Metal Wear Particles in Red Bone Marrow of Humerus, Sternum, Vertebrae and Iliac Crest in Patients Hosting a Hip or Knee Arthroplasty

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Introduction: Systemic dissemination of particulate wear debris generated by joint replacement prostheses has been described for the liver, spleen and lymph nodes [1, 2]. However, data are lacking on the distribution of wear particles in many other distant tissues [3]. Bone marrow, which is one of the largest organs of the body, is of particular interest because of its highly active production of essential red and white cells as well as other important functions. In this study, biopsies of red bone marrow at sites distant from hip or knee replacement prostheses were analyzed to determine the presence and nature of the metallic wear particles in this tissue. Our hypothesis was that prosthetic wear disseminate widely from their local site of generation to bone marrow throughout the body.

Methods: Multiple bone marrow trephine biopsies were obtained postmortem from sites of red marrow in the proximal humeri, sternum, lumbar vertebrae and the contralateral iliac crest of 3 females and 4 males after a mean of 15.6 years (range 8 to 25 yrs) following total joint arthroplasty. One subject had hosted bilateral knee replacements, 1 had bilateral revised knee replacements, 1 had a primary hip replacement, and 4 had one or more revised total hip replacements. The hip and knee replacement devices had been fabricated from commercially pure Ti, Ti6Al4V and CoCrMo alloys and utilized conventional polyethylene modular inserts. The hip replacements that had been revised also employed stainless steel plates and screws and CoCrWNi alloy cable grip systems.

The bone marrow specimens were fixed in 10% neutral-buffered formalin and decalcified. Standard paraffin embedded sections were stained with hematoxylin and eosin for study using light microscopy. Adjacent serial sections were mounted without staining on high-purity carbon planchets and examined in a scanning electron microscope (JEOL SM 6490LV) at 1,000 to 20,000 times magnification. Individual particles were imaged in the back-scattered electron mode. The elemental composition of particles was determined using energy dispersive x-ray analysis at 20 kV. Sections of liver, spleen and abdominal lymph nodes from every subject were examined in a similar manner.

Results: Intracellular metal alloy particles generated by various modes of wear of the prosthetic devices were detected in the red bone marrow of the humerus, sternum, lumbar vertebrae and contralateral iliac crest. The different particles identified included commercially pure titanium, Ti6Al4V, CoCrMo, CoCrWNi and stainless steel alloys (Figure 1). The histological appearance of the metallic wear debris in the marrow was similar for all four sites examined. The particles were observed in the cytoplasm of single or clustered macrophages which often lined the sinusoidal channels of the bone marrow (Figure 2). Only a few of the particles were resolvable, but many macrophages had gray-colored cytoplasm suggesting abundant particles at or below the resolution of the light microscope. In the scanning electron microscope, the majority of the metal alloy particles proved to be submicron in size and ranged from 0.1 to 3 micrometers in greatest dimension. No pathological changes were evident in the marrow that could be attributed to the presence of the metal wear debris in these subjects. Histological sections of liver, spleen and para-aortic lymph nodes also showed concentrations of metal alloy particles. Intracellular particles of apparent environmental sources were also detected in macrophages of the bone marrow. The particles consisted of 0.2 to 5 micrometer sized silicates, some of which contained traces of aluminum and titanium. Intracellular iron was detected in most samples.

Discussion: This study demonstrates that prosthetic wear debris can disseminate widely from its local site of generation to bone marrow throughout the body. Red bone marrow, in addition to its hematopoietic functions, contains resident macrophages that serve to recognize and phagocytize senescent or defective blood cells, bacteria, and other circulating particles in the blood. Wear particles are known to disseminate through the lymphatic drainage [1, 2]. The presence of wear particles in phagocytic cells of bone marrow provides convincing evidence that wear particles are also transported via the blood circulation.

These findings also stress the importance of reducing particle generation and release of metal ions at both bearing and non-bearing surfaces of joint replacement devices. Adverse reactions to wear particles in distant organs can include histiocytosis, necrosis, fibrosis, and rarely a systemic granulomatous response. The deposition of wear debris in distant tissues is cumulative [4], and the debris can be retained for the life time of the patient [1]. The tissue response to wear particles depends on several factors, including the concentration and rate of particle deposition as well as the physical and chemical nature of the debris. Assessing the potential long-term pathological effects of disseminated wear products in bone marrow will require further studies, including those of patients with alternative bearings.

References: