The Incidence of Upper and Lower Extremity Surgery for Rheumatoid Arthritis Among Medicare Beneficiaries

Jennifer Waljee, MD, MS, Lin Zhong, MD, MPH, Onur Baser, MS, PhD, Huseyin Yuce, PhD, MS, David A. Fox, MD, and Kevin C. Chung, MD, MS

Investigation performed at the Departments of Surgery and Internal Medicine, University of Michigan Health System, Ann Arbor, Michigan

Background: For elderly patients with rheumatoid arthritis, aggressive immunosuppression can be difficult to tolerate, and surgery remains an important treatment option for joint pain and deformity. We sought to examine the epidemiology of surgical reconstruction for rheumatoid arthritis among older individuals who were newly diagnosed with the disorder.

Methods: We identified a 5% random sample of Medicare beneficiaries (sixty-six years of age and older) newly diagnosed with rheumatoid arthritis from 2000 to 2005, and followed these patients longitudinally for a mean of 4.6 years. We used univariate analysis to compare the time from the diagnosis of rheumatoid arthritis to the first operation among the 360 patients who underwent surgery during the study period.

Results: In our study cohort, 589 procedures were performed among 360 patients, and 132 patients (37%) underwent multiple procedures. The rate of upper extremity reconstruction was 0.9%, the rate of lower extremity reconstruction was 1.2%, and knee arthroplasty was the most common procedure performed initially (31%) and overall (29%). Upper extremity procedures were performed sooner than lower extremity procedures (fourteen versus twenty-five months; $p = 0.02$). In multivariable analysis, surgery rates declined with age for upper and lower extremity procedures ($p < 0.001$).

Conclusions: Knee replacement remains the most common initial procedure among patients with rheumatoid arthritis. However, upper extremity procedures are performed earlier than lower extremity procedures. Understanding the patient and provider factors that underlie variation in procedure rates can inform future strategies to improve the delivery of care to patients with rheumatoid arthritis.

Level of Evidence: Prognostic Level III. See Instructions for Authors for a complete description of levels of evidence.

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The prevalence of rheumatoid arthritis has risen in recent years, resulting in substantial increases in rheumatoid arthritis-associated disability, cost, and mortality[1-3]. Furthermore, rheumatoid arthritis is increasingly concentrated among elderly individuals, and nearly 50% of patients who are newly diagnosed with rheumatoid arthritis are sixty-five years of age and older[4]. Although there is no cure for rheumatoid arthritis, early treatment with disease-modifying antirheumatic drugs (DMARDs) can slow disease progression and has rapidly become the standard of care for patients with newly diagnosed disease[5].

Unlike young individuals, elderly patients with rheumatoid arthritis are less likely to receive treatment with DMARDs[6,7], are more likely to suffer from multiple comorbid conditions requiring additional medications, and may be more sensitive to drug interactions and polypharmacy[8-10]. Additionally, complications from potent immunosuppressive medications may be more difficult for elderly individuals to tolerate; drug metabolism may

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be markedly different among older individuals[11,12]. Rheumatoid arthritis-related joint and soft-tissue reconstructive procedures can predictably correct deformity, avoid flexion contraction, alleviate pain, and improve function and quality of life[13,14]. Furthermore, surgical reconstruction for the upper extremity can often be performed on an outpatient basis under regional anesthetic, minimizing the physiologic stress of surgery. However, surgery is often considered only in the late stage of rheumatoid arthritis for patients who have developed severe pain, joint destruction, or function loss with failure to respond to pharmaceutical therapy[13,15,16]. Moreover, the patient and provider factors that influence the timing of surgery are not well understood.

Given the aging population in the United States, defining the epidemiology of rheumatoid arthritis-related procedures among elderly patients can identify potential areas of unmet need and systematic differences in treatment. In this context, we examined the incidence of upper and lower extremity procedures performed for rheumatoid arthritis-related deformities among a cohort of Medicare beneficiaries in the United States. Our purpose was to define the timing and rates of upper and lower limb reconstructive procedures performed following the diagnosis of rheumatoid arthritis. We hypothesized that overall rates of upper and lower limb reconstruction decline with age and are significantly associated with sociodemographic factors and regional density of specialists.

