J Shoulder Elbow Surg (2020) 29, 296–301

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

The effect of patient-reported metal allergies on the outcomes of shoulder arthroplasty

Justin C. Kennon, MD, Julia Lee, MD, Chad Songy, MD, Dave Shukla, MD, Robert H. Cofield, MD, Joaquin Sanchez-Sotelo, MD, PhD, John W. Sperling, MD*

Department of Orthopedic Surgery, Mayo Clinic, Rochester, MN, USA

Background: Although literature exists regarding hip and knee arthroplasty outcomes in patients with skin allergy to metals, there is minimal information about skin allergy implications on shoulder arthroplasty outcomes. The purpose of this study was to determine the results, complications, and failure rate among patients with a self-reported metal allergy undergoing shoulder arthroplasty.

Methods: Fifty-two shoulder arthroplasties were performed at our Institution in 43 patients with self-reported metal allergies. Forty primary and 12 revision shoulder arthroplasties were performed using anatomic (30) and reverse (22) components. Retrospective chart review was performed to determine metal allergy history, implant composition, pain, motion, and complications. Radiographs were reviewed to determine mechanical failure rates. Average follow-up time was 65 months.

Results: Allergies reported included nickel (37), cobalt chrome (4), copper (2), zinc (1), titanium (1), gold (1), and nonspecific metal allergy (8); 8 patients reported multiple metal allergies. All components implanted in patients with nickel allergies contained nickel. At most recent follow-up, pain was rated as none or mild in 88% of shoulders. Active elevation improved from 80° to 141° and external rotation from 24° to 52°. Two revisions were performed for glenoid loosening (3.8%); both were revision cases with substantial glenoid bone loss. One patient with mild pain had a radiographically loose glenoid component 12 years after anatomic shoulder arthroplasty.

Conclusion: Results from this study suggest that shoulder arthroplasty in patients with self-reported metal allergy provides satisfactory pain relief and improved range of motion with low revision rates.

Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Metal allergy; shoulder arthroplasty; aseptic loosening; nickel allergy; metal hypersensitivity

The effects of metal allergy on functional outcomes and implant survivorship in the setting of joint reconstruction remain unclear in orthopedic literature. Knee and hip arthroplasty literature has previously reported on the results of arthroplasty in the setting of metal allergy or hypersensitivity. In contrast, there is a paucity of literature investigating the impact that metal allergy has on the outcomes of shoulder arthroplasty.

Patient-reported metal allergy prevalence in the general population ranges from 15% to 40%, with a higher prevalence in the female population.[9,15] Nickel allergy is the most commonly reported, presumably because of its

Approval for this study was received from the Mayo Clinic Institutional Review Board (no. 16-006966).

*Reprint requests: John W. Sperling, MD, Department of Orthopedic Surgery, Mayo Clinic, 200 1st St SW, Rochester, MN 55905, USA.

E-mail address: sperling.john@mayo.edu (J.W. Sperling).

1058-2746/$ - see front matter © 2019 Published by Elsevier Inc. on behalf of Journal of Shoulder and Elbow Surgery Board of Trustees.
https://doi.org/10.1016/j.jse.2019.06.006

presence in jewelry more commonly worn by females.[8] In an arthroplasty-specific population, the self-reported metal allergy incidence is 1.7%-7%.[18,21] Literature also suggests evidence of immunologic sensitization to metals after hardware implantation with an increased number of positive patch tests after metal hardware implantation.[1,10,11,21] However, the clinical implication of metal sensitization after knee and hip arthroplasty is unclear as there is limited evidence correlating cutaneous metal sensitivity to implant failure.[11,17] Self-reported metal allergies have also been associated with lower functional and mental health scores after lower extremity arthroplasty.[12,13,18,19] Patients with metal allergies have previously shown incremental improvements in satisfaction and mental component scores following lower extremity arthroplasty, but these improvements were incrementally less profound than their non–metal allergy cohort.[18,19] Revision rates for total knee arthroplasty due to metal sensitivity range from 1.3% to 1.8% and up to 5.9% in total hip arthroplasty. In previous studies, preoperatively reported metal allergy did not yield an increased risk of implant failure, but those who underwent revision did have a higher prevalence of metal allergies.[17]

To our knowledge, there are no published studies with adequate follow-up investigating shoulder arthroplasty results in the setting of self-reported metal allergy. In light of the dearth of literature on the topic, the purpose of this study was to determine the results, complications, and rate of failure among patients with a self-reported metal allergy undergoing shoulder arthroplasty.

