Journal of Young Pharmacists, 2026; 18(2):260-266.
https://www.jyoungpharm.org

Review Article

Monoclonal Antibody Therapy in Rheumatoid Arthritis: A Paradigm Shift Toward Precision Immunotherapy

Kannaiyan Suria Prabha*, Joshua Albert, Daniel Catherine Grace, Selva Kumar Gokul, Sankar Kalai Kumar, Ganesan Shyam Sundar, Ravichandran Udaya Kumar

Department of Pharmaceutics, Chettinad School of Pharmaceutical Sciences, Chettinad Academy of Research and Education, Chettinad Hospital and Research Institute, Chettinad Health City, Rajiv Gandhi Salai (OMR), Kelambakkam, Chennai, Tamil Nadu, INDIA.

ABSTRACT

Rheumatoid Arthritis (RA) is a chronic autoimmune inflammatory condition that is marked by sustained synovial inflammation, joint destruction, and extra-articular complications. While methotrexate and other conventional synthetic Disease-Modifying Antirheumatic Drugs (csDMARDs) continue to be the first line of treatment, the majority of patients' poor response to these drugs has led to the development of monoclonal Antibody (mAb) therapies that target distinct immune mediators. This review critically examines the therapeutic development, mechanisms, clinical efficacy, and safety profiles of monoclonal Antibodies (mAbs) in the treatment of RA. A comprehensive literature search was conducted using keywords related to "rheumatoid arthritis," "biologic DMARDs," and "monoclonal antibodies" under studies published between 2010 and 2025 in the PubMed, Scopus, and Web of Science databases. Mechanistic selectivity, treatment efficacy, and tolerability were examined for major monoclonal antibodies, including TNF-α and IL-6 inhibitors, B-cell-depleting agents, and T-cell co-stimulation blockers. New biologics like bispecific antibodies, nanobodies, and antibody-drug conjugates are also reviewed in relation to precision immunotherapy. Clinical and real-world evidence proves mAb therapy significantly enhances disease remission, functional recovery, and patient-reported outcomes over csDMARDs, although infection risk and high cost are still issues. Further developments in pharmacogenomics, biomarker discovery, and biosimilars are anticipated to maximize individualized therapy and improve access. Together, mAb-based treatments represent a paradigm shift from empirical immunosuppression to precision-driven immunotherapy in RA.

Keywords: Abatacept, Anti-TNF, CSDMARDS, IL-6 inhibitors, mAbs, RA, Rituximab.

Correspondence:
Dr. Kannaiyan Suria Prabha
Chettinad School of Pharmaceutical Sciences, Chettinad Academy of Research and Education, Chettinad Hospital and Research Institute, Chettinad Health City, Rajiv Gandhi Salai (OMR), Kelambakkam, Chennai-603103, Tamil Nadu, INDIA.
Email: suriaprabha20july@gmail.com

Received: 06-01-2026;
Revised: 27-02-2026;
Accepted: 14-04-2026.

INTRODUCTION

RA is a systemic autoimmune disorder that is marked by ongoing synovial inflammation, pannus formation, and bone and cartilage progressive destruction with resulting pain, disability, and systemic complications. Traditional synthetic Disease-Modifying Antirheumatic Drugs (csDMARDs), especially methotrexate, are still first-line treatment and are of significant value in most patients but often relapse when tapered or stopped, the indication being for more long-lasting forms of treatment (O'Neil *et al*., 2024; Lillegraven *et al*., 2023). The pathogenesis of RA is characterized by intricate immune-cytokine interactions involving proinflammatory mediators like Tumor Necrosis Factor-alpha (TNF-α), Interleukin-1 (IL-1), and Interleukin-6 (IL-6), along with activated B and T lymphocytes, that cause chronic inflammation and promote joint destruction. With advances in molecular immunology, biologic Disease-Modifying Antirheumatic Drugs (bDMARDs) that specifically target these pathways have been developed. Drugs blocking TNF and IL-6 signaling, B-cell depletion, or T-cell co-stimulation have dramatically enhanced disease activity and radiographic response (Smolen *et al*., 2018).

The development of mAb therapy has thus been a paradigm shift from non-specific immunosuppression to precision immunomodulation. By targeting crucial pathogenic mediators, mAbs improve therapeutic efficacy with reduced off-target effects. However, continued concerns over infection risk, immunogenicity, and expensive treatment still limit their universal use. This review is a critical analysis of mAb therapy in RA, covering the immunopathological basis for their use, actions, clinical activity, safety profile, and roles of pharmacogenomics and biomarker-directed strategies. It also discusses newer biologics and antibody-engineering technologies that might further define precision immunotherapy and extend accessibility to patients with refractory or challenging-to-treat disease.

OPEN ACCESS

Manuscript TECHNOMEDIA

DOI: 10.5530/jyp.20260217

Publishing Partner : Manuscript Technomedia. [www.mstechnomedia.com]

METHODOLOGY

A systematic review of the literature was conducted to assess mAb therapies in RA. Pertinent studies were retrieved from PubMed, Scopus, and Web of Science, as well as guideline reports of the American College of Rheumatology (ACR) and European Alliance of Associations for Rheumatology (EULAR). The literature search employed the terms "rheumatoid arthritis," "monoclonal antibodies," "biologic DMARDs," "TNF inhibitors," "IL-6 inhibitors," and "rituximab," in English-language publications through July 2025. Randomized controlled trials, systematic reviews, and meta-analyses were prioritized with observational and real-world studies added for contextualization. Extracted information regarding mechanisms, efficacy, safety, biosimilars, and future trends was synthesized into a clinical overview of integration.

