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A 5-Year Cost-Effectiveness Analysis of Silicone Metacarpophalangeal Arthroplasty in Patients with Rheumatoid Arthritis

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Abstract

Background—There is a paucity of research evaluating the cost-effectiveness of surgical interventions for rheumatoid arthritis (RA) patients. Previous reports have challenged the sustainability of improved outcomes after silicone metacarpophalangeal arthroplasty (SMPA). The objective of this study is to conduct an economic evaluation of the long-term health outcomes after SMPA.

Methods—We performed a five-year prospective cohort study of 170 patients with RA (73 surgical, 97 non-surgical). Objective functional measurements and patient-rated outcomes using the Michigan Hand Outcomes Questionnaire (MHQ), and the Arthritis Impact Measurement Scale 2 (AIMS2) were collected at three and five years. A cost-effectiveness analysis using direct costs

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from Medicare outpatient claims data (2006-2010) was performed to estimate the incremental cost-effectiveness ratios (ICERs) for both MHQ and AIMS2 measurements.

Results—At five years, we observed a statistically significant difference in upper extremity outcomes (MHQ) between the two groups, with surgical patients having higher outcomes. The cost associated with improved outcomes five years after surgery was \$787-\$1,150 when measured by MHQ and \$49,843-\$149,530 when measured by AIMS2. We found that the ICERs did not substantially increase with our observed surgical revision rate of 5.5% (approximately 4% increase in ICER) or with previously published long-term revision rates of 6.2% (approximately 6% increase in ICER).

Conclusion—Short term improvements in upper extremity outcomes after SMPA are maintained over the 5 year follow-up period. Given this information, these outcomes are achieved at a relatively low cost, even with the addition of potential surgical complications.

Keywords

Cost-Effectiveness Analysis; Rheumatoid Hand Surgery

The surgical management of hand conditions in rheumatoid arthritis (RA) patients is controversial and highly variable across the geographic United States.¹ Surgeons and rheumatologists differ greatly in their opinions regarding the indications, benefits, and long-term outcomes of rheumatoid hand surgery.²⁻³ Although short-term data studying the outcomes of rheumatoid hand surgery have shown great improvements over the past decade, rigorous outcomes data are lacking, and many physicians and payors remain skeptical regarding the long-term benefits of hand surgery in RA.⁴⁻⁶

Previous retrospective long-term data have challenged the sustainability of improved short-term outcomes after hand surgery in patients with RA.⁷⁻⁸ In 2003, Goldfarb and Stern demonstrated that up to 63% of metacarpophalangeal (MCP) joint implants were fractured at an average of 14 years, and 7% of initial implants required revision.⁷ Similarly, Trail and colleagues (2004) demonstrated that two thirds of implanted silicone metacarpophalangeal joints were fractured on radiographs at 17 years follow-up with 6% requiring revision.⁸ However, these studies were published over ten years ago and included patients who received surgery at least a decade prior to publication.

Since that time, the medical management of rheumatoid arthritis has undergone massive transformation with the widespread use of biologic disease modifying anti-rheumatic drugs (DMARDs) that better target underlying disease pathology to systemically improve patients' overall condition.⁹ Aggressive use of these drugs has improved function, decreased joint destruction, and changed the medical and functional profile of patients undergoing elective hand surgery.⁹ Today, patients with RA are living longer with greater function and higher overall quality of life than patients receiving medical therapy over twenty years ago. As such, patients undergoing elective hand surgery in the current medical environment tend to have better baseline functional profiles and greater expectations regarding post-surgical outcomes than patients who received surgery prior to the widespread use of biologic agents.

Despite their effectiveness, biologic DMARDs are extremely expensive, increasing the average cost of RA care from \$6,164 to \$19,016 per patient annually.¹⁰ However, owing to medical comorbidities, pharmacologic contraindications, and other clinical factors, only 25% of patients are reported to receive biologic therapy.¹⁰ Thus, rheumatologists continue to rely on a combination of medication and surgery to effectively treat RA. Among the current literature, there is a paucity of recent long-term outcomes data for rheumatoid hand surgery patients. Specifically, there have not been any long-term studies that analyze outcomes of rheumatoid hand surgery from the clinical perspective of patients, payors and referring physicians who must decide whether the long-term benefits of rheumatoid hand surgery justify the associated cost and morbidity for their patients. The purpose of this paper is to provide long-term outcomes data and a cost-effectiveness analysis for silicone metacarpophalangeal arthroplasty (SMPA) in RA patients. The intent of this study is not to evaluate the specific implant used, but rather to provide data regarding the effectiveness of implant MCP arthroplasty. We hypothesized that short-term improvement in upper extremity outcomes after SMPA are sustained over five years, and that SMPA is a cost-effective intervention to improve upper extremity outcomes.

