



# Serum Levels of TNF- $\alpha$ , IL-10 and Albumin in Female Patients with Post-Surgical Wound Infection in Asaba Delta State, Nigeria

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## Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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## ABSTRACT

Post-operative wound infections (POWIs), sometimes referred to as post-surgical wound infections (PSWIs), are a common complication following surgery. Surgeries frequently elicit a variety of immunological responses subsequent to tissue damage and incision which may hinder wound healing and infection resolution leading to poor patient outcome. This cross-sectional study assessed the serum levels of TNF- $\alpha$ , IL-10 and albumin in female patients with post-surgical wound infection in Asaba Delta State, Nigeria. Twenty-five (25) patients with PSWIs and 25 apparently healthy individuals (control group) were recruited by random sampling method. Four millilitres (4 ml) of venous blood samples were collected for the determination of serum TNF- $\alpha$ , IL-10 and albumin levels. TNF- $\alpha$  and IL-10 levels were estimated with a sandwich enzyme-linked immunosorbent assay, whereas serum albumin was assessed with the Bromocresol green (BCG) method. The data obtained was analyzed using an independent t-test and Pearson correlation, with a p-value of <0.05 indicating statistical significance. The mean serum TNF- $\alpha$  (143.44  $\pm$ 7.35 Vs 37.32  $\pm$ 8.92; p = 0.001) and IL-10 (27.52  $\pm$ 7.77 Vs 17.12  $\pm$ 6.23; p = 0.001) levels were significantly higher while serum albumin level was significantly lower (34.14  $\pm$ 5.43 Vs 40.19  $\pm$ 3.38; p = 0.001) in the female patients with PSWIs than in the control group. However, no significant correlation was observed between the levels of TNF- $\alpha$  Vs albumin and IL-10 Vs albumin (p>0.05). The elevated levels of pro-inflammatory cytokine TNF- $\alpha$  may lead to adverse patient outcomes by hindering wound healing and slowing infection resolution.

**Keywords:** POWIs; TNF- $\alpha$ ; IL-10; albumin; patients.

## 1. INTRODUCTION

Post-operative wound infections (POWIs), sometimes referred to as postsurgical wound infections (PSWIs), are a common complication following surgery, characterized by complex and multifaceted pathophysiology (Zabaglo *et al.*, 2025). Post-operative wound infection (POWIs) is still a leading cause of morbidity and death for patients having surgery, even with improvements in surgical techniques and a better understanding of the pathophysiology of wound infection (Kallakuri *et al.*, 2024). The prevalence of POWIs is still rising in many nations, communities, and hospitals, albeit it varies greatly (Ehiaghe *et al.*, 2025b; Kallakuri *et al.*, 2024).

Surgeries frequently elicit a variety of immunological responses subsequent to tissue damage and incision (Weledji, 2021). This include the secretion of cytokines, stress responses, and acute phase proteins, which can be detrimental when excessive (Chidambaran *et al.*, 2024; Hsing and Wang, 2015). Cytokines represent a viable therapeutic target, as they regulate all phases of wound healing, and abnormalities in cytokine production can lead to inflammatory non-healing wounds (Wong *et al.*, 2025). Cytokines are soluble molecular entities synthesized by inflammatory cells. They can be broadly classified as either pro-inflammatory cytokines (e.g., interleukins (IL)-1, 2, 8, 12; tumor necrosis factor  $\alpha$  (TNF- $\alpha$ ), interferon  $\gamma$  (IFN $\gamma$ ),

etc.), or anti-inflammatory cytokines e.g., transforming growth factor beta (TGF $\beta$ ), IL-4, IL-10, IL-13 while others, like IL-6, can be both (Chidambaran *et al.*, 2024).

TNF- $\alpha$  attracts pro-inflammatory cells including neutrophils, macrophages, and fibroblasts to the wound site, where they assist remove debris and pathogens (Wong *et al.*, 2025; Jang *et al.*, 2021), thereby facilitating wound healing or resolution under physiological state. However, exaggerated TNF- $\alpha$  responses can culminate in failed wound infection resolution (Choy *et al.*, 2023; Jang *et al.*, 2021).

