

Correlation Between Serum IL-24 Level in Acne Vulgaris Patients of Varying Clinical Severity

Annisa Marsha Evanti^{1*}, Muhammad Eko Irawanto², Nurrachmat Mulianto³, Arie Kusumawardani⁴, Endra Yustin Ellistasari⁵

Universitas Sebelas Maret, Surakarta, Indonesia^{1, 2, 3, 4, 5}

Email: annisamarshae@gmail.com^{1*}, ekokepik@staff.uns.ac.id²,

nurrachmatdv@yahoo.com³, arie_dr2008@yahoo.com⁴, endra_yustin@yahoo.com⁵

ABSTRACT

Background: Acne vulgaris (AV) is a chronic inflammatory disorder of the pilosebaceous unit that significantly impacts patients' quality of life. The inflammatory process involves immune responses partially regulated by IL-24, suggesting its potential role in AV pathophysiology and clinical severity. However, data on serum IL-24 levels based on AV severity remain limited, particularly in Indonesia. This study aims to evaluate the relationship between serum IL-24 levels and acne vulgaris severity to further elucidate its molecular mechanisms. **Methods:** This observational analytical study with a cross-sectional design was conducted at Dr. Moewardi General Hospital, Surakarta, Indonesia, from November 2025 to January 2026, involving healthy individuals and acne vulgaris patients. AV severity was assessed using the Lehmann classification, and serum IL-24 levels were measured by ELISA. **Results:** A total of 60 subjects were involved, consisting of 15 healthy controls, 15 patients with mild AV, 15 with moderate AV, and 15 with severe AV. Pearson correlation analysis showed no significant relationship between serum IL-24 levels and AV severity ($p = 0.186$). However, there was a trend towards increasing serum IL-24 levels along with acne severity. In the healthy control group, IL-24 levels were lower than in the AV group. **Conclusions:** Serum IL-24 levels are not associated with acne vulgaris severity. This is likely due to its effect on local keratinocyte proliferation. Further research is needed to elucidate the pathophysiology using histopathological examination of skin tissue from patients with AV

Keywords: *Acne vulgaris, Cytokines, Interleukin-24, Severity*

This article is licensed under [CC BYSA 4.0](https://creativecommons.org/licenses/by-sa/4.0/) 

INTRODUCTION

Acne vulgaris (AV) is a chronic inflammatory disorder of the pilosebaceous follicular unit in the skin (Leung et al., 2020). The pathogenesis of AV is multifactorial, involving many key factors including increased sebum production, impaired keratinization of the pilosebaceous follicle, increased colonization by *C. acnes*, and the inflammatory process (Vasam et al., 2023). Acne vulgaris is estimated to occur in 9.4% of the global population (Eichenfield et al., 2021). Based on the Global Burden of Disease study, AV affects 85% of young adults, especially those aged 12–25 years (Sitohang et al., 2024). In Indonesia, acne vulgaris is one of the most common reasons for patients to visit dermatology, venereology, and aesthetic medicine specialists (Legiawati et al., 2023). Acne vulgaris is a disease with varying degrees of severity, ranging from mild to severe, where higher acne severity is associated with a significant decline in quality of life in patients (Tasneem et al., 2023).

Assessing the severity of AV is important in clinical practice, especially for evaluation and follow-up treatment (Alsulaimani et al., 2020). One widely used method is the Lehmann classification, which categorizes AV into mild, moderate, and severe based on the number of

comedones, papules/pustules, and cysts/nodules, as well as the total number of lesions (Damayanti et al., 2022). This classification is considered more practical than other scoring systems because it is simple yet still provides objective stratification (Saiboo et al., 2024). In several recent studies, the Lehmann classification system has been used as a basis for examining the relationship between the severity of AV and levels of proinflammatory cytokines such as interleukin (IL)-1 β , IL-19, and IL-23 (Albalat et al., 2021; Dahlan et al., 2024; Resya et al., 2021). Assessment using the Lehmann criteria employs a quantitative lesion counting method that does not require special equipment, making it practical for use in patients (Rusdy et al., 2023). The Lehmann criteria also emphasize the number and type of inflammatory lesions such as papules, pustules, and nodules, which reflect the severity of inflammation involved in AV (Bae et al., 2024).

