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Neurological Abnormalities Following a Metal-on-Metal Total Hip Arthroplasty: A Literature Review

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Abstract

Studies collectively reviewing hundreds of case studies have revealed that metal-on-metal hip implants have been failing in the body by degrading at the connection between the ball on the femur and the socket in the hip. In many older adults, these surgeries have been used to treat osteoarthritis, rheumatic disorders, trauma, bone tumors, etc., but there are various adverse side effects that come with a major surgery, as with any type of surgery. For a total hip arthroplasty, or THA, the risk of necrosis, pseudotumors and generalized pain in the surgical area are common side effects, but providers often do not note the risk of implant failure and how that impacts the body. An adverse side effect that is not as well known, but just as serious, is the physiological changes that occur in the brain to mimic dementia symptoms. Patients presenting with dementia symptoms have recently been misdiagnosed because providers would not think to run a heavy metal panel to investigate if the hip implants are the cause of the symptoms. This literature review will outline the long-term effects of metal hip implants, how patients should be aware of the possibilities presented by metal toxicity, less known adverse manifestations of metal accumulation in the bloodstream, and the subsequent neurological symptoms.

Introduction

The Human Hip:

The hip joint is one of two ball-and-socket joints in the human body and articulates the acetabulum of the pelvis with the head of the femur (Figure 1) (Derar 2015). The primary function of the hip is to provide support of the body weight and transmission of signals from the central core of the body to the lower extremities, which provides mobility (Derar 2015).

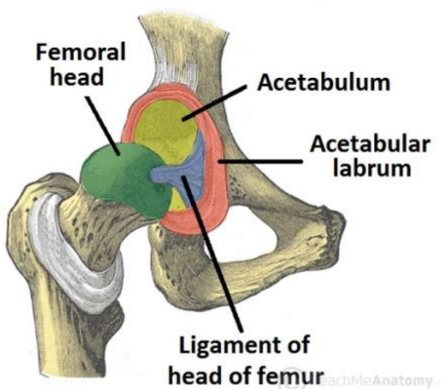

Figure 1. Anatomical visual of the ball-and-socket hip joint in the body.

There are several diseases that cause chronic hip pain, the most common being arthritis: inflammation of a joint. In arthritis of the hip, the degradation of cartilage between the hip and femur causes pain due to the bones rubbing together (Granchi et al 2018). A sub-type of arthritis, rheumatoid arthritis, results in the synovial membrane becoming thick, inflamed, and can become damaging to the cartilage in the joint (Granchi et al 2018).

Because of the various conditions that cause chronic hip pain, in severe cases, a hip replacement surgery may be necessary to alleviate pain. The three types of hip replacement surgeries are total hip replacement, partial hip replacement, and hip resurfacing. In total hip replacement, the whole ball and socket joint is removed and replaced with a prosthetic. For a total hip replacement, also known as a total hip arthroplasty, the damaged femoral head is usually replaced with a metal stem, a metal or ceramic ball, and the damaged cartilage in the acetabulum is replaced with a metal socket (Figure 2). In partial hip replacement, only the femoral head is replaced. Finally, in hip resurfacing procedures, the socket is replaced, and the femoral head is reshaped and covered with a cap.

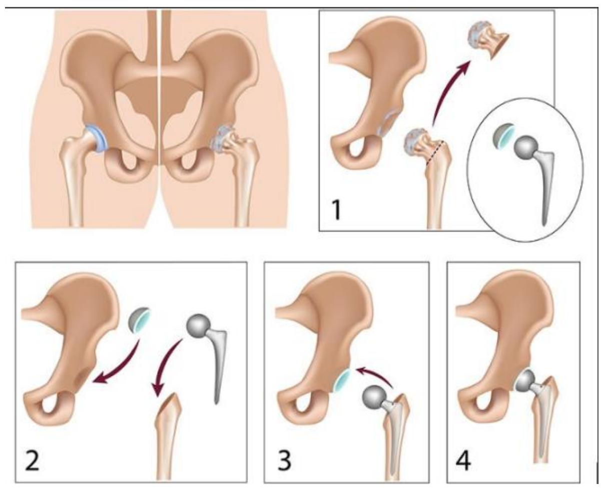

Figure 2. Visualization of the steps of a total hip arthroplasty. https://www.healthdirect.gov.au/hip-replacement

The theory behind a hip implant is to deliver universal joint movement between the ball and socket joint of the hip (Derar et al 2015). Due to the increasing life expectancies and as surgeries are offered to younger patients, a higher demand has been put on the durability of newly created implants (Evans et al 2019).

