Role of Some Nanoparticles in Certain Cardiovascular System Diseases. A Review

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Abstract
This paper gives a general overview of the many cardiovascular disorders and the therapy options that use certain nanoparticles. In order to provide tailored drug delivery to cardiovascular tissues and their biomarkers for treatment, it highlights and analyzes pertinent initiatives and advancements. The purpose of this review is to clarify the crucial and significant role that medication carriers based on nanoparticles play in the heart. This paper gives a general overview of the many cardiovascular disorders and the possible treatment options that make use of certain nanoparticles (silver, platinum, cadmium, and gold). In order to deliver tailored medications to cardiovascular tissues and associated biomarkers, it emphasizes and analyzes the pertinent efforts and advancements that have been made. We conclude that because of the qualities of nanoparticles and Nano carriers, like better target specificity and sensitivity, as well as passive and active targeting to heart tissue, the discipline of cardiology has been very interested in using them.Reportedly, nanotechnology can be used to efficiently treat a wide range of cardiovascular diseases.

Introduction
Nanoparticles in medicine offer versatile applications like drug delivery, imaging, and therapy [1]. They enable targeted drug and gene delivery, act as contrast agents, and show promise in regenerative medicine [2]. Despite their potential benefits, their side effects and toxicity require thorough consideration. These tiniest materials, measuring less than 100 nm, are specifically designed for diagnostic and therapeutic applications, offering benefits like enhanced bioavailability and customized drug administration [3,4]. Nanoparticles, which are made of different materials, have been used in the health sciences for treatment, prevention, and diagnostics [5]. Their safety is still up for question, even though they show promise in treating diseases that were previously incurable. Additionally, they are being researched for diagnostic purposes, such cancer detection [6,7].

Cardiovascular disease (CVD) is the leading cause of death worldwide. Malnutrition and unfavorable living circumstances account for almost 80% of CVD deaths [8]. Peripheral vascular disease, heart failure, cerebrovascular disease, and coronary heart disease are all considered forms of cardiovascular disease (CVD). Reducing blood pressure and avoiding hypertension could potentially reduce the risk of heart
disease development [9,10]. CVD is the primary source of rising healthcare costs and health disparities. The primary focus must be on preventative measures and lifestyle improvements in order to successfully control and prevent CVD [11]. Because nanoparticles improve drug delivery and therapeutic efficacy, they can help treat cardiovascular illnesses (CVDs). Nanotechnology offers novel strategies for tackling the challenges associated with the management of chronic disease. Nanoparticles can enhance the safety and effectiveness of conventional treatments for cardiovascular disorders by serving as drug carriers [12]. Their ability to target sick locations, enhance drug absorption, and transport diverse functional payloads confers advantages for cardiovascular disease diagnosis and treatment [13]. Additionally, nanoparticles can track stem cells in vivo, improve retention following transplantation, and help transport genes to stem cells, which may lead to the development of therapeutics for peripheral vascular disease. However, the main limitation of nanoparticles is toxicity, which is related to their size, shape, aspect ratio, and surface charge [14]. Despite the potential, there are challenges in the clinical translation of nanoparticles for CVDs, including technical, ethical, and regulatory issues [15]. Nanoparticle-based drug delivery systems have the potential to provide safer and more effective treatments for CVDs by altering the biodistribution of therapeutic agents through site-specific, target-oriented delivery and controlled drug release [16]. However, the development of nanomaterials for CVD treatment requires careful consideration of design parameters to ensure targeted therapeutic delivery to atheromatous lesions [17]. The main objective of this review is to explore recent advances in nanoparticle-based cardiovascular drug carriers.