Interleukin 10 (IL-10) is an important anti-inflammatory cytokine produced mainly by the CD4+ T cells although other leukocytes such as neutrophils, B cells, dendritic cells, natural killer cells, and macrophages also secrete it as well (Sun *et al.*, 2020). Its primary functions include anti-inflammatory, inhibitory, or self-regulating, as IL-10 appears to be a potent negative feedback regulator that influences inflammation management and resolution (Al-Qahtani *et al.*, 2024; Steen *et al.*, 2020). By suppressing the activity of macrophages and dendritic cells, IL-10 directly shuts down the inflammatory immune response (Cocea and Stoica, 2024; Saraiva *et al.*, 2020; Mittal *et al.*, 2015). It also indirectly does so by restricting T cell activation, differentiation, and effector function and encouraging peripheral tolerance (Saraiva *et al.*,

2020; Mittal et al., 2015). Excessive IL-10 production or signaling can suppress host's effective inflammatory responses, induce tolerance and immune escape, and favor microbial persistence, which can lead to the establishment of chronic or latent infections (Carlini et al., 2023; Rojas et al., 2017; Iyer and Cheng, 2012). In contrast, during acute infections, IL-10 limits the magnitude of the immune responses, preventing excessive inflammation and protecting tissues from immune-mediated damage by allowing inflammation resolution when the pathogen is cleared (Carlini et al., 2023; Rojas et al., 2017).

Nutritional deficiency has been associated with an increased risk of wound infections (Tfaily et al., 2022) and serum albumin level can be used to determine an individual's nutritional and inflammatory condition (Keller, 2019). Hypoalbuminemia has been identified as one of the risk factors for surgical site infections (SSIs) in surgery populations (Mostafa et al., 2024; Ryan et al., 2018). Hypoalbuminemia, on the other hand, can increase the expression of TNF- $\alpha$ , C-Reactive Protein (CRP) and several interleukins, all known to be acute-phase proteins that promote tissue damage (Cooper et al., 2004; Yildirim et al., 2004). Albumin influences wound healing by increasing the transcription of tissue-forming proteins, which in turn triggers the NF $\kappa$ B pathway and speeds up the healing process (Utariani et al., 2020). Identifying risk factors for surgical site infections early can improve post-operative outcomes, minimize re-admission rates (He et al., 2019; Fong et al., 2014), and reduce treatment costs by 23.8% (Javed et al., 2019).

In view of all these, it has become pertinent to evaluate the serum levels of TNF- $\alpha$ , IL-10 and albumin circulating among female patients with post-surgical wound infection in Asaba Delta State, Nigeria.

## 2. MATERIALS AND METHODS

### 2.1 Study Site

The study was conducted at the Federal Medical Center in Asaba, Delta State, Nigeria.

### 2.2 Study Design

This cross-sectional study examined the serum levels of tumor necrosis factor-alpha, interleukin-

10, and albumin in female patients with post-surgical wound infection in Asaba, Nigeria.

### 2.3 Study Population

Simple random sampling was used to select 50 participants for the study. The test group consisted of 25 female patients with post-surgical wound infection, while the control group included 25 apparently healthy participants.

### 2.4 Sample Size and Sample Size Calculation

The sample size (N) was calculated using prevalence from previous studies on the prevalence of post-surgical wound infections globally which was found to be 2.5% (Mengistu et al., 2023) according to the sample size calculation formula described by Daniel and Cross (1999).

$$N = \frac{Z^2 P(1 - P)}{D^2}$$

N = required sample size

Z = confidence level at 95% (standard value of 1.96)

P = estimated prevalence of post-surgical wound infections globally which was found to be 2.5% (Mengistu et al., 2023).

D = margin of error at 5% (standard value = 0.05)

$$N = \frac{1.96^2 0.025(1 - 0.025)}{0.05^2}$$

$$\frac{3.8416 \times 0.025(0.975)}{0.0025}$$

N = 37 minimum sample size

Therefore, a minimum of 50 participants was used for this study.