History of Hip Replacements:

The first generation of metal-on-metal hip replacements began in the 1950s with metal intramedullary femoral stems, which are nails that drill inside the shaft portion of the femur to stabilize the implant, and heads of varying shapes and sizes (Karachalios 2019). These first-generation implants aimed to improve clinical outcomes and extend the implants wear inside the body. Cobalt and chromium quickly became the first choice of metals for their high biocompatibility and ability to withstand the stress and weight that the hip joint absorbs (Karachalios 2019). Early failure rates were mostly due to loose components and complications of aseptic loosening (Karachalios 2019). Surgeons in the 70s and 80s turned to metal-on-polyethylene implants for cost efficiency but realized the polyethylene portion wore out more quickly than anticipated (Karachalios 2019). Second-generation implants were created in the 1980s to the early 2000s due to the observation of favorable long-term results from patients with first generation metal-on-metal (MoM) implants that were quality controlled with more frequent check-in visits post-op throughout the 80s (Karachalios 2019). Researchers found that bearing components require high precision in the polishing, diameter, and shape of the implant to maximize efficiency (Karachalios 2019). It has been found in recent years that patients who have received metal-on-metal hip implants and have had resurfacing surgery have required fewer regular check-ups because failure rates of resurfaced implants are on average lower than metal-on-metal stems (Matharu 2017). In fact, over 80% of patients with a resurfaced implant were asymptomatic following surgery (Matharu 2017). A newer implant has a higher success rate because of the way it was designed; the three parts, metal femoral stem, polyethylene acetabular component, and acrylic bone cement, are considered low friction due to the reduced wear on a smaller surface area (Knight et al 2011).

Complications of Hip Implants:

Due to the design of many implants, complications during and post-surgery are common. In the design of a hip joint, the femoral head articulates against the acetabular cup. With a metal-on-metal replacement, as the implant wears, metal particles flake off and are released into the bloodstream (Kovochich et al 2018). This causes a physiological reaction in the body that sends macrophages to the affected area to attack foreign debris. The destruction of this tissue often causes osteolysis and loosening of the implant (Derar et al 2015). In addition, infection rates due to resistant biofilm-forming pathogens, comorbidities with other diseases and antibiotic resistance to immunosuppressive drugs have increased since the 1970s (Stepien et al 2018). Another possible outcome of a faulty replacement is bone resorption, which occurs when the combination of a stiff prosthetic and extra stressors when the implant and natural bone are in contact causes the bone to break itself down (Triclot et al 2011). Wear of these metal surfaces has been associated with periprosthetic osteolysis, but a ceramic-on-ceramic implant bears the risk of neck-to-socket impingement if not optimally placed. A third possible outcome is periprosthetic fractures; intraoperative and postoperative fracturing of the implants are one of the most important complications because they are associated with poor clinical outcome and recovery as well as high mortality rates (Triclot et al 2011). Both types of fracturing can cause risk factors to develop such as osteoporosis and rheumatoid arthritis (Triclot et al 2011). One major physical adverse effect that occurs after a THA is necrosis, which creates a strong inflammatory response around the affected area. Necrosis prevents phagocytes from working efficiently to eliminate dead cells accurately to allow toxic cells to build up in the area (Granchi et al 2018). In recent years, studies have shown that there are complications that are not as apparent following a metal-on-metal hip implant; there is an increasing number of patients who are presenting with neurological symptoms and are found to have toxic levels of cobalt in their bloodstream due to wear and degradation of the implant.

Literature Review

Cobalt and Chromium at the Cellular Level:

In the human body, cobalt plays an essential role in various physiological functions, such as regulation of red blood cells, platelets, and DNA, as well as energy production and fatty acid synthesis, in trace amounts (Venkatraman et al, 2020). Additionally, cobalt is a component of the vitamin B12 molecule in the body, which plays an important role in keeping the blood and nervous system healthy and regulated (Czarnek et al, 2015). Cobalt was chosen as the main metal in a metal-on-metal hip implant in the 1950s due to its supposed strength and durability. Another element used in metal-on-metal hip implants is chromium because of its durability. In the body, chromium plays a role in insulin regulation of blood sugar, and natural levels may increase blood sugar and triglycerides in the body (Anderson, 1997).

In recent years, there has been increased research highlighting the effects of degrading cobalt hip implants in the human body. Normal dietary intake of cobalt (Co) ranges roughly from 5 to 50 ug daily, a normal serum concentration of cobalt is less than 0.2 ug/L (Venkatraman et al, 2020). Work has been done recently to highlight the increased levels of cobalt toxicity in the bloodstream through retrospective case studies as well as modeling Co toxicity in rodent models. Catalani et al. performed a study synthesizing information from past surgeries and highlighted multiple cases where patients had a significant increase of cobalt in serum one year after implant surgery, with many levels as high as 1.2 ug/L (Catalani et al, 2012). One case noted in Catalani et al described a 49-year-old male 36 months post hip replacement surgery, presenting with various neurological and physical symptoms. Laboratory results revealed a cobalt serum level of

