example, malaria, tuberculosis, and helminthiasis can cause or exacerbate anemia, leading to difficulties in distinguishing IDA from other forms of anemia.[11]

3.6.2. Inflammatory Interference

Inflammation can cause ferritin to be falsely elevated, making it a less reliable marker for iron deficiency in individuals with active infections or inflammatory diseases.

3.6.3. Limited access to advanced tests

In rural and remote areas, access to advanced laboratory tests such as soluble transferrin receptor (sTfR) or reticulocyte hemoglobin content is limited, making clinical diagnosis and basic CBC essential for most cases.

4. Treatment Modalities

Iron Deficiency Anemia (IDA) is a widespread health issue in India, affecting millions of individuals, especially women, children, and pregnant women. The treatment of IDA focuses on replenishing iron stores, correcting anemia, and addressing the underlying causes, such as poor diet, blood loss, or malabsorption. In India, treatment approaches are guided by national and international guidelines that emphasize the use of iron supplementation, dietary interventions, and addressing specific causes of iron deficiency.

4.1. Iron supplementation

Oral Iron Supplements are the first-line treatment for IDA in India. The most commonly prescribed forms are:

4.1.1. Ferrous sulfate

The most widely used oral iron preparation, typically given at a dose of 100-200 mg of elemental iron per day. Ferrous sulfate is effective but can cause gastrointestinal side effects like nausea, constipation, and stomach irritation.

4.1.2. Ferrous fumarate and ferrous gluconate

These are also used, especially for individuals who cannot tolerate ferrous sulfate.

The dosage is generally:

For adults: 100-200 mg of elemental iron per day (usually in divided doses).

For children: Dosage depends on age and weight, typically 3-6 mg of elemental iron per kg body weight per day.

4.1.3. Duration of treatment

Oral iron supplementation is usually continued for 3-6 months after hemoglobin levels return to normal to replenish iron stores. In some cases, longer supplementation may be required in individuals with ongoing blood loss or malabsorption issues.

4.2. Common iron supplements in India:

Iron + Folic Acid (IFA): IFA tablets are often prescribed to pregnant women, adolescents, and women of reproductive age.

Iron + Vitamin C: Vitamin C is frequently added to enhance iron absorption, as it reduces ferric iron to the more absorbable ferrous form.

4.3. Intravenous (IV) iron therapy

In cases of severe anemia, when oral iron is not tolerated, or when rapid iron repletion is needed (e.g., in severe IDA during pregnancy), intravenous (IV) iron therapy may be employed. IV iron formulations available in India include:

4.3.1. Iron dextran

An injectable iron preparation.

4.3.2. Ferric carboxymaltose and iron sucrose

These are commonly used in India for patients with more significant iron deficiency or those with chronic kidney disease (CKD).

IV iron is generally administered in a healthcare setting under supervision due to potential risks, including allergic reactions. It is particularly useful for individuals with:

1. Malabsorption issues (e.g., due to gastrointestinal diseases).
2. Chronic kidney disease (in which oral iron may not be as effective).
3. Severe anemia (Hb < 7 g/dL) where rapid correction is necessary, such as in cases of major blood loss or during pregnancy.

4.3.3. Guidelines for IV iron

1. IV iron is typically used for patients who cannot tolerate oral iron, have malabsorption disorders, or are severely anemic.
2. It is also used for individuals with chronic kidney disease (CKD), particularly those on hemodialysis, who may need additional iron supplementation.

4.4. Dietary modifications

Dietary interventions form an essential part of the treatment strategy for IDA, especially in the context of long-term prevention. The Indian government and healthcare providers emphasize improving dietary intake of iron-rich foods, particularly for populations at high risk of deficiency, including pregnant women and children.

4.4.1. Iron-rich foods

Animal-based sources (heme iron): Red meat, liver, poultry, fish, and eggs are rich in bioavailable iron (heme iron).

4.4.2. Plant-based sources (non-heme iron)
Leafy greens (spinach, fenugreek), legumes (lentils, chickpeas), fortified cereals, nuts, and seeds are good plant-based sources of iron, though non-heme iron is less efficiently absorbed.

4.4.3. Fortified foods
Iron-fortified staples like salt, wheat flour, and rice are increasingly being promoted in India to combat iron deficiency at the population level.

4.4.4. Enhancing iron absorption
4.4.4.1. Vitamin C. Consuming vitamin C-rich foods (like citrus fruits, tomatoes, and green leafy vegetables) with meals can enhance the absorption of non-heme iron from plant-based sources.

4.4.4.2. Avoid inhibitors of iron absorption. Reducing the intake of tea, coffee, and calcium-rich foods during iron-rich meals is advised, as these can inhibit iron absorption.