Immunopathogenesis of RA

RA results from intricate interactions between innate and adaptive immunity, perpetuating chronic synovial inflammation, autoantibody generation, and progressive cartilage and bone erosions. Innate cells such as macrophages and dendritic cells recognize citrullinated antigens and secrete pro-inflammatory cytokines (TNF-α, IL-1β, IL-6), stimulating synovial fibroblasts and osteoclasts and inducing pannus formation (Rufino *et al.*, 2024). A defining feature of RA is the development of pannus tissue in the synovium as illustrated in Figure 1. Adaptive immunity has $CD4^+$ T helper subsets, such as Th1 and Th17, which produce IFN-γ, IL-17A, IL-21, and IL-23 and promote inflammation and osteoclast differentiation, while Tregs and Th2 subsets are impaired, disrupting immune regulation. B cells contribute through autoantibody production (RF, ACPA), antigen presentation, and cytokine release. Additional mediators, including GM-CSF, IL-7, IL-18, IL-33, and type I interferons, amplify and sustain RA inflammation (Kondo *et al.*, 2021).

Role of TNF-A, IL-6, AND B-CELL Activation in Disease Progression

Increased levels of proinflammatory cytokines, especially TNF-α and IL-6, along with ectopic B-cell activation, are major pathogenic mechanisms driving RA and several chronic inflammatory disorders. TNF-α, a master mediator of the immune response, induces the NF-κB signaling cascade to drive the transcription of inflammatory genes and the survival and differentiation of B cells. Likewise, secreted by a variety of immune cell sources, IL-6 acts as a highly efficacious growth and differentiation factor for B cells by driving the generation of plasma cells and the increase of antibody secretion (Yu *et al.*, 2025). The sustained overexpression of these cytokines creates the inflammatory microenvironment that drives ectopic lymphoid neogenesis and autoantibody production, further driving synovial inflammation and joint destruction. Blockade of the signaling of TNF-α and IL-6 has proven to have marked effects in the regulation of the immune response and the reduction of clinical features in RA patients. An overall picture of the relationship between the signaling of cytokines and the activation of B cells is therefore important for the further discovery of therapeutic initiatives that look towards the diminution of disease progression and the long-term clinical result (Jain *et al.*, 2025).

Evolution of mAbs Therapy in RA

The development of mAb therapy for RA began in the 1970s with murine antibodies generated *via* hybridoma technology (Köhler and Milstein, 1975). Clinical application emerged in the 1990s with TNF-α inhibitors initially infliximab, followed by etanercept and adalimumab demonstrating that cytokine blockade could alleviate symptoms and slow radiographic progression. Subsequent generations of chimeric, humanized, and fully human mAbs reduced immunogenicity, while newer targets such as IL-6 and B cells (e.g., rituximab) expanded therapeutic options. More recently, treatment strategies have shifted toward earlier, aggressive use of biologic DMARDs (bDMARDs), biomarker-guided patient stratification, and optimization of mAb formats to enhance efficacy and safety (Domańska-Poboża and Wisłowska, 2025).

Conventional synthetic DMARDs (csDMARDs), particularly methotrexate, remain the initial "anchor" therapy. Patients who do not achieve remission or low disease activity within 3-6 months, or who present poor prognostic factors, often escalate to biologic or targeted synthetic DMARDs (b/tsDMARDs). Registry data from the USA (CorEvitas, 2012-2014) show TNF inhibitors as the most common first biologic, although JAK inhibitor use increased after 2015, reflecting earlier switching from csDMARDs in cases of suboptimal response. First-line b/tsDMARD duration has also shortened (~208 days in 2015-2017 vs. ~153 days in 2018-2021). Similarly, a Japanese cohort (2008-2020) reported 25.6% of patients used b/tsDMARDs in combination with csDMARDs, while 7.7% used them as monotherapy, with TNFi remaining the predominant initial biologic. These results suggest increasing biologic initiation earlier in the disease course, tighter response criteria, and increased treatment flexibility (Miyashiro *et al.*, 2024).

Mechanism of Action

Monoclonal antibodies (mAbs) regulate immunity through double-barrelled mechanisms: the Fab portion recognizes antigens, preventing pathogenic ligands or causing receptor internalization, and the Fc portion activates effector functions, such as ADCC, CDC, and ADCP, for the destruction of disease-related cells. Anti-TNF antibodies such as infliximab and adalimumab retain the IgG Fc domain, neutralizing TNF-α and triggering cytotoxicity, whereas Fc-lacking agents like certolizumab pegol do not. Antibody-Drug Conjugates (ADCs) are being explored

to combine targeted binding with anti-inflammatory payload delivery for precise immune suppression (Dixit *et al.*, 2024).