83 ug/L, which is almost 415x the normal levels of serum cobalt (Catalani et al, 2012). Gomez-Arnaiz et al conducted another study to mimic cobalt neurotoxicity in rodent models by dosing rats with low concentrations of cobalt intraperitoneally that were similar to cobalt levels seen in patients receiving MoM implants. Their results found increased change in transcript sequences using RNAi, notably in the prefrontal cortex, cerebellum, hippocampus, and the bloodstream (Gomez-Arnaiz et al, 2022). The increased change in transcript could be to mutations that are occurring in the area from cobalt toxicity. Additionally, they found that the cobalt accumulation resulted in both up and down regulated transcriptional responses in these brain regions, many of which corresponded to the choroid plexus.

There are adverse effects of revising a ceramic-on-ceramic first-generation implant with a metal-on-metal second generation implant. Catalani et al described in their study that a metal hip replacement should not be used as a revision implant following a ceramic implant because microscopic ceramic particles can remain in the space where the implant lays and act as a grinding wheel against the newly implanted metal replacement (Catalani et al, 2012). Pelclova et al investigated one 56-year-old patient that received a ceramic hip replacement in the beginning and had revision surgery 3-years later with a metal hip implant. The patient presented with a range of symptoms 14 months after MoM surgery and it was discovered that 40% of the metal head portion of the implant was degraded and his serum cobalt level was measured at 506 ug/L (Pelclova et al, 2012).

Devlin et al conducted a systematic review of failed MoM replacements, specifically on the first round of implants, and subsequently reported symptoms. Out of the 10 cases they were able to find, 6 of the 10 cases reported cobalt serum levels over 3125 x the normal amount of cobalt in serum tests, with the highest reported being 625 ug/L three months post MoM surgery

(Devlin et al, 2013). Another way to investigate cobalt concentrations post-replacement is by looking at the wearing of the implant post-surgery. Sidaginamale et al gathered information from case studies examining the influence of metal debris from the implant on immune response and soft-tissue injury (Sidaginmale et al, 2017). One part of their study looked at both alloys involved in metal-on-metal replacements, cobalt and chromium, to determine ion concentration in the blood and joint region compared to wear rate.

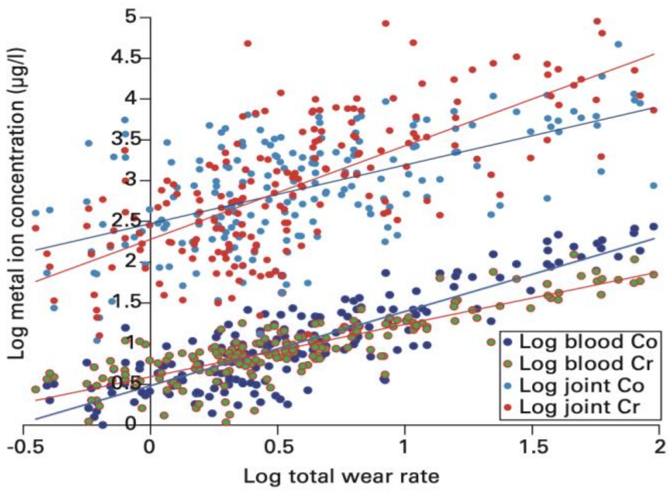

Figure 3. Comparison of Cobalt and Chromium concentrations in the bloodstream and joint area. Concentrations of both are trending higher in the joint than in the bloodstream. (Sidaginamale et al 2017).

As shown in figure 3 above, cobalt and chromium are heavily present in the bloodstream and in the surrounding joint area of a metal prosthesis (Sidaginmale et al, 2017). As wear increases, cobalt serum levels trend higher in the bloodstream, whereas in the joint area, as wear increases, the chromium serum levels trend higher. This is most likely due to cobalt's better bioavailability in the body, compared to chromium. Cobalt is more readily available to travel through the body, whereas chromium cannot, so it is found in higher levels in the surrounding tissue.

One possible mechanism for the toxicity induced by increased cobalt levels is through the formation of reactive oxygen species (ROS). Normal processes that occur during aging include mitochondrial dysfunction, neuronal calcium-ion dyshomeostasis and the buildup of damaged molecules in the brain, all of which result in the formation of ROS. Studies have shown that metals in the blood, including cobalt, have been linked to the formation of ROS and increased mitochondrial dysfunction (Catalani et al, 2012). According to a study by Catalani et al., ROSs were found to demyelinate axons in the central nervous system because oligodendrocytes, which myelinate neurons, are sensitive to harsh oxidative stress (Catalani et al, 2012). Without myelin on axons, messages will not be sent as quickly through the central nervous system, which could cause issues including headache, tingling in extremities, unsteady gait, etc. (Catalani et al, 2012).

