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Neuropeptides In Atopic Dermatitis

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ABSTRACT

Background: The literature on atopic dermatitis (AD) reveals a complex interplay of immunological, neurological, and environmental factors contributing to its pathogenesis, particularly in relation to neuropeptides and their role in the disease's symptomatology. **Literature Review:** The role of neuropeptides, particularly substance P (SP), is further elaborated by (Anggia Paramita et al., 2021), who links SP to the severity of AD. Their findings indicate that SP not only induces pruritus but also promotes inflammatory responses, thereby intensifying the disease's manifestations. This relationship is reinforced by the identification of the Mas-related G protein-coupled receptor-X2 (MRGPRX2) as a significant receptor for SP on mast cells, highlighting the intricate connections between neuropeptides and immune responses in AD. The examination of pruritogens by (Wong et al., 2021) further underscores the importance of NGF and brain-derived neurotrophic factor (BDNF) in the disease's progression. Elevated NGF levels contribute to hyperinnervation and enhance mast cell survival, indicating their pivotal roles in the transition from initial inflammation to chronic pruritus. This aligns with the therapeutic perspectives presented by (Bieber, 2021), who advocates for targeted interventions that address the multifaceted interactions among environmental factors, the skin microbiome, and immune responses. **Conclusion:** In conclusion, the literature collectively illustrates that neuropeptides, particularly substance P, along with various cytokines and immune responses, play a crucial role in the pathophysiology of atopic dermatitis. Understanding these relationships not only enhances comprehension of the disease mechanisms but also opens up new avenues for targeted therapeutic interventions aimed at alleviating symptoms and improving patient outcomes.

Keyword: Neuropeptides, Atopic Dermatitis

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INTRODUCTION

Atopic dermatitis (AD) is a multifaceted chronic inflammatory skin condition that has garnered significant attention in recent years due to its increasing prevalence and complex pathophysiological mechanisms. The literature surrounding AD reveals a convergence of immunological, neurological, and environmental factors, each contributing to the disease's symptomatology, particularly the hallmark itch.

(Ikezawa et al., 2010) provide foundational insights into the pathogenesis of AD, emphasizing the role of Staphylococcus aureus, interleukin-18, nerve growth factor (NGF), and semaphorin 3A. Their work highlights how these factors interact to exacerbate skin lesions and itch, establishing a framework for understanding the non-immunological abnormalities present in AD, such as physiological barrier dysfunctions and hypersensitivity to itch.

Building on this foundation, (Anggia Paramita et al., 2021) explore the neuropeptide substance P (SP) and its relationship to AD severity. They elucidate how SP, produced in response to skin inflammation, promotes the release of inflammatory mediators and nerve growth factors, thus exacerbating the condition. The identification of the Mas-related G protein-coupled receptor-X2 (MRGPRX2) as a key receptor for substance P on mast cells further underscores the intricate interplay between neuropeptides and immune responses in AD.

(Wong et al., 2021) extend this discussion by examining the implications of pruritogens, particularly NGF and brain-derived neurotrophic factor (BDNF), in the pathogenesis of AD. Their findings suggest that elevated levels of NGF not only contribute to hyperinnervation but also facilitate the survival and function of mast cells, which are pivotal in the early phases of AD. This work reinforces the idea that neuropeptides and growth factors are critical mediators in the transition from initial inflammation to chronic pruritus.

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In the same year, (Bieber, 2021) discusses the therapeutic landscape for AD, emphasizing the need for targeted interventions that address the complex interactions of environmental factors, skin microbiome, and immune responses. The review highlights the potential of biologics targeting specific cytokines and their receptors, which could provide a more effective management strategy for the diverse clinical phenotypes observed in AD patients.

(Fania et al., 2022) further contribute to the understanding of AD by exploring the role of cytokines as both pathogenic mediators and potential biomarkers. Their analysis of the cytokine profiles in various disease phases aligns with the concept of endotype-specific treatment approaches, offering insights into the personalized management of AD based on its immunological underpinnings.

