Elevated Chromium Levels and Prosthetic Joint Implants

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Chromium is a naturally occurring, toxic heavy metal used in many industrial processes. The US Department of Labor’s Occupational Safety and Health Administration has established specific limits for occupational exposure levels of chromium and guidelines for medical surveillance of individuals who have been exposed to chromium. The author presents a case in which a 54-year-old man who had been working with chromium exhibited persistent elevations of urinary chromium levels after the cessation of occupational exposure. The author determined that the elevated chromium levels were caused by the patient’s knee prostheses, which were made of cobalt-chromium alloy. The author also discusses mandates and screening guidelines for occupational chromium exposure and reviews the literature on chromium levels in individuals with prosthetic joint implants.

The US Department of Labor’s Occupational Safety and Health Administration (OSHA) mandates that workers cannot be exposed to more than 5 µg/m³ of Cr(VI) during an 8-hour shift. To adhere to these guidelines, workplaces have implemented occupational surveillance programs.

I present a case of a 54-year-old man who presented to his company’s chromium surveillance program with elevated levels of chromium. Physical examination revealed no signs of workplace exposure, and work site environmental sampling found no chromium. The man’s urine chromium to creatinine ratio waxed with periods of increased physical activity and waned with periods of relative inactivity. It was determined that his elevated chromium levels were caused by his knee prostheses, which were made of chromium-cobalt alloy.

I also discuss OSHA mandates and screening guidelines for occupational chromium exposure, as well as review the literature on chromium levels in individuals with prosthetic joints.

Report of Case

In August 2009, a white man, aged 54 years, participated in his company’s ongoing chromium surveillance program. He was a welder who had been grinding, cutting, and welding stainless steel for 4 months. He stated that he wore a positive air pressure respirator and practiced good hygiene in the work environment. Environmental samples, which were analyzed after his company was finished with the project he was working on, revealed low chromium levels. Settled dust samples were below the limit of detection of 1 µg Cr(VI) per sample. Air sampling and Cr(VI) measurement by means of visible absorption spectrophotometry revealed a level below the 0.2 µg/L limit of detection.

However, during routine biological monitoring as part of the surveillance program, results of laboratory tests indicated that the patient had elevated levels of chromium in the urine. The chromium to creatinine ratio in a single urine sample is a reliable indicator of an individual’s chromium status, regardless of renal function, provided that the influence of age is taken into consideration. On the basis of these findings, I recommended the patient undergo further physical examination.

Physical examination findings included no skin ulcerations, normal nasal mucosa, and normal breath sounds. Results of electrocardiography and spirometry revealed no abnor-
malities. The patient’s medical history was unremarkable except for bilateral knee replacements. He was not taking any supplements that contained chromium. The patient lived in a rural area, and his water came from a well.

Contracted industrial hygienists repeated environmental sampling on the work site in February 2010 and found no chromium. Local health departments tested the patient’s well water and also found no chromium. After it was determined that the patient’s work site and water source were clear of chromium, I contacted the patient’s surgeon to inquire about the patient’s knee implants. The surgeon indicated that the patient’s prosthetic knee implants, which were placed during the 2 years prior to presentation (April 2007 and September 2008), were made of a cobalt-chromium alloy.

The patient’s urine chromium to creatinine ratio was monitored for 14 months and found to wax with periods of increased physical activity and wane with periods of relative inactivity (range, 4.8-11.5 \( \mu g/g \); Table). Because the patient’s environment was free of chromium contamination, I determined that the elevated chromium levels were being caused by his knee prostheses. I recommended that the patient’s employer test the patient’s chromium levels every 3 months when he was working in stainless steel manufacturing. I also recommended that the employer take steps to ensure proper use of personal protective equipment and safe industrial practices. The patient was followed up in August 2011, 10 months after he was last tested, at which point he did not show any clinical findings consistent with chromium toxicity.

Comment

Occupational Exposure

In the occupational setting, individuals can be exposed to Cr(VI) by ingestion, inhalation, or skin contact. Symptoms of acute exposure include irritation of the eyes, nose, throat, and respiratory tract. This type of exposure may also result in Cr(VI) during an 8-hour shift. This amount is called the permissible exposure limit and is monitored by air sampling. Exposures exceeding the Cr(VI) action level (2.5 \( \mu g/m^3 \)) trigger specific monitoring requirements and protective measures, including medical surveillance.