Materials and methods

Following Institutional Review Board approval, a retrospective review was conducted of patients undergoing 3252 shoulder arthroplasties between January 2006 and April 2015 performed at a single institution. Patients aged >18 years undergoing shoulder arthroplasty with at least 1 self-reported metal allergy and a minimum 2-year follow-up (mean 5.4 years, range 2-15.2 years) were included in the study. All surgeries were performed by 6 reconstructive shoulder surgeons.

There were 43 patients with at least 1 self-reported metal allergy who underwent 52 shoulder arthroplasties. Allergies reported included nickel (37), cobalt chrome (4), copper (2), gold (2), zinc (1), titanium (1), and a nonspecific metal allergy (8); 8 patients reported multiple metal allergies. Despite the high percentage of reported nickel allergies, all of the implants used in patients with reported nickel allergies contained some percentage of nickel. There were 33 female and 10 male patients with an average age of 70.4 years at the time of surgery and mean follow-up of 65 months (range, 24-182 months). There were 7 patients with diabetes mellitus and 18 with current or historic tobacco use. There were 26 anatomic shoulder arthroplasties, 22 reverse shoulder arthroplasties, and 4 hemiarthroplasties performed. Of the 52 shoulder arthroplasties, 12 shoulders had at least 1 previous surgery with a metal implant prior to presentation; 5 of these had subsequent infections. Patient characteristics are summarized in Table I.

Table I Demographics of study patients with shoulder arthroplasty and self-reported metal allergy

Characteristics	Number
Sex	
Male	10
Female	33
Age at surgery, yr, mean (range)	70.4 (52-87)
Diabetes	7
Tobacco	
Yes/former	18
No	34
BMI, mean (range)	32 (17-50)
Previous surgery with metal shoulder implant	12
Reason for arthroplasty	
Osteoarthritis	29
Rotator cuff arthropathy	12
Avascular necrosis	4
Other	4
Rheumatoid arthritis	2
Fracture	1
Implant	
Biomet	26
Smith & Nephew	13
DePuy	10
Stryker	3
Shoulder arthroplasty type	
Anatomic total shoulder	26
Reverse total shoulder	22
Hemiarthroplasty	4
Self-reported allergies*	
Nickel	37
Cobalt	4
Chromium	4
Copper	2
Gold	2
Zinc	1
Titanium	1
Nonspecific metal allergy	8
Patch test (n = 13)*	
Nickel	12
Cobalt	2
Chromium	1
Nonreactive	1

* More than a single allergy reported.

Implants used in this study included Smith and Nephew Cofield 2 Shoulder Arthroplasty (Smith & Nephew, Memphis, TN, USA), Biomet Comprehensive Total Shoulder Arthroplasty (Zimmer-Biomet, Warsaw, IN, USA), DePuy Delta XTEND Shoulder Arthroplasty (Johnson & Johnson, Warsaw, IN, USA), DePuy Global Shoulder Arthroplasty (Johnson & Johnson), and Stryker ReUnion Shoulder Arthroplasty (Stryker Corporation, Kalamazoo, MI, USA). Details on their metallic composition are listed in Table II. One patient had a ceramic head placed because of metal allergies, although the stem of the particular implant was made of cobalt chrome, which contained a percentage of nickel. Implant design selection among anatomic shoulder arthroplasty,

Table II Implant composition characteristics by manufacturer in shoulder arthroplasty patients with self-reported metal allergy

