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Nanotechnology for regenerative medicine: Nanomaterial for stem cell imaging

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Abstract

The Stem Cells accumulates the great potential for the treatment of so many injuries and degenerative diseases, there are several obstacles which must be overcome before there therapeutic applications can be realized. These enlightened the need for development of various new techniques which could be helpful in understanding and controlling the microenvironmental functions of signalling and several novel methods to track and guide the stem cells which are transplanted. The application of nanotechnology to modification of stem will also face various future challenges but modifications in those will be helpful in exploring novel areas of research. These review details about the several present challenges in regenerative medicines, the applications of nanoparticles and nanotechnology in stem cell biology techniques and further future potential of nanotechnology approaches towards regenerative medicine in healthcare.

Keywords: Nanoparticle; Stem cells; Quantum dots; Regenerative medicines; Cell imaging

1. Introduction

1.1. Concept of nanotechnology for regenerative medicine

Currently, many scientists prognosticate that nanotechnology can break numerous crucial questions concerning biological systems that happen at the nanoscale. Therefore, nanomedicine is defined widely as the approach of science and engineering at the nanometer scale towards biomedical applications, has been drawing considerable attention in the area of nanotechnology. As the sizes of the functional rudiments in biology are in the nanometre scale range, thus it isn't surprising that nanomaterials interact with natural systems at the molecular position [2]. In addition, nanomaterials has electronic, optical, magnetic and structural properties that cannot be obtained from either individual molecules or bulk materials, due to which it is precise to explore biological phenomenon through numerous innovative techniques. Among them one of the major aim of biology is to depict the spatial-temporal interactions of biomolecules at the cell and integrated systems level [3]. There are several conditions which must be considered while applying nanotechnology to biology and science, this could be:

- Nanomaterials must be designed to interact with their biological.
- Though after surface modification of nanomaterials the physical properties must be maintained.
- Nanomaterials must be nontoxic.

Recently, stem cells have gained the much attention for the treatment of devastating diseases, diabetes and aging [4]. Stem cells have the capability to self-renew for long periods of time and then further differentiate into specialized cells and tissues on stimulation by appropriate microenvironmental cues. They are typically categorized as embryonic the stem cells (ESCs) or the tissue-specific adult stem cells, depending on their origin and differentiation capability.

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1.2. Application of nanomaterials for molecular & cell imaging

Although nanoparticles can be synthesized from various materials using several methods, the coupling and functionalizing of nanoparticles with biomolecules should be carried out in controlled conditions, such as a specific salt concentration or pH. With significant advancements in synthetic and modification methodologies, nanomaterials can be modified to desired sizes, shapes, compositions and properties; they can then be functionalized readily with biomolecules through combined methodologies from bioorganic, bioinorganic and surface chemistry [5,6].

