ISSN 2286-4822
www.euacademic.org

EUROPEAN ACADEMIC RESEARCH
Vol. XI, Issue 2/ May 2023

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

The Role of Nano-ophthalmology in Treating Dacryocystitis

Dr. LEART ASLLANI, M.D
Dr. RINA AVDYLI, M.D
Dr.sc inxh. MUHAMET AVDYLI

Abstract:

In recent years advancements in nanotechnology have given rise to nano ophthalmology - a specialized field exhibiting considerable potential for treating diseases like dacryocystitis that cause inflammation or infection in the lacrimal sac. By delivering drugs directly to affected sites and enhancing antibiotic effectiveness through superior penetration capabilities this approach stands on track towards revolutionizing ocular disease treatment altogether. The significance of nano ophthalmologys impact cannot be overstated when considering its transformative potential towards managing conditions like dacryocystitis effectively.

Keywords: Dacryocystitis, Inflammation, Infection, Lacrimal sac Drug delivery, Antibiotic effectiveness, Ocular disease treatment, Nanotechnology, Nano-ophthalmology, Targeted therapy

1. INTRODUCTION - UNDERSTANDING NANOTECHNOLOGY

The term nanotechnology was first used in 1974 by Norio Taniguchi (University of Tokyo) to refer to the ability to engineer materials precisely to scale nanometers. Nanotechnology is defined as the design and fabrication of materials, devices and systems with control in nanometric dimensions. Therefore, the essence of nanotechnology is size and control. Due to the diversity of applications, the term nanotechnology is preferred by some however all share the common feature of nanoscale control.(1)

Nanotechnology gives us the opportunity to build nanotools that are on the scale of molecules, allowing us to treat every cell of the human body as a patient. Nanomedicine will allow eradication of the disease at the single-cell level. Since the nanotools are self-assembled, nanomedicine has the potential to perform parallel processing medicine on a massive scale. THESE nanotools can be made from biocompatible and biodegradable nanomaterials. They can to be “smart” in that they can use sophisticated targeting strategies, which can perform error checking to prevent damage if even a very small part of they are wrongly targeted. Integrated molecular biosensors can provide delivery of controlled drug response control for individual cell dosing. If they are designed to repair existing cells and not just destroy diseased cells, these nanomedical devices can perform regenerative medicine in-situ by programming cells along less dangerous cellular pathways to prevent tissues and organs from destroyed by treatments and thus providing an attractive alternative to transplants allogeneic organs. Nanomedical devices, although small in size, can have a major impact on medicine and health care. The earliest and most advanced diagnosis sensitive will lead to presymptomatic diagnosis and treatment of the disease before permanent damage to tissues and organs occurs. This should result in the provision of more medicines good at lower costs with better results. Finally, and most importantly, someof the first uses of nanotechnology and nanomedicine are occurring in the field of ophthalmology. Some of the possible benefits of nanotechnology for the future treatment of retinopathies and optic nerve damage.(2)

2. THE ROLE OF NANOTECHNOLOGY IN TREATING EYE RELATED DISEASES

Efficient delivery of drugs to the eye is a major challenge due to the presence of barriers complex and elimination mechanisms in the eye. The various barriers present include the tear film, the ocular surface epithelium and the internal blood-aqueous and blood-blood barriers retina. However, NPs are able to overcome these obstacles due to their size their small size and highly variable surface properties. They can transport it by efficacy of the drug at the target site without toxic effects. Most NPs are biodegradable, which means they do not require surgical removal after delivering the drug. (1)

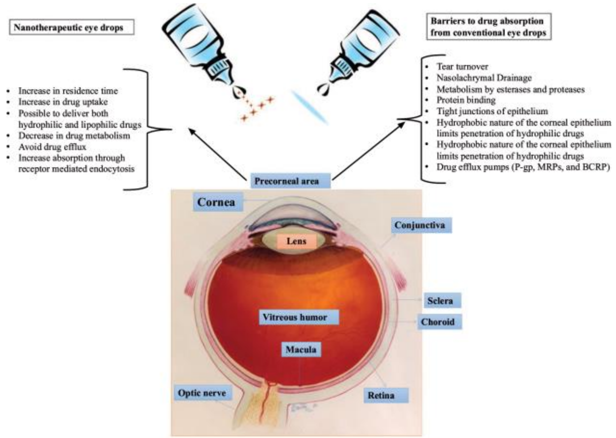

Fig.1 Nanotherapetuic drops and barriers to drug absorption from conventional eye drops (4)