4.5. Public health initiatives and supplementation programs

In India, several public health programs target the prevention and management of IDA:

4.5.1. National iron + folic acid program (NIFP)
This initiative, launched by the Ministry of Health and Family Welfare, aims to address iron deficiency anemia among pregnant women, adolescent girls, and children. The program provides iron and folic acid tablets to pregnant women, lactating mothers, and children in high-risk areas. This initiative has been a cornerstone in addressing maternal and child health in India.

4.5.2. Weekly iron folic acid supplementation (WIFS) program
Aimed at adolescent girls (ages 10-19), this program provides iron-folic acid supplements once a week to reduce the prevalence of IDA in this high-risk group.

4.5.3. Food fortification
The fortification of staple foods like wheat flour, rice, and salt with iron is an ongoing initiative to ensure that the general population receives adequate iron, especially in rural areas where dietary intake may be insufficient.

4.6. Guidelines for iron deficiency anemia treatment in India

The Indian Council of Medical Research (ICMR) and National Institute of Nutrition (NIN) have provided guidelines for the treatment of iron deficiency anemia as follows:[12–14]

4.6.1. Diagnosis
Blood tests, including serum ferritin, hemoglobin, serum iron, and TIBC, should be used for diagnosis. Clinical signs of anemia, along with laboratory tests, should guide the diagnosis of IDA.

4.6.2. Oral iron therapy
The first-line treatment for IDA, with typical doses of 100-200 mg of elemental iron daily.

4.6.3. Duration
Treatment with oral iron should continue for 3-6 months after hemoglobin levels normalize.

4.6.4. IV iron
For severe IDA, intolerance to oral iron, or cases of malabsorption, IV iron therapy should be considered, especially in hospitalized patients, pregnant women with severe anemia, or those with chronic conditions like chronic kidney disease.

4.6.5. Follow-up
Regular follow-up to monitor treatment efficacy, including hemoglobin levels and serum ferritin, is recommended to ensure full correction of iron deficiency and prevent recurrence.

4.7. Prevention of iron deficiency anemia

Prevention remains a critical aspect of managing IDA in India.[15]

4.7.1. Dietary modification and education
Promoting the consumption of iron-rich foods and enhancing public awareness about the importance of dietary iron, especially in vulnerable groups, is key to prevention.

4.7.2. Routine iron supplementation
Universal iron supplementation programs for pregnant women, children, and adolescents are vital in preventing the widespread occurrence of IDA.

4.7.3. Fortification of staple foods
Ongoing efforts to fortify rice, wheat, and salt with iron are part of long-term strategies to reduce the prevalence of IDA across the general population.

5. Conclusion

In India, the management of iron deficiency anemia is multifaceted, involving oral iron supplementation, intravenous iron in severe cases, dietary modifications, and robust public health programs. National guidelines emphasize the importance of early diagnosis, adequate treatment, and long-term prevention strategies. Despite challenges, such as access to healthcare in rural areas, India continues to make significant progress in addressing the high burden of iron deficiency anemia through a combination of clinical, nutritional, and public health interventions.

6. Future Prospects

6.1. Government policies: Future directions

6.1.1. Strengthening national nutritional programs

The Indian government has implemented a number of initiatives aimed at addressing iron deficiency anemia, but there is room for improvement in terms of coverage, effectiveness, and sustainability.

National Iron + Folic Acid Supplementation Program (NIFASP): The NIFASP targets pregnant women, lactating mothers, adolescents, and children.

The future of this program will likely involve:

1. Expansion and Universalization: Ensuring that all pregnant women, especially those in rural and underserved areas, receive adequate supplementation.
2. Improved Adherence: Strategies to improve adherence to iron supplementation, such as community-based delivery systems, mobile health platforms, or incentivizing regular consumption.

Weekly Iron and Folic Acid Supplementation (WIFS) Program: This program for adolescent girls (ages 10-19) will continue to play a critical role.[14]

Future efforts should focus on:

1. Integration with School Programs: Expanding WIFS programs in schools and rural areas, with better tracking of coverage and outcomes.
2. Digital Monitoring: Leveraging digital health tools to track individual adherence to supplementation and improve program monitoring.
3. Food Fortification: Iron-fortified staples like wheat flour, rice, and salt are part of a broader national policy aimed at preventing iron deficiency at the population level.

The future of food fortification may involve:

1. Wider Implementation and Monitoring: Expanding the coverage of iron-fortified foods in public distribution systems and monitoring its impact on nutritional outcomes across different states.
2. Fortification Standards: Setting and enforcing higher standards of fortification and ensuring that fortified foods are distributed equitably, especially in remote areas.

