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Integrated Injectable Therapies in the Modulation of Chronic Inflammation in Obesity, Cancer, and Type 2 Diabetes

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Article

Integrated Therapeutic Approaches for Modulating Inflammation in Cancer, Obesity, and Type 2 Diabetes: Injectable Use of DMSO, Coenzyme Q10, Alpha-Lipoic Acid, Curcumin, and miR-146a-Containing Phytotherapeutics

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Abstract

Chronic inflammation plays a central role in the pathogenesis of cancer, obesity, and type 2 diabetes (T2D), driven by dysregulated immune and metabolic signaling pathways including NF-κB and JNK, and molecular regulators such as microRNAs (miRNAs) miR-146a and miR-155. This review synthesizes current evidence supporting integrated therapeutic strategies using injectable dimethyl sulfoxide (DMSO), coenzyme Q10 (CoQ10), alpha-lipoic acid (ALA), curcumin, and miR-146a mimics derived from phytotherapeutics. The rationale for injectable delivery focuses on enhanced bioavailability, rapid onset, and efficient tissue targeting. The anti-inflammatory, antioxidant, and metabolic modulatory mechanisms of these agents are explored, with emphasis on miR-146a's crucial role in attenuating excessive inflammation via targeting IRAK1 and TRAF6 and restoring immune-metabolic homeostasis. Additionally, phytotherapeutic sources modulating miRNAs such as ginger, green tea, and echinacea are reviewed. This integrative approach holds promise for improving clinical outcomes in multifactorial chronic inflammatory diseases, warranting further translational and clinical studies.

Keywords: obesity; chronic inflammation; type 2 diabetes; cancer; injectable therapies; miR-146a; DMSO; CoQ10; ALA; curcumin; glutathione (GSH)

Introduction

Chronic low-grade inflammation constitutes a common mechanistic link between cancer, obesity, and type 2 diabetes (T2D). Central inflammatory pathways such as NF-κB and JNK orchestrate the production of pro-inflammatory cytokines (TNF-α, IL-6, IL-1β) contributing to insulin resistance, tumor progression, and adipose tissue dysfunction [1–4]. MicroRNAs, especially miR-146a and miR-155, regulate these processes post-transcriptionally by fine-tuning signaling components such as IRAK1 and TRAF6 [5–8]. Dysregulation of these miRNAs correlates with exacerbated inflammatory states in these diseases [9–11]. Injectable therapies delivering DMSO, CoQ10, ALA, curcumin, and miR-146a mimics optimize delivery, overcoming limitations of oral administration, enhancing therapeutic effects [12–16]. Phytotherapeutics rich in these compounds modulate miRNA expression and provide additional anti-inflammatory benefits [17–20]. This article reviews molecular and clinical data supporting these integrated injectable therapies.

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Injectable Agent	Key Benefits	Therapeutic Indications	Mechanisms of Action	Notable Considerations
DMSO (Dimethyl Sulfoxide)	- Excellent cellular membrane penetration - Enhances delivery of co-administered compounds - Anti-inflammatory and antioxidant effects by decreasing pro-inflammatory cytokines and oxidative stress	- Inflammatory conditions - Neurological injury - Facilitator vehicle for other injectables	- Facilitates rapid compound absorption - Direct inhibition of cytokines (TNF-α, IL-6) - Modulates oxidative stress pathways	- Extensive clinical use history - Generally safe when used appropriately (Refs: [14,15,26–29])
Coenzyme Q10 (CoQ10)	- Potent mitochondrial antioxidant - Reduces oxidative damage and systemic inflammation - Supports cellular bioenergetics and tissue repair	- Obesity-related inflammation - Type 2 diabetes complications - Cancer microenvironment modulation	- ROS scavenging - Mitochondrial electron transport support - Modulation of inflammatory cytokines (Refs: [16–18,30–34])	- Well tolerated - Injectable form improves bioavailability
Alpha-Lipoic Acid (ALA)	- Multifunctional antioxidant and metal chelator - Improves insulin sensitivity - Protects pancreatic β-cells and reduces tissue fibrosis	- Insulin resistance and T2D - Metabolic inflammation - Oxidative stress-related tissue injury	- Neutralizes free radicals - Inhibits NF-κB and JNK pathways - Enhances glucose uptake signaling (Refs: [19–22,35–39])	- May complement standard diabetic therapies - Requires dosing optimization for injectables
Curcumin	- Inhibits NF-κB activation and pro-inflammatory cytokines - Upregulates anti-inflammatory microRNAs (e.g.,	- Chronic inflammatory diseases - Metabolic syndrome components - Cancer adjunct therapy	- Blocks key inflammatory transcription factors - Modulates miRNA profiles - Enhances	- Low oral bioavailability; injectable forms increase efficacy

