

Case Report

Mechanically Assisted Crevice Corrosion in a Metal-on-Polyethylene Total Hip Presenting With Lower Extremity Vascular Compromise

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ABSTRACT

Mechanically assisted crevice corrosion in modular total hip replacements may lead to an adverse local tissue reaction (ALTR) with a variety of sequelae. Although an ALTR is most commonly recognized with metal-on-metal modular hip constructs, tribocorrosion at the head-neck junction of metal-on-polyethylene (MoP) total hip arthroplasties may also lead to an ALTR. We present a case of a 79-year-old woman with a history of MoP total hip arthroplasty who presented with unilateral leg swelling, joint pain, and stiffness and subsequently underwent revision for an ALTR secondary to mechanically assisted crevice corrosion. This unique case of lower extremity vascular compromise resulting from an ALTR is important because clinicians should consider corrosion-related ALTRs when treating patients with an MoP hip prosthesis presenting with new-onset lower extremity swelling.

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Introduction

Modular hip components are currently among the most commonly used components in total hip arthroplasty (THA). There is also growing recognition of tribocorrosion at the head-neck interface of the femoral component. At this site, mechanical abrasion and chemical corrosion can lead to breakdown of the metal components and release of metal ion and particulate debris in a process known as mechanically assisted crevice corrosion (MACC) [1,2]. The corrosion and fretting debris released into surrounding tissue may result in an inflammatory response known as an adverse local tissue reaction (ALTR). Such ALTRs encompass a variety of tissue responses including bone and soft-tissue necrosis and formation of complex cystic structures often referred to as pseudotumors. Of note, this phenomenon has primarily been observed in patients with at least one cobalt-chromium metal component [3].

ALTRs have typically been associated with metal-on-metal (MoM) implants, although they may occur in metal-on-polyethylene (MoP)

and modular neck constructs as well. Patients with MACC may present with a variety of symptoms including pain, weakness, and gross instability in the hip, thigh, groin, or buttock or other vague lower extremity complaints. In rare instances, lower extremity edema due to an ALTR has been described [4,5], although primarily with MoM implants [6–13]. Here we present a case of MACC occurring in a patient with a MoP modular hip prosthesis who presented with unilateral lower extremity swelling that resolved with revision to a ceramic-on-polyethylene (CoP) construct, which, to our knowledge, is the first description of documented vascular compromise due to an ALTR in a patient with an MoP hip.

Case history

The patient was a 79-year-old female with a history of bilateral MoP total hip replacements with titanium alloy stems and cobalt chromium alloy femoral heads who initially presented in 2017 with increasing right hip pain. Her primary right THA was performed in 2009, with an M/L taper stem, 0-offset 32-mm femoral head, Longevity high-dose electron beam cross-linked polyethylene, and Trilogy acetabular shell (Zimmer Biomet, Warsaw, IN). The exact model of the M/L taper stem (ie, “high or standard offset” and “standard or reduced neck length”) is not known. She had a past

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medical history significant for hypertension, hyperlipidemia, gastroesophageal reflux disease, chronic kidney disease (estimated glomerular filtration rate = 23 mL/minute, normal >60 mL/minute), and gout and had been taking aspirin for pain. She was initially treated with a trochanteric steroid injection which had little effect and re-presented several months later with persistent right hip pain. A computed tomography (CT) scan of the pelvis was obtained at that time and revealed a right groin mass, which was later drained by interventional radiology at the request of another provider. The aspirated fluid was purulent with neutrophils and necrotic tissue on pathology but was otherwise nondiagnostic. The gram stain and culture were negative. Follow-up radiograph in the spring of 2018 showed well-fixed hip components without osteolysis (Fig. 1).

The patient later developed right lower extremity swelling with an enlarging right groin mass, prompting presentation to her orthopaedic surgeon, who had performed her original surgery. Her pain had been poorly controlled with aspirin, and she had attempted elevation and the use of compression stockings with little effect on her lower extremity swelling. Ultrasound imaging of the right lower extremity was obtained, revealing a nonocclusive thrombus in the proximal right great saphenous vein with extension to the saphenofemoral junction, soft-tissue edema in the calf, and a complex cystic structure in the right groin, measuring $6.4 \times 3.8 \times 4.8$ cm. The patient was referred to vascular surgery for further evaluation, as the surgeon did not consider the mass related to the THA. CT imaging further confirmed the presence of a cystic mass with some compression of the surrounding venous system. Doppler venous imaging revealed elevated velocities and disturbed color flow in the common femoral vein at the level of the cystic lesion consistent with obstructive flow and an intraluminal thrombus in the great saphenous vein. The patient was then referred to our orthopaedic service by vascular surgery because of the concern for ALTRs, given the patient's history of right total hip replacement and presentation with a pseudotumor.