Another potential mechanism for cobalt-induced neurological issues is suppression of the Cytochrome P450 (CYPs) pathway, which is responsible for drug metabolism, detoxification, and cellular metabolism in the body (Gomez-Arnaiz et al, 2022). When a toxic amount of cobalt enters the body, the CYP pathway is one of its many targets to induce mutations. High cobalt levels may play a role in shutting down the CYP pathway, so the brain can no longer produce the neurotransmitters serotonin and dopamine, which could cause a wide variety of neurological symptoms, such as cognitive decline and vertigo (Gomez-Arnaiz et al, 2022). Gomez-Arnaiz et al. conducted a study to mimic cobalt toxicity from metal-on-metal hip replacements in rats. Findings from the study suggest that CYPs may be attracted to cobalt, as they have been shown from previous research to bind to the heme metal substrate and inactivate the complex. Heavy metals have been noted to mutate the transcripts in the choroid plexus, and the study highlights that elevated cobalt levels could be connected to neuropsychiatric symptoms that are seen in patients with cobalt toxicity (Gomez-Arnaiz et al, 2022).

In recent literature, the term arthroprosthetic cobaltism has become increasingly common when speaking about the most common symptoms associated with cobalt toxicity from a faulty hip replacement. The neurological symptoms associated with cobalt toxicity are well established, including in a recent study published by Tower (2010). This study reports of two cases that were diagnosed with arthroprosthetic cobaltsim and suffer from mostly neurological symptoms, with Case 1 also presenting with cardiac abnormalities. (Tower 2010). Case 1 reports a patient with a serum cobalt level of 50 ug/L eleven months after surgery. The classic neurological symptoms were tinnitus, hearing loss, incoordination, cognitive decline, and fatigue to name a few (Tower 2010). Forty-three months after the initial surgery, revision surgery was done and the first cardiac symptom was present, diastolic dysfunction, which occurs when the first portion of the heartbeat does not allow the heart to relax as it should (Tower 2010). The second case looked at a patient with a resurfaced femoral head revision surgery on a total arthroplasty. One year following the revision surgery, the usual neurological symptoms were present: cognitive decline, hearing loss, vertigo, etc. with a serum cobalt level of 23 ug/L (Tower 2010). Studies such as this one highlight that the increased cobalt levels seen in patients receiving metal on metal implants may lead to a range of neurological and neuropsychiatric symptoms.

Neurological Symptoms of Hip Replacement Failure:

Because a THA is a relatively common surgery, many studies have highlighted the adverse effects that occur with the physical implants and the surrounding tissue. Recent studies have begun to highlight neurological symptoms that present in certain patients, including dementia.

Dementia is defined as the loss of cognitive abilities that extends to interfere with the person's daily functioning (Weller & Budson, 2018). Dementia becomes increasingly more prevalent in ages 65 and over, and about 1/3 of people over 85 have some form of diagnosed dementia, but it is important to note that this is not a normal part of aging (Weller & Budson, 2018). Some of the major symptoms include memory loss, difficulty speaking or forming sentences, repeating questions, losing interest in normal activities, hallucinations, or paranoia, losing balance, and impulsive actions (Weller & Budson, 2018). Dementia is classified under the broader category of a neurodegenerative disease, such as Parkinson's, and there are five common disorders associated with dementia: Alzheimer's Disease, frontotemporal dementia, Lewy Body dementia, vascular dementia, and mixed dementia (Weller & Budson, 2018).

Neurological symptoms that have been attributed to metal poisoning from hip implants include structural changes in visual pathways, significant depressed mood, neurocognitive abnormalities, disorientation (Green et al, 2017), tinnitus, hearing loss, convulsions, and peripheral paresthesia (van Lingen et al, 2014). These adverse effects could be due to metal concentrations in the blood or how metal interacts with neurons in the central nervous system. Systemic cobaltism was reviewed in another study by Gessner et al., which outlined nine different symptom categories (Gessner et al, 2019). The group used a scoring tool from 0-12 in the nine categories: psychosocial, hip pain, constitutional, audio-vestibular, optic, peripheral motor sensory, cardiovascular, thyroid, and hematologic oncologic immune responses (Gessner et al, 2019). Within each category, the description of the associated pain is noted for each score, with zero being no abnormality present, and twelve being the most severe symptom in that respective category (i.e., 12 in the cardiovascular category coincides with the need for a heart transplant and 12 in audio-vestibular coincides with patient deaf despite hearing aids) (Gessner et al 2019). Figure 4, shown below, shows a summary of symptom scores across the nine categories in relation to the blood concentration levels of cobalt (Gessner et al 2019).

