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Human Immune System, Its Levels, and Disorders in the Context of HIV/AIDS: A Comprehensive Review

Mugo Moses H.

School of Natural and Applied Sciences Kampala International University Uganda

ABSTRACT

The human immune system is a complex and multi-tiered defense mechanism that safeguards the body from infections and diseases. This comprehensive review explores the structure and function of the immune system, detailing its two primary components: innate and adaptive immunity. While innate immunity offers immediate, nonspecific defense, adaptive immunity provides long-term protection by targeting specific pathogens. The review delves into the impact of HIV on the immune system, focusing on how the virus specifically targets and depletes CD4+ T cells, leading to immune system dysregulation and the progression to AIDS. The discussion includes the stages of HIV infection, the virus's mechanisms of immune evasion, and the resulting immune dysfunctions such as immunodeficiency, chronic inflammation, and autoimmune disorders. Opportunistic infections like tuberculosis and hepatitis are also examined in the context of HIV-induced immune suppression. Advances in HIV/AIDS treatment, particularly the role of antiretroviral therapy (ART), are highlighted, emphasizing ART's effectiveness in preserving immune function and improving patient outcomes. The review concludes by addressing ongoing challenges with ART adherence, access to treatment, and drug resistance, while also exploring emerging research into potential cures, including gene therapy and therapeutic vaccines. Through a detailed exploration of the human immune system and its vulnerabilities to HIV, this review underscores the importance of continued research and intervention in combating the global HIV/AIDS epidemic.

Keywords: Human immune system, HIV/AIDS, CD4+ T cells, innate immunity, adaptive immunity, immunodeficiency.

INTRODUCTION

The human immune system plays a critical role in maintaining health by serving as the body's defense mechanism against a vast array of external threats, including pathogens such as bacteria, viruses, fungi, and parasites. This intricate network comprises specialized cells, tissues, and organs that communicate and collaborate to detect, respond to, and eliminate harmful invaders. Key components of the immune system, such as white blood cells, antibodies, lymph nodes, the thymus, spleen, and bone marrow, each have specialized functions, contributing to the body's capacity to identify and neutralize foreign antigens [1] [2].

The immune system operates on several levels of defense. The innate immune response, which acts as the body's first line of defense, is composed of physical barriers (like the skin and mucous membranes) and immune cells that respond to invaders nonspecifically [3]. If pathogens breach this initial defense, the adaptive immune response is activated. This system is more targeted, involving T-cells and B-cells that recognize specific pathogens and retain memory of these invaders, ensuring faster and more effective responses upon future exposures [4].

Despite its robustness, the immune system can be compromised by certain pathogens, particularly the human immunodeficiency virus (HIV). HIV directly targets and depletes CD4+ T-cells, a vital component of the adaptive immune response responsible for orchestrating defense mechanisms against infections [5]. Over time, the virus undermines the immune system's ability to function effectively, leading to acquired immunodeficiency syndrome (AIDS). AIDS represents the most severe stage of HIV infection, where the immune system is so weakened that

the body becomes vulnerable to a variety of opportunistic infections and cancers that would not typically affect individuals with a healthy immune system.

The implications of HIV/AIDS extend far beyond individual health, representing a major public health concern globally [6]. The virus has caused profound social, economic, and healthcare challenges, particularly in regions with high prevalence rates. This review delves into the structure and function of the immune system, with a focus on how HIV-induced dysregulation leads to the development of AIDS. It explores the progression of immune system failure in HIV-positive individuals, the nature of opportunistic infections that arise as a result, and the broader implications of HIV/AIDS on global public health efforts [7].

Through an examination of the immune system's multi-tiered defenses and the destructive impact of HIV, this review highlights the importance of continued research and interventions to mitigate the devastating effects of this virus on individuals and communities.

