Journal of Cardiovascular Disease Research

ISSN: 0975-3583,0976-2833 VOL12,ISSUE07,2021

NANOTECHNOLOGY IN CARDIOVASCULAR DISEASES

Karishma Sharma[1], Dr Sonu Sharma[2]

1.Maharishi Arvind Institute of Pharmacy, (Rajasthan university of health sciences),Jaipur, Rajasthan

2.School of pharmaceutical studies,Dr KN modi University, Niwayi, Jaipur

ABSTRACT:

Cardiovascular diseases (CVDs) are a primary cause of death globally. A large number of therapeutic options have been developed for the management of cardiovascular diseases. However, they are insufficient to stop or significantly reduce the progression of these diseases, and may produce unpleasant side effects. Cardiovascular diseases are the life threatening issues in the present days, which include other diseases like angina pectoris, atherosclerosis, and myocardial infarction. Atherosclerosis and atherothrombosis, the major contributors to cardiovascular diseases (CVDs), represent the leading cause of death worldwide. Atherosclerosis is a chronic inflammatory disease accompanied by lipid deposition, smooth muscle cell (SMC) proliferation, and plaque formation. Unhealthy lifestyles such as poor diet quality, sedentariness, exposure to air pollution and noise, sleep deprivation, and psychosocial stress increase the risk of atherosclerosis. The traditional applications of drugs are limited by insufficient effectiveness, poor distribution, and lack of selectivity. Current pharmacological therapies have been associated with side effects or are insufficient at halting atherosclerotic progression effectively. Novel Drug Delivery System is an advanced drug delivery system with improved solubility, absorption, bioavailability, drug potency, control drug release to give a sustained therapeutic effect, and target oriented to a desired tissue as well as patient compliance is good. Human beings have developed evolutionary defense mechanisms against the microorganisms and foreign particles with which they might potentially interact. When effective, these mechanisms provide immunity, that is, resistance to the invasive agents. Their failure results in illness. The human immune system modulates many important biological protective processes. It coordinates responses involving a variety of cells and molecules to protect us from invading pathogens, as well as cancer cells and foreign agents. It is commonly thought that nanomaterial's first contact with the organism is via the different components of the immune system. However, if the entry route is intravenous, the first contact will be with the blood's components (erythrocytes, platelets, white cells, plasma and complement proteins). This interaction can lead to different associated pathophysiological processes.

ISSN: 0975-3583,0976-2833 VOL12,ISSUE07,2021

INTRODUCTION

Cardiovascular diseases claim a number of lives globally; many of which are preventable. With the increase in diets that consist of high saturated fat, salt, and sugar, people often living sedentary lifestyles, and a rise in cases of obesity, the incidence of cardiovascular disease is increasing. These contributing factors, coupled with more advanced methods of diagnosis, have delivered statistics that clearly show that there is a rising trend in the prevalence of cardiovascular disease. Treatment for cardiovascular diseases is limited currently to oral medicines or invasive surgery [10]. Cardiovascular diseases (CVDs) are the leading cause of death worldwide, claiming 17.7 million lives in 2015, and this figure is projected to increase to 23.6 million in 2030 (WHO 2017)[14].Traditionally small molecules are used to treat cardiovascular system diseases. Examples of commonly used drugs include atorvastatin, metoprolol, valsartan and ezetimibe. These drugs are mostly available in oral drug delivery systems and are used in the chronic management of the disease. Due to the market share of over several billions of dollars in the treatment of cardiovascular disease, there is a keen interest in developing novel drugs as well as for the delivery of these compounds.[3] Nanotechnology, as the technology of materials on an atomic, molecular, and supramolecular scale, has shown promises for CVDs application. Nanotechnology is generally defined as the use of nanotechnology in preventing, diagnosing, curing disease or repairing damaged tissues in biological systems. Nanoparticles, as the particles in the nanometric range, have shown great promises in a wide range of cardiovascular applications. Nanoparticles are mobile in both intra- and extravascular systems, making them ideal for the targeted delivery of therapeutics and imaging agents. They have shown significant potential to provide a platform for targeted delivery of drugs because of their unique multi-functionality. Delivering and targeting of drugs to its intended site are the most important characteristics of nanoparticles for the development of successful targeting strategies as well as improved medical imaging technology [23].

Types of Therapeutic Nanoparticles [19]