Non-TNF biologics, including IL-6 inhibitors, B-cell depletion therapies, and T-cell co-stimulation blockers are used in DMARD-refractory patients. Registry data, such as the Swedish Rheumatology Register, show that tocilizumab and rituximab achieve higher one-year responses (EULAR Good Response, HAQ improvement) than TNF inhibitors, particularly after prior TNFi failure. Network meta-analyses (~7,800 patients) indicate abatacept increases the likelihood of achieving ACR70 by ~2.2-fold versus tocilizumab, with rituximab intermediate and tocilizumab sometimes producing faster early responses (ACR20). Safety, tolerability, and retention vary; rituximab and tocilizumab generally show superior long-term persistence. Biologic selection depends on prior therapy, comorbidities, infection risk, extra-articular disease, and desired speed of response (Sebba *et al.*, 2023). Figure 2 illustrates the cellular and molecular mechanisms by which these mAbs reduce inflammation and prevent immune-mediated bone erosion in RA.

Therapeutic mAbs in Clinical Use and Development

Several mAbs are approved for RA, each targeting specific immune mediators. Infliximab (chimeric anti-TNF-α) and adalimumab (fully human anti-TNF-α) neutralize soluble and transmembrane TNF-α, usually with methotrexate or other DMARDs, while etanercept, a TNF receptor-Fc fusion protein, similarly inhibits TNF-α. Tocilizumab and sarilumab block the IL-6 receptor, with meta-analyses showing IL-6 inhibitors particularly tocilizumab, are highly effective for achieving ACR20/50/70 responses in methotrexate-inadequate RA. Rituximab depletes B cells and is mainly used in TNFi-refractory patients, while abatacept inhibits T-cell co-stimulation and is effective alone or in combination. Network meta-analyses (~7,800 patients) found no significant differences in ACR70 rates at six months among rituximab, abatacept, and tocilizumab, though abatacept showed a higher likelihood (RR ≈ 2.2) versus tocilizumab. In difficult-to-treat RA, tocilizumab ranked among the most effective for DAS28 improvement, often outperforming TNF blockers in high-burden disease (Pugliesi *et al.*, 2023). Table 1 lists the mAbs approved for clinical use in RA management.

Bispecific Antibodies (bsAbs) engage multiple targets simultaneously, enhancing efficacy, exemplified by FDA-approved elranatamab for relapsed/refractory multiple myeloma. Single-chain variable Fragments (scFvs) and nanobodies improve tissue penetration and reduce immunogenicity, while Antibody-Drug Conjugates (ADCs) deliver cytotoxic or modulatory agents directly to disease sites, reducing systemic toxicity. Continued development of these novel scaffolds promises safer, effective therapies for RA and other autoimmune diseases (Dhillon, 2023). Several mAbs are currently under clinical development for RA, as outlined in Table 2.

Clinical Efficacy and Outcomes

Monoclonal Antibody (mAb) treatments have dramatically changed the course of managing RA by focally targeting important immunity mediators like IL-6, TNF-α, B cells, and T-cell co-stimulatory molecules. TNF inhibitors (infliximab, adalimumab, golimumab, certolizumab pegol) effectively reduce inflammation and joint damage, while IL-6 inhibitors (tocilizumab, sarilumab, olokizumab) alleviate both joint and systemic symptoms. -cell depletion using rituximab and T-cell co-stimulation by abatacept offer alternative choices for TNF inhibitor resistant patients. Generally well-tolerable drugs have associated hazards of infection, hepatic enzyme elevations, and infusion reactions. Next-generation agents that target GM-CSF

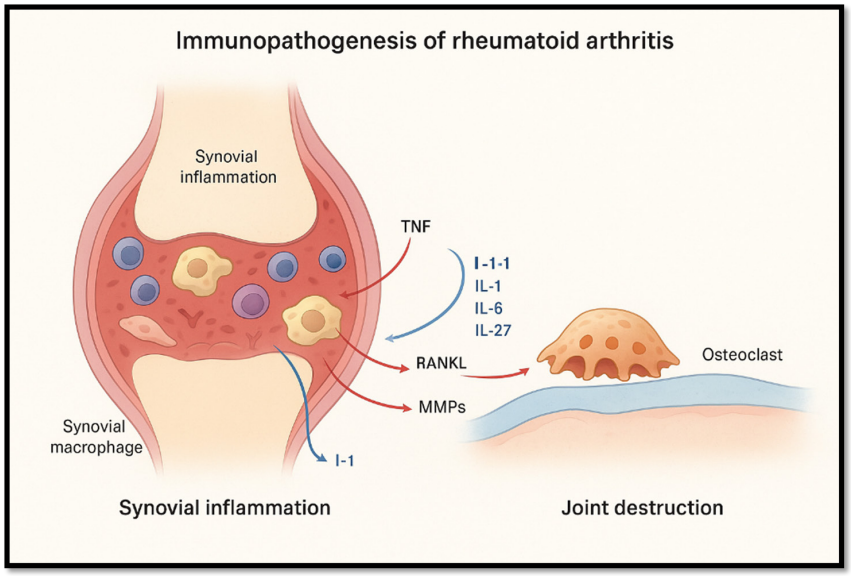

Figure 1: Immunopathogenesis of Rheumatoid Arthritis.