The patient was evaluated as an outpatient, and at that time, the physical examination revealed a wide antalgic gait to the right side with significant right lower extremity swelling to the level of the thigh (Fig. 2), guarding due to pain with flexion of the right hip past 90 degrees, and a positive Stinchfield sign [14]. Passive range of motion of the hip ranged from full extension to 100 degrees of flexion with 20 degrees of abduction and internal and external rotations of 10 degrees and 30 degrees, respectively. Abduction strength of the right hip was 4/5 compared with 5/5 on the left. Fullness of the right groin was noted with palpation. There was no warmth or erythema noted. Given suspicion for an ALTR,

inflammatory labs and metal-ion levels were obtained, revealing an elevated erythrocyte sedimentation rate (ESR) (65 mm/h, normal 0–30 mm/h), C-reactive protein (CRP) (16.5 mg/L, normal <10.0 mg/L), serum cobalt level (37.2 ppb, normal <1.0 ppb), and serum chromium level (2.5 ppb, normal <0.3 ppb), strongly supporting a diagnosis of an ALTR secondary to MACC. Metal artifact reduction sequence (MARS) magnetic resonance imaging (MRI) demonstrated a distinct anterior hip mass, emanating from the hip joint and encroaching on the anterior vascular structures (Fig. 3). Of note, we considered the aspiration of the cystic mass previously performed as an intraarticular aspiration as the fluid was contiguous with the joint space. These final cultures were obtained from the outside hospital, reviewed, and confirmed to be negative for bacterial growth before planning her revision surgery. The patient was offered revision THA with debridement of the mass, and she agreed to the procedure.

At surgery, a posterior approach to the hip was performed; before opening the pseudocapsule, the joint was aspirated and produced purulent fluid. The pseudocapsule was found to be pathologically thickened. After dislocation of the hip, the femoral head was removed, revealing Goldberg [15] grade 4 discoloration of the trunnion, corrosion evident in the femoral head bore (Fig. 4), with concomitant necrotic periarticular tissue. The trunnion was cleaned, first with a moist sponge and then with an abrasive pad (electrocautery scratch pad) for removing the adherent dark material remaining on the trunnion. Care was taken not to damage the trunnion. There were also signs of polyethylene surface discoloration and slight scratching. The femur was subluxated, and the Zimmer Trilogy cross-linked polyethylene (Longevity, Zimmer Biomet, Warsaw, IN) was revised. The locking ring of the Trilogy shell was released with much difficulty because it was already expanded and did not move freely. Although there was no apparent damage to the locking ring, and it was found to be appropriately seated in the appropriate position, there was a solid film of translucent yellow-organic material in the locking ring channel and behind the polyethylene. The Longevity (Zimmer Biomet) cross-linked liner was removed, and the periarticular tissue was debrided with a portion of the capsule sent to pathology. The interior of the cystic structure anteriorly was gently debrided, but it was not excised because of its proximity to the neurovascular structures. The joint was then irrigated with scrubbing of the remaining hip components using dilute antibiotic solution and a “sponge stick.” Irrigation and debridement were followed by placement of a new locking ring within the 52-mm shell and impaction of a cross-linked polyethylene liner. A 32-mm Option revision ceramic