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Injectable Agent	Key Benefits	Therapeutic Indications	Mechanisms of Action	Notable Considerations
	miR-146a) - Antioxidant and anticancer activities		antioxidant defenses (Refs: [14,23–27,40–44])	
miR-146a Mimics (Injectable)	- Direct repression of IRAK1, TRAF6, and NF-κB signaling - Potent negative regulator of inflammation - Reduces inflammation, fibrosis, and improves wound healing	- Chronic inflammatory diseases including cancer, obesity, T2D - Potential in autoimmune disorders - Adjunct for metabolic syndrome (Refs: 1,4,5,7,8,45-48)	- Post-transcriptional gene silencing of inflammatory mediators - Restoration of immune-metabolic balance	- Nanoparticle or exosomal delivery required - Careful monitoring needed for immunosuppression risk

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Injectable Therapeutics and Their Rationale

Injectable delivery bypasses gastrointestinal degradation and first-pass metabolism, ensuring higher systemic bioavailability and faster pharmacodynamic effects [12,21]. It allows precise dosing and co-administration of multiple agents, crucial for multimodal therapy [22]. Nanocarriers and exosomal formulations facilitate the delivery of miRNA mimics like miR-146a, protecting them from degradation and enhancing cellular uptake [23–25].

Specific Injectable Agents

Dimethyl Sulfoxide (DMSO)

DMSO is a membrane-penetrating solvent enhancing absorption of co-administered compounds and exhibits independent anti-inflammatory, antioxidant effects by reducing pro-inflammatory cytokines and oxidative stress [26–28]. Clinical experience supports its safety in inflammation and neurological conditions [29].

- DOI: 10.1007/s11010-011-0727-3
- PMID: 21674015
- PMC: PMC3106211
- Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3106211/

Coenzyme Q10 (CoQ10)

CoQ10 is a mitochondrial electron transporter with potent antioxidant activity, decreasing reactive oxygen species related to inflammation and preserving mitochondrial function [30–33]. Injectable CoQ10 ameliorates metabolic inflammation in obesity and diabetes models [34].

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- PMID: 16581168

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- PMC: PMC6272576

- Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6272576/

Alpha-Lipoic Acid (ALA)

ALA acts as a broad-spectrum antioxidant and metal chelator, improving insulin sensitivity and reducing metabolic inflammation by inhibiting NF-κB and JNK pathways [35–38]. Injectable ALA supports pancreatic β-cell preservation and metabolic homeostasis [39].

- DOI: 10.1016/j.bbamcr.2008.09.018

- PMID: 18805455

- PMC: PMC2730833

- Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2730833/

Curcumin

Curcumin, derived from Curcuma longa, inhibits NF-κB activation and pro-inflammatory cytokine production and promotes miR-146a expression, thus restoring anti-inflammatory control [40–43]. Injectable formulations overcome bioavailability limitations and enhance clinical efficacy [44].

- DOI: 10.1016/j.intimp.2009.06.005

- PMID: 19682990

- PMC: PMC2925237

- Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2925237/

miR-146a Mimics

miR-146a downregulates IRAK1 and TRAF6, providing a negative feedback loop on TLR/IL-1R–mediated NF-κB activation [5,45]. Injectable nanoparticle-encapsulated miR-146a mimics reduce inflammation and fibrosis in preclinical diabetes and cancer models [46–48].

- DOI: 10.1073/pnas.0605298103

- PMID: 16945974

- PMC: PMC1564495

- Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1564495/

Phytotherapeutics Modulating MicroRNAs

Phytochemicals modulate inflammatory miRNAs, enhancing therapeutic potential:

- *Turmeric (Curcuma longa):* Induces miR-146a expression, exerting anti-inflammatory and metabolic benefits [49].

- *Ginger (Zingiber officinale):* Promotes miR-146a expression and improves metabolic inflammation [50,51].

- *Green Tea (Camellia sinensis):* Regulates miR-125b to suppress inflammation [52].

- *Echinacea purpurea:* Downregulates miR-155 involved in immune activation [53].

- *Artemisia annua:* Modulates miR-Let-7 associated with metabolic regulation [54].

Further experimental and clinical studies are required for validation.

- DOI: 10.1016/j.molnut.2015.10.003

- PMID: 26562757

- PMC: PMC4687390

- Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4687390/

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Discussion and Future Directions

Integrated injectable therapies combining DMSO, CoQ10, ALA, curcumin, and miR-146a mimics offer multimodal intervention against chronic inflammation in cancer, obesity, and T2D. Personalized medicine approaches using circulating miRNA profiles can optimize patient stratification and treatment outcomes [55]. Careful evaluation of immunosuppression and off-target effects is imperative [56]. Ongoing clinical trials and advancements in nanodelivery systems will support translation into routine care.

Conclusions

The integration of injectable DMSO, coenzyme Q10, alpha-lipoic acid, curcumin, and miR-146a mimics, supported by phytotherapeutics modulating relevant microRNAs, provides a promising multifaceted therapeutic approach to chronic inflammatory diseases, with mechanistic and clinical rationale pending robust validation.

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