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A case example and literature review of catastrophic wear before catastrophic failure: identification of trunnionosis and metallosis in metal-on-polyethylene hip arthroplasty prior to frank failure or fracture

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Abstract
Though rare, there are documented failures of femoral prosthesis due to corrosion of the head–neck interface in total hip arthroplasty (THA), a phenomenon known as trunnionosis. This wear can result in metallosis, whereby metal debris scatters the surrounding soft tissues. We present on a 58-year-old female who presented with increase in hip and back pain 10 years following right THA using a metal-on-polyethylene construct with a large femoral head (44 mm). Aspiration withdrew metallic fluid, and intraoperative findings showed corrosion of the head–neck taper with surrounding metallosis and pseudocapsule formation. Despite advances in THA design, corrosion and wear between components still exists and may be cause for failure. We present on both the subtle clinical findings and the recommended workup when suspicion is high for trunnionosis, metallosis, or wear, ideally with identification prior to catastrophic failure such as component dislocation or fracture as previously reported.

Keywords Arthroplasty · Metallosis · Metal-on-polyethylene · Metal-on-metal · Trunnionosis

Introduction

In total hip arthroplasty (THA), there are documented failures of femoral prosthesis due to corrosion of head–neck interface, a phenomenon known as trunnionosis, and resulting metallosis, whereby metal debris scatters the surrounding soft tissues; however, the frequency is still rare [1, 2]. More specifically, tribocorrosion or material degradation due to the combined effect of corrosion and wear creates debris from cobalt alloy components and has been shown to cause symptomatic adverse local tissue reactions (ALTRs) in up to 4.9% in patients with a primary THA [3–5]. These cases are more commonly seen in metal-on-metal (MoM) bearings, in modular head–neck designs, and in large femoral head size (over 36 mm) [6, 7]. ALTR has been well documented with MoM bearings; however, it can also occur in metal-on-polyethylene (MoP) arthroplasty designs secondary to corrosion at the femoral head–neck junction with a very similar clinical presentation [8].

We report on a patient with MoP-bearing total hip arthroplasty who presented with vague hip and back pain and subtle radiographic changes that ultimately led to the diagnosis of trunnionosis and surrounding ALTR due to surrounding metallosis. The patient's nonspecific symptoms and equivocal physical examination findings could have easily been missed with the potential to overlook what was ultimately found to be catastrophic wear at the head–neck junction of her femoral prosthesis without evidence of occult fracture or dislocation as previously reported in the literature [1, 2, 9, 10].

The purpose of this case report is to review the literature related to trunnionosis and document the presentation, workup, and findings in order to help in the diagnosis of future patients with early presentation on the clinical continuum of trunnionosis with subsequent ALTR secondary to metallosis seen even in those with MoP THA without the classic findings of frank dislocation of the head–neck junction or fracture as a means for failure.

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Case report

A 58-year-old Caucasian female with past medical history of osteoarthritis, osteoporosis, tobacco use, degenerative lumbar scoliosis and previous diagnosis of bilateral hip avascular necrosis, now with bilateral THA as well as posterior spinal instrumentation, who presented with acute on chronic back pain and bilateral hip pain.

On review of previous medical records, the patient's right THA was performed in 2007 at an outside hospital, more than 10 years prior to her clinical presentation for hip pain. Operative reports detailed the use of Stryker Howmedica Osteonics Trident PSL acetabular shell with a 44-mm polyethylene insert, secured with two cancellous bone screws. On the femoral side, Stryker Accolade TMZF (titanium, molybdenum, zirconium, and fluoride) size #4 hip stem was used and paired with a −4 V40 44-mm femoral head, creating a MoP construct with an exceptionally large femoral head size.

On physical examination, she endorsed right hip and groin pain, as well as back pain with an associated 2.5-cm leg length discrepancy, in which the right leg was longer than the left. She had pain with range of motion of the hip, primarily to the groin. Range of motion to the hip was reported in flexion (100°), abduction (40°), adduction (30°), external rotation (40°), and internally rotation (30°), with full motor strength and full sensation to both lower extremities.

Radiograph imaging of the right hip and pelvis showed interval heterotopic ossification along proximal femur as well as asymmetric wear of the femoral stem at the head–neck junction when comparing her radiographs from 2 years prior (Figs. 1, 2). There was no evidence of surrounding implant lucency or obvious hardware failure.

Imaging findings as well as the patient's clinical increase in pain prompted a differential of infection, polyethylene wear, and/or metallosis given the large femoral head size.