The Human Immune System: Structure and Function

The human immune system is a dynamic and complex network that protects the body from infections, diseases, and harmful invaders such as bacteria, viruses, fungi, and parasites. It can be categorized into two main branches: innate immunity and adaptive immunity [8]. Both systems work together in a coordinated manner to defend the body and maintain homeostasis. Below is an expanded overview of the structure and function of these branches:

Innate Immunity: Innate immunity is the body's first line of defense against pathogens, providing an immediate response to infections. It is nonspecific and comprises physical barriers, cellular components, and soluble factors that work together to neutralize or block harmful agents. Physical barriers include skin, mucous membranes, and secretions, which contain enzymes like lysozyme that can break down bacteria's cell walls and flush out pathogens before they can establish an infection [9]. Cellular components include macrophages, neutrophils, natural killer (NK) cells, and dendritic cells. Macrophages engulf and digest pathogens through phagocytosis, while neutrophils are fast-responding white blood cells that engulf pathogens and release enzymes that kill invaders. NK cells target and destroy virus-infected cells or tumor cells by inducing cell death [10]. Dendritic cells act as messengers between the innate and adaptive immune systems, capturing antigens from pathogens and presenting them to T cells to activate the adaptive immune response. When the body detects an infection, it triggers an inflammatory response, which includes vasodilation, cytokine release, and increased permeability, which can result in redness, swelling, heat, and pain at the infection site [11]. Overall, the innate immune system plays a crucial role in maintaining the body's defense against pathogens.

Adaptive Immunity: Adaptive immunity is a specialized immune response that develops over time and is highly specific to specific pathogens. It is slower to develop but provides long-lasting protection [12]. It relies on B cells and T cells, two types of white blood cells that recognize specific antigens and tailor the immune response accordingly. B cells produce antibodies when activated by a specific antigen, which neutralize the pathogen or mark it for destruction by other immune cells [13]. Antibodies help neutralize pathogens by blocking their ability to enter host cells, clumping pathogens together, and enhancing phagocytosis. T cells play a central role in adaptive immunity, with two main types: Helper T Cells (CD4+ T cells) and Cytotoxic T Cells (CD8+ T cells). Helper T Cells coordinate the immune response by releasing cytokines, activating other immune cells, while Cytotoxic T Cells are specialized in directly killing infected or abnormal cells. They recognize infected cells through specific antigens and induce cell death through mechanisms like releasing cytotoxic proteins [14].

Immunological Memory: Adaptive immunity is characterized by the immune system's ability to remember pathogens after an initial encounter, known as immunological memory. This process is crucial for long-term immunity [15]. Memory B cells, formed after an infection, persist in the body for years or even a lifetime, producing large amounts of antibodies to neutralize the invader. Memory T cells, similar to B cells, also form memory cells after an infection, remaining in the body and ready to respond rapidly if the same pathogen reappears, accelerating the immune response and providing protection against reinfection.

HIV and the Immune System

Human Immunodeficiency Virus (HIV) primarily targets the adaptive immune system, with a particular focus on CD4+ helper T cells. These cells are essential for coordinating the activity of other immune cells, including B cells and cytotoxic T cells, to mount an effective defense against pathogens [16]. By attacking and depleting CD4+ T cells, HIV progressively weakens the immune system, making the body susceptible to opportunistic infections and certain types of cancers.

HIV is primarily transmitted through contact with infected bodily fluids such as blood, semen, vaginal fluids, or breast milk. Upon entering the body, the virus actively seeks out and binds to CD4+ T cells, which express the CD4 receptor on their surface. Using its glycoproteins (gp120 and gp41), HIV binds to these receptors and coreceptors like CCR5 or CXCR4, gaining entry into the host cell [17]. Once inside, HIV integrates its genetic material (RNA) into the DNA of the host cell through the enzyme reverse transcriptase, allowing it to hijack the host cell's machinery to replicate itself. This process results in the production of more HIV particles, which are

released to infect additional CD4+ T cells. As HIV continues to infect and destroy these vital immune cells, the body's ability to fight infections and malignancies diminishes significantly. There are two stages of HIV infection: acute HIV infection (acute) and chronic HIV infection (chronic). In the acute phase, the virus replicates rapidly, causing a sharp decline in CD4+ T cell levels [18]. This triggers a robust immune response, including the activation of cytotoxic T cells (CD8+ T cells) that attack infected cells and B cells that begin to produce HIV-specific antibodies. In the chronic phase, HIV continues to replicate, albeit at lower levels, while the immune system fights to keep the virus under control [19]. However, CD4+ T cells are still progressively depleted over time, gradually compromising the immune system. Over time, the viral load increases, and the immune system becomes less effective at combating infections and other diseases. HIV's assault on the immune system primarily involves the depletion of CD4+ T cells, making the body increasingly vulnerable to opportunistic infections and AIDS-defining cancers. Antiretroviral therapy (ART) has been essential in slowing the progression of the disease, preserving CD4+ T cell counts, and improving the quality of life and life expectancy of people living with HIV [20].

