Chapter 7
Nanotechnology Applications in Cardiology: Proof of Principle

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ABSTRACT

Nanotechnology studies particles and fibers in the 10e-9 m dimensional range. Multiple advancements, availability of materials, manufacturing and process technology, and improvements in targeted-delivery capabilities have dramatically impacted the use of nanotechnology in medical science. However, nowhere has the benefit been as profound as in the field of cardiology. This chapter discusses various aspects of the use of nanotechnology, including materials, design, and formulation characteristics. The authors begin by introducing the complexity of cardiovascular disease, identifying the problem of scale, and of targeted delivery, followed by a brief history of nanotechnology. Specific instances of innovation milestones, such as the invention of Drug Eluting Stents are followed by a detailed discussion of materials and a proposed classification scheme. Nanotechnology-based cardiovascular imaging systems for use in diagnostic and preventive medicine and scaffolds for the design of 3D artificial constructs as putative futuristic replacements of transplant hearts are discussed in detail.

INTRODUCTION

Cardiovascular Disease

Diseases affecting the heart and the circulatory system have consistently remained among the top five reasons for mortality due to natural causes over the past few decades. In modern times, especially in the developed world, cardiovascular disease has assumed the form of an umbrella term which encompasses a variety of morbidities and pathological states responsible for dramatic increments in national and global mortality. Each year, complications due to cardiovascular disease pose a huge economic burden on national health systems, not least in the provision of pharmaceutical care, but also in terms of loss of productivity, and a reduction in patient quality-of-life parameters. Included in this category is a diverse array of disorders. For instance, diseases such as atherosclerosis that affect blood vessel architecture, compromising the coronary and systemic circuits and leading to hemodynamic changes that may affect the whole system, while other cardiovascular

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diseases include developmental or architectural anomalies affecting the heart and/or blood vessels, and may originate from a composite of genetic and environmental factors. Importantly, differences in etiology must be taken into consideration while designing and optimizing patient-focused therapy.

Classification of Cardiovascular Disorders

On the basis of etiology and general pathological progression, cardiovascular disease can be broadly classified into two categories: (1) mechano-circulatory defects and (2) myoelectrical disturbance. Mechano-circulatory defects are disorders affecting either the structure or function of the heart, in particular its "pump"-like mechanical process, or the structure or function of the vascular bed (the blood vessels: arteries, veins and capillaries). The vasculature component may further include micro- or macrocirculation defects. Common instances of vascular diseases include aneurysm, atherosclerosis, coronary occlusion, and aortic coarctation, while cardiac disorders include myocarditis, valvular insufficiency, congestive heart failure, cardiomyopathy, and myocardial infarction. It is interesting to note that the cardiac component of these diseases ultimately stems from an amelioration of normative cardiomyocyte function. The second category of heart disease, myoelectrical disturbance, originates from aberrant electrical impulse generation and conduction, or abnormalities of the Bundle of His and the associated cardiac electrical conduction pathways leading to disorders such as dysrrhythmia, heart block and sudden cardiac death.

Cardiac disorders are notoriously multifactorial. They may be triggered or regulated by both exogenous, such as environmental, and endogenous, for instance physiological and genetic factors, with or without considerable involvement of pharmacogenetic idiosyncrasy, all of which may further complicate the pathological progression of the disease. Due to such diversity in causality and disease manifestation, significant hurdles exist in the timely detection, diagnosis and treatment

Figure 1. Classification of cardiac disorders