Translating Nanobiotechnology in Medical Theranostics

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Nanotheranostic is a word we use a bit more than a decade ago to define namaterials with potential or confirmed use as therapeutic and/or diagnostic agents. Here, we strived to define the properties characteristics and of most commonly used nanomaterials that have been proved or could be apply for a wide range of biomedical and pharmaceutical applications (e.g. biosensing, drug delivery, imaging).

Keywords: Nanomedicine ; Nanoparticles ; Innovation ; Biosensing ; Drug delivery ; Nanomaterials

1. Introduction

Nanotechnology refers to the manipulation. utilization and control of structures or systems at nanometer (nm: 10^{-9} m) scale. It has revolutionized and influenced each area of today's technology because nanomaterials (e.g., nano particles (NPS), nanostructures, nanodevices and nano systems)exhibit many unique properties compared to that of macroscale materials [1]. The scope of this field is almost impossible to define as it is growing too rapidly, covering almost every field from biotechnology to electronics encompassing physics, chemistry, molecular biology computer science, microbiology, food science, regenerative medicine and pathology [1][2][3][4][5].

Matter at nanoscale depicts striking optical, magnetic chemical and physical properties including increased reactivity, solubility, specificity, stability, efficacy, and interaction at subcellular levels [1][6][7]. Soon, theranostic nanotechnology (i.e., nanoscale techniques, methods devices, particles and operations) will replace all conventional key functioning healthcare systems.

Surface functionalization of nanomaterials confers additional specific features such as enhanced specificity biocompatibility, tunability, and effectiveness. In recent years, much attention has been paid to nanobiotechnology exploiting natures components (i.e., nucleic acids, proteins enzymes, cells) to develop nanobiomaterials (i.e., materials of nanoscale thickness designed to interface with biology) and theranostic nanobiodevices (i.e, DNA origami nanomachines, drug delivery nanosystems. nanosensors)for diagnosing, preventing and treating illness using cutting edge nanoscale materials [4][5][8]. Indeed, several biologica entities like polypeptides [9], antibodies [10][11], vitamins [12] or proteins [13][14] have been chemically attached to the surface of NPs, which favoured their inherent properties ovel methods are developed to conjugate a biologica molecule with NPs. For instance. a method described the exposition of carboxyl groups on the surface of water soluble iron oxide NPs before a cross-linker known as EDC (1-ethyl-3-(3-dimethylaminopropyl) carbodiimide)was used to link streptavidin on this surface for subsequent recognition and attachment of the resulting conjugate to a biotin-labeled oligonucleotide [15][16].

Furthermore, the most useful and practical goal and application of nanotechnology is devoted to improve and Upgrade the overall standard of life. A growing number of evidence can ilustrate this fact. For instance. selenium anoclusters are used in anti-cancerous and anti-infective orthopedic coatings, which prevent osteosarcoma proliferation and contamination at the site of implantation and promote healthy bone cell activities [17][18][19][20]. Furthermore, various bone infections (e.g., refractory osteomyelitis)have been treated using vancomycin antibiotic surrounded by NPs in the form of scaffolds and injections [21]. Furthermore, analysis and determination of bone growth could be done using strain sensors and multi-walled carbon nanotubes (CNTS) [22][23]. Besides, in order to visualize and determine the detailed anatomy, morphology and physiology of musculoskeletal systems, the unique chemical, optical and magnetic properties of NPs, such as quantum dots (QDs) functionalized with Renilla reniformis luciferase, are being exploited [24]. Moreover, nanosensors (e.g., nanobarcodes, QDs) have been deployed to determine cardiovascular diseases (CVDS) [25][26], while nanovesicles were able to specifically detect vascular antigens present in cardiac diseases, inhibit the proliferation of primary smooth muscles of the aorta in vitro and alleviate damaged vascular in vivo [27]. Interestingly, in a transplantation context myocardiocytes were generated efficiently by using stem cells (SCs) differentiated on nano-fabricated scaffolds such as carbon nanofibers [28][29]. More recently, a study reViewed the development of nanovesicles to avert non-specific binding and upregulate efficacy by improving the accumulation of drugs in lesion tissues for rheumatoid arthritis [30]. Furthermore, nanostructures can be exploited to aid in the rapid deposition of calcium mierals onto orthopedic implants, promote the effective insertion of these implants, and strengthen the interactions of bone cells with adhesion proteins [20][26][31].