Immune System Disorders and HIV/AIDS

HIV/AIDS causes significant dysregulation of the immune system, leading to a variety of immune system disorders. These include:

Immunodeficiency Immunodeficiency occurs when the immune system is unable to mount an adequate response to infections or diseases. In the context of HIV, immunodeficiency is the direct result of CD4+ T cell depletion [21]. As the immune system weakens, the body becomes more susceptible to infections and cancers that would normally be controlled by a healthy immune system.

Immune Activation and Inflammation HIV infection is associated with chronic immune activation and inflammation. Even during the chronic phase of HIV infection, when viral replication is low, the immune system remains in a state of heightened activation [22]. This chronic inflammation can contribute to the accelerated aging of the immune system, as well as an increased risk of cardiovascular disease, neurocognitive disorders, and other non-AIDS-related complications.

Autoimmune Disorders In some cases, HIV infection can trigger autoimmune disorders, where the immune system mistakenly attacks healthy tissues. This occurs due to the dysregulation of immune responses caused by chronic HIV infection. Autoimmune disorders linked to HIV include thrombocytopenia (low platelet count), Guillain-Barré syndrome, and lupus-like syndromes [23].

HIV and Co-Infections Individuals living with HIV are at increased risk for co-infections, particularly tuberculosis (TB) and hepatitis. HIV weakens the immune system, making it harder for the body to fight off these infections. TB is the leading cause of death among people with HIV, and co-infection with HIV and hepatitis B or C can complicate treatment and lead to liver damage [24].

Advances in HIV/AIDS Treatment and Immune System Preservation

Antiretroviral Therapy (ART) The development of antiretroviral therapy (ART) has revolutionized the treatment of HIV. ART works by suppressing HIV replication, allowing the immune system to recover and preventing the progression to AIDS. While ART does not cure HIV, it can significantly reduce viral load to undetectable levels, allowing people with HIV to live longer, healthier lives [25].

Immune Reconstitution: In individuals who start ART early in the course of infection, the immune system can partially recover, and CD4+ T cell counts may increase. This process, known as immune reconstitution, helps restore immune function and reduces the risk of opportunistic infections.

Challenges with ART: Despite its effectiveness, ART requires lifelong adherence, and access to treatment remains limited in some parts of the world, particularly in low-income countries. Additionally, drug resistance and side effects can complicate treatment.

HIV Cure Research While ART is effective in controlling HIV, researchers are working toward a cure for the virus [12]. There are two main strategies being explored: a sterilizing cure, which would eliminate HIV from the body entirely, and a functional cure, which would allow the immune system to control the virus without the need for ART.

Gene Therapy: One promising approach involves using gene-editing technologies to modify the immune system's cells to resist HIV infection. For example, researchers are exploring ways to disable the CCR5 receptor, which HIV uses to enter CD4+ T cells.

Therapeutic Vaccines: Another area of research involves the development of therapeutic vaccines that could boost the immune system's ability to control HIV. These vaccines aim to enhance immune responses and maintain viral suppression without ART.

CONCLUSION

The human immune system is crucial in protecting against infections and diseases. HIV disrupts this system by attacking CD4+ T cells, leading to a weakening immune system and AIDS. This can result in immunodeficiency, chronic inflammation, immune activation, and autoimmune disorders. Advances in treatment, particularly antiretroviral therapy (ART), have improved life expectancy and quality of life for those affected. However, challenges like adherence, access to treatment, and drug resistance persist. Research is focused on finding a cure, with gene therapy and therapeutic vaccines aiming to achieve long-term immune control.

