Mini Review

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Applications of Biomaterials in Cardiovascular Research: Clinical Implications

Abstract

Based on investments and demand, cardiovascular biomaterials (CB) predominate in the biomaterials category. This review article gathers data on the CB and divides it into three main categories: metals, polymers, and biological materials. One of the main factors that restrict the use of biomaterials for cardiovascular applications is their compatibility with blood. The main figures connected to blood compatibility are discussed in this study. Several surface modification techniques were being used at the time to improve the CB's compatibility. For a better understanding, some current surface modification technology applications on the components of cardiovascular devices were also covered. The use of induced human pluripotent stem cells (ihPSCs) and endothelization of cardiac implants, two contemporary CB trends, are also discussed in this review. The topic of CB is constantly expanding, and a lot of fresh academics are becoming interested in it. This review will provide as a one-stop resource for swiftly understanding the fundamental studies in the area of CB.

Keywords: biocompatible materials • cardiovascular disease (CVD) • medical Implants • cardiac tissue engineering • biomaterials • biocompatibility

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Introduction

The subject of material science has experienced remarkable expansion over the last ten decades, and it is safe to claim that some materials have been effectively employed to replace, help, and repair some bodily components and functions. They are frequently referred to as biomaterials. The notion is expanded upon by numerous definitions of biomaterial provided by other scientists. The following list includes a few definitions of biomaterials. Williams first said, "A nonviable material utilised in a medical device, intended to interact with biological systems," perhaps about 1987. Williams stated that "ability of a substance to operate with an appropriate host reaction in a certain scenario" was the definition of biocompatibility in 1999 [1]. Before this definition, successful biomaterials served primarily passive roles in the body. This definition fundamentally altered how we think about biomaterials. In addition to serving some purpose according to the definition above, such biomaterial also causes some biological reactions. In Williams Dictionary of Biomaterials (2008), a broad and clear definition of biomaterials was recently developed by taking into account the aforementioned and other factors [2].

According to current Markets and Markets research, the estimated global market for biomaterials is expected to reach $86.4 billion US in 2017 with a 15% compound annual growth rate (CAGR). In addition, it has been predicted that the Asian market will expand at the highest CAGR of 21.5% due to the high prevalence of illnesses that call for the use of biomaterials in medical products. Biomaterials are now frequently used in many different medical systems and devices, including synthetic skin, drug delivery systems, tissue cultures, hybrid organs, synthetic blood vessels, artificial hearts, cardiac pacemakers, screws, plates, wires, and pins for bone treatments, complete artificial joint implants, skull reconstruction, and dental and maxillofacial applications. The most important use of biomaterials is in the cardiovascular system, among other uses. With a market value of roughly $20.7 billion, the use of cardiovascular biomaterials is anticipated to dominate the biomaterials industry in 2014 [3].

The compatibility of cardiovascular biomaterials (CB) with blood and their assimilation into the environment where they are implanted are requirements for their use. When using CB, two crucial factors should be weighed equally: the physical and mechanical properties of the material, such as strength and deformation, fatigue and creep, resistance to friction and wear, flow resistance and pressure drop, and other characteristics to be engineered. Biocompatibility or compatibility, which refers to the interactions between the material and the tissue, should also be taken into account. Numerous in vivo and in vitro experiments must be performed to evaluate and test these properties [4].

Depending on the material selected and its inherent qualities, the first aspect described is essentially predetermined. However, the second factor, biocompatibility, is crucial since it determines the patency of any cardiac implant material. Before we get to the classification, the biocompatibility of cardiovascular biomaterials is briefly covered in the next subheading [5].

Methods and Materials

Any biomaterial's structural integrity is crucial for assessing its field-proven reliability in terms of functionality, durability, and life span. Both numerical and experimental research has been done on the structural integrity of MBBDs. However, the focus of this section is only on the numerical studies that have been conducted utilising FEA technology that is application-based. It should be noted that the terms "in silico" and "FEA" are used here interchangeably [6].

The National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention (CDC) conducted the independent cross-sectional study NHANES 2011–2014 to evaluate the health and nutritional status of a sample of the non-institutionalized, civilian general population in the United States. The survey's plan, operation, and design elements have already been covered. Laboratory testing, physical examinations, questionnaire surveys, and home interviews with demographic, nutritional, and health-related questions were all conducted. After removing participants under the age of 18, we ultimately chose 3607 adults from a total of 4848 participants who had their serum zinc levels checked. Fewer than half of the 3607 participants have multiple conditions [7].