OSHA guidelines—Mandates established by OSHA state that a worker cannot be exposed to more than 5 \( \mu g/m^3 \) of Cr(VI) during an 8-hour shift. This amount is called the permissible exposure limit and is monitored by air sampling. Exposures exceeding the Cr(VI) action level (2.5 \( \mu g/m^3 \)) trigger specific monitoring requirements and protective measures, including medical surveillance.

Medical examinations begin within 30 days of initial Cr(VI) exposure and are repeated annually and at job termination. According to OSHA guidelines, examinations should also be performed whenever a worker shows signs of possible toxic effects of Cr(VI) or after exposure during an emergency. Those completing the examination should obtain the worker’s medical and work history, including Cr(VI) exposure; history of respiratory, dermal, and nasal health issues; and tobacco use. The physical examination should focus on the lungs, nasal mucosa, and skin. Initial evaluation should include a urinalysis. In addition, laboratory findings should include complete blood cell count and levels of hepatic enzymes, blood urea nitrogen, and creatinine. Any specific testing is left to the discretion of the healthcare provider and not specified by OSHA standards.

Screening—When screening workers for Cr(VI) exposure, urine analysis is less accurate than serum analysis, but urine analysis is preferable because it is less invasive. Care must be taken when collecting samples for chromium testing; certain plastics and stainless steel may leach chromium and result in false elevations.

Urine chromium samples need to be obtained immediately after the worker completes his or her work shift because of chromium’s rapid clearance from the body. Wide individual variation in metabolism and rapid depletion of body burden limit the value of urinary chromium monitoring. Urinary chromium excretion reflects absorption over the previous 1 or 2 days. In occupational settings, a urinary chromium concentration of 40 \( \mu g/L \) to 50 \( \mu g/L \) immediately after a work shift reflects exposure to air levels of 50 \( \mu g/m^3 \) of soluble Cr(VI) compounds. According to a report by the US Depart-
ment of Health and Human Services, concentration has been associated with nasal perforations.

If sufficient time has elapsed for urinary clearance, a negative biomonitoring result (ie, <2.0 μg/L) can occur even with injurious past exposure. Assuming no source of excessive exposure, urinary chromium values are typically less than 10 μg/L for a 24-hour period in healthy adults with occupational exposure. Laboratory levels greater than normal warrant investigation for possible sources of exposure.

**Exposure From Implants**

For individuals with metal-on-metal cobalt-chromium alloy hip implants, exercise induces elevations of both cobalt and chromium in the blood and body fluids. The phenomenon is attributed to wasting or deterioration of implants caused by friction, or wear. Elevated serum chromium levels may indicate wear of the prosthesis, although 1 study has shown elevations of serum cobalt levels to be a more reliable indicator. Pritchett has studied the heat generated by knee prostheses. Prosthetic designs that used cobalt-chrome alloys had temperature increases of 5°C to 7°C after exercise. This frictional heat may lead to wear of the prostheses.

Although few studies have been published specifically evaluating the association between prosthetic knee implants and elevated chromium levels, risks of other joint implants have been studied. An epidemiologic study by Meyskens and Yang demonstrated an association between metal-on-metal hip implants and melanoma. The longer an individual had an implant, the greater the risk of the disease. Incubated fetal melanocytes that were exposed to chromium produced colonies of melanoma cells. Marker and colleagues followed up 98 patients with metal-on-metal hip implants over a 10-year period. The authors found no statistically significant association between serum cobalt or chromium concentrations and impaired renal function for the 75 patients who completed the study. One published study reported a high-grade osteosarcoma occurring adjacent to an alloy hip prosthesis. Spectroscopic analysis identified elevated levels of chromium and vanadium in the tumor. This information does not signify causation, but it is intriguing and warrants further investigation.

**Occupational Surveillance Programs**

The present case illustrates the complexity involved in a properly performed occupational surveillance program. There are various resources offered by the National Institute for Occupational Safety and Health, OSHA, and the Agency for Toxic Substances and Disease Registry that are invaluable when developing and implementing such programs.

**Conclusion**

Elevated chromium levels can be caused by prosthetic joint implants. It is important to obtain a history of prosthetic joint replacement for those enrolled in workplace chromium surveillance programs. Additional studies are warranted regarding the clinical consequences of elevated chromium levels secondary to joint replacement and how these elevations affect chromium workers.

**References**