(Tanei & Hasegawa, 2022) delve deeper into the immunological pathomechanisms of AD, focusing on the interactions between Th2 cytokines and chemokines. Their review highlights the disease's heterogeneous nature and the multifactorial influences that contribute to its chronicity, including genetic predispositions and environmental triggers.

(Mesjasz et al., 2023) explore the neurological dimensions of AD, positing that the interplay between the nervous system and immune response is crucial for understanding the mechanisms of atopic itch. They discuss the role of various neuropeptides and cytokines, such as IL-31, in modulating the sensory pathways involved in pruritus, thus linking the neurological and immunological aspects of the disease.

Finally, (Ständer et al., 2024) provide a comprehensive narrative on the cutaneous components leading to pruritus, pain, and neurosensitivity in AD. Their work emphasizes the importance of the neuro-immune axis and the role of sensory neurons in the chronic nature of the disease, highlighting how inflammatory mediators can lead to central and peripheral neuronal sensitization.

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Together, these articles paint a complex picture of atopic dermatitis, underscoring the intricate interplay between neuropeptides, cytokines, and immune responses in the pathogenesis of this chronic condition. The emerging understanding of these relationships not only enhances our grasp of AD but also opens new avenues for targeted therapeutic interventions.

LITERATURE REVIEW

The article titled "A Role of Staphylococcus aureus, Interleukin-18, Nerve Growth Factor and Semaphorin 3A, an Axon Guidance Molecule, in Pathogenesis and Treatment of Atopic Dermatitis" by (Ikezawa et al., 2010) provides an in-depth exploration of the multifaceted factors contributing to the pathogenesis of atopic dermatitis (AD). The authors present a comprehensive overview of both immunological and non-immunological abnormalities associated with this chronic inflammatory skin condition.

The article emphasizes the role of Staphylococcus aureus (SA), highlighting its prevalence on the skin of AD patients and its potential contribution to disease exacerbation. The authors discuss how the colonization of SA may lead to increased inflammation and itch, which are hallmark features of AD. This connection is crucial as it not only underscores the need for effective antimicrobial strategies in managing AD but also points to the importance of addressing skin barrier dysfunctions that predispose patients to such infections.

Additionally, the article delves into the immunological aspects of AD, particularly the involvement of interleukin-18 (IL-18). The authors suggest that IL-18 plays a significant role in modulating immune responses, potentially influencing the severity of inflammation and the itch-scratch cycle that characterizes AD. This insight is valuable as it opens avenues for targeted therapies that could mitigate the inflammatory response associated with elevated IL-18 levels.

Furthermore, the discussion surrounding nerve growth factor (NGF) and semaphorin 3A (Sema3A) provides a novel perspective on the neuroimmune

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interactions in AD. The authors posit that NGF may sensitize nerve endings, thereby exacerbating pruritus, while Sema3A could be implicated in axonal guidance and the regulation of neuronal responses in the skin. This neurobiological angle is particularly relevant, as it highlights the potential for neuropeptide-based interventions in alleviating the chronic itch associated with AD.

The article "Relationship of Substance P with the Degree of Atopic Dermatitis Severity" by (Anggia Paramita et al., 2021) provides a comprehensive examination of the role of neuropeptides, specifically substance P, in the pathogenesis of atopic dermatitis (AD). The authors effectively highlight that AD is a prevalent chronic inflammatory skin condition, particularly affecting children, with a significant global prevalence that underscores its relevance as a public health issue.

The article articulates a clear connection between substance P and the severity of AD. The authors argue that substance P is a pivotal pruritogenic factor, which not only induces itching but also exacerbates the inflammatory response in AD. They detail how substance P promotes the production of nerve growth factors and stimulates the release of inflammatory mediators from mast cells, leading to sensory nerve fiber growth and increased skin inflammation. This information is critical, as it positions substance P at the intersection of neurobiology and immunology in the context of AD.