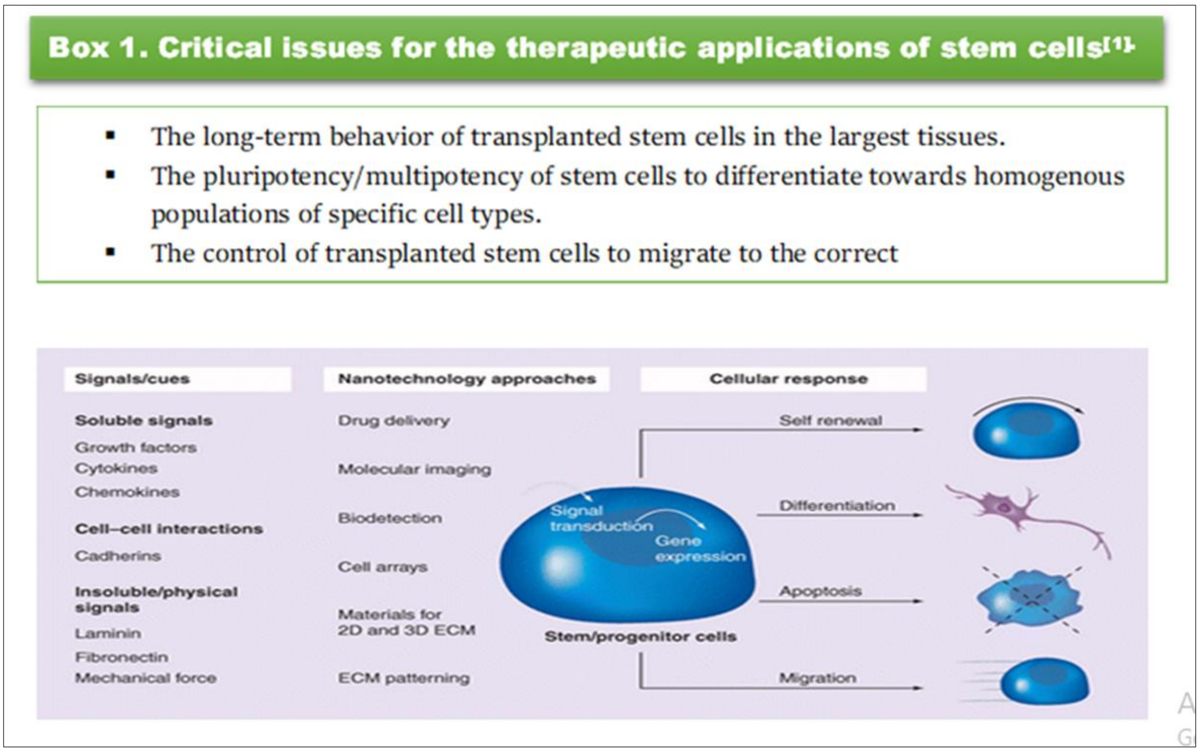

Figure 1 Regulation of stem cell fate by microenvironmental signals and the corresponding applications of nanotechnology [16].

1.3. Application of nanotechnology as magnetic nanomaterials

1.3.1. Iron oxide nanoparticles

Some of the inorganic nanoparticles, particularly iron oxide nanoparticles and quantum dots(QDs), are one of the most optimistic accoutrements for stem cell exploration because they can be synthesized fluently in large amounts from varied accoutrements using fairly simple styles. The iron oxide nanoparticles can either combine with the external cell membrane or can be internalized into the cytoplasm. Particles that are combined externally do not affect cell viability, although, they may interfere with cell-surface interactions or may simply be separated from the cell membrane [7].

1.4. Nanoparticle-based application for regenerative medicine

1.4.1. Magnetic nanoparticles for in - vivo stem cell tracking

One of the applications of nanotechnology for regenerative medicine is transplanting various progenitor (stem) cells for tissue regeneration is an extremely promising therapeutic strategy. One of the very much important key factors in this approach is the availability of techniques that would be helpful in enabling long-term, non-invasive detection of transplanted stem/progenitor cells and, at the same time, enable the monitoring of their differentiation survival and proliferation within the desired organs. Several ways, analogous as MRI, bioluminescence, positron emigration tomography and multiple photon microscopy, are now available for " In-vivo " cellular imaging; of these, MRI offers several advantages, similar as high resolution, speed, easy accessibility and 3D capabilities [8,9].

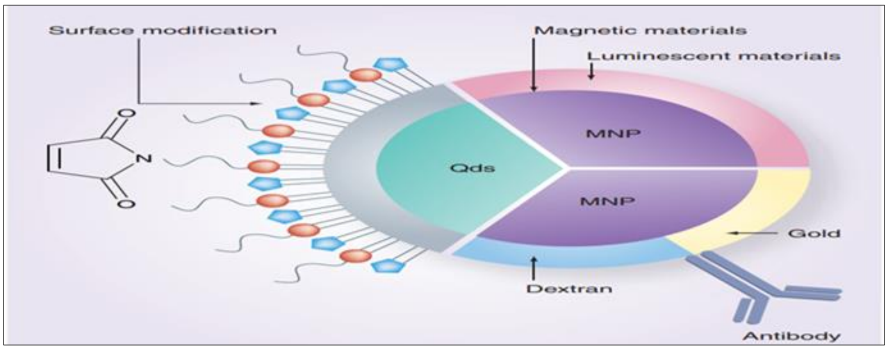

Figure 2 Multifunctional inorganic nanoparticles[17].

1.5. Quantum dots imaging for stem cells

Quantum dots(QDs) or semiconductor nanocrystals have opened many ways to an array of wide approach of applications in biological sciences, such as live monitoring of physiological types of events occurring in cells by labeling specific cellular structures or proteins with QDs having different colors, monitoring cell migration, tracing cell lineage and "*in vivo"* cell tracking [10,11]. Furthermore, QDs are advantageous for the knowledge of dynamic changes occurring in the membranes of stem/progenitor cells. Functionalized QDs bind selectively to individual molecules.

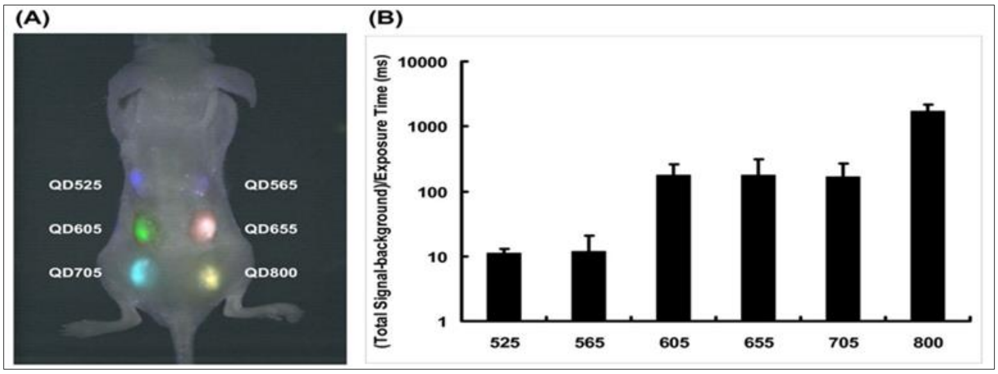

Figure 3 Quantum dot imaging for embryonic stem cells[18]