Patients and Methods

Study Sample and Outcome Measures

A prospective multi-center study was conducted to evaluate the outcomes of silicone metacarpophalangeal arthroplasty (SMPA) surgery compared to non-surgical treatment in patients with RA. Patients were recruited from three comprehensive upper extremity treatment centers with large multi-disciplinary rheumatology programs: 1) XX, 2) YY, and 3) ZZ. To reduce confounding of our outcomes data and cost-effectiveness ratios, our study did not include patients with extensor tendon ruptures or deformities (e.g., swan-neck, boutonniere) that would require additional procedures.¹⁶ Thus, the surgical cohort for this analysis only contained patients who received SMPA without any additional tendon transfers. All patients received SMPA arthroplasty of the index, middle, ring, and small finger simultaneously. Outcome measures included the Michigan Hand Outcomes Questionnaire (MHQ) and the Arthritis Impact Measurement Scales 2 (AIMS2).¹¹⁻¹³ The MHQ is a hand specific questionnaire, whereas the AIMS2 measures overall health status in RA. Objective functional measurements, including grip strength, lateral key pinch, ulnar drift, extensor lag, finger arc of motion, and Jebsen-Taylor Test, were also collected.¹⁴ Short term outcomes at one and three years after surgery, as well as a detailed description of the study sample and methods have been previously described.¹⁵⁻¹⁶

The distribution of demographic variables and other baseline variables was compared between surgical and nonsurgical groups using the 2-sample t-tests for continuous variables and chi-square tests for categorical variables. Means and standard deviations for all outcomes of interest were calculated for each study group at the one year, three year, and five year follow-up. Random-effects regression models were used to estimate and compare outcome variables between the surgical and nonsurgical groups at baseline and at the five-year follow-up. Adjusted mean differences in outcome between the two groups, correcting for differences in baseline outcomes and demographics, were calculated so that positive

values correspond to greater improvement in the surgical group relative to the nonsurgical group. Statistical significance was set at $p < 0.05$.

General Model Overview

For this study we chose to conduct a cost-effectiveness analysis. Full discussion of the principles and approaches to health care economic analyses is beyond the scope of this paper and has been previously described in detail.¹⁷⁻¹⁹ Briefly, there are four types of economic analyses used to compare alternative technologies and interventions: cost-minimization, cost-benefit, cost-utility, and cost-effectiveness.¹⁷⁻¹⁹ Each method compares the costs and clinical outcomes associated with alternative interventions or procedures, but each uses different approaches to measure the effects. Cost-effectiveness analyses are able to assess varying outcomes (unlike cost-minimization) and avoid the controversy of converting clinical outcomes to dollar values (cost-benefit) or quality-adjusted life-years (cost-utility), because they measure outcomes in naturally occurring health related units.¹⁷⁻²⁰ However, the use of cost-effectiveness analyses is thus limited to comparing interventions or studies with the same measure of outcome (i.e., cost-effectiveness analyses cannot be used to compare interventions with different methods of measuring outcomes).¹⁹⁻²⁰

To direct our analysis, we followed the guidelines of the Panel on Cost-Effectiveness in Health and Medicine developed by the United States Public Health Service in 1993.²¹⁻²² Owing to a lack of reliable and available data for outcomes and cost outside of our population of interest, we were unable to conduct our analysis using a true societal perspective. A true societal perspective theoretically considers everyone affected by the intervention and all health effects and costs that result from the intervention regardless of who experiences them.¹⁹⁻²³ Instead, we conducted our study using the clinical perspective and limited the boundary of our analysis to the costs and health effects directly affecting our population of interest.²²

