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BIOMATERIALS USED FOR THE PRODUCTION OF STENTS - HOPES AND LIMITATIONS - REVIEW ARTICLE

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Abstract: *Diseases of the cardiovascular system are on a high position in the statistics of deaths in our century. Nowadays in Poland, ischemic heart disease affects almost a million people and about 90 000 of them die every year. One of the most commonly used treatment methods is the coronary angioplasty with stent placement. There are many types of stents available, but we still need to look for new technologies and materials to provide better mechanical properties, physicochemical and biomedical stents.*

Keywords: Enter Stents, Biomaterials, Cardiology, Atherosclerosis.

1. Introduction

The term "ischemic heart disease" describes a pathophysiologically and clinically diversed state of functional or permanent damage of the heart muscle (Ziołkowski et al., 2009).

Population research has proven the steadily increasing prevalence of coronary heart disease. In Poland it is on average 620 cases per 100 000 for men and 220 cases per 100,000 for women. Rate of incidence depends on the place of the residence (lower in rural areas and higher in cities) and increases rapidly with age regardless of gender, especially after the age of 45.Currently we can notice a rise in the incidence of this disease among people between 20 and 30 years of age) (Karasek, 2008; Jakubowska-Najnigier, 2008; Ziołkowski et al., 2009).

Taking into account the risk factors division made by Polish Cardiac Society (based on the guidelines of European Society of Cardiology), the most important and modifiable ischemic heart disease risk factors are considered to be: lifestyle, cigarette smoking, diet rich in an animal fat, physiological and biochemical factors, high cholesterol level (especially LDL), elevated triglycerides, hyperglycemia or diabetes and increased levels of homocysteine.

The age over 45 years for men and over 55 for women, premenopause and other arteries disease caused by atherosclerosis should be considered as non- modifiable and independent of the patient risk factors (Murray, 2006).

2. Coronary Atherosclerosis

The most common reason (90%) of ischemic heart diseaseisa the rosclerosis of the coronary arteries. Over the years, the aging process was considered responsible forcoronary a therosclerosis. The new view on the pathomechanism of this disease was given not until the research from the mid of XIX century. The latest tests have shown, that atherosclerotic lesions are the result of a long process of inflammation, appearing in the vascular wallin response to inflammatory agents, hypoxia, free radicals or shear forces, damagingepithelial cells (Snarska, 2003).

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The formation of atherosclerotic plaque in the coronary arteries begins with the permeation of the lipoprotein excess through endothelial layer. There they are caught by the immune cells (monocytes) and put into precinct of collagen fibers, forming the early fatty infiltration. Then the smooth muscle cell migrate from the central portion to the internal part of the vessel - Fig. 1 (Szwed, 2002).

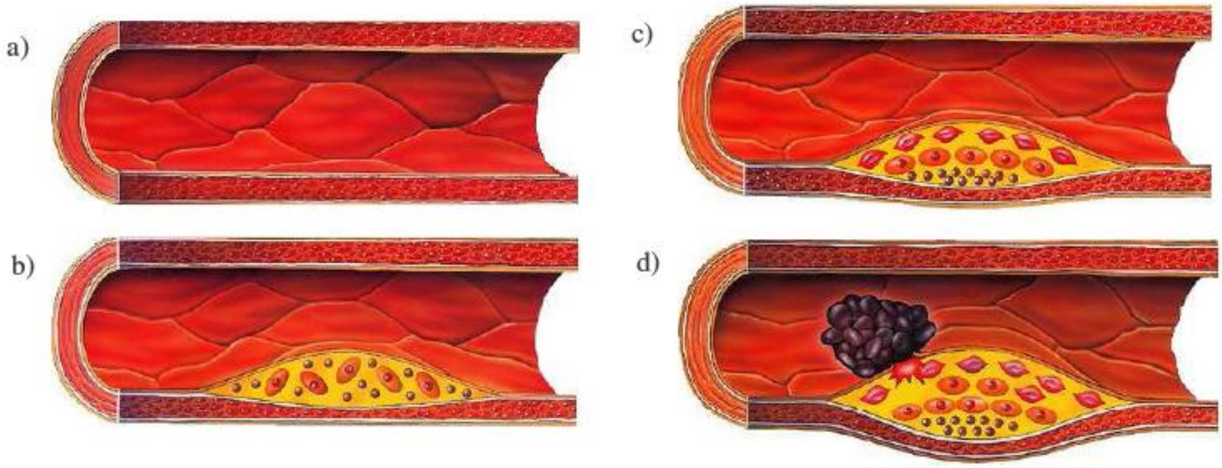

Fig. 1: The next phases of the formation atherosclerotic lesions in the coronary arteries: a) healthy artery; b) early fatty infiltration; c) atherosclerotic plaque; d) atherosclerotic plaque and thrombus (Marciniak, 2006).

2.1. Coronary stents

One of the most common treatment methods of coronary heart disease is percutaneous transluminal coronary angioplasty (PTCA). This is the procedure of expending the atheromatously changed section of coronary artery, using a baloon catheter introduced in the place of constriction. Classical angioplasty is suplemented with other techniques, using various instruments , most often with the intravascular stents implantation, which perpetuate the effect of the coronary artery extension (Szkutnik, 2010).

