CHAPTER 22

VASCULAR GRAFT MATERIALS AND THEIR STRUCTURE

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Introduction

It is well-known that thromboresistance, compliant properties and good healing are 3 major requisites for vascular grafts. These are closely interrelated and correlated with both the bio-chemical properties and the details of structure, such as porosity, of vascular graft materials. In this study a hydrogel (HM) which ionically combines heparin and a hydrogel (H-PEO) with long polyethylene oxide (PEO) chains have been developed as thromboresistant materials. The effects of the heparin release profile and of the chain length of PEO on the thromboresistance were studied in both the HM and the H-PEO. A thromboresistant material for vascular grafts, a hydrogel (HMN) with PEO chains which releases heparin has been developed. A new vascular graft has also been developed using ultra fine polyester fibers. The effects of fineness of vascular graft fiber on mechanical properties and the healing process were investigated.

Materials and Methods

Synthesis of the HM, the H-PEO and the HMN

The HM was synthesized by photo-induced graft copolymerization of methoxypolyethylene glycol methacrylate (SM) and N,N-dimethylaminoethyl methacrylate (DAEM) to the polyvinylchloride containing dithiocarbamate groups and by quarterizing and ionically heparinizing. The details of preparation have been reported by Tanzawa et al., (1973). The H-PEO was synthesized by photo-induced graft copolymerization of SM with different chain lengths of PEO as a side chain to the polyvinylchloride containing dithiocarbamate groups as reported by Mori et al., (1982). The HMN was synthesized by blending segmented polyurethane (Lycra T-127) and the cationic copolymer (SD⁺) composed of SM and quarterized DAEM, and subsequently by heparinization. The details of this process were described by Noishiki et al., (1981).
Preparation of the HMN and the SS-G grafts

The HMN grafts were prepared by the dipping and precipitating method. They are composed of a porous inner layer of the HMN polymer and a porous outer layer of Lycra T-127 reinforced with polyester fibers or meshes. The thickness and the pore size of the HMN layer range from 30 to 200 μm and from one to 3 μm, respectively. The details of preparation have been reported by Noishiki et al. (1981). The SS-G grafts have the tightly woven inner layer composed of napped ultrafine polyester fibers (UFPF, thickness: about 3 μm) and the loosely woven outer layer composed of ordinary polyester fiber (OPF, thickness: about 16 μm) for reinforcement. The preparation of the UFPF and SS-G graft have been previously published by Okamoto (1981) and Noishiki et al. (1986).

Measurement of the Heparin Release Profiles

An in vitro heparin release profile was estimated by calculating the heparin concentration of the canine ACD plasma exposed to the HM surface using thrombin time as described by Tanzawa et al., (1973). The In vivo heparin release profile was estimated from the difference in heparin content pre- and post-implantation. The heparin content was determined by detecting the intensity of the Kα line of sulfur atoms of heparin using an electron probe X-ray microanalyzer (EMX) (Noishike et al., 1981; Idezuki et al., 1978).

Thromboresistance Tests

In vitro tests were performed by examining platelet adhesion and protein adsorption onto the test surface. The surface was exposed to rabbit platelet rich plasma (PRP) and platelet poor plasma (PPP) and analyzed using scanning electron microscopy (SEM) and an amino acid analysis (Mori et al., 1982). The Inferior Vena Cava indwelling catheter (IVC) method was used for in vivo tests of the HM. The sample tube (about 30 cm in length, 0.3 cm O.D.) was inserted into the inferior vena cava of a dog, through the right femoral vein. After a 2 week-implantation it was examined for thrombus formation around the tube. For the H-PEO studies the polyester suture, coated with a test sample, was implanted in the jugular or femoral vein of a dog. After various implantation periods, the test surface and cross section were removed and examined using SEM and transmission electron microscopy (TEM) (Mori et al., 1982).

Measurement of Physical Properties

Compression behavior of the vascular grafts was measured both in the tube configuration and as a fabric using RHEOROBBOT (Kyowa Company, Ltd.) as described by Noishiki et al., (1986). The porosity of the graft was measured as previously described by Wesolowski (1962). The resistance to raveling of the vascular graft was examined by cutting the end of the grafts on the bias.

Animal Experiments Using the Vascular Grafts

In the HMN graft evaluation larger caliber grafts (8mm in I.D. and 5.7 cm long) and (8mm I.D., 3 cm long) were implanted in the thoracic descending aorta and the inferior vena cava of dogs. The smaller caliber grafts (3mm in I.D. and 4 to 7 cm long) were implanted in both external iliac arteries of dogs. The large caliber SS-G grafts (8mm in I.D., 5.7 cm long with a porosity of about 93 ml/min/cm²) were implanted in