### 2.5 Inclusion Criteria

Female patients with confirmed cases of post-surgical wound infection as well as healthy female participants who provided informed consent were included for this study.

### 2.6 Exclusion Criteria

Female patients with post-surgical wound infection and apparently healthy female individuals without post-surgical wound infection

who did not give their informed consent were excluded from this study.

### 2.7 Sample Collection

Each participant provided five milliliters (5 ml) of venous blood into a plain container for cytokine and albumin analysis. Blood samples were allowed to clot before being retracted and centrifuged for 10 minutes at 4000 rpm. Serum samples were separated and kept frozen at -20°C until analysis.

### 2.8 Estimation of Cytokine Levels

The levels of tumor necrosis factor-alpha and interleukin-10 were determined using the sandwich enzyme-linked immunosorbent assay technique.

### 2.9 Estimation of Serum Albumin

This was determined using the Bromocresol green method (BCG), as described by Doumas and Watson (1971) and cited by Okpogba et al. (2021).

### 2.10 Statistical Analysis

The data was analyzed using SPSS 20.0 and represented as mean ± standard deviation. The independent t-test and Pearson correlation were employed to determine the statistical difference and association between variables. A P value of < 0.05 was considered statistically significant.

## 3. RESULTS

The mean serum TNF-α level was significantly higher in the female patients with post-surgical wound infections than in the control group (143.44 ±7.35 Vs 37.32 ±8.92; p = 0.001). in like manner, the mean serum IL-10 level was significantly higher in the female patients with post-surgical wound infections compared to the

control group (27.52 ±7.77 Vs 17.12 ±6.23; p = 0.001).

However, there was a statistically significant decrease in the mean serum albumin level observed in the female patients with post-surgical wound infections than in the control group (34.14 ±5.43 Vs 40.19 ±3.38; p = 0.001), (see table 1).

Furthermore, there was no significant correlation observed between the levels TNF-α and albumin (r-value = -0.154; p = 0.470) as well as between IL-10 and albumin levels (r-value = 0.271; p = 0.190) in the study participants (see table 2).

## 4. DISCUSSION

The present study noted a significantly higher mean serum TNF-α level in the female patients with post-surgical wound infections than in the control group. Elevated TNF-α levels indicate a pro-inflammatory response linked to chronic illnesses and infections (Chen et al., 2017). This finding aligns with the reports of other similar studies (Ehiaghe et al., 2025a; Ehiaghe et al., 2025b). Exaggerated TNF-α responses may culminate in failed wound infection resolution (Choy et al., 2023).

Furthermore, the higher IL-10 level observed in the female patients with post-surgical wound infections show an attempt by the body to moderate the excessive inflammatory responses, a phenomenon commonly observed in chronic inflammation, where anti-inflammatory cytokines act to avoid tissue damage. IL-10 limits the magnitude of the immune responses, preventing excessive inflammation and protecting tissues from immune-mediated damage by allowing inflammation resolution when the pathogen is cleared (Carlini et al., 2023).

**Table 1. Levels of serum TNF-α, IL-10 and albumin circulating among female patients with post-surgical wound infection and apparently healthy individuals (MEAN ±SD)**

Parameter	Group	N	MEAN ±SD	T value	P value
TNF-α	TEST	25	143.44 ±7.35	45.93	0.001
	CONTROL	25	37.32 ±8.92		
IL-10	TEST	25	27.52 ±7.77	5.22	0.001
	CONTROL	25	17.12 ±6.23		
Albumin	TEST	25	34.14 ±5.43	4.73	0.001
	CONTROL	25	40.19 ±3.38		

\*Statistically significant = P<0.05; TNF-α = Tumour necrosis factor- alpha, IL-10 = Interleukin -10.

**Table 2. The correlation between the levels of TNF- $\alpha$ , IL-10 and albumin in the study population**

Parameters	r-value	p-value
<b>TNF<math>\alpha</math> Vs Albumin</b>	-0.154	0.470
<b>IL-10 Vs Albumin</b>	0.271	0.190

\*Statistically significant at  $p < 0.05$ 

Nevertheless, elevating IL-10 levels can provide some anti-inflammatory buffering, but its efficiency may be limited by pro-inflammatory cytokines like TNF- $\alpha$ , leading to an unsustainable immunological balance. Thus, increased inflammatory response shown in our current investigation may hamper infection resolution, eventually leading to poor treatment outcome in these patients.