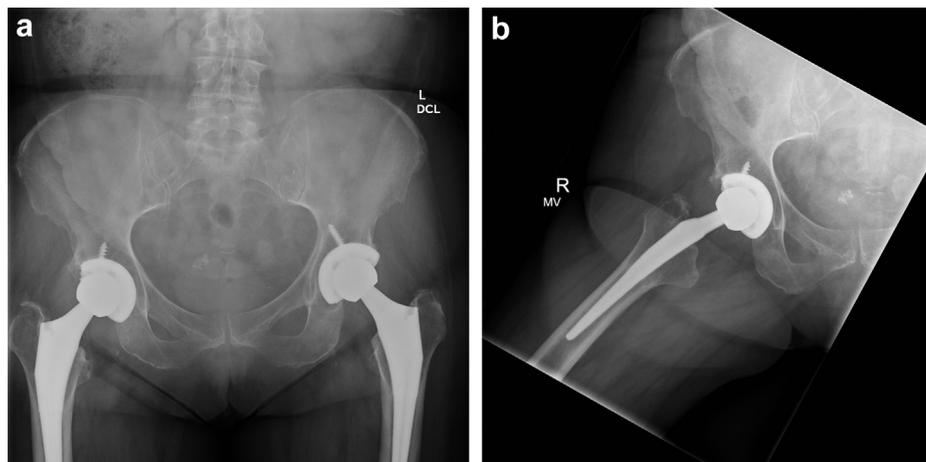


Figure 1. (a) Anteroposterior (AP) and (b) lateral presentation radiographs, 9 years after right primary total hip arthroplasty for osteoarthritis. The patient had pain and leg swelling; however, radiographs do not show obvious osteolysis or loosening. The right hip abduction is 59 degrees.

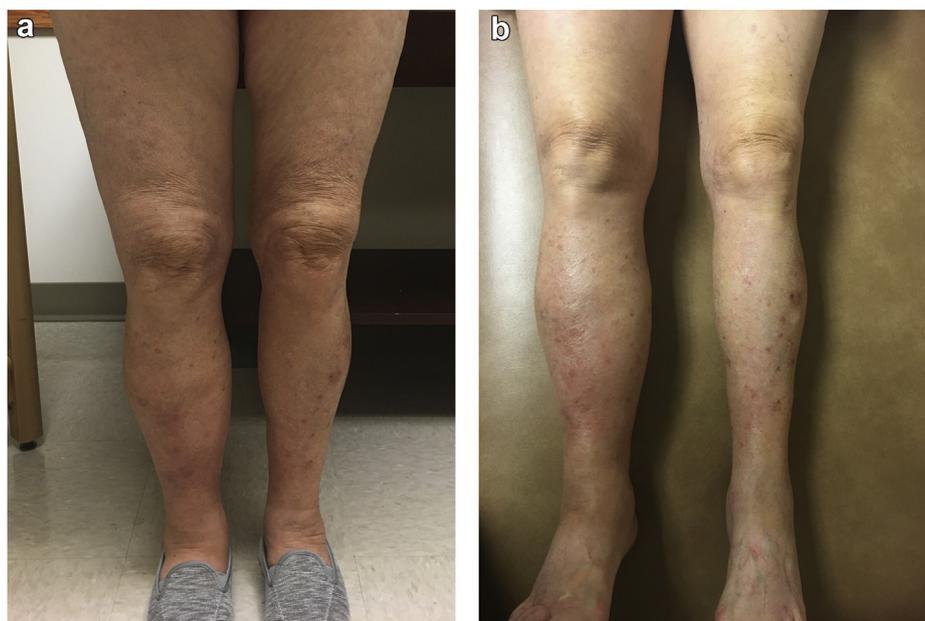


Figure 2. Clinical photographs at preoperative visit demonstrating significant right lower extremity swelling. (a) Standing anterior photograph. (b) Supine anterior photograph focusing on lower legs.

femoral head (Zimmer Biomet) was then impacted, and the hip was reduced. This choice was based on intraoperative stability testing. The joint capsule and wound were then closed with placement of 1 gram of vancomycin powder for infection prophylaxis. The patient awoke from surgery with no major complications. Pathology of the pseudocapsule revealed fibrous tissue with metal debris and chronic inflammation but no acute infection processes. An anaerobic culture obtained at surgery was negative for bacterial growth. Cell count was attempted but could not be performed (even manually) because of debris and lack of identifiable cells. The