**Silver Nanoparticles and Cardiovascular Disease**

Coronary heart disease (CHD) is a leading cause of death, especially in women, and is associated with substantial diagnostic errors [18]. It's characterized by plaque buildup in the arteries, leading to reduced blood flow to the heart. Health education is crucial for patients' understanding and motivation for lifestyle changes, as it can influence their engagement with lifestyle changes [19]. Risk communication and education about CHD are essential for patients' knowledge and awareness of the benefits of correct lifestyles to prevent the worsening of their disease [20]. Lifestyle and risk factor modifications, along with medical therapy, are effective in slowing the progression of atherosclerotic disease and reducing the risk of thrombosis [21,22]. Silver nanoparticles (AgNPs) have shown potential in the management of coronary heart disease (CHD). In a study, AgNPs demonstrated cardioprotective effects, reducing biochemical markers of cardiac toxicity and ameliorating oxidative stress in cardiac tissue [23]. Additionally, low concentrations of AgNPs increased nitric oxide (NO) production without modifying cardiac parameters, suggesting a potential role in coronary vascular tone regulation [24]. However, it’s important to note that AgNPs may have negative effects on the cardiovascular system, modulating inflammation and cholesterol uptake, which can exacerbate atherosclerosis [25]. Further research is needed to fully understand the potential benefits and risks of using AgNPs in the context of coronary heart disease.

Cerebrovascular diseases, such as stroke and dementia, are common and can lead to disability and death [26]. They are often caused by conditions like hypertension, atherosclerosis, and heart disease. Research shows that up to 80% of ischemic strokes could be prevented with available treatments for blood pressure, cholesterol, and antithrombotic therapies [27]. Identifying patients at high risk, counseling them on lifestyle changes, and controlling comorbid conditions is crucial for prevention [28]. Silent cerebrovascular disease, including silent brain infarcts and white matter hyperintensities, is common and associated with an increased risk of stroke, cognitive decline, dementia, and death. Early diagnosis and treatment are essential to prevent the devastating outcomes of cerebrovascular diseases [29,30]. Silver nanoparticles (AgNPs) have been studied for their potential applications in cerebrovascular diseases. AgNPs can easily enter the brain and interact with cellular components of the neurovascular unit, affecting the integrity of cerebral vessels [31]. They have been shown to influence the expression of tight junction proteins in cerebral microvessels, potentially altering their permeability. Additionally, AgNPs have demonstrated innate antiplatelet properties and can retard fibrin polymerization kinetics, which may impede thrombus formation. However, it’s important to consider the potential toxic effects and redistribution of AgNPs in vital organs when considering their clinical applications [32].

Peripheral vascular disease (PVD) is a common condition characterized by narrowed arteries, leading to reduced blood flow to the arms or legs. It frequently stems from atherosclerosis, resulting in symptoms including walking-related leg pain and other symptoms [33]. A considerable number of people are impacted by PVD; in the US, its prevalence is estimated to be 8.5 million. The fact that patients with PVD might not be well-informed about the illness and its risk factors emphasizes the necessity of educational programs [34]. Treatment entails modifying one's lifestyle to include exercise, a balanced diet, and quitting smoking. Medical and surgical procedures may be required in severe instances [35]. Peripheral vascular disease (PVD) may benefit from the use of silver nanoparticles. They...
were created to encourage cell adhesion and proliferation, accelerate wound healing, and lessen aseptic necrosis in the healing of femur fractures [36]. They have also been applied to improve therapeutic angiogenesis in PVD and to produce vascular endothelial growth factor (VEGF) for blood vessel repair. For a more comprehensive understanding of their uses in biomedicine, it’s crucial to remember that additional research is necessary to fully understand the effects of silver nanoparticles on the cardiovascular system and any potential harmful effects [37]. Heart failure is a dangerous disease that impacts more than 6 million Americans and was a factor in 1 in 8 fatalities in 2016. Adherence to drug regimens, physical activity, and dietary practices are among the obstacles faced by patients with heart failure in treating their illness [38-40]. End-of-life care discussions are uncommon, and physicians frequently steer clear of them out of uncertainty about prognosis and a desire to avoid setting off alarm [41]. Studies reveal that patients, however, actually enjoy these conversations. Cognitive issues and time constraints are two obstacles to communicating. For patients to receive better treatment, prognosis and end-of-life communication must be improved [42]. Heart failure (HF) treatment appears to be promising for silver nanoparticles (AgNPs). AgNPs have been shown to have cardioprotective effects by lowering biochemical indicators of cardiac toxicity and enhancing the heart’s ability to withstand oxidative stress [43]. Additionally, they decrease the expression of nuclear factor-kappa B, which is linked to inflammation, and increase the expression of transcription factors found in mitochondria. AgNPs have also been demonstrated to offer protection against cardiac harm brought on by myocardial infarction. To completely comprehend the possible uses of AgNPs in the therapy of HF, more investigation is nevertheless required [44].