The inflammatory response is one of the main factors in the pathogenesis of AV (Asatryan et al., 2021; Taghdiri, 2024; Zhang & Dhalla, 2024). During this inflammatory phase, there is an increase in the production of other proinflammatory cytokines that play a role in regulating and amplifying the immune response, including IL-24. Interleukin-24 is a proinflammatory cytokine from the IL-10 family produced by keratinocytes and various immune cells in the skin (Mitamura et al., 2020). *In vivo* studies show that TNF- α can increase IL-24 production by keratinocytes and cause inflammation in the skin (Zhong et al., 2022). In addition, the cytokine IL-1 β can also increase IL-24 expression in keratinocytes (Smith et al., 2023). Both studies show that IL-24 contributes to strengthening the skin's inflammatory response (Toskas et al., 2024). To date, no studies have specifically assessed IL-24 levels in the serum of AV patients with varying degrees of severity, especially in Indonesia. The cytokine IL-24 plays a dominant role in regulating keratinocyte proliferation and differentiation (Xu et al., 2021). Therefore, this study aims to explore serum IL-24 in patients with acne vulgaris of varying severity, thereby providing a more comprehensive picture of the molecular mechanisms underlying acne vulgaris and opening up opportunities for the development of more effective and specific molecular-based therapies in the future.

This research provides several important benefits. For the development of medical science, this study contributes to the understanding of the role of IL-24 in the pathophysiology of acne vulgaris, particularly regarding its relationship with disease severity, which remains poorly understood in Indonesia. For clinical practice, the findings may help dermatologists better understand the inflammatory mechanisms underlying acne vulgaris, potentially leading to more targeted therapeutic approaches. For patients, this research may ultimately contribute to the development of more effective treatments that specifically target the inflammatory pathways involved in acne, improving clinical outcomes and quality of life. For future researchers, this study provides a foundation for further investigations into IL-24 as a potential therapeutic target or biomarker for acne vulgaris, as well as for exploring its role in other inflammatory skin conditions. Additionally, this research adds to the limited body of knowledge on inflammatory cytokines in acne vulgaris within the Indonesian population, which may have unique genetic and environmental characteristics compared to other populations.

RESEARCH METHODS

Study Design

This study was an observational analytical study using a cross-sectional study design. It was conducted at the Dermatology and Venereology Clinic of Dr. Moewardi General Hospital in Surakarta, Indonesia, from November 2025 to January 2026. This study has been approved by the Health Research Ethics Committee of Dr. Moewardi General Hospital (No: 1.778/VII/HREC/2025).

Inclusion and Exclusion Criteria

The inclusion criteria for this study were patients with a diagnosis of acne vulgaris who were clinically assessed by three observers and were aged between 16 and 25 years. Meanwhile, the exclusion criteria were obesity, a history of psoriasis vulgaris, atopic dermatitis and malignancy, as well as a history of using certain medications including benzodiazepines, lithium, cyclosporine, ramipril, isoniazid, iodide, bromide, vitamin B complex, selective serotonin reuptake inhibitor, epidermal growth factor receptor inhibitor, progestin contraceptives, and corticosteroids within one month prior.

AV Severity Assessment

The severity of AV was assessed by three observers using the Lehmann criteria. The Lehmann criteria is a quantitative scoring system based on the number and severity of AV lesions. The examination was conducted in a room with natural lighting or bright white lighting to avoid shadows. The subject's face was then photographed using a digital camera with a minimum resolution of 16 megapixels. The classification of acne lesion types consisted of blackheads, papules, pustules, nodules, and cysts. The number of lesions in each anatomical area was counted to obtain a total Lehmann score. The classification of AV severity based on the total score was mild (blackheads <20, or papules/pustules <15, or total lesions <30), moderate (20-100 blackheads, or papules/pustules 15-50, nodules/cysts <5 or total lesions 30-125), and severe (>100 blackheads, or papules/pustules >50, nodules/cysts >5 or total lesions >125). If one lesion category met the threshold for a higher severity level, the subject was classified into that level even if the overall total number of lesions was lower. Interrater reliability was assessed using Cohen's kappa statistic.