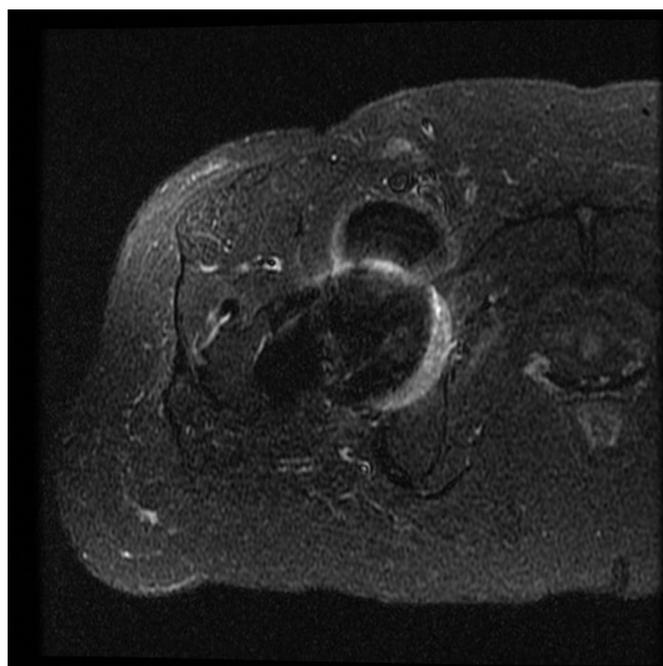


Figure 3. Metal artifact reduction sequence magnetic resonance imaging demonstrates a distinct anterior hip mass, emanating from the hip joint and encroaching on the anterior vascular structures.

implant failure was reported to the Zimmer Biomet company through the implant representative and by their report to the United States Food and Drug Administration. We did not receive any follow-up communication from the company.

The patient did not have preoperative pharmacological anti-coagulation; postoperatively, she had 6 weeks of 81 mg of aspirin twice daily. Repeat ultrasound was not performed, but compressive stockings and elevation were recommended to diminish leg swelling both preoperatively and postoperatively.

On follow-up examination at 6 weeks postoperatively, the patient's lower extremity strength was restored and swelling was significantly diminished. At 6-month follow-up, the patient was doing well without any recurrence of her groin mass or lower extremity swelling. At 1 year, her Harris hip score [16] was 84, there was no pain in either hip, she had resolution of her groin mass and lower extremity swelling (Fig. 5), and her serum metal-ion levels had decreased significantly (Co, 14.3 ppb and Cr, 2.7 ppb). Radiographs were stable (Fig. 6). There was no evidence of postphlebotic syndrome. Because we expected resolution of her abnormally elevated serum Co, evaluation of her asymptomatic THA on the left is warranted and ongoing. She may have MACC (asymptomatic) on her contralateral side as well. There is currently no hip or leg swelling, mass, muscle weakness, or radiographic osteolysis. Serial serum metal-ion levels and MARS MRI of the left hip are planned. Of note, there was no evidence of an obvious ALTR in relation to her left THA on the coronal MARS MRI of the right hip obtained before revision.

The patient has consented to submitting this article for publication.

Discussion

This case of documented lower extremity vascular compromise secondary to MACC and ALTRs is the first, to our knowledge, to be described in a patient with an MoP total hip prosthesis. As MACC and secondary ALTRs are being more frequently thought of in the differential diagnosis of a previously well-functioning MoP contemporary THA with a cross-linked polyethylene countersurface that becomes painful, we suggest that leg swelling and a groin mass also

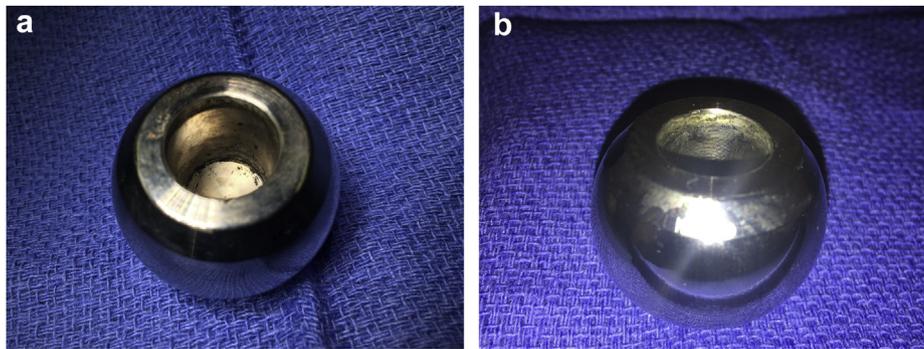


Figure 4. Photographs of a removed femoral head bore. Mechanically-assisted crevice corrosion is evident with dark discoloration (a); trunnion groove “stamping” and black debris at the bore opening (b).

