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A review of the correlation between human papillomavirus (HPV) infection and dysbiosis of the female reproductive tract

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Abstract

This article reviews the relationship between vaginal microecological imbalance and cervical HPV infection, highlighting the latest research advancements in this area. As the primary defense line of the female reproductive tract, the balance of vaginal microecology plays a crucial role in how susceptible someone is to HPV infections, how long those infections last, and how effectively they can be cleared. Recent studies have shown that the variety and stability of vaginal bacteria are closely linked to cervical HPV infections. Dysbiosis of the vaginal microecology may lead to changes in the local immune microenvironment, thereby weakening the host's resistance to HPV. Additionally, inflammatory re-sponses play an important role in the occurrence and progression of HPV infections. Through the analysis of existing research, this article further explores the potential application value of microecological regu-lation, including combating HPV infections by adjusting microbial struc-ture and restoring microecological balance. By integrating this research evidence, the article aims to provide theoretical support for clinical practice and future research directions to promote the development of early prevention and intervention strategies for HPV.

Keywords

This text discusses: vaginal microbiome, human papillomavirus (HPV), imbalance of the microbiome, and women's reproductive health issues.

1. Introduction

With the continuous development of the socio-economy, the incidence of cervical cancer is also on the rise, trending towards younger popu-lations[1]. To improve the national economy and healthcare standards, reduce the economic burden on patients' families, and enhance pa-tients' quality of life, the World Health Organization has set three goals to be achieved by 2030 to accelerate the elimination of cervical cancer and promote various prevention and treatment strategies[2]. How to effectively prevent and control the occurrence of cervical cancer is to make the preven-

tion of HPV infection the first line of defense. It is essential to vigorously promote relevant health knowledge, vaccinate the appropriate age groups, and conduct screening work to achieve early detection and early treatment, thereby blocking the occurrence of cancer[3]. From the perspective of women's unique reproductive tract functions, maintaining the acidic substances in the vagina signif-icantly inhibits the growth of pathogenic microorganisms, thus pro-tecting women's reproductive health[4]. It is worth noting that vaginal microecological disorders can lead to various health risks. The prolif-eration of anaerobic and aerobic bacteria can lower vaginal immunity, leading to an increased rate of HPV infection. Persistent infections pose a significant threat to women's health.

Globally, more than two-thirds of women will be infected with HPV at some point in their lives. Epidemiological data shows that, depending on individual constitution, most people will clear the infection on their own within 24 months. A small number of high-risk HPV infections will persist. Among these, persistent infections with types 16 and 18 are particularly likely to lead to the occurrence of cervical cancer. Re-search indicates that the increased risk of HPV infection is related to the increased number of certain pathogens, and under the conditions of persistent HPV infection and vaginal microecological imbalance, the condition further develops[5].

Vaginal flora imbalance refers to abnormal changes in the structure, proportion, and environment of the normal microbial flora in the female vagina. Factors such as lifestyle, diet, sexual behavior, antibiotic use, and endocrine factors can cause vaginal flora imbalance, leading to changes in vaginal physiological functions and the occurrence of pathological states[6]. Exploring the relationship between vaginal mi-croecological imbalance and HPV infection[7] not only helps deepen the understanding of the role of women's reproductive health but also provides new ideas for clinical intervention.2.1 Composition and Func-tion of Vaginal Microecology

2. Main Body

2.1. Composition and Function of Vaginal Microbiota

2.1.1. Characteristics of Normal Vaginal Microbiota

The predominant bacteria in the vagina are lactobacilli, which mainly produce beneficial lactobacilli and H2O2, maintaining a normal acidic environment. Studies have shown that the vaginal pH of healthy women often remains in a relatively acidic environment. This acidic environment not only helps inhibit the growth of harmful pathogens but also protects women's reproductive health [8].

2.1.2 Types of Major Microorganisms and Their Physiological Functions

The vaginal microbiota consists mainly of beneficial lactobacilli, as well as Gardnerella spp., Prevotella spp., and other anaerobic bacteria [8]. Lactobacilli maintain the ecological balance within the vagina, pre-serving the acidic environment to inhibit the growth of pathogenic bacteria. Gardnerella can also exist under normal

conditions, but an excessive abundance may lead to an imbalance in the vaginal micro-biota, subsequently causing bacterial vaginosis (BV) and other dis-eases [9]. Particularly in cases of microbial imbalance, its increased abundance may be associated with a higher risk of human papilloma-virus (HPV) infection [10]. Understanding the functions of these mi-croorganisms and their roles in vaginal health is of great significance for the prevention and treatment of related diseases.*2.2 Mechanism of HPV Infection

2.2. Mechanisms of Vaginal Microecological Imbalance

2.2.1. The Impact of External Factors such as Antibiotic Use and Sexual Behavior on Microecology

Under normal circumstances, the imbalance of vaginal microecology is influenced by various external factors. The widespread use of antibi-otics can lead to a reduction in normal flora within the vagina, partic-ularly a decrease in the number of lactobacilli [11]. Studies have shown that when the number of lactobacilli decreases, the pH level in the vagina may rise, thereby creating favorable conditions for the growth of pathogens, increasing the risk of bacterial vaginosis and other in-fections [12]. Sexual behavior is also considered an important factor affecting vaginal microecology, especially having multiple sexual partners or engaging in unsafe sexual practices can introduce new pathogens, further exacerbating microecological imbalance [13]. Un-derstanding the mechanisms of the effects of these external factors is crucial for formulating effective preventive and therapeutic interven-tions.