IL-24 Quantification

Serum IL-24 levels in this study were examined using the ELISA technique with the ThermoFisher® Human IL-24 Immunoassay ELISA standard kit. This examination uses a quantitative sandwich enzyme immunoassay technique. Previously, specific monoclonal antibodies against IL-24 were coated on microplates. Standards, samples, controls, and conjugates were pipetted into wells. All IL-24 present would bind to the antibodies in the wells. After washing, IL-24 bound to the antibodies in the wells would be recognized and bound by specific monoclonal antibodies against IL-24 that had been conjugated with enzymes (antibodies linked to enzymes). Washing was then carried out to remove unbound substances, including unbound enzyme antibodies. After that, a substrate solution was added to the wells and a color would form whose intensity was proportional to the amount of bound IL-24. The color formation reaction was stopped, and then the color intensity was measured using a Bio-Rad 680 ELISA reader.

Statistical Analysis

Statistical analysis in this study used IBM SPSS version 26. Data on serum IL-24 are presented as means and standard deviations. A p-value of less than 0.05 is considered statistically significant.

RESULTS AND DISCUSSION

This is an observational analytical study using a cross-sectional design involving patients with AV (acne vulgaris) of varying severity. A total of 45 patients with AV and 15 healthy controls were included. The aim of this study was to evaluate the relationship between IL-24 levels and acne vulgaris severity in affected patients.

Subject's Characteristics

A total of 45 subjects with AV and 15 healthy controls were involved in this study. The mean age of subjects with AV was 19.6 ± 2.50 years, while the mean age of healthy controls was 22.07 ± 1.58 years. In the AV group, females were more numerous (75.56%) than males (24.44%), while in the healthy control group, females were also the majority (60%) compared to males (40%). The mean body mass index (BMI) in the AV group was 20.93 ± 1.53 kg/m², and in the healthy control group was 21.01 ± 1.75 kg/m². The most common level of education in both groups was a bachelor's degree, and the most common occupation in both groups was a student (Table 1).

Table 1. Subject's Characteristics

Characteristics	AV (n = 45)	Healthy Control (n = 15)
Age	19.60 ± 2.50	22.07 ± 1.58
Sex		
Male	11 (24.44%)	6 (40%)
Female	34 (75.56%)	9 (60%)
BMI	20.93 ± 1.53	21.01 ± 1.75
Education		
High School	15 (25%)	0 (0%)
Diploma	6 (10%)	0 (0%)
Undergraduate	39 (64%)	15 (100%)
Occupation		
Student	13 (28.89%)	0 (0%)
College student	28 (62.22%)	14 (93.33%)
Office worker	4 (8.89%)	1 (6.67%)

Source: Primary Data Analysis, 2026

Data presented as mean ± standard deviation / n (%); AV= Acne vulgaris; BMI = Body mass index.

We also describe the characteristics of AV subjects across disease severity levels. The mean ages of patients with mild, moderate, and severe AV were 20.80 ± 3.03 years, 19.33 ± 2.02 years, and 18.67 ± 1.95 years, respectively. In the mild, moderate, and severe AV groups, the gender distribution was predominantly female at 93.33%, 66.67%, and 66.7%, respectively. The mean Body Mass Index in the mild, moderate, and severe AV groups was 21.10 ± 1.60 kg/m², 21.07 ± 1.59 kg/m², and 20.61 ± 1.43 kg/m², respectively. Across all

severity groups, the most common education level was a bachelor's degree. Students were the largest occupational group in all three severity categories, comprising more than 50% of the total subjects in each group (Table 2).

Table 2. Characteristics of AV’s Subject Across Different Severity.