Implant	Glenoid	Glenosphere/ baseplate	Humeral tray/bearing	Humeral head	Humeral stem
Biomet Comprehensive Total Shoulder	Ultra-high-molecular-weight polyethylene Tantalum Titanium alloy 316 LVM stainless steel CoCrMo alloy Screws—titanium alloy	Titanium alloy: baseplate CoCrMo alloy: glenosphere	Titanium alloy: tray Ultra-high-molecular-weight polyethylene	CoCrMo alloy	Titanium alloy (Ti-6Al-4V)
Smith & Nephew Cofield 2 Total Shoulder System	Ultra-high-molecular-weight polyethylene ± Ti-6A1-4V metal back	n/a	n/a	CoCr	CoCr
DePuy Delta XTEND	Ultra-high-molecular-weight polyethylene Screws—titanium	CoCr	Ultra-high-molecular-weight polyethylene		CoCr monobloc stem and epiphysis Titanium modular stem with HA coating
DePuy Global Advantage	Ultra-high-molecular-weight polyethylene Screws—titanium	CoCr	Ultra-high-molecular-weight polyethylene	CoCrMo alloy	Titanium alloy (Ti-6Al-4V)
Stryker ReUnion Shoulder Arthroplasty System	Ultra-high-molecular-weight polyethylene Peripheral and center screws—wrought CoCr	Wrought CoCr: humeral cup/ glenosphere CP-Ti: baseplate with coating	Ultra-high-molecular-weight polyethylene	ASTM F-1537 CoCr alloy	Titanium alloy (Ti-6Al-4V-ELI)

hemiarthroplasty, and reverse shoulder arthroplasty was not impacted by the presence or absence of self-reported metal allergy.

In our retrospective chart review, we evaluated pain scores and range of motion pre- and postoperatively as well as arthroplasty implant composition. We examined complication and reoperation rates for all patients. Radiographs were reviewed to evaluate for the presence of radiolucent lines and gross implant loosening.

Statistical analysis was performed and reported on our patient data in standard fashion. Patients were asked to quantify their pain score preoperatively and postoperatively with a visual analog scale pain score (0 none, 1-3 mild, 4-7 moderate, 8-10 severe) or to simply categorize their pain by those same descriptors. A Student paired *t* test was used to determine statistical significance in pre- and postoperative range of motion and pain scores. The alpha level was set at 0.05 for statistical significance.

Results

The incidence of self-reported metal allergy was 1.6% in this shoulder arthroplasty–specific population.

Clinical outcomes—pain and range of motion

After surgery, active forward elevation improved from a mean of 80° to 141° ($P < .001$). Active external rotation improved from a mean of 24°-52° ($P < .001$). Active internal rotation improved from mostly lumbosacral to mostly lumbar. Pain scores decreased from 96% moderate-severe preoperatively to 88% none-mild at the most recent follow-up ($P < .001$).

Radiographs

Of the 52 shoulder arthroplasties in this study, average radiographic follow-up time was 56 months (range, 3-185 months). One patient was lost to radiographic follow-up after 3 months.

Radiographically, there were 5 patients with <1-mm incomplete lucent lines at the glenoid interface and 2 patients with similar <1-mm incomplete lucent lines on the humeral side. One patient had a 1.5-mm incomplete lucent line on the glenoid side. One patient had a loose glenoid component 12 years after anatomic shoulder arthroplasty with mild pain, not requiring reoperation. There were 2 loose glenoid components in reverse shoulder arthroplasty patients, both of which were revision cases at our institution for failed anatomic shoulder arthroplasty done elsewhere. Both of these glenoid loosening patients had significant uncontained glenoid defects at the time of reverse arthroplasty implantation.

Complications and reoperations

Our reoperation rate was 3.8% (2/52), and the overall complication rate was 9.6% (5/52). Two patients had acromial fractures treated nonoperatively. We had 1 patient with glenoid loosening and mild pain, not requiring revision at 12 years. There were 2 reoperations for loose glenoid components in reverse shoulder arthroplasties, 1 was post-traumatic and 1 insidious. Both revision cases were initial salvage procedures with uncontained glenoid defects and poor bone stock at the time of salvage to reverse arthroplasty at our institution. After glenoid failure, both were revised to hemiarthroplasties with no further complications.