be considered as a presenting symptom. The uncommon presentation of lower extremity edema initially overshadowed the much more common ALTR symptoms of joint pain and stiffness several years after THA in the absence of osteolysis, infection, loosening, or fracture in this patient. Time to onset of symptoms in MACC may vary significantly, although the mean onset of pain occurs about 4 years postoperatively [17]. Our patient initially underwent workup for deep vein thrombosis (DVT), given her unilateral leg swelling, with the finding of cystic mass on CT. In the setting of a history of ipsilateral THA, a vascular surgeon with knowledge of ALTRs referred the patient to orthopaedics (although her own surgeon had not considered the possibility, according to office notes) and ultimate evaluation with serum metal-ion testing. An ALTR poses a risk of irreversible soft-tissue damage, which increases with time [2], making early diagnosis critical. Cooper et al have suggested the use of routine monitoring of serum Co and Cr levels [4], as evidence suggests that a Co-ion level greater than 1 ppb is strongly correlated with ALTRs [18,19]. Elevated intraarticular metal-ion levels may also suggest MACC and ALTRs and should be considered when aspirating a joint to rule out infection [20,21].

Imaging was crucial for diagnosis in our case, with evidence of the cystic groin mass on CT imaging raising suspicion for ALTRs.

Other diagnostic indicators of ALTRs on imaging include radiographic osteolysis, which is present in as many as 60% of cases and abnormal MARS MRI [22]. It is important to note, although MARS MRI is considered the most sensitive imaging modality, it may be normal in up to 30% of cases [22], and fluid alone in the joint may be a pathological finding. Infection is an important consideration in the differential diagnosis of postoperative joint pain and is difficult to distinguish from ALTRs based on joint cell count and differential and serum blood tests, as patients may present with both a leukocytosis and elevated inflammatory markers [5,21,22], which was observed in our patient who had both an elevated ESR and CRP.

Until recently, ALTRs, including the presence of cystic masses and fluid collections, have been more commonly associated with MoM hip prostheses and MoM hip resurfacing, although vascular compromise even in this population appears to be rare. Our review of the literature revealed 7 case reports describing unilateral leg swelling in patients with ipsilateral MoM total hip prosthesis [6-12] and 4 cases in cohort studies of leg swelling in MoP THAs [4,5]. As discussed by Grote et al, the patients in the MoM cases are usually female, with evidence of DVT present in 50% of cases and presence of a cystic mass causing vascular compression present in all cases [9]. Our patient was similar, being female and presenting with a cystic

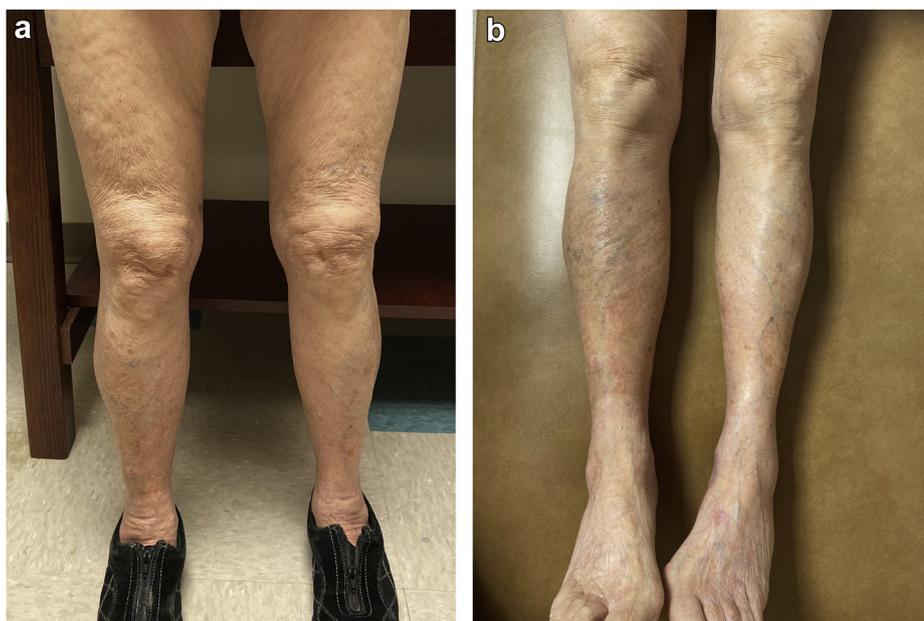


Figure 5. Clinical photographs at 1 year postoperatively, demonstrating near-complete resolution of right lower extremity swelling. (a) Standing anterior photograph. (b) Supine anterior photograph focusing on lower legs.