Anterior eye diseases, such as cataracts, conjunctivitis, keratitis, dry eye, eye injury cornea, etc., are usually treated using eye drops, but the corneal barrier makes the drugs have poor bioavailability. However, nanosystems can increase bioavailability extending the time the drug remains on the surface of the eye and improving its penetration the medicine. On the other hand, diseases of the back of the eye in the choroid and retina include retinoblastoma, glaucoma, choroidal neovascularization, macular degeneration and posterior uveitis. The points of eye drops are usually not effective in treating these diseases, so injections are given interocular, which leads to many unwanted side effects. However, nanosystems have improved distribution of drugs in the back of the eye and various nanosystems used for this purpose include nanovesicles, nanoimplants, NPs and hydrogels. (1)

3. NANOTECHNOLOGY BASED DRUG DELIVERY SYSTEMS

There are several types of nanotechnology-based drug delivery systems that have been developed for the treatment of anterior segment eye diseases. Some examples include:

Liposomes: Liposomes are spherical structures composed of a lipid bilayer that can encapsulate hydrophilic and hydrophobic drugs. They have been used to deliver drugs to the cornea and other structures of the eye.

Dendrimers: Dendrimers are highly branched, tree-like structures that can carry drugs in their interior or on their surface. They have been used for targeted drug delivery to the cornea and other ocular structures.

Nanoparticles: Nanoparticles can be made from a variety of materials, including polymers, lipids, and metals. They can be engineered to target specific cells or tissues in the body and can carry drugs or genes.

Nanogels: Nanogels are swollen networks of cross-linked polymers that can absorb large amounts of water. They have been used to encapsulate drugs and deliver them to the cornea and other ocular structures.

Nanorods: Nanorods are rod-shaped nanoparticles that have unique optical properties. They have been used for targeted drug delivery and imaging of ocular structures.

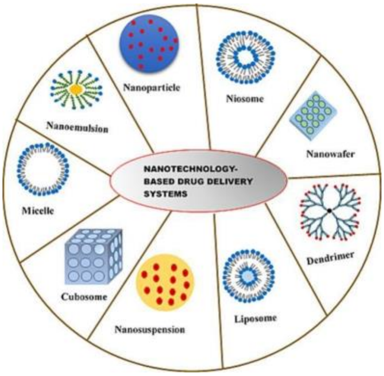

Fig 2. Nanotechnology-based drug delivery systems for ocular application. (11)

These are just a few examples of the many nanotechnology-based drug delivery systems that have been developed for the treatment of anterior segment eye diseases. Each of these systems has its own advantages and limitations, and the choice of system depends on the specific application and the drug being delivered.

4. NANOPARTICLES IN USE TODAY

Nanoparticles are colloidal carriers on the nanoscale. Trapping API's within NPs before dispersion through the hydrogel matrix provides a degree of protection to the drug from interaction with the hydrogel itself during polymerisation. Gulsen et al developed lidocaine-loaded NPs using hexadecane microemulsions (stabilised with silica shell). These NPs enabled the initial burst release of lidocaine where 50% of drug was released within the first few hours. This was followed by 80% of drug being released after 5 days [5] .

More recently, silicone hydrogels have been loaded with propoxylated glyceryl triacrylate (PGT) NPs containing timolol, a beta-blocker used in the treatment of glaucoma. It was observed that a HG with 5% drug loading was able to delivery timolol at the therapeutic concentration for 1 month at room temperature, preliminarily. In vivo testing in glaucomatous beagle dogs demonstrate a reduction in IOP but release was much faster at higher temperatures (>40°C), releasing almost 100% within 3-4 days. This is thought to be due to the ester links between the timolol and PGT [6] .

Nanocrystals (100nm) of bovine serum albumin coated meloxicam (NSAID) were prepared and dispersed in pHEMA HG for the treatment of post cataract endophthalmitis. The gel released the meloxicam-nanoaggregates for approximately 5 days in which the thickness of the lens and degree of cross-linking were the dependent variables of drug release and by altering these; the drug release rate could be optimised[7] .

Silver NPs have also been embedded into lenses to enhance the antimicrobial properties of lenses. In vitro testing using Pseudomonas aeruginosa and Staphylococcus aureus demonstrated great antimicrobial effects against P. aeruginosa but only lenses with increased concentration of silver NPs were effective against S. aureus at 48 and 72 h[8] .

More recently, anti-fungal agent voriconazole was loaded into lipid-based NPs[9] . The resulting NPs were 182.0±4.1nm in size. The poorly water soluble active was readily released from the nanocarrier and inhibited the reproduction of fungus. Lipid NPs were also utilised to encapsulate indomethacin for delivery to anterior and posterior segment ocular tissues[10].

The resulting particles (266±5nm) achieved encapsulation efficiency of 81.0±0.9%. Modifying the lipid NPs with chitosan hydrochloride increased the ocular penetration of indomethacin; showing these nanocarriers as potential vehicles in ocular drug delivery.