ISSN: 0975-3583,0976-2833 VOL12,ISSUE07,2021

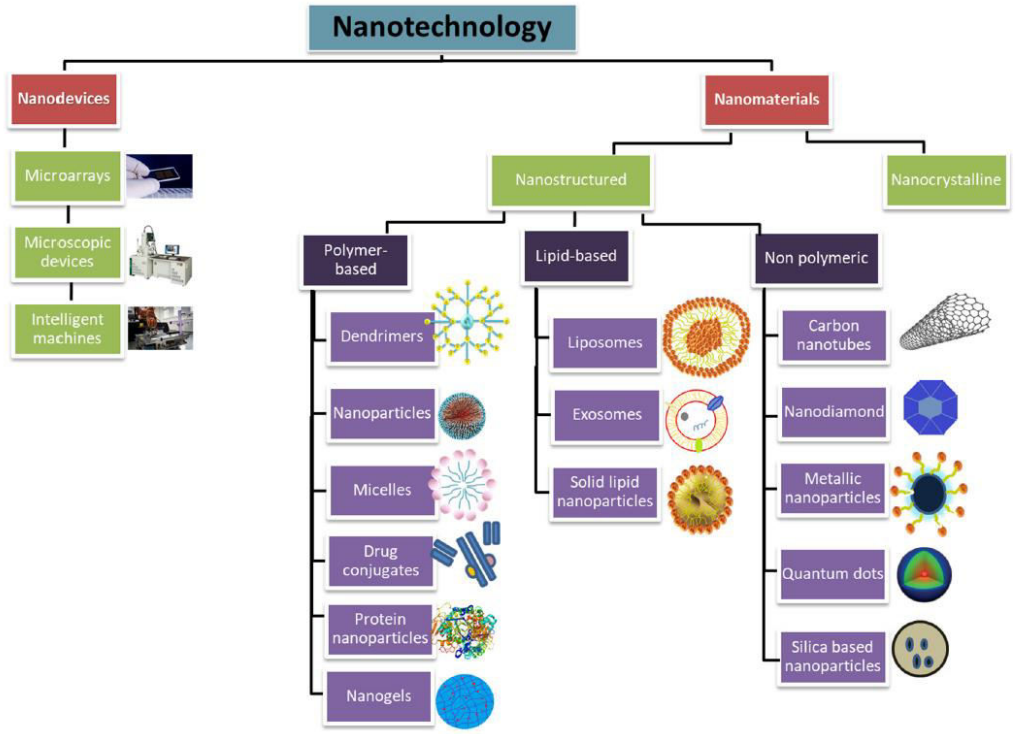


Figure 1: Elements of nanotechnology, which are utilized in therapeutic applications.

Nanotechnology in cardiovascular imaging:

Cardiac nanoimaging is an integrative strategy for diagnosis and real-time monitoring during operations and treatment. Cardiovascular nano-based imaging is linked to various sectors of diagnosis, surgery and therapy. Nanoparticular cardiovascular imaging has therefore been classified into wide fields such as thrombus imaging, stem cell, grease and theranosis depending on the site of the detection or mechanism mode [4].

ISSN: 0975-3583,0976-2833 VOL12,ISSUE07,2021

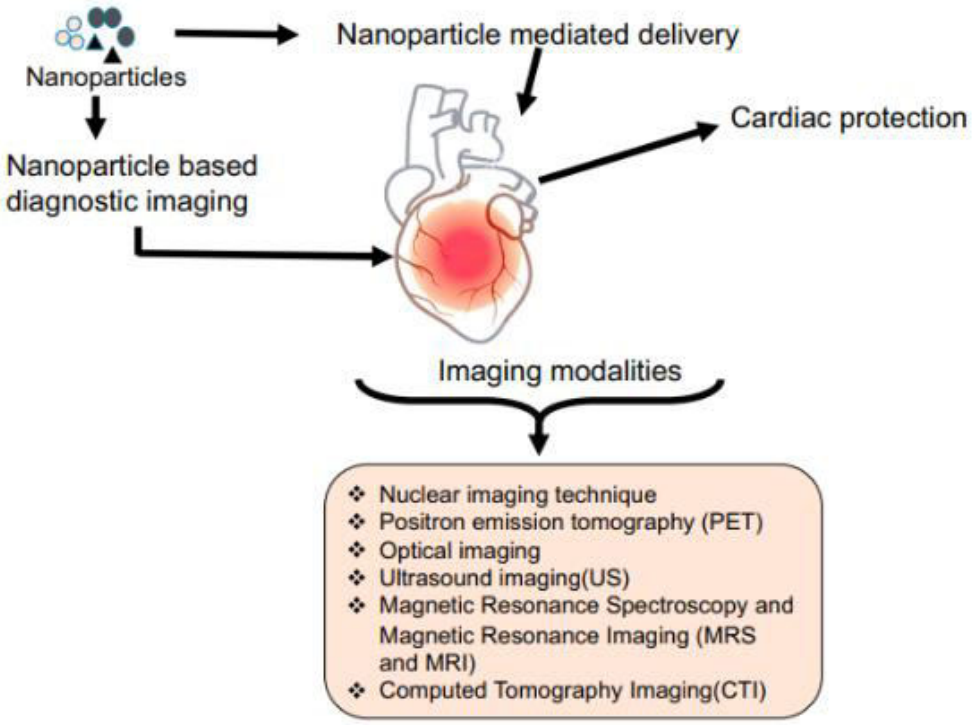


Figure 2 Nanoparticle-mediated diagnosis and imaging of CVDs.

