

Review

The Emerging Role of Non-Coding RNAs in Carcinogenesis and Tumor Metastasis

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Abstract:

Non-coding RNAs (ncRNAs) have emerged as crucial regulators of cellular processes, including gene expression, chromatin remodeling, and cellular signaling. Recent advancements in molecular biology have uncovered their pivotal role in carcinogenesis and tumor metastasis. These ncRNAs, including microRNAs (miRNAs), long non-coding RNAs (lncRNAs), and circular RNAs (circRNAs), regulate a variety of biological pathways that govern tumor initiation, progression, and spread to distant organs. miRNAs are involved in post-transcriptional regulation and can act as either tumor suppressors or oncogenes, depending on the target genes they regulate. lncRNAs contribute to the formation of complex molecular networks that modulate tumor cell proliferation, apoptosis, and migration. Furthermore, circRNAs, with their unique stable structure, are being recognized as key regulators of metastasis-related pathways. The dysregulation of these ncRNAs in cancerous cells highlights their potential as biomarkers for early diagnosis and therapeutic targets. Understanding the role of ncRNAs in carcinogenesis and metastasis is crucial for the development of novel diagnostic and therapeutic strategies, offering hope for more effective cancer treatments in the future.

Keywords: Non-coding RNAs, carcinogenesis, tumor metastasis, microRNAs, long non-coding RNAs, circular RNAs, cancer progression, biomarkers, gene regulation, therapeutic targets.

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1.1 Introduction:

Carcinogenesis, the process by which normal cells transform into cancerous cells, and tumor metastasis, the spread of cancer from the primary site to distant organs, are complex biological phenomena regulated by an intricate network of molecular factors. Historically, the focus of cancer research has been on protein-coding genes, but recent discoveries have shifted attention toward non-coding RNAs (ncRNAs), a class of RNA molecules that do not encode proteins but play essential roles in cellular processes. These ncRNAs are involved in regulating gene expression at multiple levels, from transcription to post-transcriptional modifications, influencing the behavior of cells in both normal and cancerous tissues.(1)

Non-coding RNAs are broadly classified into two categories: small non-coding RNAs, such as microRNAs (miRNAs), and long non-coding RNAs (lncRNAs), as well as circular RNAs (circRNAs), which are a newly recognized group of non-coding molecules. miRNAs are small, single-stranded RNA molecules that regulate gene expression by binding to messenger RNAs (mRNAs), leading to mRNA degradation or translational repression. lncRNAs are a heterogeneous group of longer RNAs that can modulate chromatin structure, transcriptional activity, and mRNA stability. circRNAs, a unique class of ncRNAs with a covalently closed loop structure, have recently gained attention for their involvement in regulating gene expression and their potential role in cancer progression and metastasis.(2)

The dysregulation of ncRNAs in various cancers has provided valuable insights into their involvement in tumorigenesis. Specific ncRNAs have been found to regulate critical cancer-related processes, such as cell proliferation, apoptosis, angiogenesis, invasion, and metastasis. Moreover, the aberrant expression of ncRNAs has been linked to the development of resistance to conventional cancer therapies, further emphasizing their potential as therapeutic targets. As ncRNAs are stable and detectable in body fluids, they offer promising potential as diagnostic and prognostic biomarkers for cancer.

This paper explores the emerging role of non-coding RNAs in carcinogenesis and tumor metastasis, focusing on the molecular mechanisms through which miRNAs, lncRNAs, and circRNAs regulate the processes that drive cancer progression. Understanding the intricate interactions between ncRNAs and cancer-related signaling pathways may open new avenues for the development of more precise and personalized cancer therapies.

1.2 Overview of Carcinogenesis and Tumor Metastasis:

Carcinogenesis refers to the complex, multi-step process by which normal cells acquire genetic and epigenetic alterations, leading to uncontrolled cell proliferation, resistance to apoptosis, and the ability to invade surrounding tissues. This process involves multiple stages, including initiation, promotion, and progression, each driven by a series of genetic mutations and environmental factors.(3) Tumor metastasis, on the other hand, is the spread of cancer cells from the primary tumor to distant organs and tissues, a hallmark of advanced cancer that significantly impacts patient prognosis. Metastatic cancer cells acquire unique capabilities, such as the ability to migrate, invade blood vessels, and establish secondary tumor sites. Both carcinogenesis and metastasis are regulated by complex molecular networks, involving signaling pathways, cellular interactions, and gene expression changes, in which non-coding RNAs (ncRNAs) have been increasingly recognized as crucial players.(4)