Skin patch testing subset

A subset of 13 shoulders underwent skin patch testing with 12 nickel-, 1 chromium-, and 2 cobalt-reactive patch tests. One patient reported a nickel and chromium allergy, but skin patch testing was negative. In this subset of skin patch testing patients, active forward elevation improved from a mean of 84° to 146° ($P < .001$). Mean active external rotation improved from 18° to 59° ($P < .001$). Mean active internal rotation improved from mostly lumbosacral to mostly lumbar. Pain scores decreased from 100% moderate-severe preoperatively to 92% none-mild at the most recent follow-up ($P < .001$). When comparing the 2 groups of skin patch testing vs. non–skin patch testing, the range of motion and pain scores postoperatively showed no significant difference (active elevation $P = .61$, active external rotation $P = .37$, pain scores $P = .09$). There were no reoperations in the skin patch subset. There was a single complication in this group, a mildly painful shoulder with radiographic evidence of glenoid loosening at 12 years.

Discussion

This study reports on the outcomes of 52 shoulder arthroplasty patients with self-reported and/or patch-test confirmed metal allergies. Clinical outcomes and reoperation rates at a single institution suggest that shoulder arthroplasty implants can be safely placed in patients with self-reported metal allergies. Moreover, this investigation shows significant and reliable improvements in range of motion and pain relief without significant radiographic evidence of loosening. This experience reports an acceptable rate of clinical complications in the setting of self-reported metal allergy.

The incidence of self-reported metal allergy in this study was 1.6%, slightly lower than the 1.7%-14% reported in the literature.[4,18] Self-reported allergies may actually be underestimated, as Nam et al showed a 2.3% increase in metal allergy reporting after introduction of a metal allergy–specific question on preoperative questionnaires.[18]

Similar to previous studies, nickel allergy was the most commonly reported in our shoulder arthroplasty patient population.[8] Previous studies have reported that the validity of self-reported metal allergies, specifically nickel allergy, is low, with an overestimation of the true prevalence of nickel allergy and low validity of self-reported information on metal dermatitis.[9,15] This is likely a fair claim based on previous studies and could certainly be possible in our reported patient population.

Skin patch testing is the gold standard for determining metal hypersensitivity and recommended for patients with a history of dermatitis prior to metallic implantation.[22] However, studies have also shown no correlation between positive skin patch test results and outcomes in orthopedic arthroplasty surgery.[5,11,23,25] Moreover, there is poor correlation between self-reported allergy and skin patch results, with only 30% of patients with a self-reported nickel allergy having a positive skin patch test.[15] Furthermore, it may not be feasible to send all patients with a self-reported metal hypersensitivity to the dermatologist or allergist for a comprehensive evaluation before implantation. Alternatively, it would be beneficial to have more reliable and consistent methods to document and report metal hypersensitivity in patients undergoing reconstructive orthopedic procedures. Numerous blood tests are commercially available that are designed to detect immune cell responses to different metals; however, in this study, no immune cell response blood work was routinely obtained nor did it impact our decision-making or recommendation when patients presented for consultation with previously performed immune cell response bloodwork.

In the small subpopulation of our patients with positive skin patch testing, there were no significant differences in range of motion, pain relief, or radiographic outcomes compared to the group with self-reported allergies.

With respect to clinical outcomes, all of the patients had improvements in range of motion and pain relief after shoulder arthroplasty. These outcomes are reported without significant radiographic or clinical complications. This is in agreement with other arthroplasty studies, which have shown no increased complications in patients with metal allergies who have undergone hip or knee replacements with standard implants.[17,24] Even in patients with patch test–positive metal allergies, Carlsson and Theinpont both report no complications or symptoms associated with use of standard metallic implants.[7,6,23]

In this cohort of patients, one patient underwent a hypoallergenic shoulder arthroplasty with a ceramic humeral head and all-polyethylene glenoid. The stemmed component was composed of cobalt chrome, which includes a percentage of nickel. Previous studies have looked at outcomes of metallic components vs. hypoallergenic components with pre- and postoperative

patch testing showing no difference in range of motion, patient-reported outcome scores, and metal ion concentrations.[2,3,14,16,20]

This study highlights the need for better diagnostic tools for metal hypersensitivity, reliable consistency in documentation of allergies, and improved understanding of the effects of cutaneous hypersensitivity on deep implants.