Nanotechnology in Atherosclerosis

Atherosclerosis (Figure 3) is the thickening of the arterial vessel wall due to plaque formation. The propagation of the lesions in atherosclerosis results in the formation of new blood vessels within the arterial walls like the growth of cancerous tumors. Nanotechnology can enable controlled delivery of active drugs, encapsulated in carriers, straight to the target site for the dissolution of atherosclerotic plaques that accumulate in the walls of the coronary arteries [23]. Present pharmacotherapy for hyperlipidemia includes statins, niacin, fibric acid derivatives and cholesterol absorption inhibitors. 90% of the pharmacotherapy of hyperlipidemia includes statins and these statins also suffer from limitations like, inadequate solubility, less absorption, less bioavailability and ineffectiveness in lowering of cholesterol levels only upto maximum 40% risk reduction. These drugs are to be given on daily basis which make it cumbersome for patients. [16]. The formation of nanosized assemblies for the earlier detection of atherosclerotic lesions and for cell-specific delivery of therapeutics. Replacing the current systemic pharmacological approach by a locally targeted treatment of plaques can substantially minimize the adverse effects, by lowering the drug cytotoxicity and reducing the required dosage [1].

ISSN: 0975-3583,0976-2833 VOL12,ISSUE07,2021

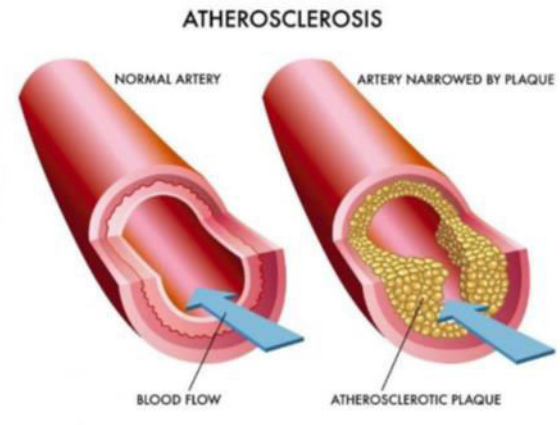


Figure 3: Atherosclerosis

Nanotechnology in Coronary artery bypass graft Nano-coated stents

Coronary artery bypass graft (CABG) and percutaneous transluminal coronary angioplasty (PTCA)/percutaneous coronary intervention (PCI) are invasive therapies used commonly within clinical practice to relive blockages in myocardial vasculature. CABG involves major cardiac surgery, whereas PTCA is a non-surgical procedure, whereby an artery is widened using a balloon and, in some instances, is held open using a stent (NICE 2008). The issue with the use of stents in reperfusion of cardiac tissue leads to a significant risk of restenosis within the vasculature. A method that can be employed to reduce the incidence of in-stent stenosis is the use of drug-eluting stents (DES), which release the incorporated drug to the locality of its placement. The stents can be coated in various polymers, such as poly(lactic-co-glycolic acid) (PLGA), polyethylene glycol (PEG), and polycaprolactone (PCL) (Acharya et al. 2012). The use of polyhedral oligomeric silsesquioxane poly(carbonate-urea) urethane (POSS-PCU) polymer with attached anti-CD34 antibodies was studied as a possible nanocomposite polymer to coat bare metal stents, in an attempt to improve endothelial revascularisation [28].

Nanotechnology in Myocardial Infarction

Reperfusion is mainly used in the early stage of myocardial infarction, but it can cause apoptosis, calcium overload and reactive oxygen species. These factors cause the opening of the mitochondrial membrane permeability transition pore (MPTP) and the increase of mitochondrial outer membrane permeability, thereby promoting cardiomyocyte apoptosis and necrosis. Clinically, the drug therapy for myocardial ischemia mainly depends on growth actors, cytokines and some small molecular compounds. These drugs have the same disadvantages of the above traditional drugs. The high permeability of blood vessels and enrichment of monocytes in ischemic myocardium can be harnessed to deliver drugs by targeting ability of nano-drug carriers [11].Incorporation by circulating monocytes and other MPS is another mechanism targeting inflammation after myocardial injury. Thus, nano-DDS may be feasible for myocardial IR injury

ISSN: 0975-3583,0976-2833 VOL12,ISSUE07,2021

targeting ischemic myocardium and inflammatory monocytes. Takahama, et al have tested PEGylated liposome dependent delivery of adenosine during myocardial reperfusion, and found that liposomes attained a higher adenosine concentration in the ischemic myocardium and showed superior cardioprotection and less systemic hypotensive effect compared with free adenosine in a rat model. Leuschner, et al have tested liposome-dependent delivery of siRNA against CCR2, and showed successful delivery to spleen, bone marrow, and liver, and the inhibition of monocyte/macrophage recruitment to the heart after IR. Treatment with siRNA-CCR2 successfully reduced MI size.[35]

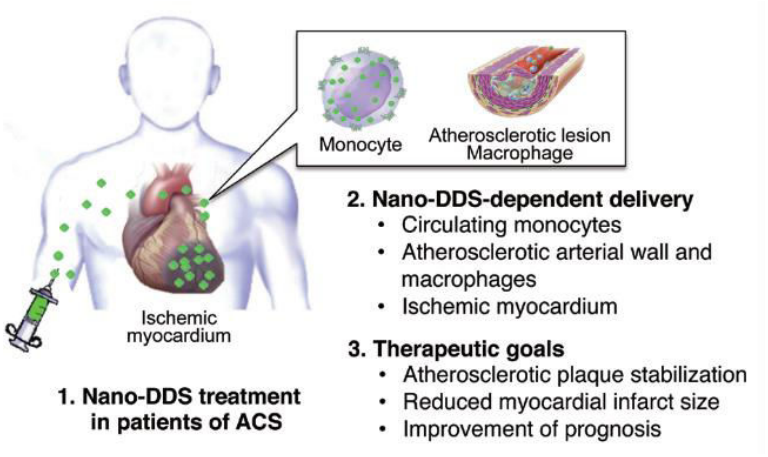


Figure 4 Perspective of nano-DDS-mediated treatment for acute coronary syndrome. Nano-DDS-mediated treatment for cardiovascular disease comprises 1) timely intravenous injection of nano-DDS, 2) nano-DDS-dependent drug delivery to circulating monocytes, atherosclerotic arterial wall and macrophages, and ischemic myocardium, and 3) therapeutic goals including atherosclerotic plaque stabilization, reduced myocardial infarct size, and improvement of patient prognosis.