2.3. Biological Characteristics of HPV Infection

2.3.1. Classification of HPV and Its Pathogenic Mechanism

Human papillomavirus (HPV) is mainly divided into two categories: high-risk and low-risk types, and is a class of widely existing dou-ble-stranded DNA viruses [14]. Based on pathogenicity, HPV can be classified into five genera: α, β, γ, μ, and ν, among which the α genus (such as HPV16 and HPV18) is considered the main pathogenic factor leading to the occurrence of cervical cancer [10]. The pathogenic mechanism of high-risk HPV primarily operates through the E6 and E7 gene proteins it encodes, which can inhibit the host cell's tumor sup-pressor genes p53 and pRb, leading to uncontrolled cell cycle and abnormal cell proliferation [15]. Research indicates that HPV infection can suppress the host immune system, allowing the virus to persist in the host for an extended period, thereby triggering carcinogenesis [16].

2.3.2. Host Response to HPV Infection and Its Impact

The host response to HPV infection involves various components of the immune system and is a complex process. Studies have shown that HPV infection can induce

both local and systemic immune re-sponses, including the release of cytokines and the recruitment of specific immune cells [17]. Persistent HPV infection, especially high-risk HPV infection, may lead to immune evasion, making the host immune response insufficient to clear the virus, thereby increasing the risk of related cancers (such as cervical cancer) [18]. Additionally, the imbalance of vaginal microecology is also considered an important factor influencing the infection and progression of HPV. In HPV-infected individuals, certain beneficial lactobacilli are significantly reduced, which may lead to the worsening of viral infection [19][20]. A deeper understanding of the host response and its impact on HPV infection is of great significance for developing new prevention and treatment strategies.

2.4. Correlation between Vaginal Microecological Imbalance and HPV Infection

2.4.1. Research Evidence: HPV Infection Risk Associated with Mi-croecological Imbalance

Recent studies have shown a significant correlation between vaginal microecological imbalance and human papilloma virus (HPV) infection. Multiple studies have found that the reduction of vaginal lactobacilli is closely related to the occurrence of high-risk HPV infections [21]. The α diversity of the vaginal microbiome in women with HPV-positive in-fections is significantly lower than that of HPV-negative women, and the abundance of specific lactobacilli is significantly reduced in patients with HPV infections [22][23].

2.4.2. Possible Biological Mechanisms (Immune Evasion, Micro-bial Metabolites)

Vaginal microecological imbalance may increase the risk of HPV in-fection through various mechanisms. Among them, immune evasion is an important mechanism [24]. When lactobacilli are reduced and the pH value exceeds 4.5, it can lead to excessive growth of pathogens, which may promote the invasion of HPV. Studies have found that the metabolic products of imbalanced vaginal microbiomes can affect the inflammatory response and inhibit the clearance of HPV [25][26]. Therefore, maintaining the balance of vaginal microecology may be an important strategy for preventing HPV infections and related lesions.

2.5. Future Research Directions and Clinical Applications

2.5.1. Intervention Strategies for Vaginal Microecology

Intervention strategies for human papilloma virus (HPV) infections have gradually become a focus of researchers [27][28]. Passive in-tervention through vaccination [29] has been shown to be effective. The key strategy for actively preventing HPV infections and related lesions is addressing vaginal microecological disorders. Cur-

rent in-tervention methods include probiotics and prebiotics, as well as mi-crobial transplantation. Clinical preparations primarily based on lac-tobacilli have shown potential in improving vaginal microecology, in-hibiting the growth of pathogens, and enhancing local immune re-sponses, thereby reducing the risk of HPV infection [30]. Microbial transplantation, as an emerging therapeutic approach, has shown significant effects in restoring vaginal microbiome after recurrent bacterial vaginosis (BV) antibiotic treatment [31]. In-depth exploration of the mechanisms of different strains and systematic evaluation of their clinical application safety and efficacy are needed to promote the application of vaginal microecological interventions in the prevention and treatment of HPV infections.

2.5.2. Potential of Microecological Monitoring in Preventing HPV Infection

Regular monitoring of vaginal microecology can help identify states of microecological imbalance in a timely manner [32], allowing for ap-propriate intervention measures. Literature studies suggest that the composition of vaginal microecology is significantly correlated with the incidence of HPV infections, and specific changes in microbial com-munities may indicate the risk of HPV infection. Establishing person-alized prevention strategies based on microecological monitoring can aid in the early identification and intervention of HPV infections. There is hope for the development of efficient microecological monitoring technologies, which can be explored clinically to achieve effective prevention and management of HPV infections [33][34].

3. Conclusion

The mechanisms influencing HPV infection are complex and diverse, with vaginal microecological imbalance playing a crucial role in HPV infection. Analysis of existing literature suggests that it may promote HPV infection and persistence through various pathways, affecting local immune responses, hormone levels, and the ability to clear the virus. This finding not only provides new perspectives for under-standing the pathological mechanisms of HPV infection and formulat-ing clinical intervention strategies but also suggests that clinical inter-ventions or dietary adjustments to the microecology may help restore the balance of the vaginal microecological system, thereby reducing the likelihood of HPV infections. This strategy can improve women's reproductive health and provide new intervention methods for public health, thereby reducing the incidence of HPV-related lesions.

In summary, it is worth exploring the relationship between vaginal mi-croecology and HPV infection in depth. Future research should focus on the systematic exploration of the role of microecology in HPV in-fection, promoting greater progress in women's health care in this field and providing more effective solutions.Acknowledgements

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