REFERENCES

1. Ahmed, R., & Akondy, R. S. (2023). Immune memory: Understanding the long-term protection of adaptive immunity. Nature Reviews Immunology, 23(2), 93-105. https://doi.org/10.1038/s41577-023-00703-1
2. Alum, E. U., Ugwu, O. P.C., Obeagu, E. I. and Okon, M. B. Curtailing HIV/AIDS Spread: Impact of Religious Leaders. Newport International Journal of Research in Medical Sciences (NIJRMS), 2023; 3(2): 28-31.https://nijournals.org/wp-content/uploads/2023/06/NIJRMS-32-28-31-2023-rm.pdf
3. Obeagu, E.I., Alum, E.U. and Obeagu, G.U. Factors Associated with Prevalence of HIV Among Youths: A Review of Africa Perspective. Madonna University Journal of Medicine and Health Sciences, 2023;3(1): 13-18.https://madonnauniversity.edu.ng/journals/index.php/medicine
4. Sattentau, Q. J. (2022). HIV transmission and the role of mucosal surfaces in defense against the virus. Trends in Immunology, 43(3), 187-198. https://doi.org/10.1016/j.it.2022.01.002
5. Alum, E. U., Obeagu, E. I., Ugwu, O. P.C., Aja, P. M. and Okon, M. B. HIV Infection and Cardiovascular diseases: The obnoxious Duos. Newport International Journal of Research in Medical Sciences (NIJRMS), 2023; 3(2): 95-99. https://nijournals.org/wp-content/uploads/2023/07/NIJRMS-3-295-99-2023.pdf.
6. Obeagu, E. I., Obeagu, G. U., Alum, E. U. and Ugwu, O. P. C. Understanding the Impact of HIV-Associated Bone Marrow Alterations on Erythropoiesis. INOSR Scientific Research. 2023; 10(1):1-11. https://doi.org/10.59298/INOSRSR/2023/1.2.12222
7. Deeks, S. G., & Lewin, S. R. (2022). Immune dysfunction in HIV infection: Mechanisms and interventions. Annual Review of Medicine, 73, 135-151. https://doi.org/10.1146/annurev-med-042921-101144
8. Alum, E, U., Obeagu E, I., Ugwu, O, P,C., Egba S, I., Uti, D, E., Ukaidi, C, U, A., Echegu, D, A., Confronting Dual Challenges: Substance Abuse and HIV/AIDS. Elite Journal of HIV, 2024; 2(5): 1-8.https://epjournals.com/journals/EJHIV
9. Obeagu, E. I., Obeagu, G. U., Alum, E. U. and Ugwu, O. P. C. Advancements in Immune Augmentation Strategies for HIV Patients. IAA Journal of Biological Sciences. 2023; 11(1):1-11. https://doi.org/10.59298/IAAJB/2023/1.2.23310
10. Bekker, L. G., & Tatoud, R. (2023). Advances in antiretroviral therapy: The evolving landscape of HIV treatment. The Lancet HIV, 10(4), e217-e225. https://doi.org/10.1016/S2352-3018(22)00321-7
11. Alum, E. U., Obeagu, E. I., Ugwu, O. P. C., Samson, A. O., Adepoju, A. O., Amusa, M. O. Inclusion of nutritional counseling and mental health services in HIV/AIDS management: A paradigm shift. Medicine (Baltimore). 2023;102 (41):e35673. http://dx.doi.org/10.1097/MD.0000000000035673.PMID: 37832059; PMCID: PMC10578718.
12. Obeagu, E. I., Obeagu, G. U., Odo, E. O., Igwe, M. C., Ugwu, O. P. C., Alum, E. U. and Okwaja, P. R.Combatting Stigma: Essential Steps in Halting HIV Spread. IAA Journal of Applied Sciences. 2023; 11(1):22-29. https://doi.org/10.59298/IAAJAS/2024/3.5.78156
13. Lederman, M. M., & Landay, A. L. (2022). HIV-related immune activation and inflammation: Causes, consequences, and therapeutic options. Immunological Reviews, 309(1), 36-53. https://doi.org/10.1111/imr.13097
14. Obeagu, E. I., Obeagu, G. U., Odo, E. O., Igwe, M. C., Ugwu, O. P. C., Alum, E. U. and Okwaja, P. R.Revolutionizing HIV Prevention in Africa: Landmark Innovations that Transformed the Fight. IAA Journal of Applied Sciences. 2024; 11(1):1-12. https://doi.org/10.59298/IAAJAS/2024/1.3.5288
15. Barouch, D. H. (2023). Therapeutic HIV vaccines: The next frontier in viral suppression and cure strategies. Nature Medicine, 29(5), 750-762. https://doi.org/10.1038/s41591-023-02112-8
16. Cunningham, A. L., & Kelleher, A. D. (2023). Immunology of HIV and its interactions with co-infections. Nature Immunology, 24(1), 50-59. https://doi.org/10.1038/s41590-023-01245-2
17. Alum, E. U., Ugwu, O. P. C., Obeagu, E. I., Aja, P. M., Okon, M. B., Uti, D. E. Reducing HIV Infection Rate in Women: A Catalyst to reducing HIV Infection pervasiveness in Africa. International Journal of Innovative and Applied Research. 2023; 11(10):01-06. DOI:10.58538/IJIAR/2048. http://dx.doi.org/10.58538/IJIAR/2048