Stents are a kind of metal, elastic scaffolding with a spatial, cylindrical construction and millimeter dimensions. They are implanted in a place of critically narrowed coronary artery section in order to support its walls and prevent from the narrowing of the vessel lumen.

2.2. Properties characterizing the implants

To avoid complications after the stent implantation and to improve its effectiveness, the metal stents construction should have the following properties (Patrick, 2001):

- flexibility, that makes it possible to carry the stent trough the bends of the coronary vessels and to implant it in a place of constriction;
- ease of movement in the catheter and arteries;
- low stent profile on the balloon;
- low thrombogenicity, that protects from thrombosis and disease relapses;
- tissue neutrality;
- good extensibility that facilitates the expansion mechanism;
- resistance to external forces, that reduces the vessel wall stretching and smooth muscle cells formation;
- small total stent surface;
- good rheological properties;
- good stent coverage of the vessel wall.

2.3. Material used in stent construction

The stents are made of biomaterial, which when introduced into the circulatory system may not result in dysfunctions of the body (damage to protein structure and blood morphotic elements, blocking the action of enzymes, changes in the composition of the electrolyte). At the same time they should not initiate toxic, mutagenic or immunological reactions (Williams, 1986). Nowadays, there are many types of stents available on the market. They are made of different types of materials. The most popular include:

- austenitic steel AISI 316L (most of stents)
- nitinol (RadiusTM , CardicoilTM, HARTSTM, Paragon™),
- alloys of platinum with iridium (AngiostentTM),
- tantalum (Wiktor®, CordisTM , StreckerTM),
- cobalt (Magic Wallstent™),
- gold (NIROYALtm),
- polymers (phosphorylcholine - DyvYsioTM stent, PTFE - Jostent®),
- alloys of cobalt (DriverTM, VisionTM),
- titanium (TTS)(Patrick W. Serruys., et al. 2001).

In the production of coronary stents the most commonly used material is an austenitic acid resistant steel (AISI 316L). The austenitic acid resistant steels are a group of materials, that the earliest were adapted to implantation in human body. It was inextricably linked with modernizing of chemical and phase composition.

Steels used for implants are of the highest quality and have the strictly defined composition. The main alloy elements in the steels of this type are chromium, nickel and molybdenum. Any other additions can cause the movement of boundaries of particular phases.

In the steels intended for stents the ratio of Cr-Ni-Mo should be about 18% - 15% - 2.5%. As a result of the nickel concentration increase, the resistance to stress corrosion of steel rises. Moreover, high energy of nickel chloride formation impede the penetration of chloride ions into the oxide passive layer. The molybdenum boosts the resistance to pitting corrosion, as well as chromium and helps to form the oxide layer on the surface.

A very important aspect for this type of steel is the kind of purity and inclusions. Type of inclusions, their shape, number and layout can have a great impact on the anisotropy of mechanical properties of the material, visualized more when the implant is miniaturized (Patrick, 2001).

2.4. Implants resistant to restenosis

Implantation of the metal stent can initiate a cascade reaction between blood components and the stent surface. This process is dangerous because it can cause blood clotting on the implant surface, which leads to recurrence of restenosis. Stents covered with the appropriate anticoagulants and materials lowering thrombogenicity, or those made of non-metallic materials, are used to prevent from such situations (Gabryel, 2009).

The most popular at present are polymer materials, which have good blood biotolerance and witch are athrombiogenic.

The number of species of non-biodegradable synthetic polymer used for the protective coating of stent surface is high, and the most popular are: polyurethane, silicone, polyethylene terephthalate, phosphorylcholine (Gabryel, 2009).

The use of biodegradable stents, made of natural polymers (such as polylactic acids, polyglycolide, a polysaccharide) can be regarded as a significant achievement. Because of its diverse structure and properties some of these materials are biodegradable. The research results show that using this type of solution is a very effective way to prevent from blood clotting process as well as from restenosis.

Concurrently with research on polymers began to use other biomaterials. The idea of using coatings of gold was aimed to improve the visibility of the stent in the screen. Reasons for choosing these coatings included the fact, that they limit the risk of blood clotting and reduce the implant's toxicity. The results showed, however, that they also can suffer from corrosion in body fluids' environment and do not prevent from restenosis (Edelman, 2001; Stefanini, 2011).

New promising test results were achieved after covering the coronary stents with amorphous silicon carbide. Preliminary results show, that this material has a good corrosion resistance in the body fluids' environment, and that the coatings effectively reduce platelet activation (Atar, 2009; Dahm, 2009).

Application of drug-eluting stents can be considered as a very important step. The athrombogenic and anti-inflammatory substances are put into the polymer coatings structure. Then, when the implant is introduced, they are released gradually into the blood and vessel tissue. The medicines used in the surface layers of stents can be classified by their impact on the arteries wall and the coronary circulation system. The most commonly used are the medicines from the groups of drugs: anti-proliferative, immunosuppressive, inhibiting cell migration, stimulating the healing process and improving endothelial function and inhibiting clotting (Alfonso, 2013; Garg, 2013; Mulukutla, 2013).

On the market there are many types of stents made of various kinds of biomaterials and covered or not with drugs. Despite this fact, many research into new technologies, that provide better mechanical and physicochemical properties of stents are still carried out.

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