# siRNA: Its Translation from Research to Therapeutic Applications

*by* Jana Publication & Research

**Submission date:** 26-May-2025 12:28PM (UTC+0700)
**Submission ID:** 2665082853
**File name:** IJAR-51862.docx (33.36K)
**Word count:** 2887
**Character count:** 18597

# siRNA: Its Translation from Research to Therapeutic Applications

## Introduction

Small interfering RNA (siRNA) is a short, double-stranded RNA molecule that has emerged as a pivotal tool for gene silencing through the RNA interference (RNAi) pathway. It is a powerful post-transcriptional gene-silencing molecule central to RNA interference (RNAi) mechanisms[1]. Typically 21–25 nucleotides in length, it guides the RNA-induced silencing complex (RISC) to a target messenger RNA (mRNA), enabling sequence-specific degradation and effectively silencing gene expression[2]. This process is highly specific and forms the foundation for siRNA's role in research and therapeutic interventions[3]. By guiding the RNA-induced silencing complex (RISC) to target mRNA, siRNA enables post-transcriptional gene regulation with unparalleled precision. This targeted action holds immense promise in treating genetic, infectious, and degenerative diseases[4]. Therapeutically, siRNA offers unique advantages over traditional treatments, including the ability to target undruggable proteins, rapid development timelines, and reduced systemic toxicity. These advantages have catalyzed interest in siRNA for precision medicine and rare genetic disorders[5].

## History and Discovery

The siRNA journey began in 1990 when gene silencing was first reported in plants (petunias). This phenomenon, termed "co-suppression," hinted at a broader biological principle[6]. The landmark discovery came in 1998 when Andrew Fire and Craig Mello demonstrated that injecting double-stranded RNA into *C. elegans* could silence specific genes — a mechanism later known as RNA interference[7]. This breakthrough revolutionized molecular genetics, and earned them the Nobel Prize in 2006. By 2001, Tuschl and colleagues synthesized siRNA and used it to silence genes in mammalian cells, marking a

significant milestone in therapeutic development. This paved the way for siRNA's translation from experimental research to clinical innovation[8].

The discovery of small interfering RNA (siRNA) marked a paradigm shift in the understanding of gene regulation. The roots of this breakthrough lie in observations from the early 1990s, where researchers noted unexpected suppression of transgenes in plants—termed post-transcriptional gene silencing (PTGS)[9]. Similar mechanisms were later identified in fungi and animals, suggesting a conserved biological process[10]. The key turning point came in 1998, when Andrew Fire and Craig Mello demonstrated that introducing double-stranded RNA (dsRNA) into *Caenorhabditis elegans* could silence specific genes far more effectively than single-stranded RNA. Their work, which earned the 2006 Nobel Prize in Physiology or Medicine, confirmed that dsRNA triggered a potent and specific gene-silencing mechanism now known as RNA interference (RNAi)[11].

Subsequent research revealed that long dsRNA is processed by the enzyme Dicer into 21–23 nucleotide fragments, termed siRNAs. These siRNAs are incorporated into the RNA-induced silencing complex (RISC), which uses one strand as a guide to recognize and cleave complementary messenger RNA (mRNA), thereby suppressing gene expression. This mechanism, initially thought to be exclusive to lower organisms, was soon confirmed to operate in mammalian cells under certain conditions[12].

siRNAs belong to a broader family of small RNAs that includes microRNAs (miRNAs) and piwi-interacting RNAs (piRNAs). While siRNAs typically originate from exogenous or synthetic sources and show perfect complementarity to their mRNA targets, miRNAs are endogenously encoded and often act through partial pairing to suppress translation[13]. In contrast, piRNAs function in germline cells to silence transposable elements and operate via Dicer-independent mechanisms[14].

The discovery of siRNA had profound implications for biomedical science. It provided a precise and reversible method to silence genes, which transformed functional genomics research[15]. Almost immediately, siRNAs were explored as potential therapeutics for a variety of genetic and infectious diseases. However, the translation from bench to bedside was not without hurdles—issues such as delivery efficiency, stability in vivo, off-target effects, and immune responses initially hampered clinical development[16].

Nonetheless, the foundational discovery of siRNA remains a landmark achievement in molecular biology, laying the groundwork for the current and future era of RNA-based therapeutics[17].

## Research Applications of siRNA

In biomedical research, siRNA serves as a critical tool for functional genomics by enabling targeted gene knockdown. Scientists have employed siRNA to:

- Study cancer biology by silencing oncogenes or tumor suppressors.
- Model neurodegenerative diseases such as Alzheimer's and Parkinson's.
- Validate drug targets and understand disease mechanisms[18].