1.6. Some other challenges and opportunities

Integration of nanotechnology and stem cell exploration will be furnishing new room for scientists to address elemental questions of stem cell biology at the single cell- molecule degree. Although numerous nanoparticle- grounded operations presently garner important discussion, other important operations of nanotechnology, regarding the regulation of stem cell technology, are also being developed. These usages include microenvironmental engineering and gene manipulation.

1.7. Surface engineering in stem cell for microenvironment

Stem cells normally reside within specific extra-cellular microenvironment (ECM) which are typically referred to as stem cell niches(environment) [12,13], which are comprised of a complex formed by the mixture of soluble and insoluble ECM and signal molecules. It is well known that morphogenic signaling molecules and ECM components can control stem cell behaviors. Even though several combinatorial high-through out screening methods showing the effect of soluble signal molecule on stem cell differentiation have been reported, similar approaches for screening the effect of insoluble cues are limited owing to the technical difficulties [14].

1.8. Gene manipulation of stem cells using nanoparticles

Gene delivery has an important part in feting the eventuality of regenerative drug. To manipulate the expression amount of position of crucial genes in stem cells, several biomolecules, similar as gene vectors, siRNA, proteins and small flecks, have been evolved. Because several transcription procurators that constrain stem cell isolation into distinct cell types have been substantiated, gene delivery could be an immensely important tool for specific isolation of stem cells.The development of safe and efficient gene delivery systems, which can lead to high levels of gene expression within stem cells, is an urgent requirement for the effective implementation of regenerative medicine [15].

2. Conclusion

In this review, we've epitomized nanoparticle- grounded approaches for stem cell imaging. Considering that nanomaterials naturally enable cellular and molecular imaging with high perceptivity and high spatial resolution, it isn't surprising that a adding number of imaging ways grounded on nanoprobes are beginning to have a great impact on stem cell-based therapies and research. Good examples of these include stem cell tracking using magnetic nanoparticles and QD-based imaging of stem cell interactions with other microenvironmental cues. In addition, other nanotechnology operations, similar as surface engineering and medicine delivery, have huge eventuality to beyond handle challenges in the area of regenerative drug. Inclusively, advances in nanotechnology enable the modulation of stem cell signalling pathways and enhancement in their remedial operations.

Future perspectives

The operation of nanotechnology in regenerative drug has formerly begun to recast several areas of stem cell probing and will continue having great goods on regenerative the optimum eventuality of nanotechnologyin regenerative medicine requires several considerations. First, suitable imaging approaches should be set precisely considering the specific biological questions regarding stem cells that necessitate to be addressed because each imaging fashion has its unique set of advantages and disadvantages. Second, nanomaterials might have undesirable side effects on stem cells owing to their number, size and physical parcels. For case, the cytotoxicity of QDs is an implicit limitation for the operation of molecular examinations for both cellular and clinical use in vitro and in vivo. Eventually, nanotechnology approaches for regenerative drug elementally necessitate synergic exertion and interdisciplinary proficiency from biology, chemistry, and engineering. In particular, this approach would be salutary to interpret the complex cellular spatial-temporal dynamics and signalling pathways in further effective ways. Addressing the challenges ahead would accelerat3e the development of nanotechnology approaches toward regenerative medicine and facilitate the therapeutic application of stem cells.

Summary

- To apply nanotechnology to stem cell biology, several conditions must be considered: Nanomaterial must be designed to interact with proteins and cells without perturbing their biological activities; Nanomaterial must maintain their physical properties after the surface conjugation chemistry; and nanomaterials must be biocompatible and nontoxic.
- Magnetic iron oxide nanoparticles, the size of which can be tuned precisely, are used to label stem cells and offer great potential for tracking them in vivo using MRI to generate ultrasensitive images.
- QD, with their unique photophysical properties and resistance to photo bleaching, can be used for multiplex imaging of stem cells in vitro and in vivo.
- Combinational extracellular matrix micro/nanoarrays, generated by soft-lithography, have great potential in studying and controlling the behavior of single stem cells.
- Nanomaterial-based gene delivery for manipulating stem cells has a vital role in recognizing the potential of regenerative medicine.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest between any author for this review.

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