1.3 The Evolution of Non-Coding RNAs in Cancer Research:

Non-coding RNAs (ncRNAs) have historically been considered as "junk" or "non-functional" RNA molecules due to their lack of protein-coding potential. However, the discovery of their regulatory roles in gene expression and cellular processes has revolutionized the understanding of cellular biology

and cancer.(5) Over the past two decades, research has uncovered that ncRNAs play critical roles in regulating gene expression at various levels, including transcription, post-transcription, translation, and chromatin remodeling. The recognition of ncRNAs as key players in cancer biology has led to a paradigm shift in cancer research, revealing that their dysregulation can contribute to tumor initiation, progression, and metastasis. Advancements in high-throughput technologies, such as RNA sequencing, have further accelerated the identification of ncRNAs with cancer-related functions, opening new avenues for the development of cancer diagnostics and therapeutics.(6)

1.4 Types of Non-Coding RNAs: MicroRNAs, lncRNAs, and circRNAs:

Non-coding RNAs are classified into two broad categories: small non-coding RNAs and long non-coding RNAs. Small non-coding RNAs, such as microRNAs (miRNAs), are typically around 20-24 nucleotides long and regulate gene expression post-transcriptionally by binding to target messenger RNAs (mRNAs) and inhibiting their translation or inducing their degradation. miRNAs have been shown to act as either tumor suppressors or oncogenes, depending on their targets, playing pivotal roles in regulating cell proliferation, apoptosis, and migration(7). Long non-coding RNAs (lncRNAs) are more than 200 nucleotides in length and can regulate gene expression through diverse mechanisms, including chromatin remodeling, transcriptional regulation, and interaction with other RNA molecules. LncRNAs are involved in various cellular processes, such as cellular differentiation, proliferation, and invasion. Circular RNAs (circRNAs) are a relatively newly discovered class of ncRNAs that form covalently closed loops. Due to their stable structure, circRNAs are highly resistant to degradation and can regulate gene expression through sponging of miRNAs, interacting with RNA-binding proteins, and modulating transcription. Each of these ncRNA types plays distinct but complementary roles in cancer biology.(8)

1.5 Role of MicroRNAs in Gene Regulation and Cancer:

MicroRNAs (miRNAs) are small, single-stranded RNAs that exert their regulatory functions by binding to complementary sequences in target mRNAs, leading to either degradation of the mRNA

or inhibition of its translation. These tiny molecules have emerged as essential regulators of gene expression and cellular processes, including growth, differentiation, and apoptosis. In cancer, miRNAs play a dual role by either promoting or inhibiting tumorigenesis.(9) Oncogenic miRNAs, or oncomiRs, are often overexpressed in cancers and promote tumor growth, invasion, and metastasis by targeting tumor suppressor genes. Conversely, tumor suppressor miRNAs are frequently downregulated or deleted in cancers, leading to the activation of oncogenes. miRNAs also regulate important pathways, such as those involved in cell cycle regulation, apoptosis, angiogenesis, and immune evasion. Given their ability to modulate multiple cancer-related pathways, miRNAs are being explored as potential biomarkers for cancer diagnosis and prognosis, as well as therapeutic targets for treatment.(10)

1.6 Mechanisms of Long Non-Coding RNAs in Tumorigenesis:

Long non-coding RNAs (lncRNAs) are versatile regulators of gene expression, with a wide range of mechanisms through which they influence tumorigenesis. lncRNAs can interact with chromatin-modifying complexes to alter the epigenetic landscape of a cell, leading to changes in gene expression that promote tumor growth and progression. Some lncRNAs act as scaffolds, recruiting proteins or RNA molecules to specific loci, thus influencing transcriptional processes.(11) Others function as decoys, sequestering regulatory factors such as transcription factors or microRNAs, preventing them from interacting with their normal targets. lncRNAs can also regulate alternative splicing and modulate the stability of mRNA transcripts, further contributing to cancer-related processes such as cell survival, invasion, and metastasis. For example, the lncRNA HOTAIR has been shown to promote metastasis by interacting with the Polycomb Repressive Complex 2 (PRC2), which represses the expression of tumor suppressor genes. The widespread dysregulation of lncRNAs in various cancer types underscores their importance in tumorigenesis and their potential as therapeutic targets or biomarkers in cancer management.(12)

