■ CASE REPORT

Metal ion levels in a triathlete with a metal-on-metal resurfacing arthroplasty of the hip

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A prospective study of serum and urinary ion levels was undertaken in a triathlete who had undergone a metal-on-metal resurfacing arthroplasty of the hip four years previously. The one month study period included the final two weeks of training, the day of the triathlon, and the two weeks immediately post-race. Serum cobalt and chromium levels did not vary significantly throughout this period, including levels recorded on the day after the 11-hour triathlon. Urinary excretion of chromium increased immediately after the race and had returned to pre-race levels six days later. The clinical implications are discussed.

The number of prostheses with metal-on-metal articulations continues to increase because their low wear can potentially eliminate osteolysis.[1] There have been no reported fractures of components or other gross material failures, and measurements of retrieved metal-on-metal hip replacements have shown that wear is comparable to that predicted from hip simulator studies.[1] This has led to the re-introduction of metal-on-metal surface arthroplasties, and these larger diameter implants have been shown to reduce the risk of dislocation and potentially improve wear.[2-4] For these reasons, metal-on-metal components have advantages, particularly in young active patients.

However, elevated levels of cobalt and chromium ions in blood and urine following this procedure are of concern.[5-7] Metallosis and potential toxic effects due to the dissemination of metal debris, in particular haematocarcinogenic and immunoallergic risks, are of particular concern. Young patients may be exposed to higher levels of ions for longer periods of time.

While a direct relationship between the wear of polyethylene bearings and patient activity has been reported for metal-on-polyethylene hip resurfacings,[8] it is not known if cobalt and chromium ion levels in patients with metal-on-metal bearings would also be positively correlated to patient activity. There is conflicting data regarding the effect of activity on ion levels *in vivo*.[9,10] However, many patients with hip resurfacings have high activity levels. We report the serum and urine ion measurements in a patient who has participated in a total of 11 half and 5 full triathlons in the four years since receiving a metal-on-metal hip resurfacing.

Case report

The patient. A 48-year-old man underwent resurfacing arthroplasty of the right hip in January 2002 for advanced osteoarthritis. A non-modular, metal-on-metal resurfacing arthroplasty (Birmingham Hip Resurfacing; Smith and Nephew, Memphis, Tennessee), with a cementless acetabular component and a cemented 54 mm femoral component was used. The implants were in a good position without signs of loosening or osteolysis (Fig. 1). He weighed 65 kg and was 1.75 m tall. Renal function, as determined by serum and renal creatinine levels, was normal and he had no other implants.

He has a busy general medical practice and is an avid triathlete. Pre-operatively, he competed in more than 20 marathons, four triathlon races (2.4 mile swim, 112 mile bike ride and 26.2 mile run) and 15 half triathlons. Post-operatively, he completed his first triathlon eight months after surgery. In total he has completed five triathlons and 11 half-triathlons in the four years after the operation. This amounts to 1317 miles of swimming (642 workouts), 28 265 miles of cycling (728 workouts) and 5522 miles of running (732 workouts) before the race, at which point the ion levels were measured. He subsequently underwent a similar procedure on the left hip and five weeks post-operatively resumed moderate swimming, cycling and running training in anticipation of competing in a further triathlon.

Study protocol. A period of approximately one month was used to evaluate changes in levels of cobalt and chromion ions; two weeks prior

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Fig. 1a

Fig. 1b

a) Anteroposterior and b) lateral radiographs of the right hip three years after surgery showing good position of the resurfacing implants without signs of loosening or osteolysis.