In the present study, the mean serum albumin level was found to be significantly lower in the female patients with post-surgical wound infection compared to the control group. This result agrees with several studies that found significantly lower serum albumin levels in PSWIs patients (Choudhary *et al.*, 2024; Sultana *et al.*, 2024; Llombart *et al.*, 2023; Singh *et al.*, 2023; He *et al.*, 2020). Hypoalbuminemia, an indicator of malnutrition and illness, has been shown to increase the likelihood of poor post-operative outcomes, especially reduced wound healing (Sultana *et al.*, 2024). In addition to increasing albumin production, inflammatory conditions can enhance albumin breakdown, which can result in hypoalbuminemia (Weaving *et al.*, 2016). Interstitial oedema results from a decrease in oncotic pressure caused by a decrease in serum albumin levels, which might impede the healing and recovery process.

## 5. CONCLUSION

This study found that female patients with post-surgical wound infections had significantly higher mean serum TNF- $\alpha$  and IL-10 levels, as well as lower mean serum albumin levels. Findings presented in the study suggest that higher levels of the pro-inflammatory cytokine TNF  $\alpha$ , may adversely impact wound healing and impede resolution of infection.

## CONSENT AND ETHICAL APPROVAL

The ethical committee of the Federal Medical Centre in Asaba, Delta State, approved the study

before it commenced. The informed consent of all involved participants was sought and gained.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

- Al-Qahtani, A.A., Alhamlan, F.S., & Al-Qahtani, A.A. (2024). Pro-Inflammatory and Anti-Inflammatory Interleukins in Infectious Diseases: A Comprehensive Review. *Tropical Medicine and Infectious Disease*, 9(1), 13. <https://doi.org/10.3390/tropicalmed9010013>
- Carlini, V., Noonan, D.M., Abdalalem, E., Goletti, D., Sansone, C., Calabrone, L., Albini, A. (2023). The multifaceted nature of IL-10: regulation, role in immunological homeostasis and its relevance to cancer, COVID-19 and post-COVID conditions. *Frontiers in Immunology*, 14. <https://doi.org/10.3389/fimmu.2023.1161067>
- Chen, L., Deng, H., Cui, H., Fang, J., Zuo, Z., Deng, J., Li, Y., Wang, X., & Zhao, L. (2017). Inflammatory responses and inflammation-associated diseases in organs. *Oncotarget*, 9(6), 7204–7218. <https://doi.org/10.18632/oncotarget.23208>
- Chidambaran, V., Duan, Q., Pilipenko, V., Glynn, S. M., Sproles, A., Martin, L. J., Lacagnina, M. J., King, C. D., & Ding, L. (2024). The Role of Cytokines in Acute and Chronic Postsurgical Pain in Pediatric Patients after