Moreover, the authors identify the Mas-related G protein-coupled receptor-X2 (MRGPRX2) as the primary receptor for substance P on skin mast cells, which is instrumental in mediating its effects. This receptor's involvement is significant as it may serve as a potential therapeutic target for managing AD symptoms. The study's findings that serum levels of substance P, alongside IL-17A, are significantly elevated in patients with AD provide a strong basis for further research into the mechanistic pathways linking neuropeptides to the clinical manifestations of the disease.

While the article presents compelling evidence regarding the relationship between substance P and AD severity, it could benefit from a more detailed discussion on

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the implications of these findings for clinical practice. For instance, the potential for targeting substance P or its receptor in therapeutic interventions is an area that warrants further exploration. Additionally, the authors could enhance their argument by discussing the limitations of their study, such as sample size or demographic considerations, which could influence the generalizability of their findings.

The article titled "The Implications of Pruritogens in the Pathogenesis of Atopic Dermatitis" by (Wong et al., 2021) provides a comprehensive examination of the role of neuropeptides, particularly substance P (SP) and calcitonin gene-related peptide (CGRP), in the pathophysiology of atopic dermatitis (AD). The authors elucidate the complex interplay between neurogenic inflammation and immune responses, emphasizing the significance of neurotrophic factors such as nerve growth factor (NGF) and brain-derived neurotrophic factor (BDNF) in the disease's progression.

A critical insight from the article is the relationship between enhanced NGF production and the hyperinnervation observed in the skin of AD patients. This hyperinnervation leads to peripheral sensitization, which is a key contributor to the intense pruritus characteristic of AD. The authors highlight that NGF not only supports the survival of mast cells (MCs) but also facilitates their activities during the early phases of AD, indicating a pivotal role in the initiation of the inflammatory cascade ((Wong et al., 2021)).

Moreover, the article discusses the elevation of serum BDNF levels in AD patients and its correlation with eosinophil cationic protein levels and disease severity. Eosinophils are identified as a primary source of BDNF in the skin, and their enhanced expression of BDNF receptors such as TrkB and p75NTR underscores their involvement in the pathogenesis of AD. The authors note that BDNF not only induces eosinophil chemotaxis but also inhibits their apoptosis, suggesting a mechanism by which eosinophils contribute to sustained inflammation in AD ((Wong et al., 2021)).

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The discussion of neuropeptides, particularly SP, is particularly noteworthy. The article details how SP, a tachykinin neuropeptide, acts as a potent neuroinflammatory mediator, modulating various cytokines and activating immune cells including T cells and eosinophils. The increased expression of SP in both serum and lesioned skin of AD patients reinforces its role in the inflammatory milieu of the disease ((Wong et al., 2021)). The ability of SP to stimulate MC degranulation and the release of pro-inflammatory mediators such as histamine and TNF-α further illustrates its central role in the pathogenesis of AD.

In the article "Atopic dermatitis: an expanding therapeutic pipeline for a complex disease," (Bieber, 2021) provides a comprehensive overview of the multifaceted nature of atopic dermatitis (AD), emphasizing its intricate pathophysiology and the potential avenues for therapeutic intervention. The author delineates the disease's clinical variability, which arises from a complex interplay of genetic, environmental, and immunological factors. This complexity is crucial for understanding the therapeutic landscape, as it highlights the necessity for a nuanced approach to treatment.

Bieber discusses the role of the immune system in AD, particularly the initial activation of skin innate immunity followed by a robust adaptive immune response characterized by T helper 2 (TH2) polarization. This TH2 response is significant, as it is associated with IgE sensitization to environmental allergens and sets the stage for a broader adaptive immune response, including TH1, TH17, and TH22 pathways. The author's discussion of the "immunological march" provides a framework for understanding the evolution of the disease and the potential for targeted interventions at various stages of its progression.

One of the critical insights from the article is the identification of the innate immune response as a crucial factor in the early stages of AD. Bieber suggests that targeting pathways such as the aryl-hydrocarbon receptor (AhR) and alarmins may offer promising therapeutic strategies. This focus on innate immunity is particularly

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relevant, as it opens new avenues for intervention that may prevent the escalation of the disease and the development of comorbidities.