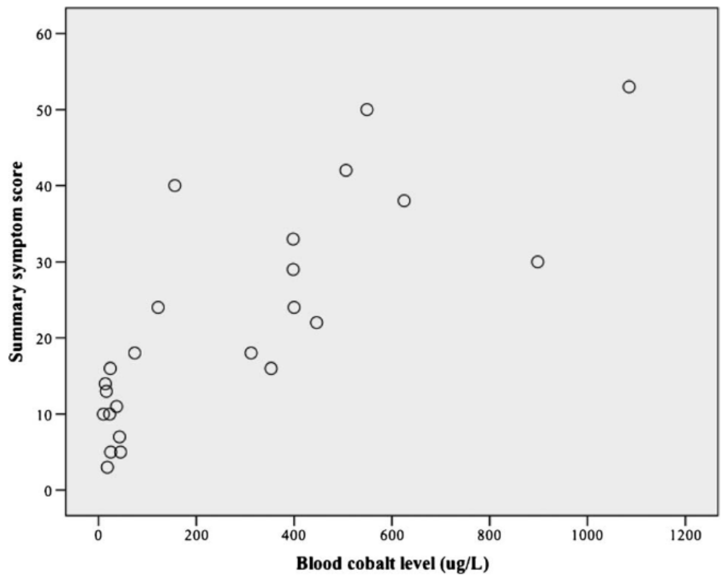

Figure 4. Relation between blood cobalt levels and symptom scores across the nine diagnostic categories.

It is clearly indicated from the graph above a higher level of cobalt circulating in the bloodstream is associated with higher scores on the symptom diagnostic questionnaire developed by Gessner and his team. Crusten et al also reviewed case reports surrounding prosthetic hip-associated cobalt toxicity in patients. Their findings produced a list of nine symptom categories that were present in most of their patients: neurological, sensory, cardiovascular, gastroenterology, musculoskeletal, skin/hair, thyroid, mental/psychosocial, and other uncategorized symptoms (Crusten et al 2022). In their data collected regarding symptoms, some of the most common symptoms included: cognitive/memory/concentration loss, hearing loss, visual impairments, dyspnea, fatigue, and cardiomyopathy (Crusten et al 2022). These in-depth questionnaires can, and should, be used by orthopedic providers in the future, to determine severity of symptoms associated with faulty hip replacements.

Analyses have been conducted to determine the effects of hypercobaltemia on the nervous system and subsequent neurological symptoms. One report conducted by Woelber et al (2016) studied a case that involved rapid acceleration of Parkinson’s symptoms following a metal-on-metal hip arthroplasty. The patient reported to have a family history of Parkinson's Disease and developed the hallmark symptoms of tremors in his upper and lower extremities 6 months post-surgery with a double metal-on-metal arthroplasty. He was prescribed L-DOPA for what was thought to be the beginning signs of Parkinson's, but the symptoms worsened over the span of a year, and he was considered for deep brain stimulation for what was thought to be his Parkinson's (Woelber et al, 2016). Upon further investigation, it was suspected that the patient may be suffering from hypercobaltemia and neurocobaltism because of his increasing pain levels localized to the hips and the increasing neurological symptoms. Because of this suspicion, the patient was given a serum cobalt test and the levels were 116 ug/L (Woelber et al, 2016). Additionally, by this time the patient was also reporting blurry vision, memory loss, tongue numbness, and dysgeusia in addition to his worsening Parkinson's symptoms. With the removal of the metal-on-metal prostheses, the patient's serum cobalt levels fell below the biological exposure threshold, at 0.7 ug/L, and almost all neurological symptoms dissipated besides a mild antalgic gait and minor tongue irritation (Woelber et al 2016). While the patient was diagnosed with early-stage Parkinson's a few years later, the neurological symptoms were apparently worsened after his double metal-on-metal arthroplasty due to the substantial wear that was found after the prostheses were removed. In this case, almost all of the patients' symptoms resolved temporarily, but with a family history of Parkinson's, his symptoms later redeveloped due to his genetic predisposition. This study is important to consider with the current research because it highlights the possibility of a misdiagnosis of a neurological disorder or neurodegenerative disease, when, the hip prosthesis may be causing the symptoms.