Nanotechnology in Hypertensive disease:

Most antihypertensive drugs have significant disadvantages, such as low bioavailability, relatively short half-life, low permeability and adverse side effects. For effective and safe administration of these drugs, delivery systems that can provide a low frequency of dosing, increased bioavailability, increased selectivity and reduced undesirable effects, are needed. Some oral drug administration systems based on nanotechnology provide alternative strategies to achieve those objectives. Some Examples of nanoparticles are [8]:

- The use of solid lipid nanoparticles (SLN) containing carvedilol has also been proposed as a promising strategy for improving the bioavailability of the poorly soluble drug.

ISSN: 0975-3583,0976-2833 VOL12,ISSUE07,2021

- The design of nanoparticles charged with telmisartan has proven be effective in significantly increasing the oral bioavailability of this antihypertensive (up to ten times) as a result of enhanced solubility and dissolution speed.
- A platform was designed using a sol-gel precursor in conjunction with a combination of chitosan and polyethylene glycol to form a fine powder of nanoparticles after drying by lyophilization. This nanomaterial retains NO or NO precursors (nitrites) in a stableform when dry. When exposed to moisture, these nanoparticles are slowly released, in a controlled and sustained manner (for several hours), furnishing therapeutic NO concentrations. After administration of this formulation the eluting NO nanoparticles decreased mean arterial pressure in a dose-dependent manner.

Nanotechnology in Restenosis after Arterial Injury:

Cardiovascular interventions continue to fail as a result of arterial restenosis secondary to neointimal hyperplasia. Development of a therapy that effectively prevents the formation of neointimal hyperplasia while simultaneously stimulating reendothelialization is a significant unmet clinical need. Targeted Nitric Oxide Delivery by Supramolecular Nanofibers for the Prevention of Restenosis After Arterial Injury developed [8].

Nanoparticles-Assisted Stem Cell Therapy for Ischemic Heart Disease:

Stem cell therapy has attracted increasing attention as a promising treatment strategy for cardiac repair in ischemic heart disease. Nanoparticles (NPs), with their superior physical and chemical properties, have been widely utilized to assist stem cell therapy. With the help of NPs, stem cells can be genetically engineered for enhanced paracrine profile. Various types of NPs can be the candidates to integrate multiple labeling properties into one particle. Besides that, it is also a task to enhance the resolution and sensitivity of NPs labeling probes in deep tissues, such as in heart. Besides that, NPs can be an excellent platform to integrate multiple applications together. In future, hybrid NPs could be developed to simultaneously deliver therapeutic genes, drugs, and labeling agents into stem cells, which could generate highly reinforced stem cells for cardiac repair and labeling.[6]

ISSN: 0975-3583,0976-2833 VOL12,ISSUE07,2021

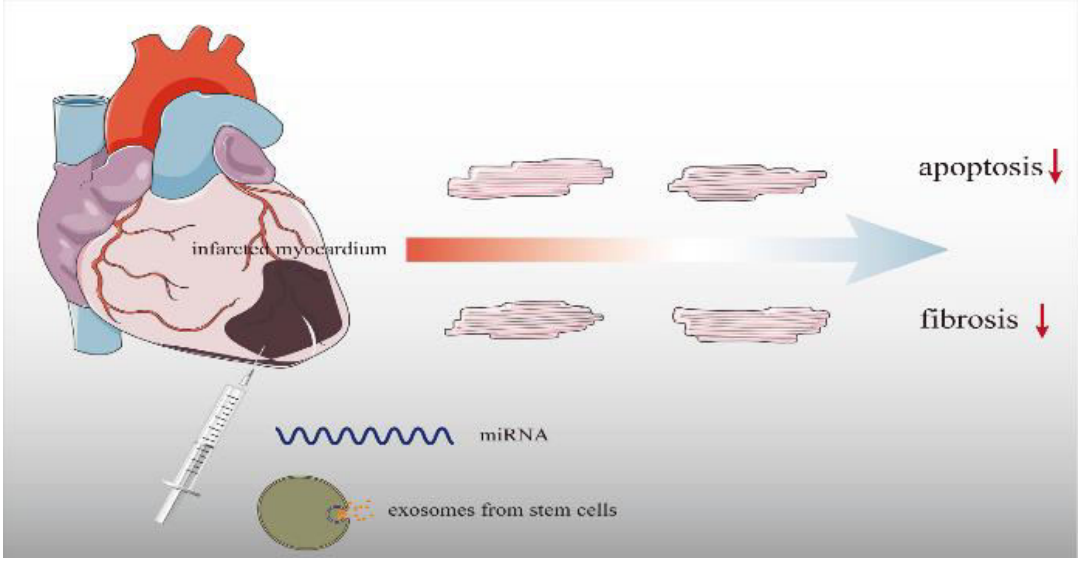
Stem cells	Species	Cell source	Type of NPs	NPs vectors	Internalization	*In vivo* test	Disease model
MSCs	Mouse	Bone marrow	Polymer	Hyperbranched poly(amidoamine)	Not reported	Yes	MI
SkMs	Human	Skeletal muscle	Liposome	Cholesterol-DOTAP liposome	Not reported	Yes	MI
MSCs	Rat	Bone marrow	Inorganics	Calcium phosphate	Not reported	No	—
MSCs	Human	Bone marrow	Blended	PEI-coated multiple QD bundled NPs	96.71% of NPs internalization after 6 h (QD655)	No	—
MSCs	Rat	Bone marrow	Blended	Cationic lipids (lysinylated, histidylated, or arginylated cholesterol)-coated PEI	99.6% of NPs internalization after 4 h (lysinylated cholesterol-coated PEI)	No	—