**Platinum Nanoparticles and Cardiovascular Disease**

Platinum nanoparticles (PtNPs) possess a variety of uses, including cancer treatment and catalysis [45]. PtNPs’ characteristics can be altered by synthesizing them in a variety of sizes and forms. For example, because of their cytotoxic effects on cancer cells, smaller PtNPs have demonstrated promise in cancer therapy [46]. PtNPs have also been investigated for their catalytic qualities, particularly in relation to fuel cell technology [47]. PtNPs can be made in a number of ways, such as through green synthesis techniques and chemical reduction. The utilisation of these approaches results in PtNPs with controlled sizes and shapes, which influences their performance in many applications [48,49].

Platinum nanoparticles (PtNPs) have been studied in connection with cardiac disease. PtNPs are used in the treatment of cancer and are believed to be safe. However, research has shown that PtNPs may negatively impact cardiac electrophysiology in the short term, potentially leading to cardiac conduction block [50]. Moreover, PtNPs have been shown to depolarize resting potentials and prevent action potentials from depolarizing in cardiomyocytes. These findings suggest that while PtNPs may have therapeutic applications, consideration should be given to their acute electrophysiological toxicities when examining their potential for the treatment of coronary heart disease [51]. Platinum nanoparticles (PtNPs) show promise in treating cerebrovascular diseases. PtNPs are potent scavengers of reactive oxygen species (ROS), which are a major contributor to the detrimental effects of ischemic stroke. Research has indicated that PtNPs can decrease infarct size and improve neurological scores while protecting the neurovascular unit and deactivating toxic enzymes [52]. Furthermore, PtNPs have demonstrated efficacy in the treatment of complicated oxidative stress-related disorders, including cerebral cavernous malformation. Moreover, PtNPs have the potential to cure disorders linked to oxidative stress by creating multifunctional nanocarriers for combinatorial targeting of redox signaling and autophagy dysfunctions [53]. There hasn’t been any particular research on platinum nanoparticles and peripheral vascular disease [54]. However, nanotechnology has shown promise in targeted drug delivery and treatment of vascular diseases [55]. Nanoparticles can deliver therapeutic agents to specific sites, enhancing treatment efficacy and reducing systemic side effects [56]. For example, polymeric nanoparticles have been developed for sustained drug release to reduce restenosis after angioplasty, a common treatment for peripheral artery disease. While platinum nanoparticles have not been directly studied, the broader field of nanotechnology offers potential for advanced and targeted treatment of peripheral vascular disease [57,58]. Platinum nanoparticles (PtNPs) have shown potential in heart failure (HF) treatment. PtNPs have been found to be nontoxic and can be used in drug delivery systems for cardiac diseases [59]. Studies have demonstrated that PtNPs do not significantly increase the generation of reactive oxygen species (ROS) and have similar acute toxic effects on cardiac electrophysiology. They have also been shown to have cardioprotective effects, reducing infarction size, improving systolic function, and inhibiting cardiac fibrosis. PtNPs can be used in nanomedicine research for the treatment of cardiovascular diseases, particularly myocardial infarction, and have been found to induce reversible cardiac hypertrophy. However, further research is needed to fully understand the potential of PtNPs in HF treatment [60,61].
Cadmium Nanoparticles and Cardiovascular Disease