Limitations

This study has several limitations. First, self-reported metal allergies are subject to recall bias. A chart review may not accurately reflect the patients' true allergies, and recollection of allergies may not be complete without prompting. The metal allergy incidence in this study, however, is similar to that of an unprompted arthroplasty-specific population. Second, the patient population and surgeon preference are widely varied, with different surgeons, diagnoses, indications for surgery, and surgical implant type. This may mask specific nuances within an arthroplasty population but also shows that, in general, there were no gross complication patterns seen with shoulder arthroplasty and metal allergy. Additionally, only 13 of the 52 arthroplasties had their metal allergies confirmed with a skin patch test, one of which resulted in a negative test. Although this is gold standard, the utility of this cutaneous test to determine reactions to a deep metallic implant have yet to be determined.

Conclusion

Results from this study suggest that shoulder arthroplasty in the setting of self-reported metal allergy offers satisfactory pain relief and improved range of motion with a low revision rate. Optimized diagnostic techniques are needed to better diagnose and understand the implications of metal allergy in the setting of shoulder arthroplasty.

Disclaimer

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Basko-Plluska JL, Thyssen JP, Schalock PC. Cutaneous and systemic hypersensitivity reactions to metallic implants. Dermatitis 2011;22:65-79.
2. Bergschmidt P, Bader R, Ganzer D, Hauzeur C, Lohmann C, Ruther W, et al. Ceramic femoral components in total knee arthroplasty—two year follow-up results of an international prospective multi-centre study. Open Orthop J 2012;6:172-8. https://doi.org/10.2174/1874325001206010172
3. Bergschmidt P, Bader R, Kluess D, Zietz C, Schwemmer B, Kundt G, et al. Total knee replacement system with a ceramic femoral component versus two traditional metallic designs: a prospective short-term study. J Orthop Surg (Hong Kong) 2013;21:294-9. https://doi.org/10.1177/230949901302100306
4. Bloemke AD, Clarke HD. Prevalence of self-reported metal allergy in patients undergoing primary total knee arthroplasty. J Knee Surg 2015;28:243-6. https://doi.org/10.1055/s-0034-1381959
5. Bravo D, Wagner ER, Larson DR, Davis MP, Pagnano MW, Sierra RJ. No increased risk of knee arthroplasty failure in patients with positive skin patch testing for metal hypersensitivity: a matched cohort study. J Arthroplasty 2016;31:1717-21. https://doi.org/10.1016/j.arth.2016.01.024
6. Carlsson AS, Magnusson B, Moller H. Metal sensitivity in patients with metal-to-plastic total hip arthroplasties. Acta Orthop Scand 1980;51:57-62.
7. Carlsson A, Moller H. Implantation of orthopaedic devices in patients with metal allergy. Acta Derm Venereol 1989;69:62-6.
8. Faschingbauer M, Renner L, Boettner F. Allergy in total knee replacement. Does it exist? Review article. HSS J 2017;13:12-9. https://doi.org/10.1007/s11420-016-9514-8
9. Fors R, Persson M, Bergstrom E, Stenlund H, Stymne B, Stenberg B. Nickel allergy—prevalence in a population of Swedish youths from patch test and questionnaire data. Contact Dermatitis 2008;58:80-7. https://doi.org/10.1111/j.1600-0536.2007.01257.x
10. Frigerio E, Pigatto PD, Guzzi G, Altomare G. Metal sensitivity in patients with orthopaedic implants: a prospective study. Contact Dermatitis 2011;64:273-9. https://doi.org/10.1111/j.1600-0536.2011.01886.x
11. Granchi D, Ciapetti G, Stea S, Cavedagna D, Bettini N, Bianco T, et al. Evaluation of several immunological parameters in patients with aseptic loosening of hip arthroplasty. Chir Organi Mov 1995;80:399-408.
12. Graves CM, Otero JE, Gao Y, Goetz DD, Willenborg MD, Callaghan JJ. Patient reported allergies are a risk factor for poor outcomes in total hip and knee arthroplasty. J Arthroplasty 2014;29:147-9. https://doi.org/10.1016/j.arth.2014.02.040
13. Hinarejos P, Ferrer T, Leal J, Torres-Claramunt R, Sanchez-Soler J, Monllau JC. Patient-reported allergies cause inferior outcomes after total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 2016;24:3242-6. https://doi.org/10.1007/s00167-015-3837-8
14. Hofer JK, Ezzet KA. A minimum 5-year follow-up of an oxidized zirconium femoral prosthesis used for total knee arthroplasty. Knee 2014;21:168-71. https://doi.org/10.1016/j.knee.2013.08.015
15. Josefson A, Farm G, Meding B. Validity of self-reported nickel allergy. Contact Dermatitis 2010;62:289-93. https://doi.org/10.1111/j.1600-0536.2010.01702.x
16. Lutzner J, Hartmann A, Dinnebier G, Spornraft-Ragaller P, Hamann C, Kirschner S. Metal hypersensitivity and metal ion levels in patients with coated or uncoated total knee arthroplasty: a randomised controlled study. Int Orthop 2013;37:1925-31. https://doi.org/10.1007/s00264-013-2010-6
17. Munch HJ, Jacobsen SS, Olesen JT, Menne T, Soballe K, Johansen JD, et al. The association between metal allergy, total knee arthroplasty, and revision: study based on the Danish Knee Arthroplasty Register. Acta Orthop 2015;86:378-83. https://doi.org/10.3109/17453674.2014.999614
18. Nam D, Li K, Riegler V, Barrack RL. Patient-reported metal allergy: a risk factor for poor outcomes after total joint arthroplasty? J Arthroplasty 2016;31:1910-5. https://doi.org/10.1016/j.arth.2016.02.016
19. Otero JE, Graves CM, Gao Y, Olson TS, Dickinson CC, Chalus RJ, et al. Patient-reported allergies predict worse outcomes after hip and