5. DACRYOCYSTITIS AND NANOTECHNOLOGY TREATMENT OPPORTUNITIES

Dacryocystitis is characterized as an inflammatory state of the nasolacrimal sac. It is typically caused by an obstruction within the nasolacrimal duct and subsequent stagnation of tears in the lacrimal sac. When the lacrimal sac inflames and swells at the inferomedial canthus, dacryocystitis can be appreciated clinically. Understanding the anatomy and flow of tears leads to a better understanding of dacryocystitis and potential multilevel involvement. (3)

The flow of tears will usually begin with tear production by the lacrimal gland. The tears will lubricate the eye until they are collected into the superior and inferior puncta and drained into the superior and inferior canaliculi. From there, tears will drain into the common canaliculus. At this point, they will then pass through the valve of Rosenmuller into the lacrimal sac. The lacrimal sac will then collect the tears and flow down the nasolacrimal duct, pass through the distal valve of Hasner, and finally pass into the nasal cavity. (3)

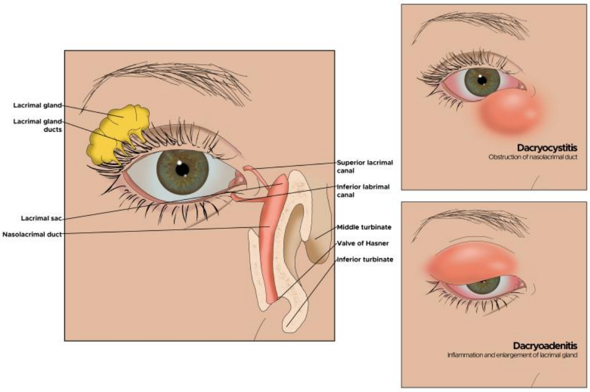

Fig.3 Illustration of eye. Lacrimal gland and ducts, lacrimal sac, nasolacrimal duct. Lacrimal canal (superior, inferior), middle turbinate, valve of Hasner, Inferior turbinate. Dacryocystitis and Dacryoadenitis. (12)

It is often treated with antibiotics and surgical interventions, but with the advancement in medical science, the field of nano-ophthalmology has emerged as a promising approach for the treatment of dacryocystitis.

Nano-ophthalmology is a subfield of nanotechnology that deals with the development of nanoscale devices for the diagnosis and treatment of eye diseases. The use of nanotechnology in ophthalmology has gained significant attention in recent years due to its potential to provide targeted and efficient therapy for ocular diseases.

In the case of dacryocystitis, nanotechnology offers several advantages over conventional treatments. One of the major advantages is the ability to deliver drugs directly to the affected area, without affecting other parts of the eye. This targeted approach reduces the risk of side effects and increases the efficacy of the treatment.

Nanotechnology offers a promising avenue to enhance current remedies for treating dacryocystitis via targeted drug delivery and amplifying drug efficiency. Antibiotic penetration into the lacrimal sac is often inadequate in conventional therapies; nevertheless, nanotechnology brings potential solutions that overcome these challenges through nanoparticle-based innovations. By employing such enhancements in patient care plans, individuals grappling with this condition stand to experience better results and improved health outcomes overall.

In addition to targeted drug delivery, nanotechnology can also be used to enhance the efficacy of existing treatments for dacryocystitis. For instance, nanoparticles can be used to improve the penetration of antibiotics into the lacrimal sac, which can be difficult to achieve with conventional treatments. This enhanced drug delivery can lead to better outcomes for patients with dacryocystitis.

Nanotechnology can also be used to develop new treatments for dacryocystitis. For example, researchers have developed nanoscale devices that can be implanted in the lacrimal sac to provide a sustained release of antibiotics over an extended period of time. These devices can be designed to degrade over time, eliminating the need for a second surgery to remove them.

6. DISADVANTAGES OF NANOTECHNOLOGY IN TREATING DACRYOCYSTITIS

While nanotechnology has shown great promise in the treatment of dacryocystitis and other ocular diseases, it is important to consider some of the potential disadvantages of this approach.

Safety concerns: The safety of nanomaterials and their potential toxicity to the eye and other organs is still not fully understood. Some researchers have raised concerns about the potential for nanoparticles to accumulate in the body and cause harm.

Cost: The development and production of nanoscale devices can be expensive, which may limit their accessibility to patients who cannot afford them.

Regulatory hurdles: The regulation of nanotechnology-based therapies is still in its early stages, and there may be significant regulatory hurdles to overcome before these therapies can be widely used.

Limited research: While there have been promising results in preclinical studies, there is still limited clinical data on the safety and efficacy of nanotechnology-based therapies for dacryocystitis.

Complex manufacturing: The manufacturing process for nanoscale devices can be complex and may require specialized equipment and expertise.

6. CONCLUSION

In conclusion, nano-ophthalmology holds great promise for the treatment of dacryocystitis. By providing targeted drug delivery, enhancing the efficacy of existing treatments, and developing new therapies, nanotechnology has the potential to revolutionize the way we treat this condition. As research in this field continues to progress, we can expect to see even more innovative approaches for the treatment of ocular diseases.

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