Moreover, the author highlights the importance of T cells in the inflammatory process and discusses emerging strategies to modulate their activity. This includes the modulation of the sphingosine 1-phosphate receptor and C-C chemokine receptor 4, which could enhance therapeutic outcomes by altering T cell migration and localization. Such targeted therapies against specific cytokines and their receptors represent a significant advancement in the pharmacological management of AD.

The article titled "Multiple Roles for Cytokines in Atopic Dermatitis: From Pathogenic Mediators to Endotype-Specific Biomarkers to Therapeutic Targets" by (Fania et al., 2022) provides a comprehensive examination of atopic dermatitis (AD), highlighting its multifaceted nature as a chronic inflammatory skin condition. The authors underscore the increasing prevalence of AD, particularly its onset during childhood, and the potential for both remission and chronic relapsing forms into adulthood. This observation is significant, as it reflects the evolving understanding of AD as not merely a pediatric condition but one that can persist or emerge later in life.

A critical aspect of the article is the detailed exploration of the pathophysiology of AD. The authors elucidate the interplay between genetic predispositions, particularly mutations in the filaggrin (FLG) gene, and the resulting skin barrier dysfunction. This dysfunction is pivotal, as it facilitates the entry of antigens that activate epidermal antigen presentation cells (APCs), leading to a Th2-mediated inflammatory response. The authors effectively connect these biological mechanisms to the clinical manifestations of AD, which range from acute pruritus and erythematous vesicular lesions to chronic lichenification.

Moreover, the article discusses the association of AD with other atopic diseases, such as asthma and allergic rhinitis, which compounds the impact on patients' quality of life. This interconnectedness is essential for understanding the broader

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implications of AD and its management. The authors emphasize the need for personalized approaches to treatment, informed by the diverse clinical phenotypes of AD patients, which is a crucial consideration for future therapeutic strategies.

The authors also highlight the role of cytokines as both mediators of inflammation and potential biomarkers for different endotypes of AD. This dual role underscores the complexity of AD management and the necessity of targeted therapies that address specific inflammatory pathways. The discussion of these cytokines as therapeutic targets reflects an important shift towards precision medicine in dermatology, aiming to improve patient outcomes through tailored interventions.

The article titled "Immunological Pathomechanisms of Spongiotic Dermatitis in Skin Lesions of Atopic Dermatitis" by (Tanei & Hasegawa, 2022) provides a comprehensive overview of the intricate immunological mechanisms underlying atopic dermatitis (AD). The authors effectively highlight the multifactorial nature of AD, emphasizing its chronic and relapsing nature, which is characterized by a variety of clinical phenotypes.

One of the key insights from the article is the role of epidermal barrier dysfunction and dry skin, which are critical in the pathogenesis of AD. The authors discuss how genetic abnormalities contribute to this dysfunction, which in turn exacerbates chronic inflammation. This connection is particularly important as it underscores the necessity of addressing both genetic and environmental factors in the management of AD.

The dominance of T helper (Th) 2 cytokine immunity is presented as a significant aspect of AD's immunological profile. (Tanei & Hasegawa, 2022) describe how this Th2-dominance is linked to the production of various cytokines and chemokines that perpetuate the inflammatory cycle characteristic of the disease. Furthermore, the article discusses the implications of persistent IgE sensitization, suggesting that it not only plays a critical role in the pathogenesis of AD but also has broader implications for associated conditions such as hypertension and carcinogenesis suppression.

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The authors also address the impact of skin dysbiosis in AD, particularly the increased prevalence of Staphylococcus aureus. This finding is crucial as it suggests that microbial factors may influence the severity and persistence of the disease, indicating potential avenues for therapeutic intervention.

The article "Is Atopic Dermatitis Only a Skin Disease?" by (Mesjasz et al., 2023) provides a comprehensive examination of the complex interplay between the neurological system, cutaneous immune response, and keratinocytes in the context of atopic dermatitis (AD). The authors argue that atopic itch is not solely a result of traditional histamine-mediated pathways but also significantly influenced by histamine-independent mechanisms.