knee arthroplasty: results from a prospective cohort study. J Arthroplasty 2016;31:2746-9. https://doi.org/10.1016/j.arth.2016.07.040
20. Pellengahr C, Mayer W, Maier M, Muller PE, Schulz C, Durr HR, et al. Resurfacing knee arthroplasty in patients with allergic sensitivity to metals. Arch Orthop Trauma Surg 2003;123:139-43. https://doi.org/10.1007/s00402-002-0429-0
21. Rau C, Thomas P, Thomsen M. Metal sensitivity in patients with joint replacement arthroplasties before and after surgery. Orthopade 2008; 37:102-10. https://doi.org/10.1007/s00132-007-1186-0
22. Schalock PC, Menne T, Johansen JD, Taylor JS, Maibach HI, Liden C, et al. Hypersensitivity reactions to metallic implants—diagnostic algorithm and suggested patch test series for clinical use. Contact Dermatitis 2012;66:4-19. https://doi.org/10.1111/j.1600-0536.2011.01971.x
23. Thienpont E, Berger Y. No allergic reaction after TKA in a chrome-cobalt-nickel-sensitive patient: case report and review of the literature. Knee Surg Sports Traumatol Arthrosc 2013;21:636-40. https://doi.org/10.1007/s00167-012-2000-z
24. Thyssen JP, Jakobsen SS, Engkilde K, Johansen JD, Soballe K, Menne T. The association between metal allergy, total hip arthroplasty, and revision. Acta Orthop 2009;80:646-52. https://doi.org/10.3109/17453670903487008
25. Webley M, Kates A, Snaith ML. Metal sensitivity in patients with a hinge arthroplasty of the knee. Ann Rheum Dis 1978;37:373-5.