MI, myocardial infarction; MSCs, mesenchymal stem cells; SkMs, skeletal myoblasts.

Table 1: Examples of NPs-based gene delivery in stem cells.

Nano microRNAs delivery system

MiRNAs are endogenous, non-coding small RNAs composed of about 22 nucleotides that play critical regulatory roles in many biological processes and are associated with various human diseases. By binding to the 3' region of targeted mRNA, miRNAs induce the degradation or silence of that and inhibit the expression of targeted genes. In MI, miRNAs play an essential role in anti-apoptosis or regeneration for cardiomyocytes and inhibition of inflammation for immune cells. Regarding the biodegradation-susceptible of miRNAs and stem cells compared to other biomolecules in vivo, the in-situ injection is applied to enhance drug delivery efficacy. However, this approach decreases the possibility of clinical translation since the in-situ injection induces a second injury to the damaged fragile myocardium [22]



ISSN: 0975-3583,0976-2833 VOL12,ISSUE07,2021

Figure 5 miRNAs induce the degradation or silence of that and inhibit the expression of targeted genes

Nanotechnology in the treatment of Cardiovascular Inflammation:

Inflammation contributes to the pathogenesis of vessel diseases such as arteriosclerosis and restenosis. The objective of cardiovascular immunotherapy is to develop approaches that suppress excessive inflammatory responses. Yi et al. engineered an injectable filamentous hydrogel depot (FM-depot) for low dosage, sustained delivery of anti-inflammatory nanocarriers. Specifically, the bioactive form of vitamin D (aVD; 1, 25-Dihydroxyvitamin D3), which inhibits pro-inflammatory transcription factor NF-kB via the intracellular nuclear hormone receptor vitamin D receptor(VDR), was stably loaded into poly(ethylene glycol)-blockpoly(propylene sulfide) (PEG-b-PPS) filomicelles. [12].

Nanotechnology in Thrombosis

Thrombosis is defined as the formation of a malignant blood clot, and it is considered one of the leading causes of death. Despite knowing that in the process of the thrombus formation, platelets, and coagulation factors play a crucial role, the diagnosis of this disease is often limited to late stages, with treatment options being limited and unable to provide reasonable and effective results. Thus, identifying innovative diagnostic and treatment options are highly recommended in thrombosis. The clinical diagnostic of thrombosis relies on CT imaging, Doppler ultrasound, x-ray, and MRI. Unfortunately, they fail in providing information about the composition and the age of the clots. Example of the use of nanomedicine in thrombosis is the development of the perfluorocarbon-core nanoparticle, which was functionalized by covalent binding to the Phe(D)-Pro-Arg-Chloromethylketone (PPACK) drug. PPACK is a synthetic peptide that can selectively and irreversibly inhibit thrombin activation. However, this drug has a short half-life in the body, and linking it to the perfluorocarboncore nanoparticle prolonged its presence in circulation and, when tested in vivo, showed significant improvements in antithrombotic activity. Another example is the use of iron oxide nanoworms (NWs) as carriers for a ligand-labeled peptide containing the Thrombin-activatable peptide (TAP); this nanoconjugate was shown to have high selectivity to thrombin.[13].