Laboratory evaluation revealed an elevation of inflammatory markers with a C-reactive protein (CRP) of 24 mg/l and an erythrocyte sedimentation rate (ESR) of 41 mm/h. Due to an elevation in inflammatory markers, serum cobalt and chromium ion measurements were deferred and instead a right hip aspiration was performed with fluoroscopic guidance, obtaining 3 cc of thick, black fluid, concerning for metallosis.

The imaging and aspirate results were discussed with the patient. Serum metal ions were not collected, as it was not felt that these values would change management. Collectively, the metallic aspirate, clinical symptoms of pain, and radiographic findings of wear suggested the need for revision arthroplasty. After risks, benefits, and alternative

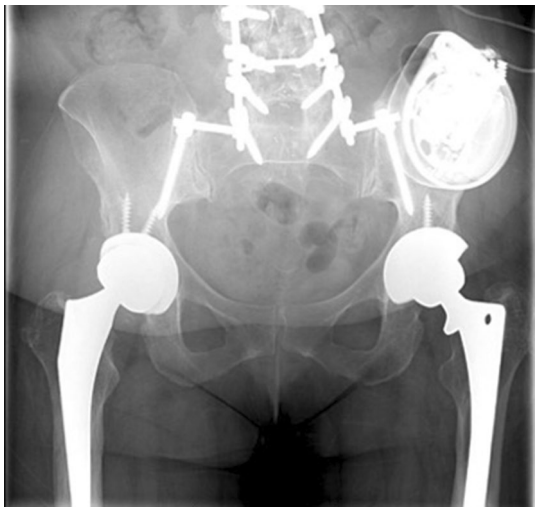

Fig. 1 Anteroposterior (AP) radiograph of the pelvis from 2015, without evidence of wear or heterotopic ossification (HO)

to surgery were discussed at length, she elected to undergo right THA revision with acetabular liner exchange, as well as complete femoral head and stem removal and replacement.

On the date of surgery, her previous posterior approach incision was utilized, readily granting access to the right hip implant. On direct visualization of the implant, there was evidence of ALTR with extensive metallosis and pseudocapsule formation with dark metal debris scattering the soft tissue, surrounded by a dark, black fluid collection (Fig. 3).

There was obvious corrosion of the head–neck taper junction (Fig. 4) with the head freely floating over the stem. There was no obvious bony erosion or loosening of the femoral stem or acetabular cup. Samples of the surrounding soft tissue and the associated periprosthetic pseudocapsule were excised and sent for histopathological examination. Joint fluid was also obtained and sent to the hematology and microbiology laboratory for evaluation.

Given the patient's previous multi-level lumbosacral fusion, a modular dual-mobility liner and restoration stem was utilized (Fig. 5). The wound was irrigated and closed primarily. The patient tolerated the procedure well and was subsequently admitted to the hospital postoperatively for pain control, routine antibiotics, and physical therapy. She discharged home on postoperative day three and subsequently began home health therapy for rehabilitation.

Final histopathological assessment resulted as fibroconnective tissue with necrosis as well as dense black pigment and foreign body deposition consistent with metallosis (Fig. 6). There was no evidence of acute inflammation that suggested infection on pathologic examination.

One of the postoperative cultures is tested positive for rare Corynebacterium at 72 h. After consultation with the

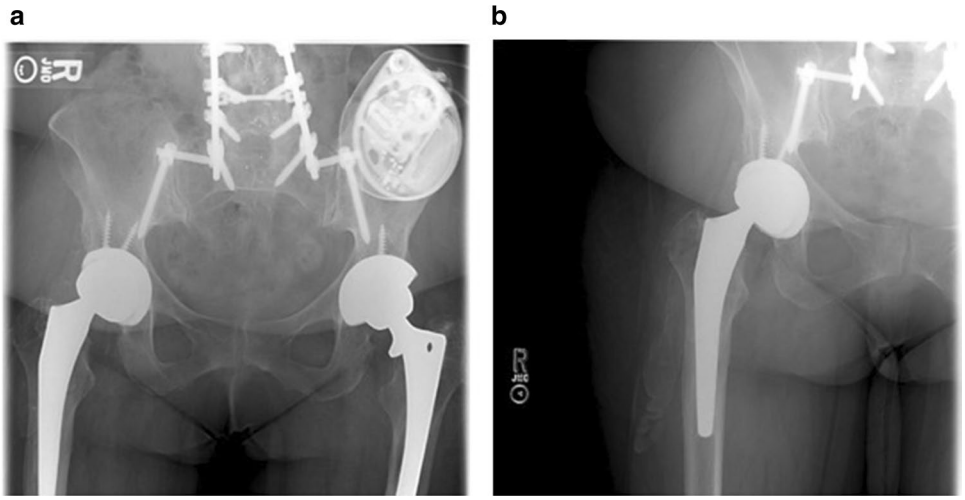

Fig. 2 **a**, **b** Anteroposterior (AP) radiograph of the pelvis (**a**) and right hip (**b**) from 2017 with evidence of heterotopic bone formation around the femoral stem and femoral neck of the arthroplasty components