Healthcare Costs

Consistent with the clinical perspective, we estimated direct costs associated with the following aspects of clinical care for SMPA: surgery, postoperative therapy, radiographs, and biologic medications. To do this, we used national Medicare reimbursement data for each aspect of clinical care. For an estimation of surgical costs, we calculated the average annual total Medicare outpatient claims (2006-2010) associated with SMPA using the procedure code for “arthroplasty, metacarpophalangeal joint; with prosthetic implant, single, each” (26531).²⁴ To adjust for inflation, each year total spending was inflated to 2013 dollar values using the all-items Consumer Price Index prior to calculating the national average.²⁵ To estimate the cost associated with postoperative care, we calculated the Medicare reimbursement rate associated with our standard postoperative physical therapy protocol and radiographic follow-up: orthotic fabrication/re-check x7 (97760), therapeutic exercise x7 (97110), edema management x6 (97140), 3-view wrist X-ray series x3 (73110). Finally, to account for the cost of biologic agents we used Medicare Part D claims to capture the cost of medication and Part B claims to capture the cost of physician fees associated with infusion and injection of biologic agents. Appendix A (see supplemental digital content 1, Appendix A shows costs associated with SMPA, *insert link*) lists all generic and brand name biologic

drugs accounted for in our analysis. Once the reimbursement associated with each drug (medication + administration) was calculated, we applied this cost estimate to the actual percentage of patients using biologic DMARDs in each study cohort to estimate the cost of biologic medication used in each study group (SMPA vs. non-SMPA). These three components (surgery, postoperative care, and biologic medications) were totaled to estimate the average cost for each study group. All expenditures that occurred over multiple years were discounted by 3% to calculate the present dollar values.

Cost-Effectiveness Analysis

To compare the cost-effectiveness of SMPA compared to non-SMPA, we calculated the incremental cost-effectiveness ratio (ICER) of the difference in direct estimated procedure spending (incremental costs) to the difference in measured outcome benefit (incremental effects).²⁶⁻²⁷ The calculation of ICERs currently serve as the most widely accepted methodology for comparing interventions in cost-effectiveness analyses.²⁷ Our costs were estimated as the average 2006-2010 Medicare spending for SMPA and our outcomes were estimated as the adjusted mean difference at five years for each MHQ and AIMS2 domain (Figure 1). Each ICER represents the marginal cost per acquiring an additional unit of outcome measure (MHQ and AIMS2).²⁶⁻²⁷

Sensitivity Analyses

To evaluate the effects of missing data, the costs associated with various complications, and potential differences in observed complication rate, we performed four one-way sensitivity analyses for our ICERs (Figure 1). First, to address the issue of individuals with missing follow-up data at the five year time point, we re-estimated improvement in MHQ and AIMS2 outcome measures (compared with baseline outcome measures) using a model with data imputation for all missing subjects. We used a multiple imputation method to account for missing covariates as well as missing outcomes.²⁸ A detailed description of our imputation methods and results has been previously described.¹⁶ Second, we adjusted our cost estimates by adding the estimated costs of complications requiring surgery that occurred during our five year study period. To determine the cost of complications, we used the five-year national average of Medicare outpatient spending for the procedure codes associated with the observed surgical complication rate that occurred during our study period (5.5%). Finally, to compensate for potential differences in observed complication rate, we performed two more sensitivity analyses adjusting the rate of complication. The first assumed a 6.2% surgical revision rate, the average revision rate of the two largest published long-term series of SMPA in RA patients.⁷⁻⁸ The second assumed a 22% surgical complication rate. This number is based on our own observed subclinical radiographic fracture or severe deformity rate at the five year follow-up time period; none of these patients required a surgical revision, however displayed evidence of implant fracture or severe deformity on X-rays at five years.

Results

A total of 170 subjects (73 surgical and 97 nonsurgical) were enrolled in the study. The one and three year outcomes have been presented previously.¹⁵⁻¹⁶ Owing to withdrawals (n=10),

deaths (n=11), losses to follow-up (n=25), and missing data (n=51), complete five year data were available in 25 surgical (34 %) and 55 nonsurgical (57%) subjects.