Characteristics	Severity		
	Mild (n = 15)	Moderate (n = 15)	Severe (n = 15)
Age	20.80 ± 3.03	19.33 ± 2.02	18.67 ± 1.95
Sex			
Male	1 (6.67%)	5 (33.33%)	5 (33.33%)
Female	14 (93.33%)	10 (66.67%)	10 (66.67%)
BMI	21.10 ± 1.60	21.07 ± 1.59	20.61 ± 1.43
Education			
High School	4 (26.67%)	4 (26.67%)	7 (46.66%)
Diploma	2 (13.33%)	3 (20%)	1 (6.67%)
Undergraduate	9 (60%)	8 (53.33%)	7 (46.66%)
Occupation			
Student	3 (20%)	3 (20%)	7 (46.66%)
College student	9 (60%)	11 (73.33%)	8 (53.34%)
Office worker	3 (20%)	1 (6.67%)	0 (0%)

Source: Primary Data Analysis, 2026

Data presented as mean ± standard deviation / n (%); BMI = Body mass index.

Cohen’s Kappa Test

The assessment of acne vulgaris (AV) severity in this study was performed by three independent evaluators. To ensure inter-rater agreement, Cohen’s kappa test was applied. A kappa value of <0.2 indicates poor agreement, 0.2–0.4 fair agreement, 0.4–0.6 moderate agreement, 0.6–0.8 substantial agreement, and >0.8 perfect agreement. The results of the Cohen’s kappa analysis showed a value of 1.000 for the agreement between raters 1 and 2, 1.000 between raters 2 and 3, and 1.000 between raters 1 and 3. All Cohen’s kappa values exceeded 0.8, indicating perfect agreement among the three observers in determining AV severity (Table 3).

Table 3. Cohen’s Kappa Test

Evaluator	Cohen’s Kappa
Evaluator 1 & 2	1.000
Evaluator 2 & 3	1.000
Evaluator 1 & 3	1.000

Source: Primary Data Analysis, 2026

IL-24 Association with AV Severity

Serum IL-24 levels were 71.14 ± 14.81 pg/mL in the healthy control group, 74.16 ± 12.20 pg/mL in the mild AV group, 77.01 ± 16.40 pg/mL in the moderate AV group, and 78.06 ± 18.33 pg/mL in the severe AV group. These findings indicate a trend towards increasing serum IL-24 levels as disease severity increases. In addition, IL-24 levels in the healthy control group were lower than those in the AV group. Correlation analysis revealed a p-value

of 0.186, indicating no statistically significant relationship between serum IL-24 levels and AV severity ($p > 0.05$). The correlation coefficient (r) was positive ($r = 0.173$), indicating a positive but weak relationship, meaning that higher serum IL-24 levels tended to be associated with greater AV severity, although the correlation was not statistically significant (Table 4).

Table 4. IL-24 Association with AV Severity.

Parameters	Health Control (n = 15)	Severity			r	p
		Mild (n = 15)	Moderate (n = 15)	Severe (n = 15)		
IL-24 (pg/mL)	71.14 ± 14.81	74.16 ± 12.20	77.01 ± 16.40	78.06 ± 18.33	0.173	0.186

*Note: r = Pearson correlation coefficient; data is significant if $p < 0.05$.

Source: Primary Data Analysis, 2026

In this study, no significant association was found between serum IL-24 levels and AV severity. However, a gradual increase in serum IL-24 levels was observed with increasing disease severity. Furthermore, serum IL-24 levels in healthy control subjects were lower than those observed in patients with AV. Previous studies on inflammatory skin diseases have reported a role for IL-24 in disease pathogenesis. A study by Qian et al. (2024) reported increased IL-24 levels in patients with atopic dermatitis, while Xu et al. (2021) showed higher IL-24 levels in patients with psoriasis vulgaris compared with healthy controls, suggesting a potential role for IL-24 in keratinocyte proliferation. However, data regarding the role of IL-24 in acne vulgaris are still limited (Qian et al., 2024; Xu et al., 2021).

