Metallosis and elevated serum levels of tantalum following failed revision hip arthroplasty— a case report

George C Babis[1], Nikolaos A Stavropoulos[2], Gregory Sasalos[2], Maria Ochsenkuehn-Petropoulou[3], and Panagiotis Megas[4]

[1]Second Department of Orthopaedics, Konstantopouleio General Hospital N. Ionia, University of Athens Medical School, N. Ionia, Athens; [2]First Department of Orthopaedics, "ATTIKON" University General Hospital, University of Athens Medical School, Chaidari, Athens; [3]Laboratory of Inorganic and Analytical Chemistry, School of Chemical Engineering, National Technical University of Athens, Athens; [4]Department of Orthopaedics, School of Medicine, University of Patras, Patras, Greece.
Correspodence: george.babis@gmail.com
Submitted 13-08-17. Accepted 14-03-24

A 70-year-old woman had a primary cemented total arthroplasty of her right hip performed elsewhere in 1967 for developmental hip dysplasia. The arthroplasty failed in 1977, due to aseptic loosening and since then the patient has undergone 3 revision procedures including 2 acetabular cup revisions. In 2006, a porous tantalum acetabular augment (PTAA) (Zimmer, Warsaw, IN) was used to support a hemispherical cementless acetabular centroid Hilock cup (SYMBIOS Orthopédie, Yverdon-les-Bains, Switzerland) made of titanium alloy (Ti6Al4V) with a porous titanium and hydroxyapatite dual coating. At that time, no cement was interpositioned between the cup and augment—as instructed by the manufacturers. 6 years later, the patient was unable to walk and suffered severe pain, and she was referred to us for an additional revision. The preoperative radiographs showed a peculiar "halo formation" surrounding the acetabular component (Figure 1). Extensive metallosis of this surrounding tissue was found intraoperatively. Black pigmentation was also found in the overlying skin (Figure 2). Following the removal of the loose Hilock cup, the tantalum augment was found to be non-osseointegrated, severely worn, and broken (Figure 3). Debridement and synovectomy was performed and a modified cup-cage construct technique was used to address the existing pelvic discontinuity.

2 peripheral blood samples were taken just before the revision operation and periprosthetic tissue samples were taken intraoperatively using a standardized technique for minimizing any potential risk of contamination during collection or handling. Quantitative determination of metal levels in serum and tissue samples was performed after the dissolution of the samples. The serum samples were diluted 10-fold with 0.14 M high-purity nitric acid in double-distilled water, and the tissue samples were digested in a temperature-controlled microwave oven (Milestone START D) (Rodushkin et al. 2004). Due to the very low concentrations of tantalum in serum reported in the literature (in the nanogram-per-liter range), the Ta content of

Figure 1. Pre-revision radiograph. An unexplained "hallo formation" can be seen surrounding the acetabular components.

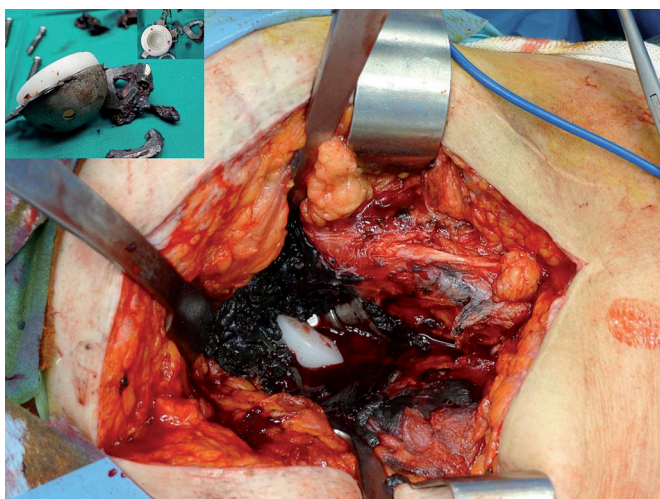

Figure 2. Skin pigmentation immediately after revision.

