Chapter 59

Preclinical Challenges and Clinical Target of Nanomaterials in Regenerative Medicine

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ABSTRACT

Currently, practical application of nanotechnological approaches and stem cell therapies remains a challenge in both preclinical and clinical settings. Many existing problems in tissue engineering to organ engineering have been solved by the combined approaches of nanotechnology and stem cell biology, but significant barriers remain. Details about the role of various types of nanomaterial in preclinical and clinical research have been reviewed elsewhere, but scant information exists about the influence of nanomaterials on stem cell biology. Herein, the authors highlight the current advances of nanotechnological approaches for expansion, differentiations, harvesting, labeling, imagining, tissue engineering, and organ engineering of different types of stem cells. The preclinical outcome of in vitro and in vivo animal experimentations along with some examples of clinical outcomes of nanomaterials on stem cell research is the main focus of this chapter. This book chapter might be an impetus for the present generation of young scientists to revolutionize the coming generation of effective human healthcare.

INTRODUCTION

Currently, nanotechnology has been extensively promoted to improve preclinical and clinical outcomes. Over past few decades, have been a lot of limitations from in vitro culture methods to in vivo imaging of transplanted cells techniques towards achieving this goal. Nanotechnological approaches have been

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solved the hundreds of previous existing limitations of basic laboratory research experiments to clinical therapy. Tissue engineering and regenerative medicine has grown tremendously to reshape human medicine by constructing a functional tissue, organ in experimental laboratory for replacement of damaged and aged tissue or organs in clinical practice. Previously, worldwide researchers depend on primary cells, isolated from non human or human model which is a long complex process and associated with ethical concerns. Isolated primary cells are always very sensitive during in vitro culture and very difficult to maintainence for long term in vitro. Primary adult stem cells provides an exciting clinical platform for treatment for many complex human diseases. Research on basic and translational aspects of stem cells is fast becoming a worldwide focus among academic centers as well as in industry. From small scale industries to high ranking pharmaceutical industries have been used stem cells for drug discovery process to in order to produce safer drug. The multipotential nature of adult stem cells is the central theme which researchers are trying to modulate for translation to clinical practice. Adult hematopoietic stem cells are currently used routinely for hematopoietic cell transplantation, for treatment of number of malignant and nonmalignant diseases. The previous limitations of current adult stem cell research such as (a) difficult to isolate them from potential donors in vivo, (b) stem cells need 3D microenvironments for expansion and differentiation, (c) stem cell harvesting, (d) stem cell imaging upon transplantation, (e) delivery of stem cells to target organs, (f) controlled release of growth factors and cytokines to support infused stem cells. All these above limitations have the potential to be solved by nanomaterials. Since the numbers of primary adult stem cells are less in number, it is important to manipulate in vitro to generate sufficient numbers of cells which could use for transplantation in a clinical practice. To achieve this, the nanomaterials have been used for providing in vivo like microenvironments for proper expansion, lineage differentiations of a number of primary adult stem cells. Further, the novel discovery of induced pluripotent technology (iPS), as alternative of human embryonic stem cells, provides the opportunity of using autologous tissue bypassing the possibility of rejection. The efficiency of iPS cell generation is low but using nanomaterial based delivery increase the efficiency the iPS cells generation. The aim of this book chapter is to present emerging preclinical and clinical applications of different kind of nanomaterials which have been used in adult stem cell expansion, differentiation, stem cell harvesting, in vivo imaging, controlled release of growth factors and cytokines.

CURRENT NEED OF NANOMATERIALS FOR STEM CELL ENGINEERING

Since the stem cell therapy is now at the forefront for treatment of human diseases. Basic scientists, clinical researchers and the industry are working towards delivery of effective clinical platform for treatment of human diseases. The cells, scaffold, growth factors and cytokines are main component of stem cell engineering in order to construct a functional tissues or organs. Cultured stem cells on hard polystyrene plastic doesn't mimic the *in vivo* situation, when stem cells are taken from in vivo body and put into culture plate, stem cells don't get appropriate favorable microenvironments, therefore degenerate quickly. Virtually cultured in vitro cells don't experience like in vivo conditions on conventional plastic. Generally, the in vivo stem cells are surrounded by extracellular matrix. The sizes of stem cells vary from 10 micrometer to 15 micrometer. Scientifically, it is believed that the size of scaffold should be smaller than the size of cells, so that the scaffold surrounds the culture cells like *in vivo* extracellular matrix in *in vivo* stem cells. Accumulating evidences suggests that nanomaterials will be able to solve this problem. Nano sized particles provide vivo-like extracellular 3 dimensional scaffolding in such a