The human IL-24 gene consists of seven exons and six introns and is located on chromosome 1q32–33 within a cytokine gene cluster that also includes IL-19 and IL-20, whereas IL-22 and IL-26 are located on chromosome 12q15. IL-24 production can be induced by various cytokines, including IFN- γ , IL-4, IL-31, IL-17A, IL-22, as well as proinflammatory cytokines such as IL-1 β , IL-6, and TNF- α (Mitamura et al., 2020). IL-24 is produced not only by immune cells, including monocytes, macrophages, mast cells, natural killer cells, and T and B lymphocytes, but also by non-immune cells such as keratinocytes and melanocytes. IL-24 is thought to participate in a complex cytokine cascade involved in cutaneous inflammatory responses, as it is capable of inducing the expression of various cytokines and chemokines. When added to cultured human keratinocytes and/or reconstructed human epidermis, IL-24 has been shown to upregulate the expression of inflammatory mediators, including increased CXCL1 and IL-20 gene expression, as well as enhanced secretion of CXCL8/IL-8, CCL20, matrix metalloproteinases, and prostaglandin E2 (Vu et al., 2021).

Acne vulgaris results from the interaction between sebaceous hypersecretion, hyperkeratinization of pilosebaceous unit follicles, colonization by *C. acnes*, and the release of various immune mediators at the site of AV lesions. Studies examining inflammatory cytokines in AV have shown that although some inflammatory mediators are generally elevated in patients compared with healthy controls, the direct relationship between specific serum cytokine levels and AV severity is often inconsistent. For example, studies evaluating several inflammatory cytokines in AV patients have shown higher levels of proinflammatory

cytokines in patients than in controls, but failed to identify a significant correlation between serum cytokine concentrations and disease severity. These findings suggest that systemic cytokine levels may not accurately reflect local inflammatory dynamics within the pilosebaceous unit (Qi et al., 2025).

Circulating IL-24 concentrations are influenced by multiple systemic factors, including production by various immune and non-immune cells and responses to systemic inflammatory stimuli, and therefore may not solely represent local cutaneous inflammation. IL-24 functions within a broad cytokine network and can be induced by multiple proinflammatory cytokines, which may contribute to the lack of a direct correlation between serum levels and local skin inflammatory activity. Consequently, serum IL-24 levels may have limited sensitivity in reflecting AV severity, which is primarily driven by localized inflammation within the pilosebaceous unit (Zhong et al., 2022; Vollenberg et al., 2025). The absence of a significant association between serum IL-24 levels and AV severity in this study may also be attributed to localized immune activation within the pilosebaceous unit, where cytokines produced by keratinocytes, macrophages, and other immune cells contribute to inflammatory lesion formation without necessarily causing detectable increases in systemic circulation (Qi et al., 2025). This observation is consistent with previous studies on inflammatory skin diseases that reported elevated IL-24 levels based on intralesional measurements rather than serum assessments (Xu et al., 2021).

Another possible explanation for the lack of association between serum IL-24 levels and AV severity is the heterogeneity in disease duration among the study participants. IL-24 levels may fluctuate during different phases of AV. A study by Liu et al. (2023) reported that certain cytokines, including IL-6, IL-8, and IL-22, exhibit dynamic changes, increasing and decreasing over the course of the disease. Moreover, AV patients in this study were not restricted by disease onset or duration, resulting in variability in disease stages. Similarly, Qi et al. (2025) reported that cytokine levels tend to rise during the acute phase and decline thereafter.

The lack of a significant association observed for IL-24 with AV severity may be explained by its biological role. Previous studies reporting increased IL-24 levels in inflammatory dermatoses have largely focused on intralesional measurements. The role of IL-24 in the pathophysiology of inflammatory dermatoses is thought to be mediated primarily through its influence on keratinocyte proliferation (Xu et al., 2021). Overall, these findings suggest that IL-24 likely exerts largely localized effects within the inflammatory process underlying AV.

CONCLUSION

This study did not find a significant association between serum IL-24 levels and AV severity. This finding suggests the possibility that IL-24 reflects the development and inflammatory burden of AV locally rather than systemically. This study has several limitations. First, IL-24 cytokine levels were only assessed systemically using serum samples, which may not fully represent local inflammatory activity within acne lesions. Second, several potential confounding factors could not be fully controlled for, including gender, genetic predisposition, dietary factors, psychological stress, and UV exposure, all of which can influence cytokine expression and AV severity. Future studies are needed to evaluate IL-

24 locally, through lesion tissue analysis, and systemically, through serum measurements, to provide a more comprehensive understanding of its role in AV pathophysiology. Furthermore, controlling for potential confounding variables such as gender, genetic factors, psychological stress, and UV exposure may help clarify the true relationship between cytokine levels and AV severity.