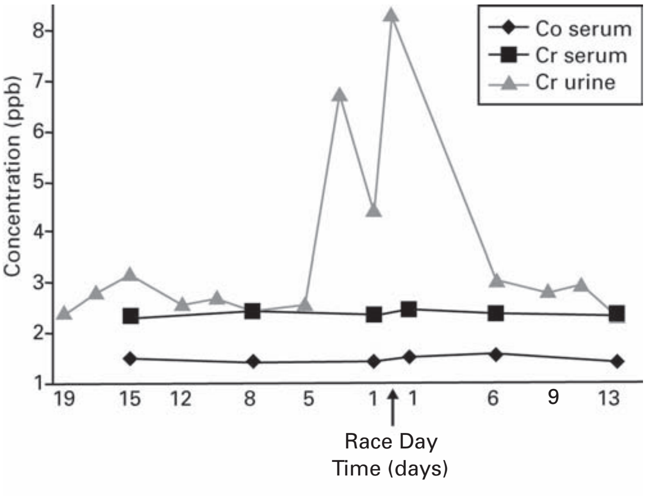

Fig. 2

Graph showing the serum cobalt (Co) and chromium (Cr) levels and urine chromium levels during the study period

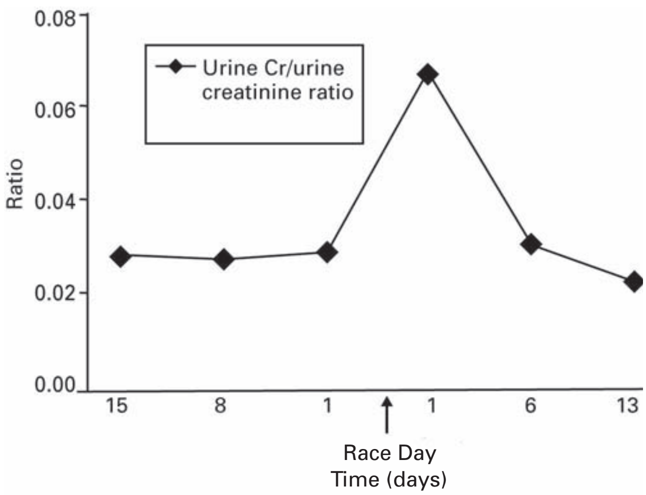

Fig. 3

Graph of the urine chromium (Cr)/creatinine ratios before and after the race.

to a triathlon and during the two weeks after it. Three early morning urine samples were collected three times a week and a blood sample was taken 15, 8 and 1 day prior to the race. Further urine samples were taken immediately after the race and blood samples taken the next day. There were thus three samples of blood and nine samples of urine before the race and three samples of blood and six of urine after.

Blood and urine collection and specimen preparation were carried out according to recommended protocols.[11] The first 5 ml of blood were discarded and two tubes were then collected for testing. The early morning urine samples were collected directly into pre-cleaned bottles. Creatinine and total protein were measured in most of the urine samples. Not all the samples were available for this secondary test as some had been completely used for the ion testing.

The concentration of cobalt and chromium in the serum and chromium in the urine were measured by graphite-furnace Zeeman (Perkin-Elmer, Norwalk, Connecticut) atomic absorption spectrophotometry.[12] The detection limits, in parts per billion (ppb), were 0.3 ppb for cobalt in serum, 0.03 ppb for chromium in serum, and 0.015 ppb for chromium in urine. Cobalt was not tested in the urine because of a lack of suitable lab protocols.

Results

The patient finished the triathlon in 11 hours, 21 mins and 18 s. Figure 2 shows the cobalt and chromium levels during the pre-and post-race period. The mean pre-race serum values for cobalt and chromium, taken over three measurements were 1.45 ppb (1.42 to 1.50) and 2.36 ppb (2.32 to 2.41), respectively. The mean post-race measurements were 1.50 (1.43 to 1.51) and 2.38 (2.32 to 2.44) for cobalt and chromium, respectively. This represents an increase of 3.4% for cobalt and 0.85% for chromium. Neither of these increases was statistically significant (paired *t*-test, $p > 0.3$).

There was considerable variation in the absolute urinary chromium concentrations both pre- and post-race (Fig. 2). When the results were expressed as a ratio incorporating urinary creatinine concentration, in order to correct for sample-to-sample fluctuations in overall urinary concentration, a rise in urinary chromium excretion immediately following the race was demonstrated (Fig. 3).