Figure 3. Intraoperative findings. Extensive periprosthetic metallosis and wear of the tantalum augment and the adjacent porous titanium and hydroxyapatite-coated acetabular SYMBIOS cup. Ta particles were embedded in the polyethylene surface (black stains).

the solutions was determined by inductively coupled plasma-mass spectrometry (ICP-MS) for the 181Ta isotope using the Agilent 7700 ICP-MS spectrometer with an octopole reaction system to eliminate possible interferences (Rodushkin et al. 2004). For study of the morphology of the tissue surface, and for semi-quantitative analysis (FEI company), a Quanta 200 scanning electron microscope (SEM) equipped with an EDX-Genesis 400 energy-dispersive X-ray fluorescence spectrometer (EDX) was used under low vacuum, without any pretreatment of the samples.

The SEM image showed an alteration on the surface of the largest part of the tissue (Figure 4). The semi-quantitative EDX analysis of area A revealed a composition with Ta as the predominant element, accompanied by Cr and Co (Ta: 76.2%; Co: 6%; Cr: 2.9%; C: 6.3%; O: 7.3%; S: 0.7%; and Ti: 0.6%).

Spot analyses of areas B and C showed almost pure pieces of Ta (88% and 75%, respectively) laid on the tissue. Area C showed a small increase in the titanium concentration (1%). EDX analysis of area D, considered to be rather free of depositions, showed a composition of C: 31%; N: 18%; O: 32%; Na: 0.5%; S: 1%; Ca: 0.4%; Ta: 18%; and Ti: 0.3%) with a reduced content of Ta in comparison to the previous examined spots B and C. The Ti level was close to the detection limit.

The actual values of tantalum serum levels determined in both preoperative serum samples were 20 (SD 2) µg/L. These values were approximately 2,000 times higher than what has been reported in the literature, which is in the 0.008–0.010 µg/L range for normal serum samples (Rodushkin et al. 2004). The total concentrations of Ta and Ti in the investigated tissue sample were 35% and 0.6% respectively. No clinical signs of systemic ion toxicity were identified, and markers of liver and kidney function were within the normal range.

At re-revision, as there was pelvic discontinuity we used a modified cup-cage concept using a jumbo Ta acetabular cup and distal augment, which were protected by a Ti Burch Schneider-type reconstruction ring—Contour (Smith and Nephew, Memphis TN)—with Palacos cement in all implant interfaces.

6 months after revision, the serum tantalum levels were 15 µg/L, a decrease of 25% compared to the levels found in the serum just before revision operation. The patient had no pain (Figure 5).

Discussion

The use of ultra-porous tantalum (Ta) metal augments is currently popular to manage extensive bone defects in the acetabulum (Jafari et al. 2010, Fernández-Fairen et al. 2010). Porous Tantalum (PT) is a biomaterial that has high volumetric porosity and a low modulus of elasticity, with exceptional biocompatibility and a good safety record in clinical applications (Kato et al. 2000, Levine et al. 2006 a, b+). The overall geom-
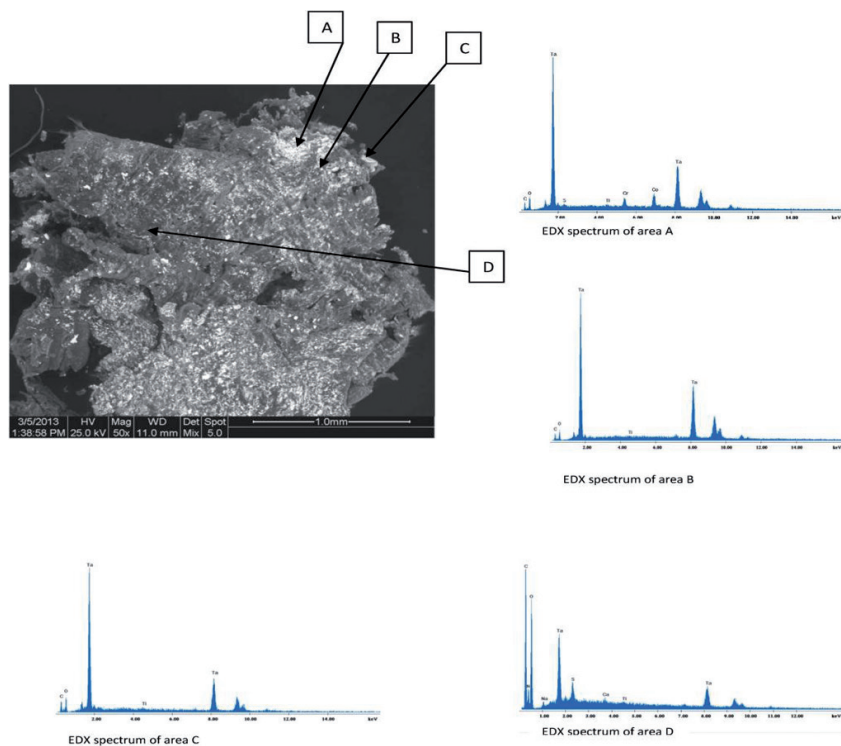