In infectious disease research, siRNA has been used to dissect host–pathogen interactions by selectively silencing host genes involved in viral entry, replication, or immune evasion—contributing significantly to antiviral drug development. For instance, siRNAs targeting host factors essential for HIV or influenza virus replication have identified novel therapeutic targets[19].

Additionally, in cardiovascular research, siRNA has been employed to study genes involved in lipid metabolism, atherosclerosis, and hypertension. Its ability to downregulate disease-associated genes in animal models has enabled the preclinical evaluation of gene-targeted therapies[20].

Collectively, siRNA continues to be a cornerstone of translational research, bridging basic molecular biology and therapeutic innovation. Its versatility and effectiveness in modeling diseases and validating targets underscore its enduring value in the biomedical research landscape[21].

It enables the systematic silencing of genes, aiding in the elucidation of gene function and the identification of disease-related pathways. siRNA has facilitated target validation, pathway

dissection, and the modeling of genetic disorders in vitro and in vivo. It has been instrumental in studying cancer biology, virology, neurodegenerative diseases, and cardiovascular conditions. The simplicity of designing siRNAs against virtually any gene, coupled with their robust knockdown capabilities, underscores their utility in preclinical research[22].

## From Research to Therapeutic Applications

siRNA's transition from research to therapy materialized with the advent of FDA-approved drugs such as Patisiran (ONPATTRO®) (2018) for hereditary transthyretin-mediated amyloidosis and Givosiran (GIVLAARI™) (2019) for acute hepatic porphyria. These drugs demonstrated the clinical potential of siRNA in silencing harmful genes systemically with minimal off-target effects[23].

The advent of Inclisiran, an siRNA targeting PCSK9 to lower cholesterol, further exemplifies siRNA's therapeutic utility[24]. Therapeutic siRNA must navigate biological barriers, remain stable in circulation, and target specific tissues. Advances in nanocarrier systems, including lipid nanoparticles (LNPs), have greatly enhanced siRNA delivery, enabling their therapeutic success in clinical trials and real-world use. Lipid nanoparticles (LNPs) and conjugate chemistries have enabled safe and effective delivery, making siRNA a cornerstone of modern therapeutics[25].

**Table.1: siRNA delivery system and its therapeutic outcome[26]**

| Sl.no | Disease | Target Genes | Delivery Systems/ Strategies | Therapeutic Outcomes |
|---|---|---|---|---|
| 1 | Cancer | KRAS, c-Myc, PD-L1 | - Lipid nanoparticles<br>- 2'-O-methylation<br>- Advanced targeting modifications | - Tumor suppression<br>- Immune activation<br>- Reversal of drug resistance |
| 2 | Rheumatoid Arthritis | NF-κB p65, STAT1 | - PEI-based nanocomplexes (Chen | - Reduced joint inflammation |

| | | | | |
|---|---|---|---|---|
| | | | et al.)<br>- RGD-modified PLGA NPs (Scheinman et al.) | - Targeted macrophage/dendritic cell suppression |
| 3 | Ulcerative Colitis | NF-κB p65 and related cytokines | - MPEG-PCL-CH2R4H2C NPs (Ibaraki)<br>- Silica-coated CaP NPs (Muller et al.) | - Suppressed inflammatory mediators<br>- Improved clinical & histopathological scores in colitis models |
| 4 | Brain Inflammation | Inflammatory genes (e.g., post-ICH) | - Poly(β-amino ester) NPs<br>- Receptor-mediated transcytosis<br>- Intranasal/intracerebral delivery<br>- LNPs, viral vectors | - Inflammation control<br>- Effective BBB penetration<br>- Neuroprotection and tumor inhibition |

## Limitations of siRNA

Despite the significant therapeutic potential of siRNA, several limitations must be addressed for its successful clinical application:

- **Instability in Biological Fluids**: Naked siRNA is highly susceptible to degradation by nucleases present in blood and tissues, limiting its half-life and therapeutic efficacy[27].
- **Rapid Renal Clearance**: Due to its small molecular size and hydrophilic nature, unmodified siRNA is quickly eliminated via the kidneys, reducing its systemic bioavailability[28].
- **Off-Target Effects**: siRNAs can inadvertently silence genes with partial sequence similarity, leading to unintended gene knockdown and potential toxicity[29].