6.1.2. Improving healthcare infrastructure for early detection and treatment

1. Screening and Diagnosis: The future of IDA management will require expanding screening programs in both urban and rural settings, with greater emphasis on

   (a) Early Detection: Ensuring that more individuals—particularly pregnant women and young children—are screened early for anemia, especially in rural and underserved areas.
   (b) Point-of-care Diagnostics: Utilizing cost-effective diagnostic tools (e.g., hemoglobin meters, ferritin tests) at the primary healthcare level, including mobile clinics, to improve diagnosis in remote areas.
   (c) Healthcare Workforce Training: Healthcare workers will need continuous training on

      i. Recognition of Iron Deficiency Anemia: Educating frontline health workers (ASHA, ANM, and Anganwadi workers) on how to identify symptoms, provide iron supplements, and refer severe cases to higher-level facilities.
      ii. Effective Counseling: Incorporating dietary and supplementation counseling into routine care for pregnant women, children, and adolescents to ensure long-term success in managing IDA.

6.1.3. Policy integration with other public health programs

Iron deficiency anemia is often intertwined with other public health issues such as malnutrition, infectious diseases, and maternal health. The future will require more integrated policy approaches that address the root causes of iron deficiency.

1. Nutrition security: Linking nutrition interventions with other government programs such as the Mid-Day Meal Scheme and the Integrated Child Development Services (ICDS) to ensure that nutritionally vulnerable populations receive adequate iron and other essential nutrients.
2. Addressing parasitic infections: Given the high prevalence of diseases like hookworm, malaria, and tuberculosis in India, integrating anti-parasitic treatments into anemia management programs can reduce the burden of IDA.
3. Maternal health programs: Strengthening maternal health initiatives, with an emphasis on preventing and treating anemia during pregnancy, as severe anemia in pregnancy leads to significant maternal and fetal complications.

6.1.4. Research and development

Government investments in nutritional research can drive the future management of IDA:

1. Innovative Iron Supplements: Research into novel forms of iron supplementation, such as liposomal iron or ferrous fumarate with reduced side effects, will help improve treatment compliance.
2. Bioavailability of Iron: Focused research on enhancing the bioavailability of dietary iron, particularly from plant-based sources, could lead to more effective dietary interventions.
3. Technology in Nutrition: Mobile apps and digital tools for tracking iron intake, supplements, and health status could help individuals and healthcare providers better manage IDA.

6.2. Individual-level interventions: Future directions

At the individual level, the future of IDA management in India will be shaped by increased awareness, empowerment, and access to better treatment options.

6.2.1. Dietary awareness and education

Improving dietary awareness is critical to preventing and managing IDA:

1. Iron-Rich Diets: Individuals, especially those in lower-income communities, need better education on affordable and accessible iron-rich foods (such as lentils, dark leafy greens, and meat). Localized nutrition education programs should promote culturally appropriate diets that improve iron intake.
2. Cooking Practices: Teaching individuals about the impact of cooking techniques (e.g., using cast-iron utensils) and combining iron-rich foods with vitamin C-rich foods (like citrus fruits) can significantly improve iron absorption.

6.2.2. Adherence to iron supplementation

For individuals already diagnosed with IDA, adherence to iron supplementation remains a major challenge:

1. Innovative Supplementation Strategies: Future supplementation programs may adopt innovative approaches like iron-fortified snacks, bio-enhanced iron supplements, or community-based distribution systems to ensure better adherence, especially in rural areas.
2. Personalized Approaches: Tailoring supplementation to individual needs (e.g., based on age, gender, and pregnancy status) and improving the palatability of supplements could enhance compliance.

6.2.3. Community and peer support

Given the social and cultural barriers to iron supplementation, future individual-level interventions will likely focus on community-driven solutions:

1. Peer Education: Involving peer educators and community leaders in educating families and individuals about the importance of iron for health.
2. Group Counseling and Support Networks: Women and adolescents can benefit from support groups where they can share experiences, challenges, and practical tips for improving iron intake and managing supplementation.

6.2.4. Technological solutions

1. Mobile Health (mHealth) Applications: The use of mHealth platforms to track iron intake, supplementation schedules, and health outcomes could help individuals maintain adherence. These apps can also provide real-time alerts and reminders for iron supplementation and dietary tips.
2. Telemedicine: Remote consultations through telemedicine platforms could increase access to healthcare professionals, especially for those in remote areas, ensuring timely diagnosis and treatment of IDA.

7. Conclusion

Iron deficiency anemia remains a significant burden in India, but future prospects for addressing this issue are promising, with a combination of innovative government policies, improved healthcare infrastructure, and individual empowerment. Government policies will likely evolve to provide more comprehensive, integrated approaches, focusing on preventive measures, wider supplementation programs, and food fortification, while better screening, diagnostic capabilities, and treatment options (such as IV iron and innovative supplements) will be more accessible to the public. At the same time, individuals must become more engaged in managing their health, with better dietary education, supplementation adherence, and community involvement.

Ultimately, tackling IDA in India will require a multi-sectoral approach, with collaboration between government agencies, healthcare providers, research institutions, and local communities to ensure the widespread success of interventions in reducing iron deficiency and improving overall health outcomes.

8. Source of Funding

None.

9. Conflict of Interest

None.

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