ISSN: 0975-3583,0976-2833 VOL12,ISSUE07,2021

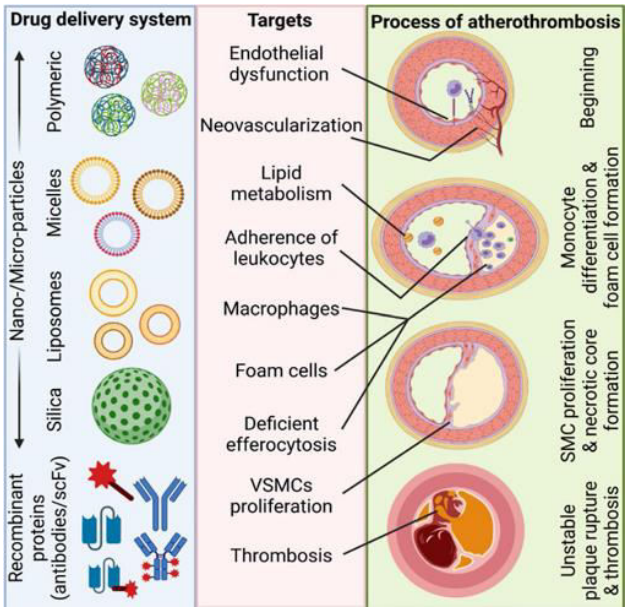


Figure 6: Site-targeting drugs and NPs for different stages of atherothrombosis. NPs can be made from different biomaterials and various formats of antibodies can be used to target and disrupt the atherothrombosis stages of endothelial dysfunction, neovascularization, lipid metabolism, recruitment of leukocytes, phagocytosis of macrophages, and formation of foam cells, along with inefficient efferocytosis, vascular SMC proliferation, and thrombosis [31].

Nanotechnology in Stroke

Stroke is a cerebrovascular disease that occurs when there is an abnormal cerebral blood flow (CBF), the disturbance then leads to either transient or permanent deficits in the function of one or more parts of the brain. An example of nanomedicine used in treating stroke is the liposome cytidine 50- diphosphate conjugate tested to treat ischemic stroke. [14].

Nanocomposites for artificial heart valve Heart valves

It allows unidirectional flow of blood in and out heart chambers. Malfunction of heart valve leads to severe health threat and even death. In such case, heart valve replacement surgery is needed. In addition to decellularized tissue, synthetic materials such as polymers, are often used to fabricate artificial heart valves. Due to the high requirements of mechanical properties and antiplatelet performance, nanocomposites become promising candidate materials. Integrating the reinforcing phase to polymer matrix could push the limit of performance of the sole polymer matrix, achieving both desired mechanical properties and biological performances. Much progress has been made to engineer nanocomposites for artificial heart valves. For example, Kidane et al. fabricated a polyurethane nanocomposite reinforced by polycarbonate soft segment and polyhedral-oligomeric-silsesquioxanes (POSS-PCU) nanoparticles [21].

ISSN: 0975-3583,0976-2833 VOL12,ISSUE07,2021

Future Perspective [7]

The status of nanomaterials is midway. Though nanomaterials had been exploited to some extent, some groundbreaking research is still on its way. The use of three-dimensional printing is not new in the pharmaceutical world. It has been used in various applications, such as dosage form preparation to complex tissue recreation. Example of latest innovation a device that can be worn on the wrist, and ECG signals after physical activity are transmitted using Bluetooth, and data is captured on a mobile phone and analyzed as an early warning. Song et al. prepared self-healing ionic hydrogel made of polyacrylic acid and oxidized alginate (OA)/gelatin (POG) (as shown in Figure)

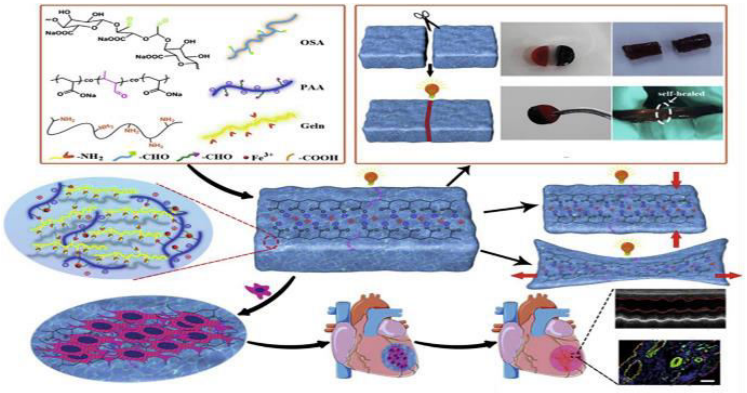


Figure 7: Schematic illustration about the tunable self-healing POG1 hydrogel fabrication and its application in myocardial infarction repair.

Commercial Market

Several drugs with different mechanisms have been used to deliver drugs to the heart with appropriate nanoscale carriers. The good news is that some heart-targeted nanoscale drug carriers have successfully passed clinical trials.Furthermore, some of them are already commercially available on the market. For instance, the intramuscular transplantation of the ultrasound-mediated destruction of microbubbles combined with bone marrow derived mononuclear cells (BM-MNCs) has been clinically applied for inducing angiogenesis in the ischemic tissue.In addition, stents are widely accepted as an effective treatment for occluded arteries.The drug-eluting stent (DES) has been reported to effectively reduce the percentage of restenosis to less than 10% in initial clinical trials.Currently, there are two DES on the market:the Cypher® stent and the Taxus® stent [34].