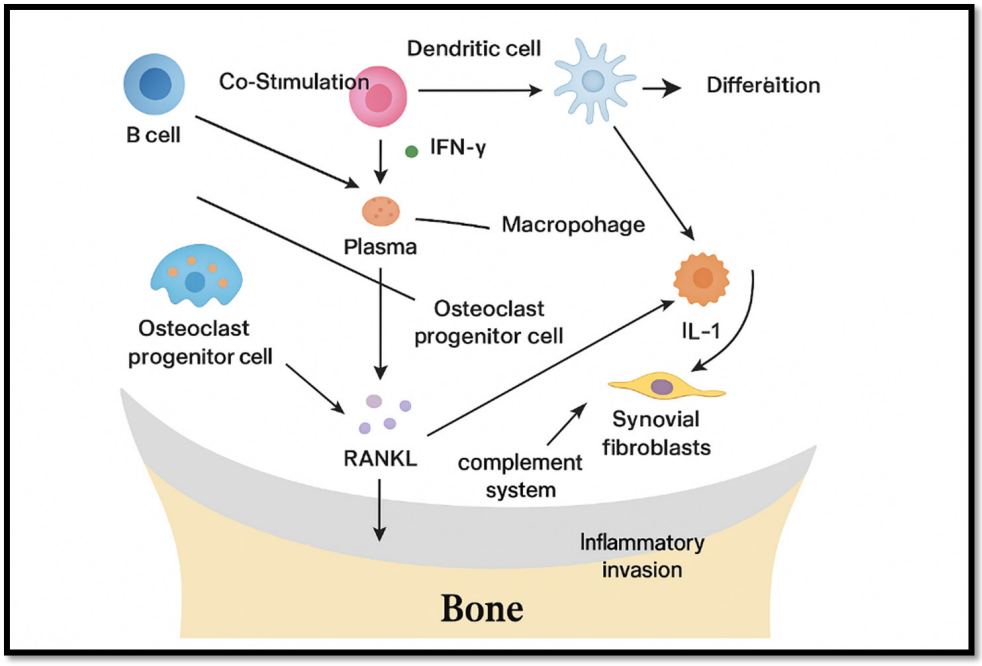

Figure 2: Cellular and molecular mechanisms of immune-mediated bone erosion.

and JAK pathways have the potential for future mechanisms for recalcitrant RA patients (Tanaka *et al.*, 2021).

Safety and Adverse Effects

Monoclonal Antibody (mAb) therapy in Rheumatoid Arthritis (RA) offers major therapeutic gains but carries predictable safety concerns requiring vigilant monitoring. Common adverse effects include mild infusion or injection-site reactions, fatigue, and upper respiratory infections. TNF-α inhibitors such as infliximab, adalimumab, and certolizumab pegol increase the risk of serious infections and tuberculosis reactivation, especially in endemic regions (Fernández-Ruiz and Aguado, 2018). Non-tuberculous mycobacterial infections have also been reported among TNF inhibitor-treated RA patients (Park *et al.*, 2023). IL-6 receptor blockers like tocilizumab and sarilumab may cause elevated hepatic enzymes, neutropenia, and dyslipidemia, warranting regular monitoring (Yu *et al.*, 2025; Kawczak *et al.*, 2025). Hepatitis B reactivation has occasionally been observed in IL-6 inhibitor-treated patients (Chen *et al.*, 2024).

Overall malignancy risk with mAbs in RA remains low, though prolonged TNF inhibition has been linked to slightly increased rates of non-melanoma skin cancer and lymphoma (Smolen *et al.*, 2018; Domańska-Poboża and Wisłowska, 2025). Long-term data on rituximab indicate no excess malignancy compared to baseline RA populations (van Vollenhoven *et al.*, 2015). Immunogenicity, particularly with chimeric antibodies, can reduce drug efficacy and provoke hypersensitivity reactions (Jain *et al.*, 2025). Pretherapy baseline screening for latent tuberculosis, hepatitis B and C, and vaccination status is necessary before therapy is started. When properly monitored, mAb therapy has an excellent safety profile, with controllable risks outweighed by great clinical advantages (Sebba *et al.*, 2023; Kawczak *et al.*, 2025).

Pharmacogenomics and Biomarker-Guided Therapy

Predictive biomarkers play a critical role in pharmacogenomics, with the ability to identify those patients who will respond to a certain therapy while reducing the occurrence of adverse reactions. Such biomarkers comprise genetic variants, gene expression patterns, and molecular markers that can predict therapeutic response or risk of severe adverse reactions. Examples include EGFR mutations in non-small cell lung cancer for targeting tyrosine kinase inhibitors and HLA-B*1502 for carbamazepine-induced hypersensitivity in autoimmune diseases, for which pre-treatment genetic screening is advocated. Combining clinical and environmental information with molecular biomarkers can further enhance treatment plans, enhance results, and decrease costs of care (Magee *et al.*, 2021; Sadee *et al.*, 2023).

In RA, biomarker and pharmacogenomic strategies facilitate precision medicine by maximizing the efficacy and safety of treatments. Polymorphisms in genes that participate in drug metabolism and immune function affect response to methotrexate and biologics and validate the use of individualized therapy choice instead of traditional trial-and-error. HLA alleles or cytokine levels are biomarkers that can direct DMARD therapy planning and forecast patient response. As accessibility and evidence increase, pharmacogenomic testing is likely to be a standard part of RA management, allowing for tailored treatment approaches in all patients independent of disease severity (Dorado and Penas-Lledo, 2024).

Table 1: Monoclonal antibodies (mAbs) approved for RA.

