Innovations

Nanotheranostics: a Kaleidoscope to the future -A review

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Abstract
Need: Nanotheranostics encompasses the combined efforts of diagnostic imaging and therapy in one system. It is also a science of which adequate awareness and research is still lagging. It is a type of personalized medicine, wherein molecular understanding of the disease and conforming the treatment, is based on the patients' genes, proteins and metabolites. It uses nano-sized particles in various polymer conjugations, dendrimers, micelles, liposomes, metal and inorganic nanoparticles, carbon nanotubes, nanoparticles of biodegradable polymers for uninterrupted, restrained and targeted co-delivery of agents.**Methods:**A current literature search of the entire database was performed using MEDLINE/PubMed/ Cochrane with "nanotheranostics", "nanotheranostics in dentistry", "nanotheranostics in imaging" and "nanotheranostics in diagnosis and therapy" as key words, in March 2019.**Discussion:**As of current literature, it has forayed into cancer detection and management, diagnostic imaging as well as autoimmune disease remedies.This review of literature aspires to address the importance of such approach, a boon to Oral Medicine and Radiology.

Keywords:1. Nanotheranostics 2. Nanotheranosticsin dentistry 3. Nanotheranostics in imaging, 4. Nanotheranostics in diagnosis and therapy

1.Introduction

Nanotheranostics encompasses the combined efforts of diagnostic imaging and therapy in one system. It is a type of personalized medicine, wherein molecular understanding of the disease and conforming the treatment,is based on the patients' genes, proteins and metabolites[1].This diagnostic and therapeutic modality utilizes nanotherapeutics, that capitalizes polymer conjugations, dendrimers, micelles, liposomes, metal and inorganic nanoparticles, carbon nanotubes, nanoparticles of biodegradable polymers for uninterrupted, restrained and targeted co-delivery of agents. This conception will have lesser side effects which is ideal for any therapeutic measure[2].
This review of literature aspires to address the importance of such approach, a boon to Oral Medicineand Radiology.

2. Methodology

A current literature search was performed using MEDLINE/PubMed/ Cochrane databases with "nanotheranostics", "nanotheranostics in dentistry", "nanotheranostics in imaging" and "nanotheranostics in diagnosis and therapy" as key words, inMarch 2019. Both original research and review articles were selected for reporting recent techniques for the development of nanotheranostics. Only the most representative publications indexed in PubMed/MEDLINE or Scopus, written in English were considered. Other relevant research articles were manually obtained from previous publications.

3. Discussion

Nanotheranostics has the potential to add another dimension to the field of Oral Medicine and Radiology. As of current literature, it has forayed into cancer detection and management, diagnostic imaging as well as autoimmune disease remedies.

Cancer

Cancer, a convoluted, diverse, and destructive disease, is globally recognized as overwhelmingly demanding in terms of early diagnosis and management.A preeminent system, nanotheranosticscan first diagnose the type of cancer class, image the heterogeneity of the tumor, apply a tailored treatment based on the diagnostic and imaging results. It is also adept atmonitoring the treatment efficacy[3].

The mechanism of action of nanoparticles: oral or intravenous ingestion followed by circulation in blood. They further accumulate in the tumourby vascular extravasation due to irregular blood vessels and the increased vascularity. These particles further penetrate tissue in the tumourmicroenvironment and internalizes within the cells, further releasing the drug intracellulary[5].

Xue at al reported the development and successful trial of a dual size/ charge- transformable, nanoparticle for delivery of ultra-small, fullyactive pharmaceutical constituents (drug) with interspersed bimodal imaging and trimodal therapeutic functions.The dual size allowedease in blood circulation and size transformation enables tumour accumulation via extravasations from blood vessels. The trimodal therapeutic functions included targeted drug delivery to tumor site, photodynamic effect and synergistic action with chemotherapy[6].

The genomic markers released by malignant cells are identified by the programmed nanoparticles, enabling targeted delivery to tumour site [6]. This in turn alleviates the drug induced toxicity to other organ systems simultaneously amplifying drug efficacy [4].

Additionally, Eyvazzadeh et al in a study reported the ability of nanoparticles to act as radiosensitizers in radiotherapy [5]. With these sterling qualities to recommend it, early cancer diagnosis, imaging and treatment is just beyond the horizon.

Imaging

Nanotheranostics has forayed into imaging as well.A metabolic by-product of the presenting pathology such as matrix metalloprotease, produced in cancer metabolism is identified.Organic nanoparticle flourophoresensitive to such by-products areused, which then accumulates within the lesion based on AIE (Aggregation induced emission).Additional advantages of these nanoparticles include emitting non-ionizing radiation during fluorescence, photo stability and biocompatibility.In photodynamic therapy, this principle is applied. Hence, simultaneous to the optical imaging during fluorescence, the heat generated on laser activation, causes therapeutic cell death[7]. Xia Q et al has investigated this modicum and reported great application prospects in cell tracking, tumor imaging and image guided treatment[8].

In CT imaging, gold nanoparticles(AuNP) have been proved for use as contrast agent. It is facilitated owing to the biocompatibility, higher atomic number and X-ray absorption coefficient. Kim et al presented novel multifunctional AuNP for targeted molecular CT imaging and therapy of prostate cancer[9].

MRI is one of the primary oncology imaging modalities. Magnetic iron oxide (IO) nanoparticles have been proven effective as target-specific MRI T2 contrast agents[10]. They are more efficient than Gadolinium-DTPA as relaxation promoters and their magnetic properties can be manipulated by controlling the sizes of core and coating surface. More importantly, IO nanoparticles have a long blood retention time, biodegradability and low toxicity[11].