Fig. 3 Intraoperative gross examination of the failed arthroplasty with surrounding soft-tissue metallosis

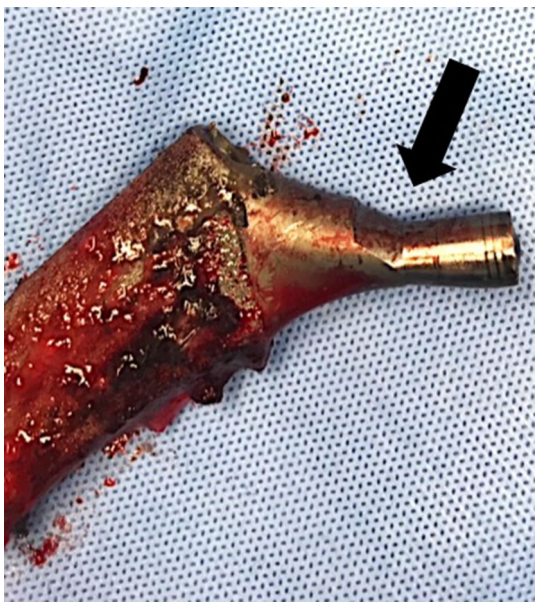

Fig. 4 Explanted femoral stem demonstrating corrosion at the head–neck taper junction

infectious disease specialists, additional 16S rRNA gene sequence for bacterial identification was sent for analysis and molecular testing was negative for bacteria. Intraoperative findings and pathology specimens were consistent with metallosis, without evidence of obvious infection. As a result, the culture results were deemed a contaminant and the final diagnosis of metallosis with pseudocapsule formation and heterotopic ossification secondary to corrosion of the head–neck taper junction was made.

The patient returned for her planned two-week, six-week, and twelve-week postoperative visits. Her incisions were found to be well healed. Her right hip pain improved significantly from baseline.

Discussion

THA is a great surgical success story in the field of orthopedic surgery, restoring mobility and function, boasting a 96% rate of postsurgical satisfaction [11]. However, there are also reports of catastrophic failures due to material flaws inherent to arthroplasty design [7].

Taper corrosion is documented even in the early beginnings of modular THA systems. The first case was reported in 1988 when taper corrosion created a soft-tissue pseudotumor in a MoM bearing [12]. Classically these ALTRs are documented in modular head–neck designs, in

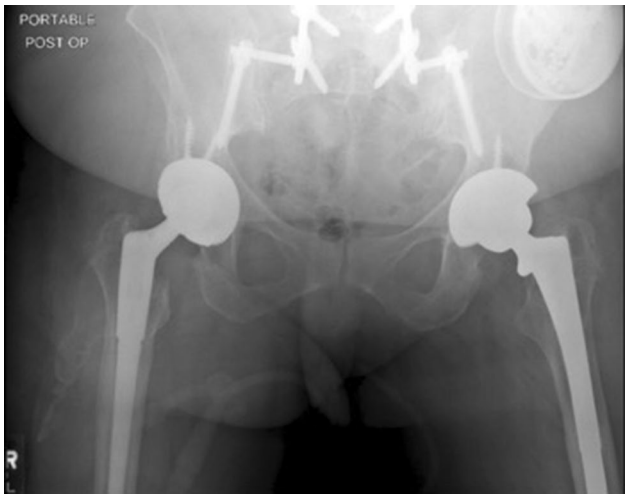

Fig. 5 Anteroposterior (AP) postoperative radiograph of the pelvis illustrating new right hip modular dual-mobility liner and restoration stem placement

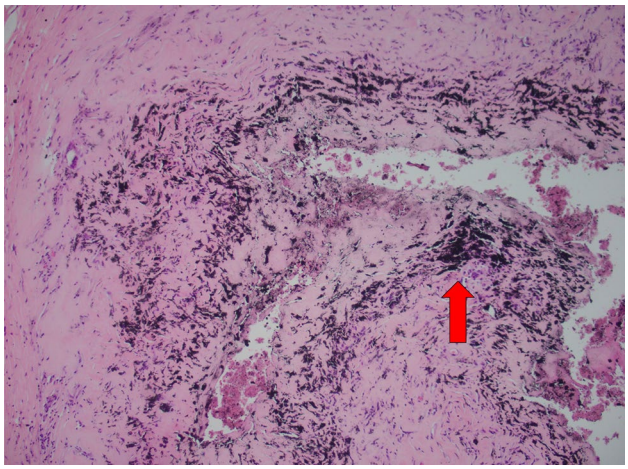

Fig. 6 Photomicrograph shows fibroconnective tissue with necrosis and dense black pigment/foreign body deposition consistent with metallosis (red arrow). Hematoxylin and eosin (H&E) stain, original magnification ×100 (color figure online)

large femoral head size (≥ 36 mm), and in MoM designs, prompting a flurry of litigation and a heavy focus on arthroplasty design fundamentals [6–8].

