A Review of Orthopedic Implant Failures due to Metallosis and the Methods Utilized to Minimize and Address this Condition

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ABSTRACT

Background: Metallosis is a common cause of adverse reactions to total joint arthroplasties that result in a complicated revisional procedure and a lengthy recovery process. Through the progression of both procedures and prosthetics, the incidence of metallosis as a cause for total joint failure has markedly decreased. The prevalence of metal on metal joints has become less common, however even with the discontinuation of metal-on-metal implants, metallosis still occurs due to complications of modern OTS (on-the-shelf) implants.

Method: Through the review of 18 research articles regarding metallosis and total joint arthroplasty prosthetics. Three studies highlighted the incidence of metallosis in joints excluding total knees and total hips, 3 studies reviewing metallosis in total joint failures, 3 studies on adverse reactions to total joint replacements, 2 studies on diagnostic findings/complications, and 7 studies on the future of total joint procedures. Further results were reviewed within discussion with current Orthopedic surgeons.

Results: Some studies attributed total joint failures to either an attributed infection only, metallosis only, or specific allergic reactions to metals causing adverse reaction. In addition, a few recognized gender specific/custom total knee replacements as a possible direction for future improvements in prosthetics, to not only reduce cost, but also outcomes. Due to the strides that have already been made in the field of orthopedics and arthroplasty, metallosis has become rare complication. With the current research being done, it is of the opinion that it is soon to become obsolete.

Conclusion: Although metallosis incidence overall is decreasing because fewer metal on metal implants are being inserted, metallosis is still an issue in non-metal implants due to the suggested increase in wear, leading to loosening prosthetics or improperly placed prosthetic pieces. The studies above highlight many reasons for why metallosis still occurs but there still lacks a body of sound and conclusive evidence as to why. This indicates the necessity for more studies to better illuminate the risk factors that can be directly traced to total joint procedures.

BACKGROUND

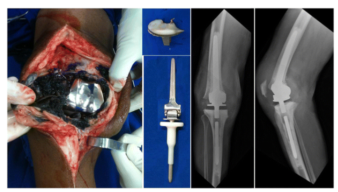
Total joint replacements are a new procedure and with progress comes a steep learning curve. The first metallic total hip replacement was in 1940, and the first total knee arthroplasty was 1968. Both were metal on metal replacements that lead to high incidence of adverse reactions to the metal particles released by wear. These particles activate local inflammatory reactions and systemic absorption of metallic particles (7). This will induce release of osteolytic cytokines causing necrosis, fibrosis, and other structural changes in regional lymph nodes, liver, and spleen. While metallosis is rare and generally associated with metal-on-metal prosthetic devices, it has also been seen in other non-metallic prosthetics. Since the introduction of polyethylene and ceramic materials into the production of prosthetic parts, the incidence of metallosis has dramatically decreased. However, it did not completely remove the possibility. The metal debris from metal-on-metal contact can occur from failure of the non-metal pieces, improper implantation, or dislodgement of the articular component (7). Adverse reactions to metal debris (ARMD) is a rare cause of hip arthroplasty failure (0.6%), it is separated into 3 stages- Aseptic Lymphocyte-dominated Vasculitis-Associated Lesion (ALVAL), metallosis, and finally pseudotumor. ALVAL is a type IV hypersensitivity reaction with lymphocytic infiltrate, localized bleeding, and necrosis. This immunologic response is not limited to the type of metal used in the implants. Chromium, cobalt, and titanium have all been implicated as culprits of causing inflammatory cascades leading to metallosis (7). Many of the patient present with signs and symptoms including but not limited to pain, intermittent fever, malaise, decreased ROM, swelling, and "red-colored urine". The presentation of metallosis has shown to be fairly general and nonspecific. However it has been conclusive that there is currently no non-surgical intervention available for the treatment of metallosis.

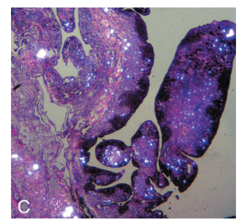
OBJECTIVES

- Review the progress of total joint arthroplasty procedures
- Review the attributed causes to total joint arthroplasty failure
- Define Metallosis and the origin of this condition following total joint arthroplasty
- Diagnose Metallosis in a clinical environment

CASE PRESENTATION

- **Upon review of the limited case study from VCOM-Auburn anatomy dissections, there was necessity for further exploration of material regarding the pathology and presentation of Metallosis. Below is the presented case via case study:**
- Case 16-0006- 98 yo Caucasian female-- L knee
- Gross description: the finding is examined in-situ with accompanying photographs submitted in this report. Grossly there is a left knee implant which appears to be firmly in place and is without apparent functional defect. The surrounding tissue revealed a dark "ink-like" appearing soft material. A small irregular section of the discolored soft tissue of the implant is submitted for microscopic evaluation.
Cassette A: irregular dark soft tissue
Microscopic description: the histology revealed multiple variable sized fragments of polyethylene flakes likely surrounded by foreign body giant cells.
- Final diagnosis: the gross appearance of the in-situ findings, as well as the sectional histologic presentation of the surrounding synovial tissue is most consistent and essentially a classic representation of metallosis. Metallosis is indicative of the presence of metal particles in the surrounding soft tissue around a prosthetic implant resulting from failure due to wear and tear. Minute metallic fragments accumulate in histiocytes and synovial cells and may be transported to regional lymph nodes. The metal particles liberated from prosthetic joint are essentially inert, typically only stimulating low grade inflammation with little clinical significance. Of note, there is no apparent gross evidence of the presence of acute infection. In my opinion this case is a classic example of prosthetic implant metallosis.
    - Dr. David J. Stephen