Autoimmune disease

Autoimmune diseases are protracted, detrimental diseases that can cause functional disability and eventual multiple organ failure. Despite compelling advances in the multitude of therapeutic agents, constraints in the routes of administration, the need for incessant long-term dosing and meager targeting options resulted in suboptimal effects, systemic adverse reactions and patient non-compliance[12].In the context of autoimmunity, nanoparticles primarily target the immune cells. They have demonstrated uses as antigen linked nanoparticles in artificial apoptotic antigen presenting cells, peptide MHC based nanovaccinesand targeting dendritic cells[17, 18,19].Also,cellular toxicity associated with certain nanomaterials has been used to kill or inhibit pathogenic cell types by preferential accumulation into specific sub-cellular compartments of immune cell types.This principle avails the potential to enhance the desired biological activity while limiting the off-target toxicity of drugs. Some of the key autoimmune disorders clinically tested include type 1 diabetes,multiple sclerosis, systemic lupus erythematosus and rheumatoid arthritis[17,19,20].

Autoimmune diseases are extremely challenging to control and cure is next to impossible by contemporary standards. However, with nanotheranostics, the disadvantage of current treatment protocol is becoming a thing of the past.

Conclusion

Nanotheranostics and its advantages are multiplying by the second. It's potential to benefit multiple challenging diseases and disorders in Oral medicine and to revolutionize the diagnosis through Radiology is staggering. However, it's relative neoteric aspect and the compounding cost of this therapy is a limiting factor.

References

1. Kim T, LeeS,Chen X. Nanotheranostics for personalized medicine. Expert Rev. Mol. Diagn.2013;13(3):257–269.
2. KP Mahesh."Nanotheranostics-Novel Modality for Integrating Diagnosis and Therapy for Oral Cancer". Acta Scientific Dental Sciences.2018; 2 (9): 57-58.
3. Silva C, PinhoJ, Lopes J , Almeida A, Gaspar M, Reis C. Current Trends in Cancer Nano-theranostics : Metallic, Polymeric, and Lipid-Based Systems. Pharmaceutics 2019;11:22.
4. XueX et al. Trojan horse nanotheranostics with dual transformability and multi functionality for highly effective cancer treatment. Nature communications. 2018;9:3653.
5. EyvazzadehN et al. Gold-coated magnetic nanoparticle as a nanotheranostic agent for magnetic resonance imaging and photothermal therapy of cancer. Lasers Med Sci 2017;32:1469–1477.
6. Abiodun-Solanke, Ajayi DM, Arigbede AO. Nanotechnology and its Application in Dentistry.Ann Med Health Sci Res. 2014; 4(3): S171–S177.
7. Wang L, Chuang M, Ho J A. Nanotheraostics – a review of recent publications. Int J Nanomedicine. 2012; 7: 4679–4695.

8. Xia Q, Chen Z, Zhou Y, Liu R. Near-Infrared Organic Fluorescent Nanoparticles for Long-term Monitoring and Photodynamic Therapy of Cancer. Nanotheranostics 2019; 3(2): 156-165.
9. S Jain, D G Hirst, J M O'Sullivan. Gold nanoparticles as novel agents for cancer therapy.Br J Radiol. 2012; 85(1010): 101–113.
10. Peng X et al. Targeted magnetic iron oxide nanoparticles for tumor imaging and therapy.Int J Nanomedicine. 2008; 3(3): 311–321.
11. Rogers WJ, Basu P. Factors regulating macrophage endocytosis of nanoparticles: implications for targeted magnetic resonance plaque imaging. Atherosclerosis. 2005; 178(1):67-73.
12. Marjan G, Slawomir M, MariannaF.Therapeutic applications of nanomedicine in autoimmune diseases: From immunosuppression to tolerance induction. Nanomedicine: Nanotechnology, Biology, and Medicine.2015.
13. Serra P, Santamaria P. Nanoparticle-based autoimmune disease therapy. Clin. Immunol. 2015.
14. Badea, I., Virtanen C, Verrall R., Rosenberg A, FoldvariM. Effect of topical interferon-γ gene therapy using gemini nanoparticles on pathophysiological markers of cutaneous scleroderma .Gene Therapy . 2011;19: 978-987.
15. Rao V, Bowman S. Latest advances in connective tissue disorders. Therapeutic advances in musculoskeletal disease 2013; 5: 234-249.
16. Klippstein R,Pozo D. Nanotechnology-based manipulation of dendritic cells for enhanced immunotherapy strategies. Nanomedicine : nanotechnology, biology, and medicine 2010;6: 523-529.
17. Lutterotti A et al. Antigen-specific tolerance by autologous myelin peptide-coupled cells: a phase 1 trial in multiple sclerosis. Science translational medicine 2013; 5: 188-175.
18. Tsai Set al. Reversal of autoimmunity by boosting memory-like autoregulatory T cells. Immunity 2010; 32:568-580.
19. Look M, Saltzman W M, Craft J, Fahmy T.M. The nanomaterial-dependent modulation of dendritic cells and its potential influence on therapeutic immunosuppression in lupus. Biomaterials 2014;35:1089-1095.
20. Clemente-Casares X, Tsai S, Huang, C, Santamaria, P. Antigen-specific therapeutic approaches in Type 1 diabetes. Cold Spring HarbPerspect2012;2.