Figure 4. SEM image and results of EDX analysis of areas A, B, C, and D revealing the predominance of Ta.

Figure 5. 6 months after re-revision of the acetabular components. A modified jumbo Ta cup-Ti cage construct and peripheral Ta augment were used due to pelvic discontinuity. The patient had no pain at the latest follow-up.

etry, shape, and size of PT are similar to those of cancellous bone (Levine et al. 2006). High-volume porosity enables extensive osseointegration and strong attachment. Tantalum is the most corrosion-resistant metal in common use today (Davis 2006). The thin layer of oxide that forms on metallic surfaces is called the passivation layer. This layer prevents corrosion effectively. Tantalum forms oxides quite readily, and this passive layer shows remarkable tenacity. However, in the presence of mechanical abrasion even the most tenacious passive film can be breached. After this layer is damaged, it can be repaired at a rate that will depend on the metal itself and on the availability of free oxygen. In the presence of an insufficient amount of oxygen, the layer may not be re-established and corrosion is likely to occur (Roberge 2006).

Few researchers have addressed the issue of the possible side effects of tantalum in human tissues. Tantalum does not react with or irritate body fluids and its biocompatibility in vivo is excellent (Black 1994). In the Health-Based Reassessment of Administrative Occupational Exposure Limits of the Health Council of the Netherlands, there are few case reports of dermatitis caused by contact with tantalum metal. Werman and Rietschel (1981) reported on a 39-year old woman with widespread urticarial lesions on the face, trunk, and extremities every day for 6 months. The personal history showed that femoral vein stripping had been performed due to recurrent deep vein phlebitis. The earliest urticarial lesions had been

found in and around the surgical scars. It became known, later, that the staples used in the surgery were composed entirely of tantalum. An intradermal test using tantalum solution resulted in positive reactions. In addition, Romaguera and Vilaplana (1995) reported on a 73-year-old man who had broken his left ankle and had been fitted with a metal endoprosthesis consisting of a Ti-Ta-Nb alloy. 2 months later, exudative and itchy, papular, erythematous, vesicular lesions appeared on the overlying skin. A patch test using 1% tantalum chloride gave a positive reaction.

To the best of our knowledge, although there are a considerable number of reports in the literature on the use of PT augments (PTAs) in complex hip and knee revisions, there has been little or no discussion about Ta metallosis and the possible release of tantalum elements from these implants in peripheral blood serum.

In our case, the previous surgeon used a tantalum augment to support a titanium HA-coated cup without the use of polymethylmethacrylate (PMMA) between the augment and the cup, as has been suggested by the manufacturers of tantalum augments (Issack et al. 2009, Nehme et al. 2004, Zimmer INC. 2006). Moreover, in the presence of pelvic discontinuity, this construct was unstable from the beginning and none of the implants osseointegrated. As a consequence, micro- and even macromotion and friction between the cup and the augment led to excessive corrosion, metallosis, and dissemination of tantalum particles into the peripheral serum. Thus, the cause of failure in our case was probably iatrogenic because the surgeon failed to put PMMA in the interface.

