Necrotic Effect of Cobalt Content of Prosthetic Alloys on Retrieved Human Fibroblasts

Richard A. Mostardi, Mark W. Kovacik, Jody M. Finefrock, Thomas F. Bear, Michael J. Askew
Walter A. Hoyt, Jr. Musculoskeletal Research Laboratory, Summa Health System Hospitals, Akron, Ohio.

Statement of Purpose: The most common cause of long-term failure in total joint replacement (TJR) surgery is aseptic loosening caused by osteolysis. The initiator of the osteolytic process is particulate debris derived from a variety of materials, which include metals, plastic and bone cement. Although the macrophage is a major phagocytic cell in the synovial system, the fibroblast makes up the majority of cells of the periprosthetic tissue and has been a cell of interest in our laboratory as well as others [1,2].

We have published data on the fibroblast necrosis when exposed to micro-particles of commercially pure (cp) metals that included titanium (cpTi) and tantalum (cpTa), as well as a cobalt-chromium alloy (AS CoCr) used in joint prostheses (Astro Met Inc., Cincinnati, OH) [1]. An interesting aspect of this work was that there appeared to be a variation in the necrotic threshold between these metals and alloys, as a function of individual patient donors. This mechanism of metal sensitivity has aroused interest as evidenced by several publications [3,4].

Recently we have acquired prosthetic alloys in micro-particle form from Zimmer Inc. (Warsaw, IN) that include titanium-6%a1uminum-4%vanadium (Ti-6-4) and F-75 CoCr material. The purpose of this work was to examine the effect of metal composition on the necrosis of fibroblasts exposed to micro-particles of these latter prosthetic alloys in comparison to those seen for the previously studied alloy and commercially pure metals.

Methods: Following signed consent, synovial fibroblasts were obtained from non-inflamed tissue harvested from the superior medial plica of four volunteers undergoing total knee replacement. The tissue was processed as described previously [1]. Each metal sample was examined by scanning electron microscopy (SEM) and found to be <3μ in diameter. Each sample was examined for the presence of endotoxin using limulus amebocytelysate assay. Verification of the elemental composition of each metal and alloy was carried out using X-ray photoelectric spectroscopy (XPS).

Following the first passage, the cells were permitted to grow to a confluent state (about 4 days). The metals, at masses of 0.004 gm and 0.04 gm, were then added to the cultures. Five days following the addition of the metals, the cells were trypsonized and counted by trypan blue exclusion.

Results/Discussion: The XPS compositional percentages of the metals used in this study are shown in Table 1. Figure 1 is the composite cell count viability versus metal for all four patient volunteers.

As we have shown before, the greatest metal dosage (0.04gms) produced the most necrotic effect for all the metals used. The F-75 CoCr alloy was the most necrotic at both metal masses. With a 36% reduction in the cobalt content, the AS CoCr alloy was less necrotic ($p<0.05$) than the F-75 CoCr alloy.

Elemental and ionic metals have repeatedly been shown to produce cell necrosis in tissue culture as well as in patient populations. The hierarchal nature of this metal-induced necrotic affect has been an area of interest. Cobalt, although not considered the most deleterious of metals, has been shown to induce hypersensitivity and contribute to aseptic loosening.

Sample ID	% Composition
cpTa	92% Ta, 8% Na
cpTi	96% Ti, 4% Ca
AS CoCr (Astro Met)	29% Co, 29% Cr, 13% Mo 7% Mn, 22% Si
F-75 CoCr (Zimmer)	65% Co, 31% Cr, 4% Mo
Ti 6A1 4V (Zimmer)	90% Ti, 10% A1, 0% V

Table 1 - XPS Analysis for Metals Used in This Study

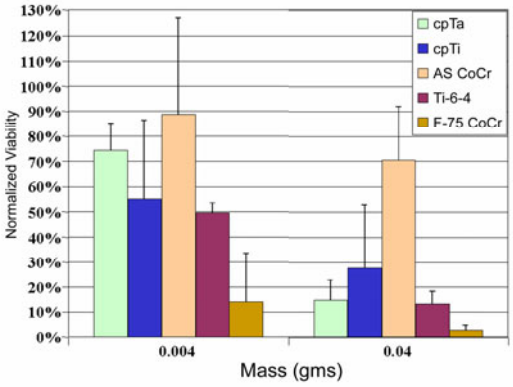

Figure 1

Conclusions: The necrotic effect of metal micro-particles on synovial fibroblasts is positively correlated with the mass dosages of the metal. The necrotic effect of mirco-particles of CoCr alloys increases with increasing cobalt concentration in the metal.

Acknowledgement: This work was supported, in part, by the Summa Hospitals Foundation and The Robertson-Hoyt Fund of Akron Community Foundation.

References: 1. Mostardi, R.A., et al. J Biomed Mat Res. 2002;59(4):605-610. 2. Evans, E.J. Biomat. 1994;15:713-717. 3. Hallab, N.J., et al. J Biomed Mat Res. 2002; 60: +420-433. 4. Hallab, N., et al. JBJS.2001;83:428-436.