Discussion

The results of our investigation demonstrated that the primary modifiable CVD risk factors were widespread, frequently clustered individually in the adult population of Vietnam that was under study, rising with age and showing varied patterns across sexes. We admit that the self-reported data and cross-sectional design may introduce some misclassification and that the data may not accurately capture the time- and context-bound characteristics of CVD risk factor patterns [8]. Additionally, it was difficult to quantify some characteristics, such as stress, and there was no conclusive research on how to prevent stress in the first place. Although the data were only available from two provinces rather than the eight provinces in the national surveys due to limited financial resources, both glucosaemia and lipidaemia disorders were extensively investigated in this study to fill gaps in our understanding of major metabolic CVD risk factors in the Vietnamese population. These provinces were Hanoi and Thai Binh. With these limitations in mind, the study attempted to take a broad picture of nine modifiable risk factors, which together accounted for over 90% of the risk of cardiovascular events. It then extrapolated and went on to imagine the current population burden of CVD risk factors as both individual risk factors and within-individual clusters [9].

The three most significant risk factors for chronic and cardiovascular illnesses are thought to be hypertension, smoking, and excessive alcohol consumption. According to our study's extrapolations, 12.5 million adults (aged 25 and older) were estimated to have hypertension, however only 26.7% (or 3.3 million) of these individuals received treatment. But according to our findings, unhealthy nutrition (54.6% of the sample, or 25.9 million people) and lipid abnormalities (60%) were more prevalent in both sexes than smoking and excessive alcohol consumption (which affected exclusively men). In nations like Vietnam, where changes in cholesterol levels can be used to measure dyslipidaemia and other newly developing CVD risk factors, such as poor diets or dyslipidaemia, future intervention programmes to address these issues may be crucial [10].

People with lower social economic position would be more sensitive and likely to develop CVD risk factors, leading to cardiovascular events later in life. CVD risk was influenced cumulatively by socioeconomic, behavioural, and biological factors acting over the life course. Even more so than hereditary variables, lifestyle and cultural practises have an impact on metabolic disorders. After controlling for age and other social factors, our findings supported findings from other studies and pointed to the significance of urban living situations where persons had higher prevalence's of metabolic illnesses [11].

Our extended estimate, however, indicated that treating a CVD risk factor like hypertension on its own without also addressing other modifiable CVD risk factors like smoking or a poor diet would not be an effective strategy for reaching a large general health impact. The top objective should be a demographic plan to lower male tobacco use and stop the rise in female use. The next tactic would be to use the media to promote a population-wide effort to reduce salt content in food given the high prevalence of unhealthy diet and possible benefits from interventions. The population as a whole would gain more from the high-risk person strategy than from focusing on hypertensive patients. Simplified formulae utilising age, sex, cigarette usage, blood pressure levels, and BMI may be used to estimate the overall risk if there weren't enough resources to assess overall CVD risk on a large scale, particularly if pricey blood tests are necessary. Additionally, when resources are available, a combined community approach (primarily through the promotion of a healthy lifestyle) and individual approaches using easier and more practical metrics to identify high-risk individuals could be used [12].

Conclusion

With a market value of roughly $20.7 billion, cardiovascular biomaterials were predicted to dominate the biomaterials industry in 2014. Blood compatibility is a major issue with CB, and many criteria have developed to assess its biocompatibility. As a result, the biomaterials employed in cardiovascular applications are of high quality. CB mostly belongs to three groups: biological materials, polymers, and metals. These materials' characteristics prevent their usage in a variety of applications. For many cardiovascular applications, polymers have become a versatile option. The issue of blood compatibility is still a significant one, hence various surface changes are used to get around it and create CB that is biocompatible.

Cardiovascular biomaterials have grown over the past two decades, but more fundamental studies and clinical data must still be produced in large quantities by researchers to further this discipline. Still, it is necessary to create composite materials that have characteristics of both natural and synthetic materials in order to create materials that mirror the characteristics of the natural cardiac tissues. To create more biocompatible cardiac biomaterials, new surface modification techniques should be developed. This can be accomplished by conducting endothelization studies and modifying the CB surface using nanotechnology.

Acknowledgments

None

Conflict of interest

None

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