- **Immune Stimulation**: Certain siRNA sequences may activate innate immune responses through Toll-like receptors (e.g., TLR3, TLR7/8), triggering inflammation or cytokine release[30].
- **Poor Cellular Uptake**: siRNA cannot easily cross cell membranes due to its negative charge and hydrophilicity, requiring specialized delivery systems to ensure intracellular access[31].
- **Limited Tissue Specificity**: Achieving targeted delivery to specific tissues or cell types remains challenging, particularly in non-hepatic tissues[32].
- **Risk of Saturating the RNAi Machinery**: High doses of exogenous siRNA may overload components of the endogenous RNAi pathway, potentially disrupting normal microRNA function[33].

Addressing these limitations necessitates the development of **advanced delivery platforms** (e.g., lipid nanoparticles, polymeric carriers) and **chemical modifications** (e.g., 2'-O-methyl, phosphorothioate linkages) to improve stability, specificity, and safety[34].

## Approaches to overcome limitations of siRNA as a therapeutic agents

The clinical translation of siRNA has been significantly advanced through the development of innovative strategies aimed at overcoming its biological and pharmacokinetic limitations. These approaches span chemical engineering, delivery system design, and molecular optimization[35]:

**Table.2: Strategies to Enhance siRNA Therapeutics[36]**

| Sl.no | Strategy | Description |
|---|---|---|
| 1 | Chemical Modifications to Enhance Stability and Reduce Immunogenicity | -**2'-O-Methyl (2'-OMe)** & **2'-Fluoro (2'-F)**: Improve nuclease resistance and reduce immunostimulation. -**LNA**: Locked conformation enhances stability and binding. -**Phosphorothioate Linkages**: Improve plasma |

| | | |
|---|---|---|
| | | stability and degradation resistance.<br><br>**Note:-**These modifications improve pharmacokinetics, reduce dosing frequency, and enhance safety profiles. |
| 2 | Advanced Delivery Systems | - **Lipid Nanoparticles (LNPs)**: Prevent degradation and support cellular uptake.<br>- **Polymeric Carriers (e.g., PLGA, PEI)**: Controlled release and targeted delivery.<br>- **Peptide-Based Systems**: Tissue-specific targeting via CPPs and ligands. |
| 3 | Hybrid & Multifunctional Platforms | - **Combinatorial Systems**: Integrate lipids, polymers, and targeting ligands for synergistic benefits.<br>- Can include **imaging agents** for theranostics and monitoring therapeutic efficacy. |
| 4 | Sequence Optimization and Design | - **Bioinformatics Tools**: Aid in designing siRNAs with minimal off-target effects.<br>- **Guide Strand Modifications**: Prevent unintended mRNA interactions and improve specificity. |
| 5 | siRNA Pooling Strategies | - **Smart Pooling**: Combines multiple siRNAs targeting different regions of the same gene.<br>- Reduces off-target effects while maintaining silencing potency—useful in screening and early therapy stages. |

## Challenges in Development and Deployment of siRNA Therapeutics

Several challenges continue to hinder siRNA's widespread therapeutic use. Efficient and targeted delivery remains a bottleneck, especially for extrahepatic tissues. Formulating stable, biocompatible delivery vehicles that can navigate the immune system and reach target cells is critical[37]. Additionally, large-scale manufacturing, cost, and regulatory hurdles affect clinical

translation. Dosing regimens, long-term effects, and patient variability must be addressed through rigorous clinical studies. Despite these challenges, the expanding siRNA therapeutic pipeline reflects strong industry and academic interest in overcoming these barriers[38].

**Table.3: Key Challenges at a Glance – siRNA Therapeutics[39]**

| Sl.no | Challenges | Description |
|---|---|---|
| 1 | Targeting Beyond the Liver | siRNA therapies work well in the liver, but efficient delivery to organs like the brain, lungs, or joints remains a major hurdle. |
| 2 | Building the Perfect Carrier | Requires stable, biocompatible vehicles that evade the immune system, resist degradation, and accurately reach target cells. |
| 3 | Scale-Up Struggles | Large-scale production faces challenges in maintaining consistency, stability, and cost-efficiency for clinical deployment. |
| 4 | Cost and Complexity | High production and formulation costs limit affordability and accessibility, especially in low-resource healthcare settings. |
| 5 | Regulatory Roadblocks | Complex and evolving regulatory requirements demand robust safety and efficacy data, slowing clinical progress. |
| 6 | Dosing and Duration Dilemmas | Determining effective dosing and assessing long-term impacts is essential, with concerns around toxicity and therapeutic duration. |
| 7 | Patient-Specific Variability | Genetic and physiological differences require tailored strategies to ensure consistent |

| | | |
|---|---|---|
| | | therapeutic outcomes across diverse patient populations. |

## Future Prospects of siRNA Therapeutics

The future of siRNA lies in expanding beyond liver targets through innovative delivery methods and personalized approaches, positioning it as a key player in next-generation precision medicine[40].