- Major Musculoskeletal Surgeries. *medRxiv : the preprint server for health sciences*, 2024.03.27.24304974. <https://doi.org/10.1101/2024.03.27.24304974>
- Choudhary, S., Shaikh, A.I., Kansal, A., Patidar, N. (2024). Role of Hypocholesterolemia and Hypoalbuminemia as a predictor of Surgical Site. *Journal of Cardiovascular Disease Research*, 15(7), 3190-3206.
- Choy, E., Bykerk, V., Lee, Y. C., van Hoogstraten, H., Ford, K., Praestgaard, A., Perrot, S., Pope, J., & Sebba, A. (2023). Disproportionate articular pain is a frequent phenomenon in rheumatoid arthritis and responds to treatment with sarilumab. *Rheumatology (Oxford, England)*, 62(7), 2386–2393. <https://doi.org/10.1093/rheumatology/keac659>
- Cocea, A.-C., & Stoica, C. I. (2024). Interactions and Trends of Interleukins, PAI-1, CRP, and TNF- $\alpha$  in Inflammatory Responses during the Perioperative Period of Joint Arthroplasty: Implications for Pain Management—A Narrative Review. *Journal of Personalized Medicine*, 14(5), 537. <https://doi.org/10.3390/jpm14050537>
- Cooper, B. A., Penne, E. L., Bartlett, L. H., & Pollock, C. A. (2004). Protein malnutrition and hypoalbuminemia as predictors of vascular events and mortality in ESRD. *American Journal of Kidney Diseases: the official journal of the National Kidney Foundation*, 43(1), 61–66. <https://doi.org/10.1053/j.ajkd.2003.08.045>
- Daniel, W.W., & Cross, C. L. (1999). Determination of Sample Size for Estimating Proportions. *Biostatistics: A Foundation for Analysis in the Health Sciences*, 8, 189-190.
- Doumas, B.T., Watson, W.A., & Biggs, H.G. (1971). Albumin standards and the measurement of serum albumin with bromocresol green. *Clinica Chimica Acta; International Journal of Clinical Chemistry*, 31(1), 87–96. [https://doi.org/10.1016/0009-8981\(71\)90365-2](https://doi.org/10.1016/0009-8981(71)90365-2)
- Ehiaghe, F.A., Ogonna, J., Ehiaghe, I.J., Erhunmwunse, R.U., Anyaegbu, I.H., Chukwuanukwu, R.C., Onyenekwe, C.C., Osakue, O.N., Okafoanyali, O., & Ogbodo, E.C. (2025a). Elevated Levels of Interferon Gamma, Interleukin-4, Neutrophil-Lymphocyte Ratio and Platelet-Lymphocyte Ratio As Biomarkers of Post-Surgical Wound Infections Amongst Female Patients in Nnewi, Nigeria. *Asian Journal of Medicine and Health*, 23(4), 109-114. <https://doi.org/10.9734/ajmah/2025/v23i41211>.
- Ehiaghe, J.I., Ogbemor, A.O., Asiriwuwa, I., Erhunmwunse, R.U., Ayanlere, KM., Amengialue, O.O, Ehiaghe F.A., & Ogbodo, E.C. (2025b). Effect of Misuse of Antibiotics on Cytokine Patterns and Antibiogram of Bacteria Isolates from Surgical Site Infection in Benin City, Edo State, Nigeria. *Asian Journal of Medicine and Health*, 23(4), 153-162. <https://doi.org/10.9734/ajmah/2025/v23i41216>.
- Fong, Z.V., Ferrone, C.R., Thayer, S.P., Wargo, J.A., Sahara, K., Seefeld, K.J., Warshaw, A.L., Lillemoe, K.D., Hutter, M.M., & Fernández-Del Castillo, C. (2014). Understanding hospital readmissions after pancreaticoduodenectomy: can we prevent them?: a 10-year contemporary experience with 1,173 patients at the Massachusetts General Hospital. *Journal of Gastrointestinal Surgery: official journal of the Society for Surgery of the Alimentary Tract*, 18(1), 137–145. <https://doi.org/10.1007/s11605-013-2336-9>
- Hsing, C.H., & Wang, J.J. (2015). Clinical implication of perioperative inflammatory cytokine alteration. *Acta Anaesthesiologica Taiwanica : official journal of the Taiwan Society of Anesthesiologists*, 53(1), 23–28. <https://doi.org/10.1016/j.aat.2015.03.002>
- He, Y., Xiao, J., Shi, Z., He, J., & Li, T. (2019). Supplementation of enteral nutritional powder decreases surgical site infection, prosthetic joint infection, and readmission after hip arthroplasty in geriatric femoral neck fracture with hypoalbuminemia. *Journal of Orthopaedic Surgery and Research*, 14(1), 292. <https://doi.org/10.1186/s13018-019-1343-2>
- He, Z., Zhou, K., Tang, K., Quan, Z., Liu, S., & Su, B. (2020). Perioperative hypoalbuminemia is a risk factor for wound complications following posterior lumbar interbody fusion. *Journal of Orthopaedic Surgery and Research*, 15(1), 538. <https://doi.org/10.1186/s13018-020-02051-4>
- Iyer, S.S., & Cheng, G. (2012). Role of interleukin 10 transcriptional regulation in inflammation and autoimmune disease. *Critical Reviews in Immunology*, 32(1), 23–63.