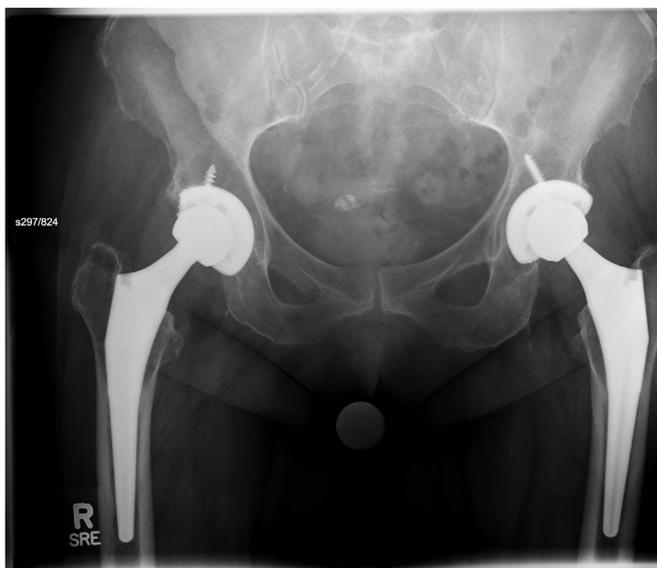


Figure 6. (a) Anteroposterior (AP) pelvis 1-year follow-up radiograph demonstrating a stable appearance of both THAs without osteolysis or loosening.

mass on imaging with evidence of superficial venous thrombosis. One study by Glyn-Jones et al reports that women have an 8 times higher revision rate for pseudotumors than men [23]. It has been proposed that this female predominance may be due to increased incidence of metal sensitivity in women due to wearing jewelry [10,24], with some evidence showing a higher incidence of metal sensitization among female patients presenting with pain after THA than among male patients [25]. This theory is further supported by histologic examination of ALTR specimens, which typically show chronic inflammatory changes similar to that of a type IV hypersensitivity reaction [26,27], as demonstrated in our case.

Owing to the high incidence of revisions due to corrosion, implant failure, and ALTRs associated with their use, MoM prosthetics have largely been phased out in favor of alternative bearing surface implants, such as MoP and CoP THA. However, as demonstrated by Cooper et al, MoP prosthetics still carry a risk of corrosion and ALTRs [4]. In fact, in their case series of 10 patients with MoP total hip prosthetics who underwent revision for modular head-neck corrosion, Cooper et al found elevated serum cobalt and chromium levels in all patients as well as signs of femoral head-neck corrosion intraoperatively consisting of an accumulation of flaky black material at the taper base. Of note, one of the 10 patients they described did have lower extremity swelling [4]. Further evidence of MACC and ALTRs in MoP THA was shown in a larger, cross-sectional study by Hussey and McGrory who found a 3.2% prevalence of symptomatic MACC in a cohort of 1352 consecutive titanium alloy primary hip replacements using highly cross-linked polyethylene and cobalt chromium alloy femoral head components [28]. In the cohort, 27 of the 43 cases with evidence of MACC required revision surgery, which was correlated with higher starting Co levels and steeper trajectories of serum Co level rise over time. As with our case and the case series by Cooper et al [4], Hussey and McGrory noted that accumulation of dark material on the trunnion femoral components was observed during revision surgery [28]. No patients in the cross-sectional study by Hussey and McGrory presented with a documented compressive extraarticular cystic mass and significant ipsilateral lower extremity edema, as we have described [28].

This case presented with an atypically high serum Co level of 37.2 ppb and a higher ratio of serum Co to Cr than is normally seen with MACC in MoP THA. This may be related to her renal

insufficiency, as metal ions are usually cleared by the kidneys. Alternatively, the possibility of bilateral MACC, with additive ion levels, may also have played a part in these findings.