A critical insight from the article is the emphasis on the role of the transient receptor potential (TRP) ion channel superfamily, particularly the overexpression and heightened sensitivity of TRPV1, TRPA1, TRPV3, and TRPV4 in AD-affected skin. This highlights a shift in understanding the pathophysiology of itch, suggesting that these channels play a pivotal role in the sensory perception of itch in AD patients. The activation of interleukin-31 receptor A (IL-31RA) on TRPV1+/TRPA+ sensory neurons by Th-2 derived IL-31 is particularly noteworthy, as it underscores the importance of cytokine interactions in the modulation of pruritus ((Mesjasz et al., 2023)).

Moreover, the article discusses the implications of other cytokines, such as IL-13 and thymic stromal lymphopoietin (TSLP), in the disease's progression. The authors provide evidence that TSLP can regulate the secretion of cytokines from keratinocytes, which in turn affects CD4+ T cell populations, thus modifying immune responses. This suggests a multifaceted role of neuropeptides and cytokines in both the initiation and maintenance of atopic dermatitis.

The authors also address the neurogenic inflammation aspect, noting that harmful stimuli and stress can increase the release of neuropeptides like neuropeptide Y (NPY), substance P, calcitonin-gene regulated peptide (CGRP), and brain natriuretic peptide (BNP). These neuropeptides are implicated in regulating the

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function of inflammatory cells, including mast cells, and the subsequent release of cytokines, further complicating the pathophysiological landscape of AD ((Mesjasz et al., 2023)).

The article "Cutaneous Components Leading to Pruritus, Pain, and Neurosensitivity in Atopic Dermatitis: A Narrative Review" by (Ständer et al., 2024) provides a comprehensive examination of the interplay between various biological components in the pathophysiology of atopic dermatitis (AD). The authors highlight the chronic nature of AD, emphasizing how prolonged exposure to inflammatory mediators and skin trauma can lead to significant changes in sensory neuron afferents and central synapses, resulting in heightened sensitivity to pruritic stimuli.

A critical evaluation of the article reveals that the authors effectively articulate the mechanisms of central and peripheral neuronal sensitization, which are pivotal in understanding the complexities of pruritus and pain associated with AD. The concepts of hyperknesis and alloknesis are particularly noteworthy, as they underscore the transition from normal sensory processing to abnormal perceptions of itch and pain. This aspect is crucial for clinicians and researchers alike, as it elucidates the need for targeted therapeutic strategies that address these sensory abnormalities.

The authors meticulously describe the structural components of the skin, including the epidermis, dermis, and hypodermis, and their roles in the pathophysiological processes of AD. They detail the composition of the epidermis, emphasizing the importance of the stratum corneum as a barrier against environmental irritants and its role in maintaining skin microbiome homeostasis. The involvement of various skin cell types, such as keratinocytes, Langerhans cells, and immune cells, is well-articulated, providing insight into the multifaceted nature of immune responses in AD.

Moreover, the article highlights the intricate neural network that innervates the skin layers, illustrating how sensory nerves interact with immune cells and contribute to

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the disease's chronicity. This discussion is particularly relevant as it points to potential therapeutic targets for alleviating symptoms of AD, such as pruritus and pain.

However, while the review provides an extensive overview of the involved components, it could benefit from a more detailed exploration of the neuropeptides implicated in these processes. Neuropeptides, such as substance P and calcitonin gene-related peptide, play critical roles in mediating itch and inflammation in AD, and a deeper analysis of their specific contributions could enhance the understanding of the neuroimmune interactions described.

CONCLUSION

The literature on atopic dermatitis (AD) reveals a complex interplay of immunological, neurological, and environmental factors contributing to its pathogenesis, particularly in relation to neuropeptides and their role in the disease's symptomatology. The foundational work by (Ikezawa et al., 2010) outlines critical components such as Staphylococcus aureus, interleukin-18, nerve growth factor (NGF), and semaphorin 3A, which collectively enhance inflammation and the sensation of itch. This establishes a basis for understanding how non-immunological factors, including physiological barrier dysfunctions, exacerbate the condition.