There are multiple factors that can contribute to the corrosion of an arthroplasty implant. Morlock and others theorize that there are two prerequisites for corrosion: relative motion between components and the presence of fluid. Fluid is always present around the hip joint and creates a lubricated environment for direct contact between metal implants. Additionally, small motions from an imperfect fit of the implant head and neck will cause degeneration from both the surface friction and any allowing fluid to seep into the small crevices as these two surfaces wear on one another.

Goldberg et al. [13] discussed flexural rigidity of the neck as a predictor for fretting and mechanically assisted crevice corrosion. He illustrated the role of mechanically assisted crevice corrosion on fretting and corrosion of modular hip tapers and demonstrated loads required to initiate fretting were below loads produced by walking. This study suggested that once conditions for crevice corrosion were established, corrosion can continue in the absence of loading. In addition, the increase in nationwide obesity rates and a larger implant head diameter size may only further the potential for early and extensive wear in arthroplasty patients.

Implant design has been implicated as a primary variable in arthroplasty wear, namely head length ≥ 2 mm, smaller taper diameter, larger head sizes (> 36 mm), varus stems, higher offset stems, and head material [5]. Variability in surface morphology (smooth or rough) has so far been inconclusive. Specifically, for this implant, TMZF (titanium, molybdenum, zirconium, and fluoride) is an alloy with a low modulus of elasticity, thereby potentially contributing to extensive trunnion wear. This prompted a product recall secondary to wear concerns and subsequent litigation.

In the current literature, metallosis and trunnionosis have been well documented in MoM THA implants. We are increasingly seeing similar cases in MoP implants as well [14]. Mechanically assisted crevice corrosion (MACC) in MoP THA is reported to be as high as 3.2%, though no identifiable demographic, clinical, or radiographic differences were found to predict those that would develop MACC [5].

Matsen Ko et al. [9] reported on five cases at a single institution in which the femoral head became dissociated from the femoral stem trunnion due to severe corrosion and ultimately thought secondary to multiple factors: BMI of ≥ 30 kg/m^2, male sex, and corrosion resulting from the use of a larger metal head with a neck length of greater than the default and a stem with high offset. Fokter et al. [15] sought to understand why titanium alloy arthroplasties with a modular neck failed and concluded at a high body weight and a longer femoral neck may put patients at an increased risk for catastrophic failure, suggesting that surgeons avoid using long necks, whenever possible.

Early identification of MACC and subsequent ALTR is important, as time from onset to revision theoretically causes worsening tissue damage and may be overlooked as a pain source in the postoperative period [8]. The clinical presentation can at times be confusing—ranging along the continuum of vague pain, progressive weakness or numbness due to femoral nerve compression [16] or dramatic alteration in weightbearing with frank fracture or failure, and everywhere between [1, 2, 9, 10].

Recommendations for workup of this suspected diagnosis include: radiographs, complete blood count, ESR, CRP, as well as blood metal ion level assessment and/or direct synovial assessment via joint aspiration. Metal artifact reduction

sequence (MARS) magnetic resonance imaging (MRI) may also be a helpful tool in assessing soft-tissue changes [5].

The present study is an illustration of how a MoP failure due to MACC leading to trunnionosis and surrounding ALTR may present with subtle clinical and radiograph findings, with catastrophic wear preceding catastrophic failure illustrated by clear head–neck dissociation as previously reported [1, 2, 9, 10]. A heightened sense of awareness is necessary when assessing patients with persistent hip pain after THA, as this higher level of suspicion may be of advantage in diagnosing trunnionosis and metallosis in hip replacement patients earlier, prior to frank failure, dislocation, or fracture seen in advanced wear patterns.

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Compliance with ethical standards

Conflict of interest The authors whose names are listed immediately below certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements) or non-financial interest (such as personal or professional relationships, affiliations, knowledge, or beliefs) in the subject matter or materials discussed in this manuscript.

Statement of informed consent Each author certifies that his or her institution approved the reporting of this case report, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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