- <https://doi.org/10.1615/critrevimmunol.v32.i1.30>
- Jang, D.I., Lee, A.H., Shin, H.Y., Song, H.R., Park, J.H., Kang, T.B., Lee, S.R., & Yang, S.H. (2021). The Role of Tumor Necrosis Factor Alpha (TNF- $\alpha$ ) in Autoimmune Disease and Current TNF- $\alpha$  Inhibitors in Therapeutics. *International Journal of Molecular Sciences*, 22(5), 2719. <https://doi.org/10.3390/ijms22052719>
- Javed, A.A., Teinor, J., Wright, M., Ding, D., Burkhart, R.A., Hundt, J., Cameron, J.L., Makary, M.A., He, J., Eckhauser, F.E., Wolfgang, C.L., & Weiss, M.J. (2019). Negative Pressure Wound Therapy for Surgical-site Infections: A Randomized Trial. *Annals of Surgery*, 269(6), 1034–1040. <https://doi.org/10.1097/SLA.0000000000003056>
- Kallakuri, K., Suprada, K., Bahadur, B. R., & Rao, G. (2024). Post operative wound infection: a descriptive study. *International Journal of Reproduction, Contraception, Obstetrics and Gynecology*, 13(7), 1731–1734. <https://doi.org/10.18203/2320-1770.ijrcog20241767>
- Keller, U. (2019). Nutritional Laboratory Markers in Malnutrition. *Journal of Clinical Medicine*, 8(6), 775. <https://doi.org/10.3390/jcm8060775>
- Llombart, R., Mariscal, G., Barrios, C., de la Rubia Ortí, J. E., & Llombart-Ais, R. (2023). The Impact of Hypoalbuminemia on Postoperative Complications in Patients Undergoing Shoulder Arthroplasty: A Meta-Analysis. *The Journal of Nutrition, Health & Aging*, 27(12), 1248–1254. <https://doi.org/10.1007/s12603-023-2050-6>
- Mengistu, D.A., Alemu, A., Abdulkadir, A.A., Mohammed Husen, A., Ahmed, F., Mohammed, B., & Musa, I. (2023). Global Incidence of Surgical Site Infection Among Patients: Systematic Review and Meta-Analysis. *Inquiry: a journal of medical care organization, provision and financing*, 60, 469580231162549. <https://doi.org/10.1177/00469580231162549>
- Mittal, S.K., Cho, K.J., Ishido, S., & Roche, P.A. (2015). Interleukin 10 (IL-10)-mediated Immunosuppression: March-I induction regulates antigen presentation by macrophages but not dendritic cells. *The Journal of Biological Chemistry*, 290(45), 27158–27167. <https://doi.org/10.1074/jbc.M115.682708>
- Mostafa, O.E., Al-Allaf, O., Tahir, M., Hossain, F., & Blackwell, J. (2024). Do Hypoalbuminaemia Increase the Risk of Surgical Site Infection in Neck of Femur Fracture Patients: A Systematic Review and Meta-Analysis. *Cureus*, 16(5), e61372. <https://doi.org/10.7759/cureus.61372>
- Okpogba, A.N., Odeghe, O.B., Ogbodo, E.C., Okwara, N.A., Izuchukwu, E.C.O., Ejovi, O., Gbodo, E.A., & Obi-Ezeani, C.N. (2021). Effect of occupational exposure to heavy metals on the liver functions in persons working in cable manufacturing factory in Nnewi. *IP International Journal of Forensic Medicine and Toxicological Science*, 6(1), 20-27.
- Rojas, J.M., Avia, M., Martín, V., & Sevilla, N. (2017). IL-10: A Multifunctional Cytokine in Viral Infections. *Journal of Immunology Research*, 2017, 6104054. <https://doi.org/10.1155/2017/6104054>
- Ryan, S.P., Politzer, C., Green, C., Wellman, S., Bolognesi, M., & Seyler, T. (2018). Albumin Versus American Society of Anesthesiologists Score: Which Is More Predictive of Complications Following Total Joint Arthroplasty?. *Orthopedics*, 41(6), 354–362. <https://doi.org/10.3928/01477447-20181010-05>
- Saraiva, M., Vieira, P., & O'Garra, A. (2020). Biology and therapeutic potential of interleukin-10. *The Journal of Experimental Medicine*, 217(1), e20190418. <https://doi.org/10.1084/jem.20190418>
- Singh, R.K., Shakya, P., Bhutani, S. (2023). Role of serum cholesterol and albumin levels as a risk factor for developing surgical site infection. *International Journal of Academic Medicine and Pharmacy*, 5 (2), 1271-1278.
- Steen, E.H., Wang, X., Balaji, S., Butte, M. J., Bollyky, P.L., & Keswani, S.G. (2020). The Role of the Anti-Inflammatory Cytokine Interleukin-10 in Tissue Fibrosis. *Advances in Wound Care*, 9(4), 184–198. <https://doi.org/10.1089/wound.2019.1032>
- Sultana, M., Sultana, N., Mostafa, B., Khair, A.B., Islam, S., & Jannat, F. (2024). Association of Serum Albumin Level with Wound Healing after Caesarean Section. *Scholars International Journal of Obstetrics and Gynecology*, 7(6): 263-272
- Sun, Z.L., Feng, Y., Zou, M.L., Zhao, B.H., Liu, S.Y., Du, Y., Yu, S., Yang, M.L., Wu, J.J., Yuan, Z.D., Lv, G.Z., Zhang, J.R., & Yuan, F.L. (2020). Emerging Role of IL-10 in