Although elevated systemic serum levels of ions other than Ta have been identified in many cases of failed metal-on-metal hip arthroplasty, there have been no reports of substantially elevated serum tantalum levels (Lavigne et al. 2011). We found a 2,000-fold increase in serum tantalum concentration after significant tantalum metallosis, which had dropped by 25% six months postoperatively even though tantalum cup and augments were used in the re-revision (Figure 5).

In conclusion, we suggest that the interfaces between Ta augments and other acetabular components (including Ta cups, Ti cups, or cages) must be stable, thus precluding macro- or micromotion which might lead to abrasion, corrosion, and consequently metallosis. Use of PMMA in the Ta augment-acetabular cup interface is therefore mandatory until newer methods of mechanical fixation between the cup and the Ta augment are introduced.

No competing interests declared.

Black J. Biologic performance of tantalum. Clin Mater 1994; 16: 167–73.

Davis J R. Tantalum and tantalum alloys. Corrosion of nonferrous alloy weldments. In: Corrosion of Weledments. Chapter 8. ASMInternational. 2006: 164.

Fernández-Fairen M, Murcia A, Blanco A, Meroño A, Murcia A Jr, Ballester J. Revision of failed total hip arthroplasty acetabular cups to porous tantalum components A 5-year follow-up study. J Arthroplasty 2010; 25 (6): 865-72.

Issack P S, Nousiainen M, Beksac B, Helfet D L, Sculco T P, Buly R L. Acetabular component revision in total hip arthroplasty. Part II: management of major bone loss and pelvic discontinuity. Am J Orthop 2009; 38 (11): 550-6.

Jafari S M, Bender B, Coyle C, Parvizi J, Sharkey P F, Hozack W J. Do tantalum and titanium cups show similar results in revision hip arthroplasty? Clin Orthop 2010; (468) (2): 459–65.

Kato H, Nakamura T, Nishiguchi S, Matsusue Y, Kobayashi M, Miyazaki T, Kim H M, Kokubo T. Bonding of alkali- and heat-treated tantalum implants to bone. J Biomed Mater Res 2000; 539 (1): 28–35.

Lavigne M, Belzile E L, Roy A, et al. Comparison of whole-blood metal ion levels in four types of metal-on metal femoral head total hip arthroplasty: the potential influence of the adapter sleeve. J Bone Joint Surg (Am) (Suppl 2) 2011; 93: 128.

Levine B, Della Valle C J, Jacobs J J. Applications of porous tantalum in total hip arthroplasty J Am Acad Orthop Surg 2006a; 14: 646–55.

Levine B R, Sporer S, Poggie R A, Della Valle C J, Jacobs J J. Experimental and clinical performance of porous tantalum in orthopedic surgery. Biomaterials 2006b; 27: 4671–81.

Nehme A, Lewallen D G, Hanssen A D. Modular porous metal augments for treatment of severe acetabular bone loss during revision hip arthroplasty. Clin Orthop 2004; (429): 201-8.

Roberge P. Corrosion basics. An introduction. 2nd Edition. NACE press. 2006: 76-92.

Rodushkin I, Engstrom E, Stenberg A, Baxter D C. Determination of low-abundance elements at ultra-trace levels in urine and serum by inductively coupled plasma–sector field mass spectrometry. Anal Bional Chem 2004; 380: 247-57.

Romaguera C, Vilaplana J. Contact dermatitis from tantalum. Contact Dermatitis 1995; 32: 184.

Werman B S, Rietschel R L. Chronic urticaria from tantalum staples. Arch Dermatol 1981; 117: 438-9.

Zimmer Inc. Trabecular Metal™ Technology the Best Thing Next to Bone. 2006; 97-7255-062-00 7.5ML