Cadmium nanoparticles have been produced using a range of methods, such as wet chemical processes and chemical precipitation [62]. These particles have been used to create quantum dots for application in medicine. Their sizes range from 2 to 6 nm [63]. Studies [64-68] have highlighted their potential for targeted medicine administration and cancer treatment by utilizing their size-tunable fluorescence. Further studies in the toxicological and pharmacological fields are required to assess the risks and safety of cadmium nanoparticles in medicinal applications. Additionally, the global issue of cadmium pollution in soil is being researched for in-situ remediation employing nanomaterials. Cadmium nanoparticles have been connected to coronary heart disease (CHD) [69]. Exposure to cadmium has been linked to cardiovascular oxidative damage, inflammation, and apoptosis, which can result in a variety of heart disorders, including congestive heart failure (CHD) [70]. Studies show that cadmium exposure can lead to cardiac dysfunction, poor energy balance, and structural abnormalities in the heart, all of which can exacerbate atherosclerosis and heart failure. Moreover, it has been proposed that one possible tactic for treating cardiovascular diseases like CHD is to use nanotechnology. Nanoparticles have enhanced target specificity and sensitivity, making them a viable treatment alternative for CHD [71-74]. Cadmium nanoparticle-related conditions have been linked to cerebrovascular illnesses. An increased risk of ischemic stroke, endothelial dysfunction, and atherosclerosis have all been associated with cadmium exposure. Cadmium exposure has been linked to an increased risk of atherosclerosis, according to research, since it causes endothelial dysfunction, speeds up the formation of atherosclerotic plaque, and increases oxidative stress [75]. Moreover, it has been found that cadmium increases the risk of rupture and ischemic stroke, increasing the susceptibility of carotid plaques to ischemic stroke events [76]. Additionally, cadmium nanoparticles have been studied for potential therapeutic applications in reducing oxidative and nitrosative damage associated with stroke [77]. Vascular dysfunction and peripheral arterial disease (PAD) have been associated with cadmium nanoparticles. Cadmium exposure has been linked to oxidative stress, inflammation, and endothelial dysfunction, contributing to PAD [78]. Studies [79-82] suggest that cadmium nanoparticles inhibit angiogenesis and cellular migration, leading to impaired vascular health. However, zinc supplementation has shown protective effects against cadmium-induced vascular damage. Additionally, nanomedicine, particularly nanoparticles, has been proposed as a promising approach for targeted vascular disease treatment, including PAD. Nanoparticles can serve as drug carriers for pro-angiogenic proteins and enhance cell therapy for PAD treatment. Cadmium nanoparticles are generally linked to vascular disorders, and nanomedicine presents possible treatment options for peripheral artery disease. Heart failure has been linked to cadmium nanoparticles. Studies [83-86] have demonstrated the prognostic power of cadmium for mortality in individuals with cardiovascular illness. Cadmium has also been connected to atherosclerosis, osteomalacia, acute heart failure, chronic renal failure, and secondary hypertension. Cadmium exposure has been shown to have negative effects on the vascular system and has been linked to a higher death rate in people suffering from cardiovascular disease. Cadmium nanoparticles have also been demonstrated to cause oxidative stress and cardiac cell damage in cardiomyocytes, in addition to their cytotoxicity. These results indicate that heart failure may be influenced by cadmium nanoparticles throughout its onset and progression.

Gold Nanoparticles and Cardiovascular Disease

Gold nanoparticles (AuNPs) possess a multitude of uses in the field of biomedicine. Because of their exceptional stability, biocompatibility, and low toxicity, they can be employed as drug carriers, in the treatment of cancer, and in biomedical imaging [87-88]. A variety of techniques, such as chemical, laser ablation, and microbiological synthesis, can be used to create AuNPs. Because of their superb optical qualities and compact size, they have showed potential in targeted medication delivery, cancer treatment, and diagnostic tools [89]. However, challenges such as scale-up, cost, low drug payload, toxicity, and stability need to be addressed for successful commercialization [90].

Gold nanoparticles (GNPs) have shown promise in the treatment and diagnosis of coronary heart disease (CHD) [91]. They can be used for targeted drug delivery near the diseased area, providing new perspectives in the prevention and regression of atherosclerosis, the main cause of CHD. GNPs coated with high-density lipoprotein (HDL) have been used for the simultaneous detection and therapy of unstable plaques, showing potential for specific unstable plaque diagnosis and recovery [92,93]. Additionally, GNPs have been found to reduce high glucose-induced atherosclerosis-related complications in macrophages, indicating their potential for minimizing atherosclerosis. Furthermore, GNPs have been used for imaging cardiovascular diseases, allowing the detection of atherosclerotic plaques, intravascular thrombus, or fibrotic tissue. Overall, GNPs show promise in the diagnosis, treatment, and imaging of CHD [94]. Gold nanoparticles (AuNPs) show promise in cerebrovascular diseases. They can cross the blood-brain barrier (BBB) and have potential therapeutic effects. Studies suggest that 20-
nm AuNPs can ameliorate cerebral ischemia-reperfusion injury, reducing neurologic deficits and infarction volumes [95]. Additionally, they protect primary cortical neurons against ischemic injury, possibly by decreasing apoptosis and oxidative stress, while activating Akt signaling and mitochondrial pathways [96]. However, the use of AuNPs in cerebrovascular diseases is still in the preclinical stage, and further research is needed before clinical translation [97]. Therefore, while AuNPs show promise, more studies are required to fully understand their potential for treating cerebrovascular diseases. Gold nanoparticles (AuNPs) have shown promise in treating peripheral arterial disease (PAD). AuNPs have anti-inflammatory effects, reducing arterial neointima formation and monocyte adhesion [98,99]. They can also be used to deliver therapeutic agents and target specific vascular injuries. Furthermore, AuNPs can be utilized in multimodality imaging to track the effectiveness of PAD treatments in real time. Moreover, collagen-targeting peptide-functionalized AuNPs on the surface have shown selective binding to vascular damage sites and biocompatibility. These uses demonstrate AuNPs' potential for PAD diagnosis and treatment [100-102]. Gold nanoparticles (GNPs) have potential for treating heart failure (HF). They can be applied to enhance cardiac fibrosis molecular imaging and enable targeted medication delivery to stop or reverse heart failure [103]. GNP s have been shown to accumulate in infarcted hearts, decrease infarction size, improve systolic function, and inhibit cardiac fibrosis and TNF-α accumulation, indicating cardioprotective effects [104]. Additionally, GNP s can be used in cardiac tissue engineering to improve cell proliferation and expansion of cardiomyocytes, offering a new platform for cardiac regeneration [105]. The fact that this investigation confirms previous findings highlighting the importance of applied research in nature is particularly noteworthy [106,107]. However, further research is needed to fully understand the potential of GNPs in HF treatment.

Conclusion

Nanotechnology and nanomedicine, as theranostic agents, offer customized treatment in the areas of cardiovascular disease diagnosis and treatment. For the purpose of successfully delivering medications to the site of injury, nanosized particles function as nanodevices or nanocarriers. Drugs and genes can be administered efficiently and selectively with the use of nanocarriers, resolving problems with solubility, bioavailability, and other pharmacokinetic properties. The disadvantages of conventional treatment approaches include systemic toxicity, thrombosis in stents, unique immune system activation, and poor therapy of cardiovascular diseases (CVDs). These techniques focus on many processes, including the coagulation cascade, blood volume, lipid metabolism, and arterial constriction. As a result, the efficient and controlled administration of drugs into injured heart tissue has been replaced by the application of nano-drug delivery systems. Similarly, nanoparticles have several uses in CVD imaging and diagnostics since they allow for real-time tracking during therapy and simple diagnosis. Nanoimaging for CVD uses multifunctional and multimodal imaging vehicles, which are not possible with conventional imaging techniques.

Conflict of Interests

Authors declare no conflict of interest.

References


Association of Nanoscale Gold Polyethylene - Magnetic Biomedical Gold.


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