Baseline demographic information for the subjects included in our analysis is shown in Table 1. We did not observe any statistically significant differences between the surgical and nonsurgical patients at baseline in terms of age, race, education, and income. However, our nonsurgical group contained more females ($p = 0.02$) and a greater number of our surgical patients reported being disabled at baseline ($p = 0.02$). With regards to missing outcomes data at five years, we did not find any statistically significant difference in demographic variables between those with complete five-year outcomes and those with missing data. However, for nonsurgical patients we found that missing data was significantly associated with more severe baseline symptoms, and for surgical patients we found that missing data was more likely to occur among patients who demonstrated a greater improvement in outcomes.

Table 2 shows the estimated adjusted average outcomes for surgical (SMPA) versus nonsurgical subjects over time and their corresponding differences at five years. To estimate the adjusted mean differences, we accounted for variations in observed baseline outcomes and demographics between the two study cohorts (e.g., surgical subjects had significantly worse hand functioning at baseline compared to nonsurgical subjects). Positive scores in the adjusted mean difference reflect better outcomes in the surgical SMPA group compared to the nonsurgical group at five years, controlling for any observed differences in baseline outcomes. Our results demonstrated that most of the MHQ hand outcome domains among surgical patients significantly improved after surgery and exceeded the nonsurgical cohort at five years. However, overall RA health outcomes as measured by the AIMS2 did not show a statistically significant difference after SMPA in the surgical group. With regards to objective functional measures, we found statistically significant improvement in ulnar drift, extensor lag, and PIP and MCP arc of motion in the surgical cohort after SMPA compared to the non-surgical patients.

Throughout the five-year follow-up period, four of our 73 surgical patients (5.5%) experienced a complication requiring surgical intervention. Two patients experienced implant dislocation and recurrent ulnar drift requiring implant removal and replacement. One patient had an implant infection requiring replacement, and another patient received a PIP fusion after SMPA and experienced an infection of their buried K-wire necessitating removal. Although this event was not related to the SMPA surgery it occurred on a previously operated digit within the study period and was counted as a postoperative complication.

Table 3 demonstrates the results of our cost-effectiveness analysis and additional sensitivity testing. Among RA patients included in our study, we found that the cost associated with improved outcomes five years after hand surgery was between \$977 and \$1,059 when measured by MHQ and between \$42,350 and \$127,050 when measured by AIMS2. This finding is not surprising given that hand surgery is a targeted intervention to improve upper extremity specific outcomes and may not necessarily be effective in improving overall RA outcomes in patients with other systemic factors contributing to their overall quality of life.

Using multiple imputation technique, to account for missing subject data over time, we were able to evaluate the relative cost of improving each MHQ domain. Improvements in work (\$2,541) and pain (\$1,270) were the most costly, followed by function (\$1,155) and ADLs (\$907), followed by satisfaction (\$706) and aesthetics (\$635). Our findings implied that within isolated upper extremity outcomes for RA patients undergoing SMPA, it is most expensive to achieve benefits in work status and pain, followed by function and ADL, followed by aesthetics and satisfaction. Data imputation did not substantially change our ICER estimates for MHQ outcomes (5-19% change). However, for AIMS outcomes, using imputed data resulted in a 25-50% change in ICER.

To evaluate the economic effects of surgical complications, we also calculated the ICERs associated with varying frequencies of surgical complications. We found that the ICERs did not substantially increase with our observed surgical revision rate of 5.5 % (approximately 4% increase in ICER) or previously published long-term revision rates with an average 6.2% (approximately 6% increase in ICER). However, when increasing the surgical revision rate to 22%, the frequency of our subclinical radiographic fractures and severe deformities at five year follow-up, the ICERs increased by approximately 20% for both MHQ and AIMS2 domains. This suggests that the anticipated cost associated with improved outcomes does not increase substantially with the currently observed surgical revision rate but may increase considerably if all fractured or deformed implants observed at five years required surgical revision.