Conclusion:

The present review discusses the recent advances in nanomedicines, including technological progresses in the delivery of old and new drugs as well as novel diagnostic methodologies. During the last decade, development of nanoparticle-based therapeutic agents has been

ISSN: 0975-3583,0976-2833 VOL12,ISSUE07,2021

extensively studied, and nano-delivery systems are the area of prime importance for specifically targeting the desired area in the treatment of many diseases. Currently, the majority of nanoparticles used for the targeting delivery approach are made of polymers or lipids. As of today, therapeutic nanoparticles are mostly developed for the treatment or prevention of only one disease. However, researchers started to combine various drug molecules as well as various types of nanoparticles thereby, the future of therapeutic nanoparticles is guided to the direction of multi-therapeutic nanoparticles to be designed for the treatment of more than one disease. Although nanoparticle-based delivery systems contribute significantly to the targeted therapy with improved efficiency, reduced side effects, and better bioavailability, we still know very little about the metabolism, clearance, and toxicity of nanoparticles. To date, most of the published studies demonstrate the encapsulation of clinical drugs with nanoparticles. However, the studies on other therapeutics, like genes, enzymes, or DNA/RNA, are still limited. Nanomedicine will be the future of medicine, and nanoparticle-based therapeutics lies at the heart of it. However, a long ground should be gained before prosperity. Most importantly, long-term safety/toxicity of the nanoparticles should be investigated. Meanwhile, the discoveries on disease mechanisms and new drugs will lead to ways of placing more efficient and safer nanoparticle-based therapeutics in treatment regimens.

REFERENCES:

1) Iwona Cicha *, Stefan Lyer , Christoph Alexiou and Christoph D. Garlichs. Nanomedicine in diagnostics and therapy of cardiovascular diseases: beyond atherosclerotic plaque imagin.
2) Cristina Buzea*(1), Ivan. I. Pacheco Blandino**(2), and Kevin Robbie***(1) Nanomaterials and nanoparticles: Sources and toxicity.
3) WJ Geldenhuys1, MT Khayat1,2, J Yun3, and MA Nayeem1. Drug Delivery and Nanoformulations for the Cardiovascular System.
4) K.Sumangali, Sk.Janbee Analysis On Nano Drug Delivery Systems On Cardiovascular Diseas Treatement.
5) Rodríguez-Fragoso, Jorge Reyes-Esparza, Anahí Rodríguez-López, Rocío Gómez-Cansino and Lourdes Rodriguez-Fragoso Interaction of Nanoparticles with Blood Components and Associated Pathophysiological Effects.
6) Kai Zhu,1,2 Jun Li,1,2 YulinWang,1,2 Hao Lai,1,2 and Chunsheng Wang1,2 Review Article Nanoparticles-Assisted Stem Cell Therapy for Ischemic Heart Diseas

ISSN: 0975-3583,0976-2833 VOL12,ISSUE07,2021

7) Hitesh Chopra ,1 Shabana Bibi,2,3 Awdhesh Kumar Mishra ,4 Vineet Tirth,5,6 Sree Vandana Yerramsetty,7 Sree Varshini Murali,7 Syed Umair Ahmad , Yugal Kishore Mohanta ,9 Mohamed S. Attia ,10 Ali Algahtani ,5,6 Fahadul Islam,11 Abdul Hayee ,12 Saiful Islam,13 Atif Amin Baig ,14 and Talha Bin Emran Nanomaterials: A Promising Therapeutic Approach for Cardiovascular Diseases.
8) Virna Margarita Martín Giménez, Diego E. Kassuha and Walter Manucha Nanomedicine applied to cardiovascular diseases: latest developments
9) Edward S.M. Bahnson,1,2,* Hussein A. Kassam,1,2,* Tyson J. Moyer,1,3 Wulin Jiang,1,2 Courtney E. Morgan,1,2 Janet M. Vercammen,1,2 Qun Jiang,1,2 Megan E. Flynn,1,2 Samuel I. Stupp,1,3–6,{ and Melina R. Kibbe lar Targeted Nitric Oxide Delivery by Supramolecular Nanofibers for the Prevention of Restenosis After Arterial Injury.
10) Meera Chandarana1 · Anthony Curtis1 · Clare Hoskins1 The use of nanotechnology in cardiovascular disease.
11) Yudi Deng1,2†, Xudong Zhang2†, Haibin Shen2, Qiangnan He2, Zijian Wu2, Wenzhen Liao2* and Miaomiao Application of the Nano-Drug Delivery System in Treatment of Cardiovascular Diseases.
12) YuanWenguo Cui 1*, Aijun Wang2*, Chao Zhao3* and Wuqiang Zhu4* Editorial: Nanotechnology in Cardiovascular Regenerative Medicine.
13) Nura A. Mohamed 1,*, Isra Marei 2,3, Sergio Crovella 1 and Haissam Abou-Saleh 1,4,*Recent Developments in Nanomaterials-Based Drug Delivery and Upgrading Treatment of Cardiovascular Diseases.
14) Rajasekharreddy Pala 1,2 VT Anju 3 Madhu Dyavaiah 3 Siddhardha Busi 4 Surya M Nauli Nanoparticle-Mediated Drug Delivery for the Treatment of Cardiovascular Diseases.
15) Naima Nashat1 and Zeshan Haider2* Therapeutic applications of nanozymes and their role in cardiovascular disease.
16) Shah Asma Farooq*, Vipin Saini, Randhir Singh, Kamaldeep Kaur Application Of Novel Drug Delivery System In The Pharmacotherapy of Hyperlipidemia.

ISSN: 0975-3583,0976-2833 VOL12,ISSUE07,2021

17) Nikita Lomis1,2, Susan Westfall3, Dominique Shum-Tim4, Satya PrakashID Synthesis and characterization of peptide conjugated human serum albumin nanoparticles for targeted cardiac uptake and drug delivery.