1.7 Circular RNAs: A New Frontier in Cancer Biology:

Circular RNAs (circRNAs) represent a novel and unique class of non-coding RNAs that form covalently closed loops without 5' to 3' polarity or a

poly-A tail. Their stable structure makes them highly resistant to exonuclease-mediated degradation, which has contributed to their emerging recognition in cancer biology. Unlike linear RNAs, circRNAs do not follow the typical degradation pathway, allowing them to accumulate in cells and perform specific regulatory functions.(13) CircRNAs primarily act as sponges for microRNAs (miRNAs), sequestering them and preventing miRNA-induced silencing of their target mRNAs. Additionally, some circRNAs interact with RNA-binding proteins, modulating gene expression by influencing alternative splicing, transcriptional regulation, or protein function. In cancer, circRNAs have been implicated in various processes, including tumor cell proliferation, survival, and resistance to therapies. Their dysregulation in multiple cancer types, along with their stable presence in body fluids, makes them promising candidates for cancer biomarkers and potential therapeutic targets.(14)

1.8 Non-Coding RNAs and Their Contribution to Tumor Progression:

Non-coding RNAs play a critical role in regulating tumor progression by controlling various molecular and cellular processes essential for the development and advancement of cancer. These processes include cell proliferation, apoptosis resistance, epithelial-to-mesenchymal transition (EMT), angiogenesis, and immune evasion.(15) MicroRNAs, long non-coding RNAs (lncRNAs), and circular RNAs (circRNAs) are all involved in orchestrating these processes, either by directly regulating target genes or by interacting with other cellular components, such as chromatin, transcription factors, and RNA-binding proteins. Dysregulation of ncRNAs in cancer cells can result in the activation of oncogenic pathways or the inactivation of tumor suppressor genes, promoting tumor initiation, growth, and metastasis. The contribution of ncRNAs to tumor progression has been shown to be dynamic, with their expression levels frequently altered in response to environmental stimuli or therapeutic interventions, making them valuable targets for both diagnostic and therapeutic strategies.(16)

1.9 MicroRNA-Mediated Regulation of Tumor Suppressors and Oncogenes:

MicroRNAs (miRNAs) are small, non-coding RNA molecules that regulate gene expression post-transcriptionally by binding to complementary sites on target mRNAs, leading to translational repression or mRNA degradation. In cancer, miRNAs are

pivotal regulators of tumor suppressor genes and oncogenes. Oncogenic miRNAs, or oncomiRs, are often overexpressed in cancer cells and promote tumorigenesis by downregulating tumor suppressor genes that control critical processes such as cell cycle arrest, apoptosis, and DNA repair.(17) Conversely, tumor-suppressive miRNAs are frequently downregulated or deleted in cancers, resulting in the upregulation of oncogenes that drive cancer cell proliferation and metastasis. For instance, miR-34a, a well-known tumor suppressor miRNA, is often downregulated in various cancers, leading to the activation of its target genes such as MYC and BCL-2. By controlling the balance between oncogenes and tumor suppressors, miRNAs serve as key molecular switches in tumor initiation and progression, making them attractive candidates for therapeutic interventions and biomarkers for cancer diagnosis and prognosis.(18)

1.10 Long Non-Coding RNAs: Modulating Chromatin and Transcription:

Long non-coding RNAs (lncRNAs) are a diverse class of RNA molecules greater than 200 nucleotides in length that do not encode proteins but regulate a variety of cellular processes, including gene expression, chromatin remodeling, and transcription. LncRNAs can influence tumorigenesis through direct interactions with chromatin and transcriptional machinery. By recruiting chromatin-modifying enzymes, lncRNAs can modify histones and alter chromatin structure, leading to the activation or repression of specific genes.(19) For example, the lncRNA XIST plays a key role in X-chromosome inactivation by recruiting polycomb repressive complexes to the inactive X chromosome. LncRNAs can also interact with transcription factors to enhance or inhibit the transcription of target genes. In cancer, the dysregulation of lncRNAs can lead to the aberrant activation of oncogenes or silencing of tumor suppressor genes, driving tumor initiation and progression. Additionally, some lncRNAs are involved in regulating alternative splicing, modulating the stability of other RNAs, and controlling cell cycle progression, all of which contribute to cancer pathophysiology. As critical regulators of gene expression, lncRNAs are emerging as potential therapeutic targets for cancer treatment.(20)