Drug	Target	Approval Year	Route/ Dosing	Key Benefits	Safety Concerns	References
Infliximab	TNF-α	1999	IV 3-10 mg/kg q8w	Rapid anti-inflammatory, slows joint damage	Infusion reactions, infections	Wijibrandts *et al.* (2005)
Adalimumab	TNF-α	2002	SC 40 mg q2w	Sustained efficacy, improved function	Anti-drug antibodies, infection risk	Maleki *et al.* (2023)
Golimumab	TNF-α	2009	SC 50 mg monthly	Effective in refractory RA	Infection, malignancy risk	Voulgari (2020)
Certolizumab pegol	TNF-α	2008	SC 400 mg wk0,2,4 then 200 mg q2w	Safe in pregnancy, rapid onset	Injection site reactions, infections	Gracia *et al.* (2017)
Tocilizumab	IL-6R	2010	IV 4-8 mg/kg q4w / SC 162 mg weekly	Monotherapy efficacy, systemic symptom relief	Dyslipidemia, liver enzyme elevation	Ogata *et al.* (2019)
Sarilumab	IL-6R	2017	SC 200 mg q2w	Effective in MTX-intolerant patients	Neutropenia, liver enzyme elevation	Kawczak *et al.* (2025)
Rituximab	CD20	2006	IV 1000 mg days 1 and 15 q24w	TNF-refractory RA, sustained response	Infusion reactions, rare PML	Korhonen *et al.* (2010)
Abatacept	CD80/86	2005	IV 10 mg/kg q4w / SC 125 mg weekly	Reduces inflammation, good tolerability	Slower onset, infection risk	Korhonen *et al.* (2010)

Table 2: Pipeline mAbs in clinical development for RA.

Candidate Name	Target Molecule	Phase	Developer	Unique Feature	References
ABBV-3373	TNF-α + Glucocorticoid Receptor	II	AbbVie	Bispecific with immunomodulatory domain	D'Cunha *et al.* (2024)
ALX-0061	IL-6R	III	Ablynx/Sanofi	Nanobody-based design for enhanced tissue penetration	Tillib *et al.* (2020)
GSK2618960	CD25	II	GSK	Selective Treg activation to restore tolerance	Ellis *et al.* (2019)
MOR103 (Otilimab)	GM-CSF	III	MorphoSys/GSK	Targets macrophage-driven inflammation	Buckley *et al.* (2020)
Rozanolixizumab	FcRn	II	UCB Pharma	Increases IgG clearance to reduce autoantibodies	Sandhu and Murakhovskaya (2025)

Biosimilars and Cost Considerations

Biosimilars are highly similar biologic drugs to approved reference products without any clinically meaningful differences in safety, potency, or purity. Their production requires stringent analytical, preclinical, and clinical tests, including structural and functional characterizations, pharmacokinetics, and immunogenicity followed by post-marketing pharmacovigilance. Strict standards have been set by regulatory authorities like the USFDA and EMA to ascertain quality and similarity prior to approval. Although biosimilar development is labour-intensive and expensive, their launch enhances patient access to necessary biologics in a less expensive way (Mascarenhas-Melo *et al.*, 2024; Ranbhor and Kulkarni, 2025).

From an economic standpoint, biosimilars reduce the costs of therapy and increase access worldwide. Hospital-level research, including the introduction of infliximab biosimilar CT-P13 in 2024, validated cost savings, albeit with varying benefits depending on local prices, procurement deals, and market share. In total, biosimilars increase the affordability and accessibility of biologic therapy without compromising clinical effectiveness (Chen *et al.*, 2024; Krstic *et al.*, 2024).

Challenges and Future Directions

Even with the progress of biologic and targeted therapies, effectiveness is constrained by resistance, heterogeneity in patient response, and safety. Initial and secondary resistance due to immune evasion, bypass signaling, or mutational changes can

diminish drug action. New methods in targeted drug delivery and nanomedicine are directed toward decreasing systemic toxicity, improving specificity, and enabling more personalized treatment paradigms (Kapare *et al.*, 2025).

Antibody engineering advances are developing multispecific and bispecific platforms with enhanced targeting, modularity, and lower off-target activity. Computational protein design, Fc domain engineering, and valency optimization enable antibodies to bind more than one disease-related epitope at a time, enhancing potency and therapeutic window. Nanomedicine-based delivery vehicles improve biologic targeting, extend drug release, decrease systemic exposure, and enhance pharmacokinetics. Collectively, these innovations have the potential for safer, more effective, and more convenient antibody-based therapies with reduced dosing frequency, co-delivery strategies, and individualized RA management (Keri *et al.*, 2023; Nasra *et al.*, 2022).

CONCLUSION

Monoclonal Antibody (mAb) therapy has revolutionized RA treatment through the targeting of specific cytokines, B cells, and T-cell co-stimulation processes involved in disease pathogenesis. The drugs suppress synovial inflammation, prevent or mitigate joint damage, and enhance patient-reports of physical function, pain, and quality of life. Data from observational and randomized controlled trials ongoing repeat that mAbs are superior to traditional synthetic DMARDs, especially among patients with an inadequate response to initial therapy. The prospects for mAb precision immunotherapy in RA are promising. Further developments in pharmacogenomics, biomarker-guided treatment, bispecific and multispecific mAbs, antibody-drug conjugates, and nanomedicine-based delivery systems can increase the precision of treatment selection, increase therapeutic efficacy, and reduce adverse effects. By employing these approaches, clinicians can better anticipate response in patients, overcome resistance, and customize therapy, taking RA care closer to a more individualized, precise model.