Swiatkowska et al (2022) conducted a case-control study to compare self-reported neurological symptoms from patients who have received a metal-on-metal (MoM) arthroplasty and a ceramic-on-ceramic (CoC) arthroplasty. The patients chosen in the MoM group were 12+ months post-surgery and had elevated cobalt serum concentrations > 20 ug/L and the CoC group was age-matched accordingly (Swiatkowska et al 2022). The researchers conducted four separate questionnaires to determine neurological function: the Neurotoxic Symptom Checklist-60 (NSC-60), the Diabetic Neuropathy Score (DNS), the Douleur Neuropathique (DN-10), and the Systemic Symptom Checklist (SSC). The NSC-60 is a Dutch questionnaire that determines neurobehavioral symptoms and the severity of reported symptoms, the DNS is a scoring system to determine the prevalence of peripheral neuropathy, the DN-10 is another questionnaire used to diagnosed neuropathic pain, and the SSC was written by the authors that involves 12 of the most reported symptoms from patients with elevated cobalt levels (Swiatkowska et al 2022). From statistical analysis, it was found that there was a significantly higher prevalence of the following symptoms in the MoM group from the NSC-60 questionnaire: cognitive problems, chest complaints, balance disturbances, sleep disorders, mood changes, sensorimotor disorders, physical complaints, and fatigue (Swiatkowska et al 2022). Significantly higher scores on the DNS and DN-10 were reported in the MoM group as well. This report highlights the important difference between a MoM arthroplasty and a CoC arthroplasty because of the possible neurological side effects involved with increased cobalt concentrations in the body.

Bridges et al (2019) used F-18 FDG PET and CT brain imaging to assess hypometabolism in areas that are known to be more susceptible to damage from cobalt toxicity. F-18 FDG PET, otherwise known as positron emission tomography with fluorodeoxyglucose, is based on increased glucose uptake to depict metabolic changes (Almuhaideb et al 2011). In addition to cobalt serum screening, patients were questioned based on 10 common symptoms: forgetfulness, fatigue, moodiness, imbalance, tremors, poor sleep, numbness, deafness or tinnitus, global pain, and non-refractive blindness (Bridges et al 2019). Figure 4 highlights four representative cases of patients from the study with severe hypometabolism in various brain regions.

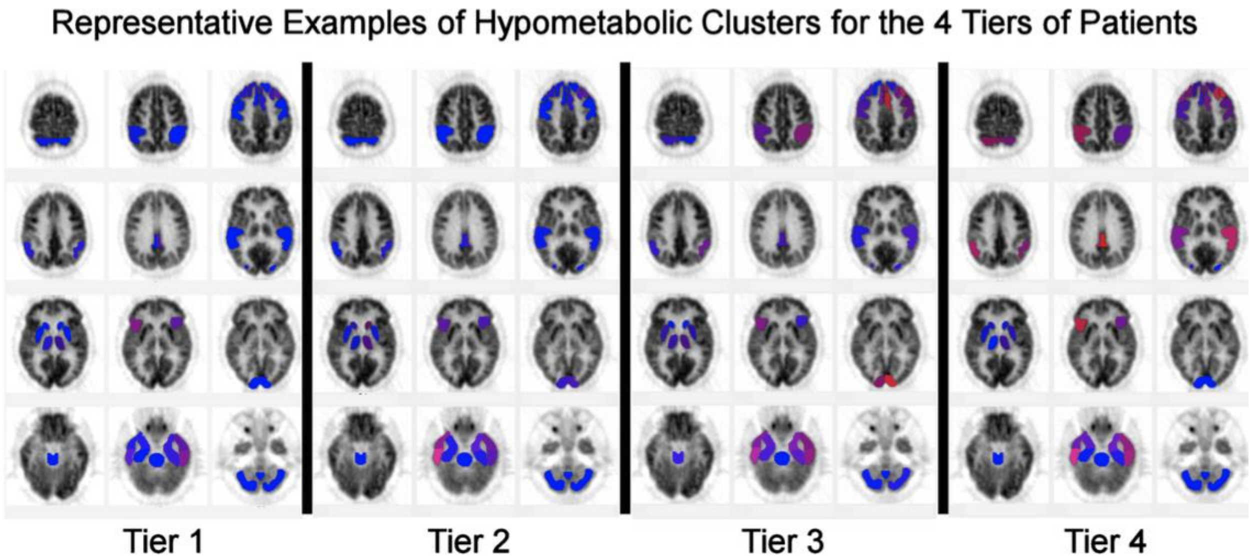

Figure 5. Representative scans of patients from various tiers in experiment. Blue represents normal and shades towards red indicates increased hypometabolism (Bridges et al 2019).

The representative PET scans in figure 5 highlight the brain regions with the most hypometabolism from cobalt toxicity, some of which include: temporal lobes, frontal lobes, anterior cingulate gyri, parietal lobes, posterior cingulate gyri, visual cortex, thalamic areas, and caudate (Bridges et al 2019). The temporal lobe was found to have one of the highest rates of hypometabolism, which may account for the repetition of tinnitus and hearing loss as a symptom in patients with MoM replacements. Bridges et al are one of the first groups of published researchers to use functional PET as a diagnostic tool for hypometabolism and cobalt toxicity, and with the addition of serum cobalt testing, it will be increasingly easier to diagnose cobalt toxicity in patients with MoM replacements before misdiagnosing them.