1.11 Circular RNAs and Their Impact on Cancer Metastasis:

Circular RNAs (circRNAs) have gained significant attention for their role in cancer metastasis, the process by which cancer cells spread from the primary tumor to distant sites. CircRNAs can act as molecular sponges for microRNAs (miRNAs), preventing miRNAs from suppressing their target genes. This "sponge effect" allows circRNAs to regulate the expression of metastasis-related genes. For instance, circRNAs can influence pathways involved in cell migration, invasion, and angiogenesis, all of which are essential for metastasis.(21) Additionally, circRNAs can interact with RNA-binding proteins, affecting cellular processes such as alternative splicing and transcription. Studies have shown that certain circRNAs, such as circ_ITCH and circHIPK3, are involved in regulating key signaling pathways such as the Wnt/ β -catenin and PI3K/Akt pathways, which are critical for metastasis. The stable and abundant nature of circRNAs in body fluids, coupled with their ability to modulate gene expression, makes them promising biomarkers for predicting metastatic potential and monitoring disease progression. As research into circRNAs continues, their role in metastasis may lead to new therapeutic approaches aimed at inhibiting or reversing metastatic spread.(22)

1.12 Non-Coding RNAs in Tumor Cell Proliferation and Apoptosis:

Non-coding RNAs (ncRNAs) play a crucial role in regulating tumor cell proliferation and apoptosis, two fundamental processes that determine cancer progression and survival. In normal cells, the balance between cell proliferation and apoptosis is tightly controlled to maintain tissue homeostasis. However, in cancer cells, this balance is often disrupted, leading to uncontrolled proliferation and evasion of programmed cell death. MicroRNAs (miRNAs) and long non-coding RNAs (lncRNAs) are key regulators of these processes.(23) For example, certain miRNAs can promote tumor cell proliferation by targeting tumor suppressor genes such as p53, while others induce apoptosis by upregulating pro-apoptotic factors. LncRNAs, on the other hand, can modulate the expression of genes involved in the cell cycle, such as cyclins and cyclin-dependent kinases, promoting uncontrolled cell division. Additionally, some lncRNAs, such as lncRNA HOTAIR, can inhibit apoptotic pathways, enhancing cancer cell survival. The dysregulation of ncRNAs that affect cell proliferation and apoptosis

contributes to the malignant behavior of tumors and their resistance to treatment.(24)

1.13 The Role of Non-Coding RNAs in Tumor Invasion and Angiogenesis:

Tumor invasion and angiogenesis are critical steps in the metastatic spread of cancer. Non-coding RNAs (ncRNAs) have been shown to regulate both of these processes by modulating key signaling pathways. MicroRNAs (miRNAs) can influence the expression of genes involved in extracellular matrix remodeling, cell adhesion, and motility, thereby promoting tumor cell invasion. For instance, miR-10b has been found to regulate genes involved in the epithelial-to-mesenchymal transition (EMT), a process essential for invasion and metastasis. (25) Long non-coding RNAs (lncRNAs) also play a significant role in invasion by interacting with chromatin-modifying complexes and transcription factors to regulate the expression of genes involved in cell migration and invasion. Moreover, ncRNAs are key players in angiogenesis, the formation of new blood vessels to supply growing tumors with nutrients and oxygen. lncRNAs, such as MALAT1, have been shown to promote angiogenesis by regulating the expression of pro-angiogenic factors like VEGF (vascular endothelial growth factor). Through these mechanisms, ncRNAs contribute to the ability of tumors to invade surrounding tissues and form secondary tumors at distant sites, highlighting their importance in cancer progression.(26)

1.14 Dysregulation of Non-Coding RNAs in Cancer:

The dysregulation of non-coding RNAs (ncRNAs) is a hallmark of cancer, with alterations in their expression patterns often correlating with tumor initiation, progression, and metastasis. In normal cells, ncRNAs regulate a variety of biological processes, such as gene expression, chromatin structure, and RNA splicing, maintaining cellular homeostasis. However, in cancer, the expression of ncRNAs is frequently altered, leading to the activation of oncogenic pathways or the silencing of tumor suppressor pathways. (27) For example, microRNAs (miRNAs) may be overexpressed or deleted in cancers, promoting tumorigenesis by

regulating critical genes involved in cell cycle control, apoptosis, and metastasis. Similarly, long non-coding RNAs (lncRNAs) can be either upregulated or downregulated in cancer, influencing gene expression through a variety of mechanisms such as chromatin remodeling and transcriptional regulation. Circular RNAs (circRNAs), with their stable structure, are also often dysregulated in cancer, impacting miRNA and RNA-binding protein interactions. This dysregulation of ncRNAs disrupts normal cellular processes, driving cancer development and progression. Understanding how these ncRNAs become dysregulated in cancer is critical for developing targeted therapies aimed at restoring normal ncRNA function.(28)