- Hypertrophic Scars. *Frontiers in Medicine*, 7, 438.  
<https://doi.org/10.3389/fmed.2020.00438>
- Tfaily, M.A., Ghanem, P., Farran, S.H., Dabdoub, F., & Kanafani, Z.A. (2022). The role of preoperative albumin and white blood cell count in surgical site infections following whipple surgery. *Scientific Reports*, 12(1), 19184. <https://doi.org/10.1038/s41598-022-21849-2>
- Utariani, A., Rahardjo, E., & Perdanakusuma, D. S. (2020). Effects of Albumin Infusion on Serum Levels of Albumin, Proinflammatory Cytokines (TNF- $\alpha$ , IL-1, and IL-6), CRP, and MMP-8; Tissue Expression of EGRF, ERK1, ERK2, TGF- $\beta$ , Collagen, and MMP-8; and Wound Healing in Sprague Dawley Rats. *International Journal of Inflammation*, 2020, 3254017.  
<https://doi.org/10.1155/2020/3254017>
- Weaving, G., Batstone, G.F., Jones, R.G. (2016). Age and sex variation in serum albumin concentration: An observational study. *Annals of Clinical Biochemistry*, 53 Pt 1, 106–111.
- Weledji, E.P. (2021). The role of cytokines in enhanced recovery after surgery. *International Journal of Surgery: Short Reports*, 2021;6(1), pe21.  
<https://doi.org/10.1097/SR9.0000000000000021>
- Wong, R.S.Y., Tan, T., Pang, A.S.R., Srinivasan, D.K. (2025). The role of cytokines in wound healing: from mechanistic insights to therapeutic applications. *Exploration of Immunology*, 5, 1003183.  
<https://doi.org/10.37349/ei.2025.1003183>
- Yildirim, K., Karatay, S., Melikoglu, M. A., Gureser, G., Ugur, M., & Senel, K. (2004). Associations between acute phase reactant levels and disease activity score (DAS28) in patients with rheumatoid arthritis. *Annals of Clinical and Laboratory Science*, 34(4), 423–426.
- Zabaglo, M., Leslie, S.W., Sharman, T. (2025). Postoperative Wound Infections. In: StatPearls Treasure Island (FL): StatPearls Publishing; 2025 Jan-. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK560533/>

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