Discussion

To our knowledge, this is the first reported study of serum and urinary ion levels in a triathlete competing with a metal-on-metal hip resurfacing arthroplasty. This level of activity is unlikely to be duplicated by many patients, nor would it be a normal recommendation. However, the subject is a medical practitioner who has a good understanding of the stresses to which the prosthesis, and his hip joint are being exposed. From a scientific point of view, his continued participation in training for, and racing in, triathlons offers a unique opportunity to study serum and urinary metal levels.

The first significant finding of this study is that the serum ion concentrations in this athlete were similar to those reported in previous studies of far less active individuals with metal-on-metal resurfacing and total hip arthroplasties.[9,12] Heisel et al[10] reported mean serum cobalt and chromium concentrations of 1.40 ppb and 2.08 ppb, respectively in patients who had avoided "exercise, long walks and sports activities" for the previous seven days. The mean post-race serum and cobalt and chromium concentrations in our patient were 1.50 ppb and 2.38 ppb, respectively after 11 hours of continual activity that included 2.4 miles of swimming, 112 miles of cycling and 26.2 miles of road running. Furthermore, the post-race serum ion levels were not significantly different from those recorded during his pre-race training and post-race recovery.

Studies of exercise-related changes in serum ion levels following metal-on-metal hip resurfacing or replacement have yielded varying results.[9,10] A hip simulator study employing a 'jogging' mode reported a rise in wear.[13] Khan et al[11] reported that one hour of running or fast walking on a treadmill resulted in a mean rise of serum cobalt and chromium of 13% and 11%, respectively in 15 patients with either metal-on-metal hip resurfacing or replacement *in situ* for a mean of 28 months. In contrast, Heisel et al[10] found no increases in the serum concentrations of these ions in a group of seven patients with metal-on-metal resurfacing or replacement from seven to 25 months post-operatively, over periods of low and high activity. Blood samples were taken throughout the study period including during a moderate intensity exercise test on a treadmill. There were no significant differences between the mean serum cobalt and chromium levels in the low exercise week (serum cobalt 1.4 ppb SD 0.85; chromium 2.08 ppb SD 0.9), compared with the high exercise week (cobalt 1.29 ppb SD 0.63; chromium 2.12 ppb SD 0.87).[10] The serum cobalt and chromium levels of the triathlete in this study are within the range of the group studied by Heisel et al,[10] although the subject underwent months of high activity training culminating in the triathlon.

Previous work by Heisel et al[10] to investigate the relationship between urinary chromium concentration and physical activity showed high variability. However, they did not correct for variations in concentration and dilution of the urine. To correct for fluctuations in absolute urinary chromium concentration that might be caused by conditions such as reduced total body water, as might occur after prolonged exercise, we expressed the urinary chromium relative to urinary creatinine. When the urinary data were expressed in this way, it became evident that there was a significant rise in the urine chromium/urine creatinine ratio immediately following the race (Fig. 3). Thus, more chromium ions were being excreted in the urine at this time than at other times during the study.

There may be several explanations for this. A significant rise in urinary chromium excretion following exercise has been shown in volunteers without implants.[14,15] A proportion of body chromium is intra-cellular, where it is thought to enhance insulin receptor activity.[16] It is possible, therefore, that cellular damage to skeletal muscle fibres and red blood cells during the race, for example, may have contributed to the rise. The contribution of increased wear of the metal-on-metal bearings in our patient is unknown but must also be considered a possibility. The rise in urinary chromium excretion was temporary and levels had returned to pre-race amounts within a week.

Failure to show a change in serum chromium concentration in correlation with the rise in urinary chromium excretion may have been due to different sampling times for urine and blood. Urine sampling occurred on the evening of the race and blood was taken the following morning. The later sampling of blood may have resulted in an immediate post-race rise of serum chromium being missed. Another possible factor is the higher sensitivity of the measuring equipment for urinary chromium than for serum chromium (0.015 ppb *vs* 0.03 ppb). However, these data demonstrate that in this individual, activity-related increases in metal ions were transitory.

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