## Conclusion

siRNA has revolutionized gene silencing, transitioning from a powerful research tool to a clinical therapeutic platform. Despite inherent limitations, continuous innovations in molecular design and delivery systems have substantially enhanced its viability. The success of drugs like Inclisiran and Patisiran underscores the therapeutic promise of siRNA. Future breakthroughs in targeting, safety, and scalability will determine its role in mainstream medicine. As the field evolves, siRNA is poised to reshape the landscape of disease management and personalized therapy.

## References


1) Dana H, Chalbatani GM, Mahmoodzadeh H, Karimloo R, Rezaiean O, Moradzadeh A, Mehmandoost N, Moazzen F, Mazraeh A, Marmari V, Ebrahimi M. Molecular mechanisms and biological functions of siRNA. International journal of biomedical science: IJBS. 2017 Jun;13(2):48.
2) Agrawal N, Dasaradhi PV, Mohmmed A, Malhotra P, Bhatnagar RK, Mukherjee SK. RNA interference: biology, mechanism, and applications. Microbiology and molecular biology reviews. 2003 Dec;67(4):657-85.
3) Kang H, Ga YJ, Kim SH, Cho YH, Kim JW, Kim C, Yeh JY. Small interfering RNA (siRNA)-based therapeutic applications against viruses: principles, potential, and challenges. Journal of Biomedical Science. 2023 Oct 16;30(1):88.
4) Pratt AJ, MacRae IJ. The RNA-induced silencing complex: a versatile gene-silencing machine. Journal of Biological Chemistry. 2009 Jul 3;284(27):17897-901.

5) Friedrich M, Aigner A. Therapeutic siRNA: state-of-the-art and future perspectives. BioDrugs. 2022 Sep;36(5):549-71.
6) Eamens A, Wang MB, Smith NA, Waterhouse PM. RNA silencing in plants: yesterday, today, and tomorrow. Plant physiology. 2008 Jun 1;147(2):456-68.
7) Zamore PD. RNA interference: big applause for silencing in Stockholm. Cell. 2006 Dec 15;127(6):1083-6.
8) Tuschl T. More than a Messenger: Discovering the Gene-Regulating Power of Small RNAs and Their Potential as Novel Therapies.
9) Chen X. Small RNAs–secrets and surprises of the genome. The plant journal. 2010 Mar;61(6):941-58.
10) Dunlap JC, Loros JJ. Making time: conservation of biological clocks from fungi to animals. Microbiology spectrum. 2017 Jun 30;5(3):10-128.
11) Fire AZ. Gene silencing by double-stranded RNA (Nobel lecture). Angewandte Chemie International Edition. 2007 Sep 17;46(37):6966-84.
12) Carthew RW, Sontheimer EJ. Origins and mechanisms of miRNAs and siRNAs. Cell. 2009 Feb 20;136(4):642-55.
13) Ghildiyal M, Zamore PD. Small silencing RNAs: an expanding universe. Nature reviews genetics. 2009 Feb;10(2):94-108.
14) Tóth KF, Pezic D, Stuwe E, Webster A. The piRNA pathway guards the germline genome against transposable elements. Non-coding RNA and the Reproductive System. 2016:51-77.
15) Malakondaiah S, Julius A, Ponnambalam D, Gunthoti SS, Ashok J, Krishana PS, Rebecca J. Gene silencing by RNA interference: a review. Genome Instability & Disease. 2024 Oct;5(5):225-41.
16) Zhang J, Chen B, Gan C, Sun H, Zhang J, Feng L. A comprehensive review of small interfering RNAs (siRNAs): mechanism, therapeutic targets, and delivery strategies for cancer therapy. International journal of nanomedicine. 2023 Dec 31:7605-35.
17) Guo W, Chen W, Yu W, Huang W, Deng W. Small interfering RNA-based molecular therapy of cancers. Chinese journal of cancer. 2013 Sep;32(9):488.
18) Motamedi H, Ari MM, Alvandi A, Abiri R. Principle, application and challenges of development siRNA-based therapeutics against bacterial and viral infections: a comprehensive review. Frontiers in Microbiology. 2024 Jun 13;15:1393646.
19) Chorro FJ, Such-Belenguer L, López-Merino V. Animal models of cardiovascular disease. Revista Española de Cardiología (English Edition). 2009 Jan 1;62(1):69-84.