Discussion

Medicare Part D was a landmark legislation that was signed into law as part of the Medicare Prescription Drug Improvement and Modernization Act of 2003. Implemented in 2006, Part D has substantially increased access to many outpatient prescription drugs, including expensive biologic therapies for RA.²⁹ The introduction of biologic agents into the market over the past few decades has greatly improved and transformed the overall care of patients with RA. However, widespread use of these agents has also resulted in a substantial increase in the cost of care.^{10,37} Since the implementation of Part D, literature evaluating the cost-effectiveness of various medical therapies for RA has rapidly expanded and received a considerable amount of political attention.^{10,30-36} A recent study by Michaud and colleagues evaluating 7,527 patients demonstrated that the use of biologic agents has resulted in a three-fold increase in the total annual direct cost of treating RA patients.³⁷ Thus, despite their effectiveness in treating systemic disease, the chronic use of biologic therapies in RA has the potential to substantially exceed the cost of multiple surgical interventions when evaluated over the long-term duration of treatment. Additionally, as patients with RA are living longer with increasing comorbidities, there are several sub-groups of patients who may not be candidates for biologic therapy, such as older patients with compromised auto-immune systems or patients with pharmacologic contraindications or allergies.

To date, there have been no published studies evaluating the cost-effectiveness of surgical interventions in RA. Due to historical reports of high implant fracture and recurrent hand deformity at long-term follow-up, patients, physicians, and payors have remained skeptical of the benefits of hand surgery despite proven improvements in short-term patient-rated

outcomes and satisfaction. The results of this study demonstrate that SMPA resulted in significantly improved patient-rated hand outcomes (MHQ) as well as objective functional upper extremity outcomes (ulnar drift, extensor lag, and PIP/MCP arc of motion) at both three and five years follow-up. However, given that SMPA is a targeted intervention for the hand, it did not significantly improve overall RA outcomes, as measured by AIMS2. We also found that improvements in upper extremity outcomes, as measured by MHQ, were associated with a relatively low cost, even with the addition of observed (5.5%) and previously reported (6.2%) rates of surgical revision. This information may be of particular interest to insurance payors, because it demonstrates that the current clinical rate of surgical revision does not substantially impact the spending required to improve outcomes.

The results of our study should be interpreted with caution, as our methodology has several limitations. Our model was designed to estimate the direct costs and cost-effectiveness of SMPA for patients with RA from the clinical perspective. Owing to a lack of reliable available data, we did not include indirect costs such as lost work productivity. We were able to perform sensitivity analyses to include the impact of additional cost associated with surgical complications. However, due to a lack of available spending data, we were not able to account for complications that did not require surgical intervention in our analysis. Finally, we did not convert our outcomes to a quality-adjusted measure, such as quality adjusted life years (QALYs). This limited our ability to compare SMPA with medical therapy outcomes measured using a different assessment tool (non-AIMS2 or MHQ). Despite the aforementioned study limitations, we believe that our research makes a unique and meaningful contribution to the existing literature.

Under the Patient Protection and Affordable Care Act (ACA), signed into law in 2010, many individuals including those with pre-existing conditions such as RA, will have access to affordable health coverage. Therefore, to determine the best available algorithms for patient care, cost- and comparative-effectiveness analyses have become more paramount than ever. This is even more pronounced in treatment of RA; often depending on age, severity, years of diagnosis, and many other clinical factors, rheumatologists use a combination of medical and surgical treatments to best respond to patient's need.

To our knowledge, this is the first cost-effectiveness analysis to examine surgical interventions for rheumatoid hand surgery. The purpose of this study was not to make definitive long-term conclusions regarding hand surgery outcomes in RA, but rather to provide additional outcomes data and cost-analysis to help inform clinical decision-making and reimbursement policy. Our results indicate that short term improvement in patient rated hand outcomes are sustained over the five year period and that the cost of achieving these improvements in outcome are relatively low, even with the addition of potential surgical complications. This information may be helpful to both clinicians and patients in their shared clinical decision making and understanding of patient expectations. The methodology and results of this paper may also serve as a foundation for researchers aiming to further advance this cost-effectiveness work beyond the clinical hand surgery perspective, incorporating other aspects of RA treatment and outcomes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Cost-Effectiveness and Sensitivity Analyses

Table 1
Patient Demographics

Demographic Variables	SMPA (n=73)	Non-surgical (n=97)	P-value
Age (mean $\pm$ SD)	59.8 $\pm$ 8.2	61.8 $\pm$ 10.5	0.18
Gender (number (%))			
Male	13 (17.8)	33 (34.0)	0.02
Race/Ethnicity (number (%))			
Caucasian	62 (91.2)	81 (86.2)	0.33
Education Level (number (%))			
Less than or equal to high school degree	39 (57.4)	39 (41.5)	0.05
Income Level (number (%)) ^{ψ}			
\$50,000 per year	51 (77.3)	62 (68.9)	0.25
Disability Status ^{γ}			
Report being disabled	19 (27.9)	13 (13.5)	0.02

Eight (5%) of participants are missing race/ethnicity data

^{ψ} Fourteen (8%) of participants are missing income data

^{γ} As reported in the Arthritis Impact Measurement Scale 2 (AIMS2) Questionnaire, question number 43: "What has been your main form of work?"