1.15 Potential of Non-Coding RNAs as Diagnostic and Prognostic Biomarkers:

The growing understanding of the roles of non-coding RNAs (ncRNAs) in cancer biology has led to their potential as diagnostic and prognostic biomarkers. The stability and abundance of ncRNAs in various biological fluids, such as blood, urine, and saliva, make them attractive candidates for non-invasive cancer detection. MicroRNAs (miRNAs), long non-coding RNAs (lncRNAs), and circular RNAs (circRNAs) have been found to exhibit distinct expression profiles in cancer tissues compared to normal tissues, allowing for their use in early detection and disease monitoring.(29) For example, specific miRNAs have been identified as biomarkers for cancers such as breast, lung, and colorectal cancer. Moreover, ncRNAs can also serve as prognostic markers, providing valuable information regarding disease progression and the likelihood of metastasis. For instance, the expression of certain lncRNAs has been associated with poor prognosis and resistance to therapy in various cancers. Additionally, ncRNAs can be used to predict the response to specific therapies, helping to guide personalized treatment strategies. The potential of ncRNAs as biomarkers lies not only in their ability to detect cancer but also in their capacity to provide insights into the underlying molecular mechanisms of the disease, ultimately leading to more accurate and tailored therapeutic interventions.(30)

Non-Coding RNA Type	Key Functions	Role in Carcinogenesis	Role in Tumor Metastasis
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MicroRNAs (miRNAs)	Regulate gene expression post-transcriptionally by binding to target mRNAs, leading to degradation or translational repression.	Act as oncogenes or tumor suppressors, regulating critical pathways in cell proliferation, apoptosis, and migration.	Promote metastasis by regulating EMT, cell migration, and invasion through the modulation of specific genes and signaling pathways.
Long Non-Coding RNAs (lncRNAs)	Regulate gene expression through diverse mechanisms, such as chromatin remodeling, transcriptional regulation, and interaction with RNA-binding proteins.	Influence key processes like cell proliferation, survival, differentiation, and invasion by regulating tumor suppressors and oncogenes.	Regulate the expression of genes involved in invasion, migration, and metastasis by interacting with chromatin and transcription factors.
Circular RNAs (circRNAs)	Act as sponges for miRNAs, regulate transcription, and interact with RNA-binding proteins, influencing gene expression.	Modulate metastasis-related pathways, such as cell migration, invasion, and angiogenesis.	Splice miRNAs and RNA-binding proteins to regulate key metastasis-related genes and pathways.

CONCLUSION:

Non-coding RNAs (ncRNAs) have emerged as pivotal regulators in the complex molecular landscape of cancer. Their involvement in key processes such as carcinogenesis, tumor progression, metastasis, cell proliferation, apoptosis, and invasion underscores their critical role in cancer biology. MicroRNAs (miRNAs), long non-coding RNAs (lncRNAs), and circular RNAs (circRNAs) collectively modulate gene expression and cellular behavior through diverse mechanisms, ranging from chromatin remodeling to post-transcriptional regulation. The dysregulation of these ncRNAs often drives tumorigenesis, contributing to the initiation, progression, and spread of cancer. Their ability to regulate crucial cancer-related pathways, such as cell cycle control, angiogenesis, and apoptosis, highlights their potential as both biomarkers and therapeutic targets.

Given their stability and detectability in biological fluids, ncRNAs hold immense promise as non-invasive diagnostic and prognostic biomarkers for early cancer detection and monitoring disease progression. Moreover, targeting ncRNAs offers a novel approach for therapeutic interventions, with the potential to overcome challenges such as drug resistance and tumor recurrence. However, while research into the roles of ncRNAs in cancer has progressed significantly, further studies are needed to better understand their full scope of functions and to translate these findings into clinical applications. In conclusion, ncRNAs represent a promising frontier in cancer research. Their regulation of tumorigenic processes opens up new avenues for

early diagnosis, prognosis, and personalized treatment strategies, offering hope for improved cancer management in the future. As our understanding of these molecules continues to evolve, non-coding RNAs may become central players in the development of innovative, targeted therapies, ultimately transforming the landscape of cancer care.