20) Ding Y, Chen QB, Xu H, Adi D, Ding YW, Luo WJ, Zhu WZ, Xu JC, Zhao X, Shi XJ, Luo J. siRNA nanoparticle targeting Usp20 lowers lipid levels and ameliorates metabolic syndrome in mice. Journal of Lipid Research. 2024 Sep 1;65(9):100626.
21) Friedrich M, Aigner A. Therapeutic siRNA: state-of-the-art and future perspectives. BioDrugs. 2022 Sep;36(5):549-71.
22) Leung RK, Whittaker PA. RNA interference: from gene silencing to gene-specific therapeutics. Pharmacology & therapeutics. 2005 Aug 1;107(2):222-39.
23) Padda IS, Mahtani AU, Patel P, Parmar M. Small interfering RNA (siRNA) therapy. InStatPearls [Internet] 2024 Mar 20. StatPearls Publishing.
24) Ray KK, Stoekenbroek RM, Kallend D, Leiter LA, Landmesser U, Wright RS, Wijngaard P, Kastelein JJ. Effect of an siRNA therapeutic targeting PCSK9 on atherogenic lipoproteins: prespecified secondary end points in ORION 1. Circulation. 2018 Sep 25;138(13):1304-16.
25) Kalita T, Dezfouli SA, Pandey LM, Uludag H. siRNA functionalized lipid nanoparticles (LNPs) in management of diseases. Pharmaceutics. 2022 Nov 19;14(11):2520.
26) Grimm D. Small silencing RNAs: state-of-the-art. Advanced drug delivery reviews. 2009 Jul 25;61(9):672-703.
27) Sajid MI, Moazzam M, Kato S, Yeseom Cho K, Tiwari RK. Overcoming barriers for siRNA therapeutics: from bench to bedside. Pharmaceuticals. 2020 Oct 7;13(10):294.
28) Yang C, Zhang C, Zhao Z, Zhu T, Yang B. Fighting against kidney diseases with small interfering RNA: opportunities and challenges. Journal of Translational Medicine. 2015 Dec;13:1-2.
29) Fedorov Y, Anderson EM, Birmingham A, Reynolds A, Karpilow J, Robinson K, Leake D, Marshall WS, Khvorova A. Off-target effects by siRNA can induce toxic phenotype. Rna. 2006 Jul 1;12(7):1188-96.
30) Weber C, Müller C, Podszuweit A, Montino C, Vollmer J, Forsbach A. Toll-like receptor (TLR) 3 immune modulation by unformulated small interfering RNA or DNA and the role of CD14 (in TLR-mediated effects). Immunology. 2012 May;136(1):64-77.
31) Meade BR, Dowdy SF. Enhancing the cellular uptake of siRNA duplexes following noncovalent packaging with protein transduction domain peptides. Advanced drug delivery reviews. 2008 Mar 1;60(4-5):530-6.
32) Shalaby K, Aouida M, El-Agnaf O. Tissue-specific delivery of CRISPR therapeutics: Strategies and mechanisms of non-viral vectors. International Journal of Molecular Sciences. 2020 Oct 5;21(19):7353.

33) Olejniczak M, Galka P, Krzyzosiak WJ. Sequence-non-specific effects of RNA interference triggers and microRNA regulators. Nucleic acids research. 2010 Jan 1;38(1):1-6.
34) Lu H, Zhang S, Wang J, Chen Q. A review on polymer and lipid-based nanocarriers and its application to nano-pharmaceutical and food-based systems. Frontiers in nutrition. 2021 Dec 1;8:783831.
35) Zhang MM, Bahal R, Rasmussen TP, Manautou JE, Zhong XB. The growth of siRNA-based therapeutics: Updated clinical studies. Biochemical pharmacology. 2021 Jul 1;189:114432.
36) Ali Zaidi SS, Fatima F, Ali Zaidi SA, Zhou D, Deng W, Liu S. Engineering siRNA therapeutics: challenges and strategies. Journal of Nanobiotechnology. 2023 Oct 18;21(1):381.
37) Ebenezer O, Oyebamiji AK, Olanlokun JO, Tuszynski JA, Wong GK. Recent Update on siRNA Therapeutics. International Journal of Molecular Sciences. 2025 Apr 8;26(8):3456.
38) Chehelgerdi M, Chehelgerdi M, Allela OQ, Pecho RD, Jayasankar N, Rao DP, Thamaraikani T, Vasanthan M, Viktor P, Lakshmaiya N, Saadh MJ. Progressing nanotechnology to improve targeted cancer treatment: overcoming hurdles in its clinical implementation. Molecular cancer. 2023 Oct 9;22(1):169.
39) Gavrilov K, Saltzman WM. Therapeutic siRNA: principles, challenges, and strategies. The Yale journal of biology and medicine. 2012 Jun 25;85(2):187.
40) Yu L, Liu S, Jia S, Xu F. Emerging frontiers in drug delivery with special focus on novel techniques for targeted therapies. Biomedicine & Pharmacotherapy. 2023 Sep 1;165:115049.

