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Perspective

Genetic Susceptibility and Environmental Interactions in Leukemia Pathogenesis

John Greg*

Department of Hematology and Oncology, Harvard Medical School, Boston, MA, USA

DESCRIPTION

Leukemia is a complex hematologic malignancy that arises from the uncontrolled proliferation of abnormal white blood cells in the bone marrow and peripheral blood. Despite major advances in diagnosis, treatment, and supportive care, leukemia remains a significant cause of morbidity and mortality worldwide. The etiology of leukemia is multifactorial, involving both genetic predispositions and environmental or occupational exposures. Over the years, researchers have identified numerous risk factors that contribute to the onset of leukemia, ranging from ionizing radiation and chemical carcinogens to occupational hazards encountered in various industries. Understanding these environmental and occupational determinants is essential not only for early prevention but also for formulating public health strategies aimed at reducing exposure to potential leukemogens.

Leukemia encompasses several subtypes, including Acute Lymphoblastic Leukemia (ALL), Acute Myeloid Leukemia (AML), Chronic Lymphocytic Leukemia (CLL), and Chronic Myeloid Leukemia (CML). Each subtype has distinct biological and clinical features, yet all share the common pathway of disrupted hematopoiesis. While some cases arise sporadically without identifiable risk factors, others are closely associated with environmental exposures or workplace-related hazards. The interplay between these external factors and individual susceptibility, such as genetic polymorphisms or immune status, determines the likelihood of developing leukemia.

Occupational exposure to agricultural chemicals, particularly pesticides and herbicides, has also been implicated in the pathogenesis of leukemia. Farmers, agricultural workers, and pesticide applicators often handle organophosphates, carbamates, and chlorinated hydrocarbons, which may exert genotoxic effects. The influence of Electromagnetic Fields (EMFs) on leukemia risk has been a topic of debate for decades. Early studies suggested an association between residential proximity to high-voltage power lines and childhood leukemia, sparking considerable public concern. However, subsequent research has produced mixed findings, with many studies failing to confirm a strong causal relationship. While extremely low-frequency EMFs may induce biological changes at the cellular level, the evidence for their carcinogenic potential remains inconclusive.

Children represent a particularly sensitive group due to their rapidly dividing cells and immature detoxification systems. Prenatal and early-life exposures to environmental carcinogens, such as maternal smoking, radiation, and pesticides, have been linked to childhood leukemia. The latency period between exposure and disease manifestation complicates epidemiological studies, yet the cumulative evidence highlights the long-term impact of early environmental insults on hematologic health.

Preventive strategies must therefore focus on minimizing environmental and occupational exposure through policy interventions and public awareness. Strict enforcement of industrial safety regulations, regular workplace monitoring, and the substitution of hazardous substances with safer alternatives are crucial steps. Employers should provide adequate ventilation, protective clothing, and health surveillance for workers at risk. At the community level, environmental monitoring of air, water, and soil contamination is essential to identify potential carcinogenic hotspots. Public education campaigns can also inform individuals about the risks of smoking, pesticide misuse, and radiation overexposure.

Despite these advances, challenges remain. Many studies rely on retrospective exposure assessments, which can introduce bias or uncertainty. Confounding factors, such as lifestyle habits and co-exposures, further complicate causal inference. Moreover, low-dose, chronic exposures often operate below regulatory thresholds but may still have cumulative effects over decades. The societal and economic burden of leukemia underscores the importance of proactive prevention. Occupational safety should not be a privilege but a universal right. In developing countries, where industrial expansion often outpaces regulatory oversight, workers are particularly vulnerable. Strengthening occupational health policies, enforcing global standards, and supporting research into safer chemical alternatives are ethical imperatives.

Correspondence to: John Greg, Department of Hematology and Oncology, Harvard Medical School, Boston, MA, USA, E-mail: gregj@gmail.com

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