Importance of the Paper to the Field of Pharmacy

This paper provides a comprehensive and clinically relevant overview of monoclonal Antibody (mAb) therapy in rheumatoid arthritis, highlighting mechanisms of action, therapeutic outcomes, safety considerations, and emerging strategies. For the field of Pharmacy, the review is significant because:

- It bridges pharmacological science and clinical application, enabling pharmacists to better understand the role of biologics in autoimmune disease management.
- It emphasizes biosimilar uptake and cost-effectiveness, issues directly tied to pharmacy practice, healthcare policy, and patient access.
- It underscores the need for precision medicine, therapeutic monitoring, and biomarker-guided therapy, areas where pharmacists play a central role in optimizing treatment regimens.
- By synthesizing guideline-based and real-world evidence, it provides a valuable reference for clinical pharmacists, academic researchers, and pharmacy students aiming to enhance patient-centered care in autoimmune disorders.

ACKNOWLEDGEMENT

The authors thank the management of Chettinad Academy of Research and Education and Chettinad Hospital and Research Institute for their continuous support, encouragement, and provision of necessary resources that enabled completion of this manuscript. Appreciation is also extended to colleagues and peers for their valuable input in refining the review.

ABBREVIATIONS

ACR: American College of Rheumatology; **ADA:** Anti-Drug Antibodies; **AE:** Adverse Events; **bDMARDs:** Biologic Disease-Modifying Anti-Rheumatic Drugs; **CRP:** C-Reactive Protein; **csDMARDs:** Conventional Synthetic Disease-Modifying Anti-Rheumatic Drugs; **DAS28:** Disease Activity Score in 28 Joints; **DMARDs:** Disease-Modifying Anti-Rheumatic Drugs; **ESR:** Erythrocyte Sedimentation Rate; **FDA:** Food and Drug Administration; **IL:** Interleukin; **JAK:** Janus Kinase; **mAb:** Monoclonal Antibody; **NSAIDs:** Non-Steroidal Anti-Inflammatory Drugs; **RA:** Rheumatoid Arthritis; **RF:** Rheumatoid Factor; **TNF-α:** Tumor Necrosis Factor-alpha; **WHO:** World Health Organization.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES

The authors of this study used ChatGPT for language editing and Canva for image creation.

REFERENCES

Buckley, C. D., Simón-Campos, J. A., Zhdan, V., Becker, B., Davy, K., Fisheleva, E., ... and Tak, P. P. (2020). Efficacy, patient-reported outcomes, and safety of the anti-granulocyte macrophage colony-stimulating factor antibody Otilimab (GSK3196165) in patients with rheumatoid arthritis: a randomised, phase 2b, dose-ranging *study.The Lancet Rheumatology*, 2(11), e677-e688. https://doi.org/10.1016/S2665-9913(20)30229-0

Chen, H. H., Yemeke, T., and Ozawa, S. (2024). Reduction of biologic pricing following biosimilar introduction: Analysis across 57 countries and regions, 2012-19.PloS one,19(6), e0304851. https://doi.org/10.1371/journal.pone.0304851

D'Cunha, R., Kupper, H., Arikan, D., Zhao, W., Carter, D., Blaes, J., ... *and Pang, Y. (*2024). A first-in-human study of the novel immunology antibody-drug conjugate, ABBV-3373, in healthy participants.British Journal of Clinical Pharmacology,90(1), 189-199. https://doi.org/10.1111/bcp.15888

Dhillon S. (2023). Elranatamab: *First Approv*al.Drugs,83(17), 1621-1627. https://doi.org/10.1007/s40265-023-01954-w

Dixit, T., Vaidya, A., and Ravindran, S. (2024). Therapeutic potential of antibody-drug conjugates possessing bifunctional anti-inflammatory action in the pathogenies of rheumatoid arthritis.Arthritis research and ther*apy,26(1), 216. https://doi.org/10.1186/s*13075-024-03452-0

Domańska-Poboża, J., and Wisłowska, M. (2025). Evolving strategies in the treatm*ent of rh*eumatoid arthritis: a historical perspective.Reumatologia,63(2), 116-130. https://doi.org/10.5114/reum/195012

Dorado, P., and M Penas-Lledo, E. (2024). Pharmacogenetic and pharmacogenomic treatment of rheumatoid arthritis: a review of Pharmacogenomics *Knowledge Base scientific evid*ence.Pharmacogenomics,25(2), 55-58. https://doi:10.2217/pgs-2023-0230

Ellis, J., van Maurik, A., Fortunato, L., Gisbert, S., Chen, K., Schwartz, A., ... and Ferna*ndo, D. (20*19). Anti-IL-7 receptor α monoclonal antibody (GSK2618960) in healthy subjects-a randomized, double-blind, placebo-controlled study.British Journal of Clinical Pharmacology, 85(2), 304-315. https://doi.org/10.1111/bcp.13748

Fernánde*z-Ruiz, M., an*d Aguado, J. M. (2018). Risk of infection associated with anti-TNF-α therapy.Expert Review of Anti-Infective Therapy,16(12), 939-956. https://doi.org/10.1080/14787210.2018.1544490

Garcia, V. R., Burls, A., Cabello, J. B., Casasempere, P. V., Bort-Marti, S., and Bernal, J. A. (2017). *Cert*olizum*ab pegol (CDP870) for rheumatoid* arthritis in adults.Cochrane Database of Systematic Reviews, (9). https://doi.org/10.1002/14651858.CD007649.pub4