The role of neuropeptides, particularly substance P (SP), is further elaborated by (Anggia Paramita et al., 2021), who links SP to the severity of AD. Their findings indicate that SP not only induces pruritus but also promotes inflammatory responses, thereby intensifying the disease's manifestations. This relationship is reinforced by the identification of the Mas-related G protein-coupled receptor-X2 (MRGPRX2) as a significant receptor for SP on mast cells, highlighting the intricate connections between neuropeptides and immune responses in AD.

The examination of pruritogens by (Wong et al., 2021) further underscores the importance of NGF and brain-derived neurotrophic factor (BDNF) in the disease's

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progression. Elevated NGF levels contribute to hyperinnervation and enhance mast cell survival, indicating their pivotal roles in the transition from initial inflammation to chronic pruritus. This aligns with the therapeutic perspectives presented by (Bieber, 2021), who advocates for targeted interventions that address the multifaceted interactions among environmental factors, the skin microbiome, and immune responses.

Moreover, the exploration of cytokines by (Fania et al., 2022) and (Tanei & Hasegawa, 2022) emphasizes their dual role as pathogenic mediators and potential biomarkers for endotype-specific treatments. This perspective is crucial for developing personalized management strategies based on the immunological profiles of AD patients.

The neurological dimensions of AD are addressed by (Mesjasz et al., 2023), who discuss the interplay between the nervous system and immune response, particularly the role of neuropeptides like IL-31 in modulating sensory pathways related to itch. This is complemented by (Ständer et al., 2024), who provide a comprehensive narrative on the cutaneous components leading to pruritus and pain, emphasizing the neuro-immune axis and sensory neuron involvement.

In conclusion, the literature collectively illustrates that neuropeptides, particularly substance P, along with various cytokines and immune responses, play a crucial role in the pathophysiology of atopic dermatitis. Understanding these relationships not only enhances comprehension of the disease mechanisms but also opens up new avenues for targeted therapeutic interventions aimed at alleviating symptoms and improving patient outcomes.

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REFERENCES

1. Ikezawa, Z., Komori, J., Ikezawa, Y., Inoue, Y., Kirino, M., Katsuyama, M., & Aihara, M., 2010. A Role of Staphyococcus aureus, Interleukin-18, Nerve Growth Factor and Semaphorin 3A, an Axon Guidance Molecule, in Pathogenesis and Treatment of Atopic Dermatitis. ncbi.nlm.nih.gov
2. Anggia Paramita, D., Nasution, K., & Zairina Lubis, N., 2021. Relationship of Substance P with the Degree of Atopic Dermatitis Severity. ncbi.nlm.nih.gov
3. Wong, L. S., Yen, Y. T., & Lee, C. H., 2021. The Implications of Pruritogens in the Pathogenesis of Atopic Dermatitis. ncbi.nlm.nih.gov
4. Bieber, T., 2021. Atopic dermatitis: an expanding therapeutic pipeline for a complex disease. ncbi.nlm.nih.gov
5. Fania, L., Moretta, G., Antonelli, F., Scala, E., Abeni, D., Albanesi, C., & Madonna, S., 2022. Multiple Roles for Cytokines in Atopic Dermatitis: From Pathogenic Mediators to Endotype-Specific Biomarkers to Therapeutic Targets. ncbi.nlm.nih.gov
6. Tanei, R. & Hasegawa, Y., 2022. Immunological Pathomechanisms of Spongiotic Dermatitis in Skin Lesions of Atopic Dermatitis. ncbi.nlm.nih.gov
7. Mesjasz, A., Zawadzka, M., Chałubiński, M., & Trzeciak, M., 2023. Is Atopic Dermatitis Only a Skin Disease?. ncbi.nlm.nih.gov
8. Ständer, S., Luger, T., Kim, B., Lerner, E., Metz, M., Adiri, R., M. Canosa, J., Cha, A., & Yosipovitch, G., 2024. Cutaneous Components Leading to Pruritus, Pain, and Neurosensitivity in Atopic Dermatitis: A Narrative Review. ncbi.nlm.nih.gov

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