REFERENCES:

1. Mandal S, Mandal S. Topical Delivery of Sulfasalazine via Nanosponges-Loaded Hydrogels: A Novel Approach for Enhanced Psoriasis Management. *International Journal of Multidisciplinary Science and Innovation*. 2025 Apr 25:19-23.
2. Topi D, Dubey CK, Sharma S, Fasiha B, Mandal S. A Review of Plant-Based Natural Products for the Management of Diabetes: From Ethnobotany to Clinical Evidence. *International Journal of Natural Products and Alternative Medicine*. 2025 Mar 20:16-22.
3. Mandal S, Kumar M, Bhumika K, Ali S, Jahan I, Mandal S. Impact of Electronic Health Records and Automation on Pharmaceutical Management Efficiency: A Narrative Review. *International Journal of Health Sciences and Engineering*. 2025 Feb 17:21-36.
4. Kumar M, Manda S, Bhumika K, Ali S, Jahan I, Mandal S. Targeted Drug Delivery Systems in Oncology: A Review of Recent Patents and future directions. *International*

- Journal of Health Sciences and Engineering. 2025 Feb 17:37-57.
5. Mandal S. Advances and Future Prospects of Lipid-Based Nanocarriers in Targeted Cancer Therapy: A Comprehensive Review. *Current Cancer Drug Targets*. 2025 May 13.
 6. Chatterjee S, Ahamed IN, Aggarwal M, Mandal S, Mandal S. Bioadhesive Self-Nanoemulsifying Drug Delivery Systems (BSNEDDS): A Novel Strategy to Enhance Mucosal Drug Absorption and Bioavailability. *International Journal of Multidisciplinary Science and Innovation*. 2025 Apr 25:24-7.
 7. Velraj M, Bhyan B, Mishram R, Padhy RP, Mandal S. Recent Advances in the Isolation and Characterization of Antimicrobial Compounds. *International Journal of Natural Products and Alternative Medicine*. 2025 Mar 20:23-9.
 8. Kotnala M, Porwal P, Mandal S, Mandal S. The Role of Plant Metabolites in Enhancing Immunomodulatory Responses in Autoimmune Diseases. *International Journal of Natural Products and Alternative Medicine*. 2025 Mar 20:30-6.
 9. Monisha R, Jaqueline RS, Yadav K, Mandal S, Mandal S. Psychological Well-Being and Oral Health: The Role of Dentistry in Comprehensive Healthcare. *International Journal of Integrative Dental and Medical Sciences*. 2025 Mar 17:22-9.
 10. Ismail A, KR PK, Mandal S. The Role of Oral Microbiota in Systemic Diseases: Bridging the gap between Dentistry and Medicine. *International Journal of Integrative Dental and Medical Sciences*. 2025 Mar 17:30-6.
 11. Chatterjee S, Ahamed IN, Aggarwal M, Mandal S, Mandal S. Advances in Dental Biomaterials: Bridging Dentistry and Medicine for Improved Patient Outcomes. *International Journal of Integrative Dental and Medical Sciences*. 2025 Mar 17:1-6.
 12. Kumar S, Mandal S, Bhyan B, Pandey A, Mishra R, Jain A. Digital Marketing Trends and Consumer Engagement: A Review. *The International Journal of Humanities, Social Sciences and Business Management*. 2025 Feb 27:6-10.
 13. Mandal S, Mandal S. Cryptocurrency and the Future of Financial Markets: A Mini Review. *The International Journal of Humanities, Social Sciences and Business Management*. 2025 Feb 27:21-7.
 14. Mandal S, Mandal S. Mesalamine Microemulsions for Crohn's Disease: A Review. *International Journal of Health Sciences and Engineering*. 2025 Feb 17:1-8.
 15. Bhumika K, Ali S, Jahan I, Kumar M, Mandal S, Mandal S. Enhanced Bioavailability and Targeted Delivery of Mesalamine for Crohn's Disease Using Microemulsion Formulations. *International Journal of Health Sciences and Engineering*. 2025 Feb 17:16-20.
 16. Mandal S, Mandal S. Design and Evaluation of Liposomal Carriers for Targeted Delivery of siRNA In Cancer Therapy. *Current Pharmaceutical Letters And Reviews*. 2024 Oct 3:53-63.
 17. Bhumika K, Mandal S. Exploring the Chemical Composition and Cardioprotective Properties of *Plumeria obtusa* Using Advanced LC-MS/MS and Computational Methods in a Rabbit Model of Adriamycin-Induced Myocardial Injury. *Current Pharmaceutical Letters And Reviews*. 2024 Oct 3:64-70.
 18. Mandal S, Mandal S. Green Biomaterials from plants: Harnessing Nature for Sustainable Solutions. *Current Pharmaceutical Letters And Reviews*. 2024 Oct 3:11-24.
 19. Shiva K, Mandal S. Development and Characterization of Bioinspired Cationic Lipid Nanocarriers for Enhanced Anti-Cancer Vaccine Delivery and Tumor Inhibition: In Vitro and In Vivo Evaluation. *Current Pharmaceutical Letters And Reviews*. 2024 Oct 3:71-7.
 20. Mandal S, Mandal S. Strategic Design and Synthesis of Betulinic Acid Derivatives for Targeted Cancer Treatment. *Current Pharmaceutical Letters And Reviews*. 2024 Oct 3:88-94.
 21. Jahan I, Mandal S. Development of Multi-Functional Nanocarriers for Combined Chemo and Photothermal Cancer Therapy. *Current Pharmaceutical Letters And Reviews*. 2024 Oct 3:78-87.
 22. Mandal S, Singh AP. Development and In-Vitro Characterization of Gentamycin Sulphate Nanoemulgel for Ophthalmic Applications. *International Journal of Drug Delivery Technology*.