Table 2

Outcomes for SMPA and Nonsurgical Subjects

	Preoperative ψ		3 Year ψ		5 Year ψ		Adjusted Difference ^{γ}
	SMPA Ω	Nonsurgical	SMPA Ω	Nonsurgical	SMPA Ω	Nonsurgical	
MHQ α	N = 69	N = 95	N = 44	N = 72	N = 25	N = 55	N = 79
Overall	38 (18)	55 (19)	58 (22)	59 (21)	54 (23)	62 (19)	12 (5,19)
Function	38 (23)	57 (19)	60 (20)	57 (21)	54 (23)	61 (19)	13 (5, 21)
ADL*	36 (27)	59 (24)	55 (28)	61 (27)	54 (30)	64 (26)	1 (1, 19)
Work	42 (23)	58 (23)	52 (29)	61 (28)	47 (28)	63 (27)	-3 (-14, 8)
Pain	48 (27)	36 (25)	37 (26)	31 (24)	40 (29)	27 (21)	0 (-11, 10)
Aesthetics	32 (22)	47 (24)	61 (22)	54 (20)	59 (25)	56 (20)	17 (7, 26)
Satisfaction	28 (21)	47 (25)	56 (27)	53 (25)	50 (25)	53 (25)	18 (7,29)
AIMS2 α	N = 69	N = 95	N = 44	N = 72	N = 25	N = 55	N = 111
Physical	3.8 (2.4)	2.5 (1.9)	3.3 (2.3)	2.6 (2.2)	3.5 (2.5)	2.3 (2.0)	- 0.2 (-0.8, 0.5)
Affect	4.1 (1.9)	3.1 (1.8)	3.7 (2.2)	2.7 (1.6)	3.1 (1.6)	2.4 (1.3)	- 0.3 (-0.8, 0.3)
Symptom	5.5 (2.9)	4.3 (2.4)	5.0 (2.2)	4.0 (2.5)	4.6 (2.7)	3.5 (2.5)	-0.2 (-1.0, 1.4)
Social Interaction	4.1 (2.0)	3.6 (1.4)	4.1 (2.1)	3.6 (1.6)	3.6 (1.7)	3.5 (1.4)	-0.1 (-0.6, 0.7)
Objective Measurements α	N = 73	N = 97	N = 41	N = 65	N = 23	N = 45	N = 67
Grip Strength (kg)	5.6 (5.3)	8.8 (7.7)	6.4 (4.4)	9.9 (6.1)	5.8 (5.3)	9.9 (5.5)	-1.5 (-4.0, 1.0)
Key/Lateral Pinch (kg)	3.5 (2.3)	4.1 (1.8)	3.1 (2.1)	3.5 (1.9)	4.1 (6.1)	3.3 (1.6)	-1.8 (-0.4, 4.1)
Jebsen-Taylor Test (sec)	54 (26)	43 (11)	44 (13)	40 (12)	48 (18)	40 (15)	-0.5 (-8.1, 7.1)
Ulnar Drift (°)	37 (15)	35 (15)	14 (11)	35 (17)	18 (15)	32 (14)	19.1 (12.1, 26.2)
Extensor Lag (°)	64 (23)	49 (19)	29 (15)	54 (21)	30 (13)	49 (20)	30.1 (20.6, 39.7)
MCP τ Arc of Motion (°)	20 (16)	36 (19)	31 (14)	28 (16)	32 (14)	30 (18)	11.9 (2.5, 21.4)
PIP θ Arc of Motion (°)	58 (27)	70 (22)	65 (26)	67 (21)	59 (27)	67 (19)	4.0 (-3.6, 11.6)