REFERENCES

- Alsulaimani, H., Kokandi, A., Khawandanh, S., Hamad, R., 2020. Severity of acne vulgaris: Comparison of two assessment methods. *Clin Cosmet Investig Dermatol* 13, 711–6. <https://doi.org/10.2147/CCID.S266320>
- Asatryan, B., Asimaki, A., Landstrom, A. P., Khanji, M. Y., Odening, K. E., Cooper, L. T., Marchlinski, F. E., Gelzer, A. R., Semsarian, C., & Reichlin, T. (2021). Inflammation and immune response in arrhythmogenic cardiomyopathy: state-of-the-art review. *Circulation*, 144(20), 1646–1655.
- Bae, I.H., Kwak, J.H., Na, C.H., Kim, M.S., Shin, B.S., Choi, H., 2024a. A Comprehensive Review of the Acne Grading Scale in 2023. *Ann Dermatol* 36, 65–73. <https://doi.org/10.5021/ad.23.094>
- Dahlan, N.H., Sitohang, I.B.S., Indriatmi, W., Wibowo, H., Enggy, L.E., 2024. Correlation between reduced IL-1 β levels in acne lesions and the decrease in acne inflammatory lesions following topical vitamin D administration: A Double-blind randomized controlled trial. *Clin Cosmet Investig Dermatol* 17, 2183–2195. <https://doi.org/10.2147/CCID.S475068>
- Damayanti, Umborowati, M.A., Ollyvia, Z.Z., Febriyana, N., 2022. The impact of acne vulgaris on the quality of life in teen patients. *Jurnal Berkala Epidemiologi* 10, 189–198. <https://doi.org/10.20473/jbe.v10i22022.189-198>
- Eichenfield, D.Z., Sprague, J., Eichenfield, L.F., et al. (2021). Management of acne vulgaris: A review. *JAMA*, 326, 2055–2067. <https://doi.org/10.1001/jama.2021.17633>
- Legiawati, L., Halim, P.A., Fitriani, M., Hikmahrachim, H.G., Lim, H.W., 2023. Microbiomes in Acne Vulgaris and Their Susceptibility to Antibiotics in Indonesia: A Systematic Review and Meta-Analysis. *Antibiotics*. <https://doi.org/10.3390/antibiotics12010145>
- Leung, A.K.C., Barankin, B., Lam, J.M., Leong, K.F., Hon, K.L. (2020). Dermatology: How to manage acne vulgaris. *Drugs Context*, 10, 1–18. <https://doi.org/10.7573/dic.2021-8-6>
- Liu, Y., Sun, Q., Xu, H., Ma, G., & Wu, P. (2023). Serum level changes of inflammatory cytokines in patients with moderate to severe acne vulgaris treated with dual-wavelength laser. *Chinese Journal of Plastic and Reconstructive Surgery*, 5(2), 47-52.
- Mitamura, Nunomura, S., Furue, M., Izuhara, K., 2020. IL-24: A new player in the pathogenesis of pro-inflammatory and allergic skin diseases. *Allergology International* 69, 405–11. <https://doi.org/10.1016/j.alit.2019.12.003>
- Qian, X., Tong, M., Zhang, T., Li, Q., Hua, M., Zhou, N., Zeng, W., 2024. IL-24 promotes atopic dermatitis-like inflammation through driving MRSA-induced allergic responses. *Protein Cell* 1, 188–210. <https://doi.org/10.1093/procel/pwae030>
- Resya, W.B., Kusumaningrum, N., Jaeri, S., Utomo, A.W., 2021. Differences in interleukin-23 serum levels towards the severity of acne vulgaris in women. *Diponegoro Medical Journal (Jurnal Kedokteran Diponegoro)* 10, 310–315. <https://doi.org/10.14710/dmj.v10i4.30029>
- Rusdy, R.S.N., Legiawati, L., Sitohang, I.B.S., Sirait, S.M.H.A.P.S., 2023. Adjuvant therapies of acne: Review of literatures. *Bali Dermatology Venereology and Aesthetic Journal* 5, 17–22. <https://doi.org/10.51559/bekrds92>