Jain, A., Bishnoi, M., Prajapati, S. K., *Acharya, S., Kapre, S.,* Singhvi, G., and Palakurthi, S. (2025). Targeting rheumatoid arthritis: a molecular perspective on biologic therapies and clinical progress.Journal of biological engineering,19(1), 67. https://doi.org/10.1186/s13036-025-00534-8

Kapare, H., Bhosal*e, M., and Bhol*e, *R. (2025). N*avigating the future: advancements in monoclonal antibody nanoparticle therapy for cancer.Journal of Drug Delivery Science and Technology,104, 106495. https://doi.org/10.1016/j.jddst.2024.106495

Kawczak, P., Feszak, I. J., and Bączek, T. (2025). Abatacept, golimumab, and sarilumab *as selected bio-originator disease*-mod*i*fying antirheumatic drugs with diverse mechanisms of action in their current use in treatment.Journal of Clinical Medicine, 14(6), 2107. https://doi.org/10.3390/jcm14062107

Keri, D., Walker, M., *Singh, I., Nishikawa, K., and* Garc*es*, F. (2023). Next generation of multispecific antibody engineering.Antibody therapeutics,7(1), 37-52. https://doi.org/10.1093/abt/tbad027

Kondo, N., Kuroda, T., and Kobayashi, D. (2021). Cytokine Networks in the Pathogenesis of Rheumatoid Arthritis.Internationa*l journal* of molecular sciences,*22*(20), 10922. https://doi.org/10.3390/ijms222010922

Korhonen, R., and Moilanen, E. (2009). Abatacept, a novel CD80/86-CD28 T cell co-stimulation modulator, in the treatment of rheumatoid arthrit*is. Basic and Clin*ical Pharmacology and Toxicology, 104(4), 276-284. https://doi.org/10.1111/j.1742-7843.2009.00375.x

Krstic, M., Devaud, J. C., Sadeghipour, F., and Marti, J. *(2024).* Does the introduction of an infliximab biosimilar always result in savings for hospitals? A descriptive study using real-world data.Health economics review,14(1), 31. https://doi.org/10.1186/s*13561-024-00507-5*

Köhler, G., and Milstein, C. (1975). Continuous cultures of fused cells secreting antibody of predefined specificity.nature,256(5517), 495-497. https://doi.org/10.1038/256495a0

Lillegraven, S., Sundlisæter, *N. P., Aga, A. B., Sexton, J.,* Sol*omo*n, D. H., van der Heijde, D., and Haavardsholm, E. A. (2023). Discontinuation of conventional synthetic disease-modifying antirheumatic drugs in patients with rheumatoid arthritis and excellent disease control.Jama,329(12), 1024-1026. https://doi.org/10.1001/jama.2023.0492

*Magee, C., Je*thwa, H., FitzGerald, O. M., and Jadon, D. R. (2021). Biomarkers predictive of treatment response in psoriasis and psoriatic arthrit*is*: a systematic review.Therapeutic advances in musculoskeletal disease,13, 1759720X211014010. https://doi.org/10.1177/1759720X211014010

Maleki, A., Patel, P. D., and Foster, C. S. (2023). Juvenile id*iopa*thic *a*rthritis and its associated uveitis.Expert Review of Clinical Immunology,19(9), 1157-1169. https://doi.org/10.1080/1744666X.2023.2231154

Mascarenhas-Melo, F., Diaz, M., Gonçalves, M. B. S., Vieira, P., Bell, V., Viana, *S., Nunes, S., Paiva-Santos, A. C., an*d Veiga, F. (2024). An Overview of Biosimilars-Development, Quality, Regulatory Issues, and Management in Healthcare.Pharmaceuticals (Basel, Switzerland),17(2), 235. https://doi.org/10.3*390/ph17020235*

*Miyashir*o, M., Asano, T., Ishii, Y., Miyazaki, C., Shimizu, H., and Masuda, J. (2024). Treatment Patterns of Biologic Disease-Modifying Antirheumatic Drugs and Janus Kinase Inhibitors in Patients with Rheumatoid Arthritis in Japan: A Claims-Based Cohort Study.Drugs - real world outcomes,11(2), 285-297. https://doi.org/10.1007/s40801-024-00423*-4*

Nasra, S., Bhatia, D., and Kumar, A. (2022). Recent advances in nanoparticle-based drug delivery systems for rheumatoid arthritis treatment. Nanoscale advances, 4(17), 3479-3494. https://doi.org/10.1039/d2na00229a

Ogata, A., Kato, Y., Higa, S., and Maeda, K. (2019). Subcutaneous tocilizumab: recent advances for th*e treatment of rheumatoid a*rthr*i*tis.Expert Opinion on Drug Delivery,16(6), 639-648. https://doi.org/10.1080/17425247.2019.1618828

O'Neil, L. J., Alpízar-Rodríguez, D., and Deane, K. D. (2024). Rheumatoid arthritis: the continuum of *disease and strat*egies for prediction, early intervention, and prevention.The Journal of rheumatology,51(4), 337-349. https://doi.org/10.3899/jrheum.2023-0334

Park, H. J., Choi, B., Song, Y. K., Oh, Y. J., Lee, E. B., Kim, I. W., and Oh, J. M. *(2023). Associa*tion of tumor necrosis factor inhibitors with the risk of nontuberculous mycobacterial infection in patients with rheumatoid arthritis: a nationwide cohort study.Journal of Clinical Medicine,12(22), 6998. https://doi.org/10.3390/jcm*12226998*