 ^{ψ} Data presented as mean (standard deviation) ^{Ω} Abbreviation: SMPA = Silicone Metacarpophalangeal Joint Arthroplasty ^{γ} Difference in 5 year outcomes between SMPA and non-surgical group, adjusted for baseline values of the following outcome variables: age, gender, baseline severity stage, education level, income level, study site, use of biologic, and SMPA group indicator. Positive values represent better outcomes in the SMPA group relative to the non-surgical group. Data presented as mean (95% confidence interval)

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Abbreviation: MHQ = Michigan Hand Outcomes Questionnaire

α N-values represent the number of subjects with complete data for each outcome measure at the specified follow-up period

* Abbreviation: ADL = Activities of Daily Living

δ Abbreviation: AIMS2 = Arthritis Impact Measurement Scale 2

τ Abbreviation: MCP = Metacarpophalangeal Joint

θ Abbreviation: PIP = Proximal Interphalangeal Joint

Cost-Effectiveness Analysis

Table 3

	Average Spending ^γ				ICER ^π (c/ E) - MHQ ^Ω				ICER (c/ E) - AIMS ² θ			
	Overall	Function	ADL ^λ	Work	Pain	Aesthetics	Satisfaction	Physical	Affect	Symptom	Social Interaction	
Adjusted change *	\$977	\$977	\$1,059	-	-	\$553	\$669	\$42,350	-	\$24,410	\$127,050	
Adjusted change with data imputation ^φ	\$847	\$1,155	\$907	\$2,541	\$1,270	\$635	\$706	\$63,525	\$15,881	\$18,150	\$63,525	
Adjusted change adding potential complication spending (5.5%) ^ζ	\$906	\$1,236	\$971	\$2,719	\$1,359	\$680	\$755	\$67,973	\$16,993	\$19,421	\$67,973	
Adjusted change adding potential complication spending (6.2%) ^μ	\$905	\$1,234	\$969	\$2,714	\$1,357	\$679	\$754	\$67,852	\$16,963	\$19,386	\$67,852	
Adjusted change adding potential complication spending (22%) ^σ	\$1,052	\$1,434	\$1,127	\$3,155	\$1,578	\$789	\$876	\$78,879	\$19,720	\$22,537	\$78,879	

^π Abbreviations: ICER = Incremental cost-effectiveness ratio; represents the change in cost over the change in respective outcome unit; calculated by dividing the 2013 inflation adjusted 5-year average Medicare spending by the adjusted mean difference in outcome measure (see Table 3)

^γ Average Spending: 5-year average of Medicare outpatient spending (2006-2010) for silicone metacarpophalangeal arthroplasty (SMPA) using CPT code 26531 + cost of postoperative therapy and X-rays – cost of biologic agents (since undergoing surgery resulted in decreased use of biologic therapy)

^Ω Abbreviations: MHQ = Michigan Hand Outcomes Questionnaire

^θ Abbreviations: AIMS2 = Arthritis Impact Measurement Scale 2

^λ Abbreviations: ADL = Activities of Daily Living

* ICERs are calculated by dividing the Average Spending by the 5-year adjusted change (compared with the baseline) in MHQ/AIMS measures for patients who went through the SMPA surgery

^φ Sensitivity analysis adjusting for missing data using multiply imputed data set: ICERs are calculated by dividing the Average Spending by the 5-year adjusted change (compared with the baseline) in MHQ/AIMS measures for patients who went through the SMPA surgery, using the imputed data (N=170)

^ζ Sensitivity analysis including the cost of observed complications (5.5%): ICERs are calculated using a higher cost including the cost of observed surgical complications using the corresponding CPT codes: 20670, 26320, 26531

^μ Sensitivity analysis accounting for a higher surgical complication rate based on previously published data⁷⁻⁸ (6.2%): ICERs calculated using a higher cost including a 6.2% probability of acquiring any potential surgical complication corresponding to the following CPT codes: 20670, 26320, 26531, 26850, 26852, 26010, 26011, 26075

^σ Sensitivity analysis accounting for a higher surgical complication rate based on our observed rate of sub-clinical implant fracture seen on 5-year follow-up radiographs of the hand (22%), assumes that all observed fractures on radiograph will progress toward eventual surgical revision: ICERs calculated using a higher cost including a 6.2% probability of acquiring any potential surgical complication corresponding to the following CPT codes: 20670, 26320, 26531, 26850, 26852, 26010, 26011, 26075