Thus, the state-of-the art approaches and applications of nanobiotechnology in medicine led us closer to what was seen as "impossible" to date and include [1][8] (i) the selectively search for the disease causative agent to destroy it both in vivo and outside the body (environment)using rationally-designed nanosystems; (ii) the interaction o functionalized nanosystems with the body's own machinery to stimulate, restore and regulate its functioning, thereby placing organ (i.e., bone transplantation).

Nevertheless, ethical and technical challenges (e.g., toxicological issues) remain to be addressed for more efficient and safer translational nanobiotechnology into medicine.

2. Bomiedcal Applicatons of Nano Inechnology

The field of nanotechnology is as vast and diverse as diseases and ailments of living organisms. It is a challenging area but it is rapidly growing every day. The modification of nanomaterials' properties by controlling their structure and surface makes them attractive candidates for their use in healthcare. from fundamental innovative scientific studies to next-generation commercially viable and accessible theranostic technologies [1][3][8][32].

Biomedical nanotechnology embodies from controlled targeting to bioimaging nanoplatforms and novel therapeutic nanosystems. For instance, NPS, nanostructures, and nanodevices (e.g., nanorobots) are being applied to detect and screen key cardiovascular symptoms (e.g., heart o respiratory rates) and pathologies (e.g., atherosclerosis, thrombosis, hypertension), or perform minimal invasive cardiovascular surgeries, respectively [33][34][35].

3. Major Theranostic Nanomaterials: A Glimpse over the Horizon

Nanomaterials include NPs (e.g., lipid based-, metallic based-, magnetic based-, polymer based-, semiconductor based-) and nanostructures (e.g., dendrimers, hydrogels, nanofilms, nanowires, graphene and other carbon allotropes) [36][37][38]. They can be functionalized, doped or conjugated with organic or inorganic molecules to enhance their features for a wider range of environmental and theranostic applications (e.g., compound, drug, gene or cell delivery, bioimaging, biosensing) [39][40].

4. "Smart" Nheranostic Nanodevices and Nanosystems: A Road to the Cure

Other types and classes of multifunctional nanoplatforms (e.g., chips, microfluidics, and biosensors) are routinely used for a diverse range of applications. Thereby, microfluidic systems combine several processes over a single circuit or chip. Importantly, the role of nanosensors in our dally life is increasingly expanding due to their high precision power, overall stabllity, outstanding biocompatibility, high efficiency In terms of sensitivity and specificity [41]. The scope of these more complex nanoplatforms In healthcare is beyond every technology making them useful in pre-clinical assessments, encompassing molecular and synthetic biology to environmental monItoring (e.g., pollution control to establish the link between air quality and pathogens in asthma, infections, allergies, or oral cancers). Each nanoplatform has its own attributes and characteristics depend upon the substrate, cost, adaptability, efficacy specificity, heterogeneity, outcome generation, diversity and specific process [42]. For instance, a novel approach involving a microfluidic system, namely disruption and field-enhanced (DFE) delivery, was recently employed to mechanically squeeze cells, disrupt membranes and promote DNA transfer at exceptional rates [43].

5. Conclusion and Perspectives

The prominent role of nanotechnology in current healthcare advancements has been thoroughly investigated These maior advancements include advanced nanomaterials (e.g., NPs and nanostructures), nanodevices and nanosystems. Despite remaining concerns, progress in the field of nanobiotechnology opened many new avenues which Is encouraging the perspective to deal with the matter at nanoscale when human health is especially concerned. The growing interest aims to quantify the mechanisms and behaviors of living systems, as well as record the signals produced by them using means that can be encoded and read through the naked eye. This implicates measuring and calculating the Individual's early symptoms and changes In a given type of cells (including SCs, engineered cells)or from a specific disease (i.e., cancers, diabetes, CVD, obesity, rare genetic syndromes). According to us, studies devoted to demonstrate the benefits of nanotechnology over (or combined with)genetic engineering and/or SC theranostics will represent a veritable asset for humanity.

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