Cobalt from metal-on-metal hip replacements may be the clinically relevant active agent responsible for periprosthetic tissue reactions

Alister J. Hart a,⇑, Paul D. Quinn b, Ferdinand Lali a, Barry Sampson c, John A. Skinner d, Jonathan J. Powell e, John Nolan f, Keith Tucker f, Simon Donell f, Adrienne Flanagan g, J. Fred W. Mosselmans b

a Department of Orthopaedic Surgery, Imperial College and Imperial College Healthcare NHS Trust, Charing Cross Hospital Campus, Fulham Palace Road, London W6 8RF, UK
b Science Division, Diamond Light Source, Harwell Science and Innovation Campus, Didcot, Oxon OX11 0DE, UK
c Department of Clinical Chemistry, Imperial College and Imperial College Healthcare NHS Trust, Charing Cross Hospital Campus, Fulham Palace Road, London W6 8RF, UK
d Department of Orthopaedics, Royal National Orthopaedic Hospital, Brockley Hill, Stanmore, London HA7 4LP, UK
e Medical Research Council Human Nutrition Research Centre, Elsie Widdowson Laboratory, Cambridge CB1 9NL, UK
f Orthopaedic and Trauma Department, Norfolk and Norwich University Hospital, Colney Lane, Norwich NR4 7UY, UK
g Department of Histopathology, Royal National Orthopaedic Hospital, Brockley Hill, Stanmore, London HA7 4LP, UK

Article info
Article history:
Received 31 December 2011
Received in revised form 30 April 2012
Accepted 4 May 2012
Available online 9 June 2012

Keywords:
Metal-on-metal hip arthroplasty
Chemical analysis
Periprosthetic tissue
Inflammatory response
Synchrotron

abstract
Some types of metal-on-metal (MOM) hip replacements have unacceptably high rates of failure, such as the Ultima TPS MOM hip, with 13.8% failure at 5 years. This has been attributed to an inflammatory reaction following the release of cobalt (Co) and chromium (Cr) from the bearing surfaces and modular junctions. There is in vitro evidence that Co is more important than Cr in the inflammatory process, but there are no reported human tissue studies of the analysis of implant-derived metals.

1. Introduction

The failure rates of some types of metal-on-metal (MOM) hips are unacceptably high and higher than many non-MOM hips [1,2]. This has been attributed to an adverse tissue response to material lost (the implants are made from an alloy of 60% cobalt, 30% chromium, and 7% molybdenum) from wear of either the bearing surfaces [3] or the modular (stem–head) junctions [4,5]. The risk of requiring further surgery, because of pain, is positively correlated with the levels of cobalt (Co) and chromium (Cr) in the blood [6].

A better understanding of the mechanism of the inflammatory response will help determine those patients most at risk and how to solve and avoid the problem. In vitro experiments suggest that Co is more reactive than Cr [7], but in vivo or ex vivo data is limited. Recently it was shown that the predominant implant-derived species in the tissues surrounding failed Non-Ultima MOM hips is Cr phosphate [8]. Previously Cr₂O₃ was thought to be the predominant species, but the use of synchrotron X-ray absorption spectroscopy (XAS) and X-ray absorption near edge spectroscopy (XANES) has enabled increased sensitivity and specificity over non-synchrotron techniques [9].

Agreement of the in vitro and ex vivo evidence may be explained if Co is more reactive and more soluble than Cr. The solubility of metals is dependent on the pH of the surrounding solution. Synchrotron XAS and XANES offer the best chance of detection of transitory Co and its chemical form, such as its oxidation state (zero for metallic and possible 2+ or 3+ valency).

The Ultima TPS modular MOM hip (DePuy, Leeds, UK) has very poor clinical results with a failure rate of 14% after 7 years [10] and a mode of failure that involves severe bone and muscle destruction. Such changes are rarely seen with the current generation large diameter types. There are no studies on the analysis of implant-derived debris within the tissues for this type of hip implant.

We hypothesized that implant-derived debris in the periprosthetic tissue of Ultima hips was different to that derived from large diameter MOM hips. We had two research questions. First, was...