Although management of MACC and ALTRs continues to evolve, surgical revision to remove the Co-ion generator with debridement of necrotic tissue is the most common approach for symptomatic patients [17,29]. Proposed indications for revision in ALTRs include joint pain, joint dysfunction, bone or soft-tissue necrosis, and elevated ion levels [5,17,22,29–31]. Observation may be appropriate for transient symptoms without positive findings on MARS MRI and can consist of annual testing of serum metal-ion levels and surveillance MARS MRI [1,4,17,28]. Although evidence as to whether ALTRs will continue to grow or stabilize with time is mixed [32,33], it is generally thought that revision surgery leads to ALTR involution. Thus, the risks of permanent tissue damage from reactive and necrotic tissue and continued compressive symptoms must be weighed against the risks of revision surgery. In our case, the presence of vascular compromise strongly favored operative management, and partial revision was performed with a new Longevity cross-linked polyethylene liner and an Option (Zimmer Biomet) ceramic femoral head component. The revision was successful with resolution of vascular obstruction and improvement in pain, strength, and range of motion.

These results are similar to those described in the previously mentioned case reports of lower extremity vascular compromise in the setting of MoM total hip implants, in which all patients eventually had improvement or resolution of vascular symptoms after revision to ceramic-on-ceramic (CoC) or CoP total hip components [6–12]. Of note, in the case described by Maurer-Ertl et al [6], the patient was first treated with partial resection of inflamed, necrotic tissue and developed a recurrence of swelling that permanently subsided after revision to CoC THA. In the case series by Cooper et al, all patients were treated with head and liner exchanges, with 2 receiving metal femoral heads and 8 receiving ceramic heads with recurrent instability reported in one patient and a postoperative decrease in serum cobalt levels reported in all 6 patients who had follow-up serum cobalt testing [4]. Of note, the authors did not comment on the outcome of the single patient in their cohort who presented with leg swelling. Although contemporary ceramic heads do carry a small risk of fracture, to our knowledge, there have been no reports of ceramic head fracture in cases of revision for MACC and ALTRs. Given the evidence that revision surgery can be curative, we recommend that revision with head and liner exchange to ceramic implants should be strongly considered cases, where an ALTR has resulted in vascular compromise.

Two other concepts deserve mention. Increased offset has been one factor linked to elevated serum Co, and by association MACC [34]. Although we did not have the offset specifications of the stem initially implanted, radiographic measurements (including radiographic magnification normalization) show that the original surgery increased the patient's offset by 2 mm compared with the arthritic preoperative radiograph. Also, the acetabular placement at the original surgery was at approximately 59 degrees of abduction, which is out of the so-called "Lewinnek safe zone" [35]. Experimental research has shown that forces may be abnormal with high acetabular abduction, even in MoP constructs [36,37]. This could have altered the frictional torque and theoretically transferred stress to the head-neck junction, initiating MACC [38]. These are both theoretical concerns and by no means conclusive as to the patient's failure.

Treatment of the patient's greater saphenous vein thrombus and DVT prophylaxis postoperatively deserves discussion. The patient was sent to our office by a vascular surgeon. He, the patient, and her medical doctor had decided not to treat the superficial vein thrombus with pharmacological blood thinner. There remains controversy for treatment of this presentation of superficial thrombus in an elderly

patient without thrombophilia, but with mechanical compression [39]. From an orthopaedic viewpoint, we followed this decision but recommended compression stockings and twice-daily leg elevation preoperatively and postoperatively for 6 weeks. Removing the source of the compression was paramount, and once this was addressed at surgery, we followed our usual protocol for DVT prophylaxis: 81-mg aspirin, twice daily for 6 weeks.

Summary

MACC may produce metallic-ion and fretting debris in modular MoP hip implants, which can lead to an ALTR as previously seen in MoM total hip prostheses. Although pain and stiffness are common presenting symptoms, an ALTR may also lead to lower extremity vascular compromise through direct compression and/or venous thrombus formation. Here we describe the case of a 79-year-old female who presented with unilateral lower extremity edema documented by imaging to be directly caused by an ALTR, which is, to our knowledge, the first case of its kind to be documented in a patient with an MoP hip implant. The possibility of an ALTR should be considered in any patient presenting with lower extremity swelling who has previously undergone THA, and the clinician should consider the use of diagnostic imaging such as MARS MRI in conjunction with inflammatory markers and serum or synovial Co and Cr metal-ion levels to aid diagnosis and expedite management with revision surgery.

Conflict of interest

The authors declare there are no conflicts of interest.

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