# siRNA: Its Translation from Research to Therapeutic Applications

ORIGINALITY REPORT

| 14% | 9% | 11% | 5% |
|---|---|---|---|
| SIMILARITY INDEX | INTERNET SOURCES | PUBLICATIONS | STUDENT PAPERS |

PRIMARY SOURCES

| | | |
|---|---|---|
| 1 | www.frontiersin.org<br>Internet Source | 2% |
| 2 | Submitted to Johns Hopkins Unversity<br>Student Paper | 1% |
| 3 | Submitted to Monash University<br>Student Paper | 1% |
| 4 | epdf.pub<br>Internet Source | 1% |
| 5 | Harikumar Pallathadka, Majid Jabir, Khetam Habeeb Rasool, H. Malathi et al. "siRNA-based therapy for overcoming drug resistance in human solid tumours; molecular and immunological approaches", Human Immunology, 2025<br>Publication | 1% |
| 6 | facts.net<br>Internet Source | 1% |
| 7 | scholars.hkbu.edu.hk<br>Internet Source | 1% |
| 8 | Submitted to University of Glasgow<br>Student Paper | 1% |
| 9 | "RNA-Based Cancer Therapeutics", Springer Science and Business Media LLC, 2025<br>Publication | 1% |

| | | |
|---|---|---|
| 10 | María J. Blanco-Prieto, Elisa Garbayo. "Preface: RNA delivery technologies: From concept toward the clinic", Advanced Drug Delivery Reviews, 2024<br>Publication | 1 % |
| 11 | B Haley. "In vitro analysis of RNA interference in Drosophila melanogaster", Methods, 2003<br>Publication | 1 % |
| 12 | GA Dissen, A Lomniczi, RL Boudreau, YH Chen, BL Davidson, SR Ojeda. "Targeted Gene Silencing to Induce Permanent Sterility", Reproduction in Domestic Animals, 2012<br>Publication | 1 % |
| 13 | bmcbiol.biomedcentral.com<br>Internet Source | 1 % |
| 14 | patents.justia.com<br>Internet Source | 1 % |
| 15 | worldwidescience.org<br>Internet Source | 1 % |
| 16 | Makhloufi Zoulikha, Qingqing Xiao, George Frimpong Boafo, Marwa A. Sallam, Zhongjian Chen, Wei He. "Pulmonary delivery of siRNA against acute lung injury/acute respiratory distress syndrome", Acta Pharmaceutica Sinica B, 2021<br>Publication | <1 % |
| 17 | era.library.ualberta.ca<br>Internet Source | <1 % |
| 18 | Wardina Humayrah, Nindy Sabrina, Megah Stefani, Nurpudji Astuti Taslim et al. "The role of micro-ribonucleic acid and small interfering-ribonucleic acid in precision | <1 % |

nutrition for obesity management", Clinical Nutrition ESPEN, 2025
Publication

| | | |
|---|---|---|
| 19 | pmc.ncbi.nlm.nih.gov<br>Internet Source | <1% |
| 20 | Harshini Kurakula, Swetha Vaishnavi, Mohammed Yaseen Sharif, Satheesh Ellipilli. "Emergence of Small Interfering RNA-Based Gene Drugs for Various Diseases", ACS Omega, 2023<br>Publication | <1% |
| 21 | Houman Isazadeh, Farshid Oruji, Shima Shabani, Javad Behroozi, Hadi Nasiri, Alireza Isazadeh, Morteza Akbari. "Advances in siRNA delivery approaches in cancer therapy: challenges and opportunities", Molecular Biology Reports, 2023<br>Publication | <1% |

| | | | |
|---|---|---|---|
| Exclude quotes | On | Exclude matches | Off |
| Exclude bibliography | On | | |