Leyssens et al (2020) conducted a study to gather information regarding patient-reported neurological outcomes following metal-on-metal hip replacements (Leyssens et al 2020). Many neurological symptoms that have been reported in the literature include hearing loss and balance-related issues, which have appeared to be present in roughly 30-50% of self-reported symptoms. Their assessment aimed to determine a causal relationship between time- and dose-dependent amounts of cobalt and its toxic effects from metal hip replacements. Objective auditory and vestibular assessments were completed before patients received hip replacement surgery to create a baseline to be compared to post-surgery, which is something that previously had never been done (Leyssens et al 2020). Additionally, pre-surgery neurological symptoms were tested using the *Neurotoxic Symptom Checklist – 60* and the *Diabetic Neuropathy Symptom* score, both of which are used as objective baseline measurements with close-ended questions to determine severity of symptoms before surgery. (Leyssens et al 2020). Their results show statistically significant data in multiple symptom categories compared to the control group: the general presence of auditory-related symptoms, tinnitus, and hyperacusis, or decreased speech understanding in noisy environments (Leyssens et al 2020). Their findings are consistent with previous literature that deems tinnitus as one of the most common auditory symptoms that arise after a metal hip replacement surgery

Higher cobalt and chromium concentrations have been found in the blood after MoM implants were inserted, which have been found to change brain structures and functions. In a study by Green et al., some of the symptoms noted were weight loss, cognitive impairment, low energy and when revision surgery was done, all the symptoms cleared (Green et al 2017). The patients underwent evaluations using the Diagnostic and Statistical Manual of Mental Disorders (DSM), the Mini Mental State Examination (MMSE) and the Beck Depression Inventory (BDI) because these tests can be administered quickly at the bedside by a physician to find possible neuropsychiatric conditions (Green et al 2017). The results yielded a significant number of depressed patients involved in the study who responded to the BDI as well as neurocognitive abnormalities in 7 out of the 10 patients (Green et al 2017). Green et al concluded that all clinicians working on cases that involve significant surgeries with possible complications should complete the neuropsychiatric state of patients, especially after the MoM implant surgeries (Green et al 2017).

Optic Deterioration:

One of the symptoms reported by many of the case studies investigated was a loss of vision in some capacity. A study by Clark et al highlights clinical neurological manifestations of metal poisoning that in turn affect cognitive abilities (2020). Some of the most common symptoms included tinnitus, impaired vision, hearing loss, headaches, peripheral neuropathy, and hypothyroidism (Clark et al 2020). The paper examined the changes in brain structures and function after MoM hip replacements and concluded that chronic exposure to heavy metals, such as cobalt, is connected to degradation of gray matter in the occipital lobe of the brain, the area of the brain containing the visual cortex (Fig. 6). Voxel-based morphometry was used in figure 6 to indicate brain gray matter.

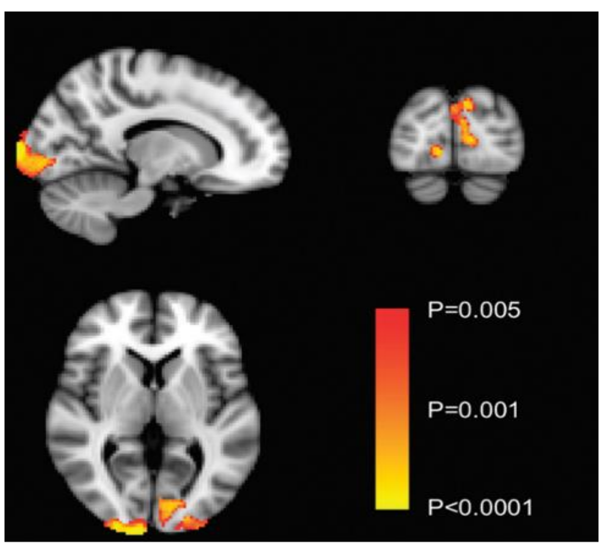

Figure 6. Atrophying gray matter located in the occipital lobe (Clark et al 2020)

Apostoli et al conducted a study in rabbits to mimic cobalt and chromium toxicity from metal hip implants and their related symptoms. Three separate groups were conducted to determine metal toxicity: cobalt-treated rabbits, cobalt-chromium treated rabbits, and chromium-treated rabbits. Interestingly, the rabbits that were treated with chromium only showed no signs of clinical or pathological alterations even with high amounts of accumulation in the bloodstream and surrounding tissue. However, the cobalt treated and cobalt-chromium treated rabbits showed signs indicative of optic and auditory deterioration. These rabbits were found to have severe retinal and cochlear cell depletion, optic nerve damage, and loss of cochlear hair cells (Apostoli et al 2012). It was also noted that the severity of symptoms was directly correlated to the time of exposure and dosage of cobalt.