- **Due to the case being limited, not having any previous clinic visits, studies, blood work, or diagnostic films while the patient was alive, it is difficult to recreate a full picture of a classic metallosis presentation. Through review of many studies regarding cases of metallosis, an accurate depiction of a classic case of metallosis may be surmised as follows:**
- **Patient presentation:** Depending on the joint that is affected there will be different specific locations of pain, but the trend of generalized pain, instability (the joint tends to "give way"), and generalized swelling or a mass (8,9,10). There have also been more severe cases that present similarly to an infection with malaise, intermittent fever, and red urine(7). Advanced metallosis can present as pseudotumor which is an inflammatory aseptic cystic or solid mass close to the joint and can lead to prosthesis malfunctioning . These pseudotumors may have villi comparable to bowel mucosa with the core being fibrinous material and pigmented histiocytes.(2) In many instances the presentation can be nonspecific, therefore warranting regular imaging and fluid aspiration.
- **Diagnostic imaging/labs:** The aspirate from the total joint will reveal a dark black fluid that is enough information to diagnose metallosis(2), the black liquid color is due to the presence of metal components (7,10). Blood work from the patient should be evaluated. Metal ion indicators over 7ppb (the threshold value for cobalt and chromium) should warrant suspicion of early metallosis(2,10). CRP and SED rate are usually not elevated (unlike infection) due to long term inflammation from metal debris(6,7). Urine analysis may present with increased levels of metal ions.
- From plain imaging, the 'cloud sign' (amorphous densities in the periprosthetic tissues) and bubble sign (hyperdense rounded images with metal deposits around the exterior) may be present, would be a strong indicator of metallosis (2,7,13). CT is preferred to XR due to the ability to find high density material outlining the joint capsule or bursa (6,13). The imaging modality of choice is the Metal Artefact Reduction Sequence of MRI (MARS-MRI), it can reliably diagnose and confirm the extent of metallosis and osteolysis (7,10,13).
- **Histology:** The findings would present with a spectrum of necrotic and inflammatory tissue in response to depositions from cobalt-chromium prosthetics(6). Metallic staining of the localized tissue will be present, the extent of which is dependent on the degree of metallic wear debris. There is profound macrophage response to the debris with foreign body giant cells showing numerous black intracellular particles(10). The slides would present with a dark tissue color in the periprosthetic region, filled with giant foreign body cells of metallic shavings.

METHODS

Through the review of 18 research articles regarding metallosis and total joint arthroplasty prosthetics. Three studies highlighted the incidence of metallosis in joints excluding total knees and total hips, 3 studies reviewing metallosis in total joint failures, 3 studies on adverse reactions to total joint replacements, 2 studies on diagnostic findings/complications, and 7 studies on the future of total joint procedures. Further results were reviewed within discussion with current Orthopedic surgeons.

RESULTS

Some studies attributed total joint failures to either an attributed infection only, metallosis only, or specific allergic reactions to metals causing adverse reaction. In addition, a few recognized gender specific/custom total knee replacements as a possible direction for future improvements in prosthetics, to not only reduce cost, but also outcomes. Due to the strides that have already been made in the field of orthopedics and arthroplasty, metallosis has become rare complication. With the current research being done, it is of the opinion that it is soon to become obsolete.

CONCLUSIONS

Metallosis is a complication of total joint replacement procedures from improper placement of prosthetics, increased wear and tear, injury following total joint procedure. Some of the recent successes in decreasing the incidence of this complication can be attributed to improvements in polyethylene technology in the last decade, especially the absence of polyethylene sterilized by gamma radiation in the air (9,13). The improvement in technique of each procedure can also result in decreased risk of metallosis in the total joint, example would be the anterior approach for total hip arthroplasties or the use of the MAKO robot for total knee arthroplasties. It also needs to be acknowledged that prosthetic advancements has not removed incidence of metallosis as there are still instances through which metal debris accumulates. However, as total joint procedures continue to evolve, become more specific to the individual, and techniques improves metallosis incidence will continue to fall.

It is apparent that loosening of prosthetics, improper placement of implants, metal on metal total joints, and accidental injury following a total joint procedure are leading factors with high correlation to occurrence of metallosis. Further experimentation and case review regarding the causation of metallosis could allow for a more conclusive study. Though the diverse reaction to the presence of metallic flakes is commonly attributed to the patient having a metal hypersensitivity, there are insufficient studies comparing the presence of metallosis to the patient having metal allergies. In the future, a further topic to review would be revision total replacements following joint failure and their success rates/recovery with previous metallosis.

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21. https://link.springer.com/article/10.1007/s00256-014-1860-3 - image 1

- http://ispub.com/IJPA/4/2/10194 -image 2