18) Wensen Jiang a, Dana Rutherford b, Tiffany Vuong b, Huinan Liu Nanomaterials for treating cardiovascular diseases: A review.

19) Abuzer Alp Yetisgin 1 , Sibel Cetinel 2 , Merve Zuvin 3, Ali Kosar 3,4 and Ozlem Kutlu 2,4,* Therapeutic Nanoparticles and Their Targeted Delivery Applications.

20) Rabia Shabbira, Abida Razab,*, Afrose Liaquatc, Saeed Ullah Shahd, Sidra Saeedb, Usama Sarwarb, Muhammad Hamzaa, Fayyaz Chudharya, Zajif Hussaine, N.M. Butta,*Nanoparticles as a Novel Tool to Inhibit Inflammatory Cytokines in Human Lymphocytes and Macrophages of Coronary Artery Disease.

21) Hong-tao Shi,a,b,c,d,e,1 Zi-hang Huang,a,b,c,d,1 Tian-zhao Xu,f,1 Ai-jun Sun,a,b,c,d* and Jun-bo Ge a,b,c,d* New diagnostic and therapeutic strategies for myocardial infarction via nanomaterials.

22) Clement Kleinstreuer1,2*, Sriram Vasudevan Chari1, Shantanu Vachhani1Potential Use of Multifunctional Nanoparticles for the Treatment of Cardiovascular Diseases.

23) Abbas Afrasiabi Rad 1, Naser Safaei1, Sara Salatin2, Elham Ahmadian3, Simin Sharifi3, Sepideh Zununi Vahed4, Farzaneh Lotfipour 2,5, Shahriar Shahi3,6, Solmaz Maleki Dizaj3 The Application of Nanomaterials in Cardiovascular Diseases: A Review on Drugs and Devices.

24) Jayanta Kumar Patra1 , Gitishree Das1, Leonardo Fernandes Fraceto2,3, Estefania Vangelie Ramos Campos2,3, Maria del Pilar Rodriguez-Torres4 , Laura Susana Acosta-Torres4 , Luis Armando Diaz-Torres5 , Renato Grillo6, Mallappa Kumara Swamy7, Shivesh Sharma8, Solomon Habtemariam9 and Han-Seung Shin10*Nano based drug delivery systems: recent developments and future prospects.

25) Haikun Liu1, Geoffrey Pietersz2,3,4, Karlheinz Peter2,4,5,6 and Xiaowei Wang1,2,4,5,6* Nanobiotechnology approaches for cardiovascular diseases: site-specific targeting of drugs and nanoparticles for atherothrombosis.

26) Jingwen Zhang1, Aiqun Ma1* and Lijun Shang2* Conjugating Existing Clinical Drugs With Gold Nanoparticles for Better Treatment of Heart Diseases.

ISSN: 0975-3583,0976-2833 VOL12,ISSUE07,2021

27) S.Gousia Begum, D.Mustafa Various Novel Drug Delivery Systems in Treatment of Cardiovascular Diseases.

28) Karin Kornmueller , Ivan Vidakovic and Ruth Prass Artificial High Density Lipoprotein Nanoparticles in Cardiovascular Research.

29) Hagar B. Abo-zalam a , Ezzeldein S. El-Denshary b , Rania M. Abdelsalam b,e , Islam A. Khalil c , Mahmoud M. Khattab b , Mohamed A. Hamzawy Therapeutic advancement of simvastatin-loaded solid lipid nanoparticles (SV-SLNs) in treatment of hyperlipidemia and attenuating hepatotoxicity, myopathy and apoptosis: Comprehensive study.

30) Raphae¨l Duivenvoorden1,2,*, Jun Tang1,3,*, David P. Cormode1,w, Aneta J. Mieszawska1 , David Izquierdo-Garcia1 , Canturk Ozcan1 , Maarten J. Otten1 , Neeha Zaidi1 , Mark E. Lobatto1,2, Sarian M. van Rijs1 , Bram Priem1 , Emma L. Kuan4, Catherine Martel5, Bernd Hewing6,7, Hendrik Sager8, Matthias Nahrendorf8, Gwendalyn J. Randolph5, Erik S.G. Stroes2, Valentin Fuster9,10, Edward A. Fisher7, Zahi A. Fayad1 & Willem J.M. Mulder1, A statin-loaded reconstituted high-density lipoprotein nanoparticle inhibits atherosclerotic plaque inflammation.

31) Kathryn E. Haley a,b , Talal Almas b,c , Saeed Shoar d , Shan Shaikh d , Maimoona Azhar a,f , Faisal Habib Cheema d,e , Aamir Hameed b,g,*,1 The role of anti-inflammatory drugs and nanoparticle-based drug delivery models in the management of ischemia-induced heart failure

32) Meifang Liu1, Minghui Li1, Guangtian Wang1, Xiaoying Liu1, Daming Liu1, Haisheng Peng1 2∗, and Qun Wang2 ∗ Heart-Targeted Nanoscale Drug Delivery Systems.

33) Tetsuya Matoba,1 MD and Kensuke Egashira,1,2 MD Nanoparticle-Mediated Drug Delivery System for Cardiovascular Disease.