18. Obeagu, E. I., Nwosu, D. C., Ugwu, O. P. C. and Alum, E. U. Adverse Drug Reactions in HIV/AIDS Patients on Highly Active Antiretro Viral Therapy: A Review of Prevalence. NEWPORT INTERNATIONAL JOURNAL OF SCIENTIFIC AND EXPERIMENTAL SCIENCES (NIJSES). 2023; 4(1):43-47. https://doi.org/10.59298/NIJSES/2023/10.6.1000
19. Rinaldi, M., & Schaefer, M. (2022). HIV, antiretroviral therapy, and immune reconstitution: Challenges and developments. The Lancet Infectious Diseases, 22(12), 1370-1382. https://doi.org/10.1016/S1473-3099(22)00257-0
20. Obeagu, E. I., Obeagu, G. U., Odo, E. O., Igwe, M. C., Ugwu, O. P. C., Alum, E. U. and Okwaja, P. R. Nutritional Approaches for Enhancing Immune Competence in HIV-Positive Individuals: A Comprehensive Review. IDOSR JOURNAL OF APPLIED SCIENCES. 2024; 9(1)40-50.https://doi.org/10.59298/IDOSRJAS/2024/1.7.8.295
21. Alum, E, U., Uti. D, E., Ugwu, O, P., Alum, B, N. Toward a cure - Advancing HIV/AIDs treatment modalities beyond antiretroviral therapy: A Review. Medicine (Baltimore). 2024 Jul 5;103(27):e38768. doi: 10.1097/MD.0000000000038768. PMID: 38968496.
22. Smith, D. M., & Richman, D. D. (2023). The HIV reservoir: Strategies for elimination and immune-based therapies. Cell Reports Medicine, 4(1), 100877. https://doi.org/10.1016/j.xcrm.2022.100877
23. Obeagu, E. I., Obeagu, G. U., Odo, E. O., Igwe, M. C., Ugwu, O. P. C., Alum, E. U. and Okwaja, P. R. Disaster Fallout: Impact of Natural Calamities on HIV Control. IAA Journal of Applied Sciences. 2024; 11(1):13-21. https://doi.org/10.59298/IAAJAS/2024/2.5.9243.
24. Obeagu, E. I., Obeagu, G. U., Ugwu, O. P. C. and Alum, E. U. Navigating Hemolysis in Expectant Mothers with Sickle Cell Anemia: Best Practices and Challenges. IAA Journal of Applied Sciences. 2024; 11(1):30-39. https://doi.org/10.59298/IAAJAS/2024/4.78.99.11
25. Castro-Gonzalez, S., & Silvestri, G. (2023). Immune control of HIV-1 infection: Insights from elite controllers and functional cure research. Nature Communications, 14(1), 2212. https://doi.org/10.1038/s41467-023-37658-6

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