Pugliesi, A., de Oliveira, A. B., Oliveira, A. B., Xavier, R., da Mota, L. M. H., Bertolo, M. B., Gonzalez-Gay, M. A., Citera, G., and de Carvalho, L. S. F. (2023). Compared efficacy of rituximab, abatacept, and tocilizumab in patients with rheumatoid arthritis refractory to methotrexate or TNF inhibitors agents: a systematic review and n*etwork meta-analysis.Advanc*es *in* rheumatology (London, England),63(1), 30. https://doi.org/10.1186/s42358-023-00298-z

Ranbhor, R., and Kulkarni, P. (2025). Evaluating Biosimilar Development Projects: An Analytical Framework Utilizing Net Present Value.Biologics: targets and therapy,19, 125-135. https://doi.org/10.2147/BTT.S514767

Rufino, A. T., Freitas, M., Proenca, C., Ferreira de Oliveira, J. M., Fernandes, E., and R*ibeiro, D. (2024).* Rheumatoid ar*thritis molecu*lar targets and their importance to flavonoid-based therapy.Medicinal Research Reviews, 44(2), 497-538. https://doi.org/10.1002/med.21990

Sadee, W., Wang, D., Hartmann, K., a*nd Toland, A. E. (202*3). Pharmacogenomics: Driving Personalized Medicine.Pharmacological reviews,75(4), 789-814. https://doi.org/10.1124/pharmrev.122.000810

Sandhu, M., and Murakhovskaya, I. (2025). FcRn Blockade as a Targeted Therapeutic Strategy in Antibody-Mediated Autoimmune Diseases: A F*ocus on W*arm Autoimmune Hemolytic *An*emia.Antibodies, 14(3), 65. https://doi.org/10.3390/antib14030065

Sebba, A., Bingham, C. O., Bykerk, V. P., Fiore, S., Ford, K., Janak, J. C., P*appas, D. A., Blac*hley, T., Dave, S. S., Kremer, J. M., Yu, M., and Choy, E. (2023). Comparative effectiveness of TNF inhibitor vs IL-6 receptor inhibitor as monotherapy or combination therapy with methotrexate in biologic-experienced patients with rheumatoid ar*thritis: An* analy*s*is from the CorEvitas RA Registry.Clinical rheumatology. 42(8), 2037-2051. https://doi.org/10.1007/s10067-023-06588-7

Smolen, J. S., Aletaha, D., Barton, A., Burmester, G. R., Emery, P., Firestein, G. S., Kavanaugh, A., McInnes, I. B., Solomon, D. H., Strand, V., and Yamamoto, K. (2018). Rheumatoid arthritis.Nature reviews. Disease primers,4, 18001. https://doi.org/10.1038/nrdp.2018.1

Tanaka, Y., Takeuchi, *T., Yamanaka,* H., Nanki, T., Umehara, H., Yasuda, N., Tago, F., Kitahara, Y., Kawakubo, M., Torii, K., Hojo, S., Kawano, T., and Imai, T. (2021). Efficacy and Safety of E6011, an Anti-Fractalkine Monoclonal Antibody, in Patients with Active Rheumatoid Arthritis with Inadequate Response to M*ethotrexate: Res*ults of a Rando*mized,* Dou*b*le-Blind, Placebo-Controlled Phase II Study.Arthritis and rheumatology (Hoboken, N.J.),73(4), 587-595. https://doi.org/10.1002/art.41555

Tillib, S. V. (2020). Prospective applications of single-domain antibodies in biomedicine.Molecular Biology, 54(3), 317-326. https://doi.org/10.31857/S0026898420030167

van Vollenhoven, R. F., Fleischmann, R. M., Furst, D. E., Lacey, S., and Lehane, P. B. (2015). Longterm safety of rituximab: final report of the *rheumatoid arthritis global clinical* tri*al pro*gram over 11 years.The Journal of rheumatology,42(10), 1761-1766. https://doi.org/10.3899/jrheum.150051

Voulgari, P. V. (2010). Golimu*mab: A new anti-TN*F-α ag*e*nt for rheumatoid arthritis, psoriatic arthritis and ankylosing spondylitis.Expert review of clinical immunology,6(5), 721-733. https://doi.org/10.1586/eci.10.49

Wijbrandts, C. A., Reinders-Blankert, P., Klarenbeek, P., Smeets, T. J. M., Vervoordeldonk, M. J., and Tak, *P.* P. (2005). *Infliximab* treat*m*ent does not induce apoptosis in peripheral blood mononuclear cells up to 24 hours after initiation of treatment in rheumatoid arthritis patients. Arthritis Research and Therapy, 7(Suppl 1), P114. https*://doi.org/10.1186/ar1635*

Yu, Z., Liu, J., Chen, L., and Xie, J. (2025). Role of Interleukin-6 in Rheumatoid Arthritis-Associated Interstitial Lung Disease: Focus on the JAK/STAT Pathway and Macrophage Polarization.Journal of inflammation research,18, 10953-10967. https://doi.org/10.2147/JIR.S530754.

Cite this article: Prabha KS, Albert J, Grace DC, Gokul S, Kumar SK, Sundar GS, *et al*. Monoclonal Antibody Therapy in Rheumatoid Arthritis: A Paradigm Shift Toward Precision Immunotherapy. J Young Pharm. 2026;18(2):260-6.