- Saiboo, A.A., Listiawan, M.Y., Sari, M., Indramaya, D.M., Murtiastutik, D., Damayanti, Anggaraeni, S., 2024. Profile of mild acne vulgaris patients at tertiary hospital at Surabaya, Indonesia. *Berkala Ilmu Kesehatan Kulit dan Kelamin* 36, 26–30. <https://doi.org/10.20473/bikk.v36.1.2024.26-30>
- Sitohang, I.B.S., Norawati, L., Yenny, S.W., Kusumawardani, A., Murlistyarini, S., Setiawan, S.V., Kekalih, A., Riany, G., Kerob, D. (2024). Effectiveness and safety of a dermocosmetic cream as an adjunct to adapalene for mild and moderate acne in Indonesia: Results of a multicenter randomized controlled study. *Clin Cosmet Investig Dermatol* 17, 2283–2296. <https://doi.org/10.2147/CCID.S474331>
- Smith, S., Lopez, S., Kim, A., Kasteri, J., Olumuyide, E., Punu, K., de la Parra, C., Sauane, M., 2023. Interleukin 24: Signal transduction pathways. *Cancers (Basel)* 15, 1–13. <https://doi.org/10.3390/cancers15133365>
- Taghdiri, A. (2024). Inflammation and arrhythmogenesis: a narrative review of the complex relationship. *International Journal of Arrhythmia*, 25(1), 4.
- Tasneem, T., Begum, A., Chowdhury, M.R.K., Rahman, S., Macassa, G., Manzoor, J., Rashid, M., 2023. Effects of acne severity and acne-related quality of life on depressive symptoms among adolescents and young adults: a cross-sectional study in Bangladesh. *Front Psychol* 14, 1–9. <https://doi.org/10.3389/fpsyg.2023.1153101>
- Toskas, A., Miliias, S., Papamitsou, T., Meditskou, S., Kamperidis, N., Sioga, A., 2024. The role of IL-19, IL-24, IL-21 and IL-33 in intestinal mucosa of inflammatory bowel disease: A narrative review. *Arab Journal of Gastroenterology* 26, 9–17. <https://doi.org/10.1016/j.ajg.2024.01.002>
- Vasam, M., Korutla, S., Bohara, R.A., et al. (2023). Acne vulgaris: A review of the pathophysiology, treatment, and recent nanotechnology-based advances. *Biochem Biophys Rep*, 36, 1–8. <https://doi.org/10.1016/j.bbrep.2023.101578>
- Vollenberg, R., Schütte-Nütgen, K., Strauss, M., Trebicka, J., Fischer, J., & Tepaspe, P. R. (2025). IL-24 in COVID-19 Patients: Correlations with Disease Progression. *International journal of molecular sciences*, 26(17), 8403. <https://doi.org/10.3390/ijms26178403>
- Vu, Y.H., Furue, M., Minardo, A., 2021. The role of interleukin-24 in atopic dermatitis. *Exploration of Immunology* 1, 4–15. <https://doi.org/10.37349/ei.2021.00002>
- Xu, X., Prens, E., Florencia, E., Leenen, P., Boon, L., Asmawidjaja, P., Mus, A.M., Lubberts, E., 2021. Interleukin-17A drives IL-19 and IL-24 expression in skin stromal cells regulating keratinocyte proliferation. *Front Immunol* 12, 1–10. <https://doi.org/10.3389/fimmu.2021.719562>
- Zhang, H., & Dhalla, N. S. (2024). The role of pro-inflammatory cytokines in the pathogenesis of cardiovascular disease. *International Journal of Molecular Sciences*, 25(2), 1082.
- Zhong, Y., Zhang, X., Chong, W.P., 2022. Interleukin-24 immunobiology and its roles in inflammatory diseases. *Int J Mol Sci* 23, 1–10. <https://doi.org/10.3390/ijms23020627>