- 2024;14(4):2347-58. doi:
10.25258/ijddt.14.4.56
23. Suraj Mandal, Murraya koenigii: A Source of Bioactive Compounds for Inflammation and Pain Management, *Current Bioactive Compounds*; Volume 21, Issue , Year 2025, e15734072348822. DOI: 10.2174/0115734072348822250324073439
24. Jiyaul Hak, Iram Jahan, Nasiruddin Ahmad Farooqui, Atul Pratap Singh, Himanchal Sharma, Smriti Gohri, Anshu Gujjar, Suraj Mandal, Nanochips in the Field of Oncology: Advancements and Potential for Enhanced Cancer Therapy, *Current Cancer Therapy Reviews*; Volume 21, Issue , Year 2025, e15733947343855. DOI: 10.2174/0115733947343855241230115820
25. Iram Jahan, Jiyaul Hak, Suraj Mandal, Shadab Ali, Sayad Ahad Ali, Nasiruddin Ahmad Farooqui, Isoquinoline Quaternary Alkaloid (IQA) Nano-dressings: A Comprehensive Review on Design Strategies, Therapeutic Applications, and Advancements in Transdermal Delivery for Chronic Wound Management, *Recent Advances in Drug Delivery and Formulation*; Volume 19, Issue , Year 2025, e26673878330005. DOI: 10.2174/0126673878330005250326060103
26. Mandal S, Vishvakarma P. Nanoemulgel: A Smarter Topical Lipidic Emulsion-based Nanocarrier. *Indian J of Pharmaceutical Education and Research*. 2023;57(3s):s481-s498.
27. Mritunjay Kumar Ojha, Nalluri Satish Kumar, Umesh Kumar Sharma, Prakash Gadipelli, Suraj Mandal, Farah Deeba, Monalisa Khuntia, Hariballav Mahapatra (2024) Exploring the Potential of Artificial Intelligence in Optimizing Clinical Trial Design for More Efficient Drug Development. *Library Progress International*, 44(3), 9498-9510.
28. Mandal S, Jaiswal DV, Shiva K. A review on marketed Carica papaya leaf extract (CPLE) supplements for the treatment of dengue fever with thrombocytopenia and its drawback. *International Journal of Pharmaceutical Research*. 2020 Jul;12(3).
29. Mandal S, Bhumika K, Kumar M, Hak J, Vishvakarma P, Sharma UK. A Novel Approach on Micro Sponges Drug Delivery System: Method of Preparations, Application, and its Future Prospective. *Indian J of Pharmaceutical Education and Research*. 2024;58(1):45-63.
30. Mandal S, Vishvakarma P, Bhumika K. Developments in Emerging Topical Drug Delivery Systems for Ocular Disorders. *Curr Drug Res Rev*. 2023 Dec 29. doi: 10.2174/0125899775266634231213044704. Epub ahead of print. PMID: 38158868
