BLOOD COMPATIBILITY OF POLYETHYLENE AND OXIDIZED POLYETHYLENE IN A CANINE A-V SERIES SHUNT: RELATIONSHIP TO SURFACE PROPERTIES

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INTRODUCTION

The contact of blood with a polymer surface results in the initial deposition of proteins, platelets, and other formed elements. Proteins deposit during the first moments of blood contact, while platelets start to adhere after about one minute of blood contact, when the protein layer is about 200 Å thick. The polymerization of fibrinogen to fibrin, and the activation and aggregation of platelets, lead to thrombus formation and growth on the artificial surface.

Blood-surface interactions depend greatly on the nature of the polymer surface. The surface chemistry and morphology affects the composition and conformation of the initially deposited proteins. These initial events subsequently determine the magnitude and extent of platelet activation, aggregation, and thrombus formation.

In this study, the relationship between surface structure and thrombogenicity for a biomedical polymer, polyethylene, was investigated. Polyethylene is used in a number of blood-contacting applications, including chronic shunts and catheters. The biomedical grade polyethylene was in the form of an extruded tube (PE). In addition, the same PE tubing was oxidized and etched with chromic acid (OX-PE). A multiprobe approach was used to characterize the surfaces of PE and OX-PE before blood contact in order to establish surface property information.
A recently developed canine ex-vivo femoral arteriovenous (A-V) series shunt technique \(^7,^8\) was used to study platelet deposition, and thrombus formation and embolization on PE and OX-PE. In this technique, radiolabeling techniques and scanning electron microscopy (SEM) were used to follow early (1/2 to 60 minutes) platelet and fibrinogen deposition, and platelet morphological changes on the two surfaces.

EXPERIMENTAL

Polymer Materials: 1/8" I.D. extruded Intramedic PE-350 polyethylene (PE) was used as the polyethylene test material. Sections of this tubing were oxidized and etched with chromic acid (Chromerge\(^\circ\)) to make oxidized polyethylene (OX-PE) according to the following procedure: (a) mild oxidation with Chromerge\(^\circ\) at 60°C for 15 minutes (b) rinsing with excess dilute nitric acid to remove any inorganic residue (c) copious rinsing with distilled water (d) drying with nitrogen gas, followed by drying in a vacuum chamber. The PE and OX-PE tubings were rinsed with double distilled water prior to use.

Surface Characterization: Sections of the same tubing used in the blood contact experiments were used in the surface characterization experiments. Contact angle measurements were made using the captive bubble technique of Hamilton\(^9\) with air and octane as the probe fluids. Five measurements were made for each probe fluid on each surface studied. The technique was modified to apply to curved specimens\(^5\). Electron spectroscopy for Chemical Analysis (ESCA) was performed using a Physical Electronics Phi 548 spectrometer using a 280W Mg anode at pass energies of 100 eV (broad scan) and 25 eV (high resolution scan). Attenuated total reflection infrared spectroscopy (ATR-IR) spectra were obtained using a Nicolet 7199 FTIR with a variable angle ATR accessory (Barnes 300) at a resolution of 2 cm\(^{-1}\). Longitudinal slices of the polymers were placed with their inner surfaces in contact with 45° and 60° Germanium crystals. SEM analysis was performed using a JEOL 35C SEM at 7 kV accelerating voltage.

Animal selection: Adult mongrel dogs weighing 18-35 kg were selected by screening for platelet aggregability\(^10\) to ADP and epinephrine, and for a normal range of platelet count (150,000-400,000/µl), fibrinogen level (100-300 mg/dl) and hematocrit (35-50%).

Animal Surgery: The surgical procedure has been described in detail\(^7,^8\). Autologous platelets were labeled with \(^51\)Cr\(^\circ\) and injected into the dog 18 hours prior to surgery. Following anesthetization with thiamylal sodium, \(^125\)I-labeled fibrinogen\(^12\) was injected into the animal. The femoral artery and vein in one