Grillo et al conducted a case study of a patient with decreasing vision post metal-on-metal hip replacement to determine if the visual damage coming from metal implants took place in the optic nerve, retina, or both (Grillo et al 2016). The patient in this study, a 66-year-old man, was born with childhood amblyopia in his right eye, so only the left eye was subjected to the various visual tests. He received a ceramic replacement that was repaired with a metal-on-metal replacement three years later. Nine months past his revision surgery, some of the symptoms he developed included: difficulty seeing distance and close-up, difficulty hearing, lack of color differentiation, ankle swelling, incoordination, and subjective loss of mental clarity (Grillo et al 2016). Upon further testing, it was determined that his measured Co serum was over 1000 ug/L and ceramic fragments were found around the joint that contributed to significant wear of the head and cup portions (Grillo et al 2016). One test that was conducted to determine visual deterioration is an electroretinogram (ERG) that determines retinal activity in response to light stimuli (Parvaresh 2018). The ERG test in the patient’s non-amblyopic eye showed normal limits of activity during measurement. However, another test that was computed was the multifocal visual evoked potential, or the mfVEP, that measures electrical signal created in response to visual stimulation that is in the visual cortex (Kothari et al 2016). The patient had decreased central amplitudes on the mfVEP, which is consistent with dysfunction along some component in the visual pathway (Grillo et al 2016).

Another case study by Garcia et al featured the effects of a MoM replacement being used to repair a ceramic-on-ceramic replacement in a 59-year-old female (2020). The patient received a ceramic hip that fractured and was replaced with a cobalt-chrome femoral head and a polyethylene acetabular insert (Garcia et al 2020). Four months later, the patient presented with several neurological symptoms including: hearing loss, headaches, fatigue, and paresthesia in lower extremities. However, it wasn't until a year later that she was evaluated for beginnings of visual loss with the presentation of 'white spots' in her field of vision that became progressively worse (Garcia et al 2020). Initially, the symptoms were not associated with her previous implant surgery, so the treatments of corticosteroids and plasma exchange were ineffective (Garcia et al 2020). After a suggestion by the patient's daughter, a cobalt serum test was done, and levels were found to be > 1000 ug/L and she was given N-acetylcysteine for treatment (Garcia et al 2020). With the variety of visual testing done, it was found that the mfERG found decreased tracing in both eyes, severe ganglion cell thinning, and sluggish pupils (Garcia et al 2020). The patient's implant was promptly removed and a month post-op, her mfERG showed improvement in both eyes, but thinning of the ganglion cells continued (Garcia et al 2020). This case study indicates that visual deterioration is possible from high levels of cobalt in serum levels, and it is important to diagnose and treat cobalt toxicity, because if cobalt is not excreted from the system, it is possible the patient will never regain their eyesight.

Treatments:

Currently, the most utilized treatment for cobalt toxicity from a metal hip replacement is removing the degrading implant and replacing it with a newer implant made of titanium. It has been highlighted above that in many cases with severe symptoms, the treatment for the patient was to remove the implant, and symptoms improved drastically. Giampreti et al highlighted a potential new treatment with N-acetylcysteine (NAC) as an effective chelating agent. A chelation treatment is a type of compound that binds to the excessive metal in the bloodstream to treat metal toxicity, and in the case of metal-on-metal hip implants, clear excessive cobalt, and chromium from the blood (2016). Their case report showed two cases, both of which had an increased urine elimination and decreased tissue concentration of cobalt after NAC treatment of 300 mg/kg/day for 9 days. There are very few cases using NAC as a treatment for the degradation of metal hip implants, but it may be a compound worth using in the future with patients who have less severe cobalt toxicity to stop symptoms from worsening. While there may not be many treatments for cobalt toxicity, it is important to remember the severity of symptoms, especially the ones that are irreversible. Today, modern hip implants are made with a blend of titanium alloys, stainless steel, and plastic materials.

Conclusions:

Metal-on-metal implants are now seen in less than 1% of total surgical operations due to the high possibility of systemic cobaltism (Merola and Affattato 2019). The possibility of neurological symptoms following hip implants should be thoroughly discussed, regardless of the type of implant, if there is a potential of metal toxicity from the implant. A heavy metal screening should also be implemented as a normal part of post-operative care in THA cases to ensure that metal toxicity is followed post-surgery.

This review highlights the importance of understanding the impacts of metallosis and resulting symptoms created by hip implant failure. Metallosis from hip replacements is most likely much more prevalent than we believe it to be, so it is extremely important to bring these possible adverse side effect to light in patient populations. Providers informing patients of the potential risks will play a crucial role in combating metal poisoning that is occurring from metal hip replacements and hopefully, future research will further tease out the connection between cognitive decline and metal poisoning from replacements.

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