Materials and Methods

Data Sources and Creation of the Study Cohort

We analyzed a random 5% longitudinal sample of Medicare beneficiaries diagnosed with rheumatoid arthritis between 2000 and 2005. To identify new cases, we excluded patients with any rheumatoid arthritis-related claims twelve months before their first diagnosis of rheumatoid arthritis after 2000, and this study cohort was followed until the end of 2010. We used Medicare Inpatient, Outpatient, and Carrier claim files to identify rheumatoid arthritis diagnoses and health-care utilization during the study period. These files contain fee-for-service claims data submitted by the inpatient institution, outpatient institution, and physicians. Diagnoses were coded using the International Classification of Diseases, Ninth Revision (ICD-9) codes, and surgical procedures were coded by ICD-9 procedure codes (Medicare Inpatient files) or Current Procedural Terminology (CPT) codes (Medicare Outpatient and Carrier files). We included only patients with greater than two outpatient services with rheumatoid arthritis as the primary diagnosis (ICD-9 codes 714.0, 714.1, 714.2, 714.3, and 714.4), seven to 365 days apart between 2000 and 2005, to increase the reliability of the rheumatoid arthritis diagnosis. Patients entered the study cohort on the date of first rheumatoid arthritis diagnosis if they were without any rheumatoid arthritis-related claims in the prior twelve months, and stayed in the cohort until death or disenrollment from Medicare.

We used the Medicare Beneficiary Summary file to capture demographic and enrollment information of patients. Our cohort only included patients with rheumatoid arthritis who were sixty-six years or older on entry into the study and were continuously enrolled in Medicare Parts A and B for at least twelve months before the first diagnosis of rheumatoid arthritis during the study period. Patients younger than sixty-six years enrolled in Medicare for other indications were specifically excluded. We excluded all of the patients who were Health Maintenance Organization (Part C) enrollees at any time during the study period because of the lack of their Part-B data in the Centers for Medicare & Medicaid Services (CMS).

TABLE I Characteristics of Medicare Beneficiaries Diagnosed with Rheumatoid Arthritis in 2000 to 2005

Characteristic	No. of Patients (N = 18,037)
Age (yr)	
66-69	3468 (19%)
70-74	4544 (25%)
75-79	4449 (25%)
≥80	5576 (31%)
Sex	
Male	4390 (24%)
Female	13,647 (76%)
Race	
White	15,327 (85%)
Black	1655 (9%)
Other	1055 (6%)
Socioeconomic status	
Low	4643 (26%)
Middle	4914 (27%)
High	8480 (47%)
Elixhauser comorbidity score quartile	
1 (<5)	5030 (28%)
2 (5-12)	5436 (30%)
3 (13-21)	4142 (23%)
4 (>21)	3429 (19%)
Location of residence	
Metropolitan area	14,650 (81%)
Nonmetropolitan area	3387 (19%)
State assistance for Medicare premium	
No	16,233 (90%)
Yes	1804 (10%)
Density of rheumatologists where patient resided (per 1 million population)	
<10	6891 (38%)
10-15	7975 (44%)
>15	3171 (18%)
Density of orthopaedic surgeons where patient resided (per 1 million population)	
<58	5495 (30%)
58-68	5861 (32%)
>68	6681 (37%)

Measures

Outcome Variables

We followed patients until December 31, 2010, to determine the rate of rheumatoid arthritis-related reconstructive surgery of the upper and lower extremities. The time from diagnosis to surgery was measured for each patient in years. We calculated the rate of surgery as the probability of undergoing surgery within the study period. The ICD-9 procedure codes and CPT codes used to identify each procedure are listed in a table in the Appendix. Upper extremity procedures included arthroplasty of the shoulder, elbow, wrist, and hand; arthrodesis of the hand and wrist; synovectomy of the shoulder, elbow,

TABLE II Number of Upper and Lower Extremity Procedures Performed During the First Operation for Rheumatoid Arthritis After Diagnosis and During the Study Period

Procedure*	Initial Procedures Performed Following Diagnosis, (N = 452)	Total No. of Procedures During the Study Period (N = 589)
Hand		
Tendon reconstruction and/or muscle release	38 (8%)	50 (8%)
Synovectomy	37 (8%)	42 (7%)
MCP, IP, or CMC arthroplasty	44 (10%)	65 (11%)
MCP, IP, or CMC arthrodesis	21 (5%)	32 (5%)
Wrist		
Synovectomy, arthrodesis, or arthroplasty	34 (8%)	46 (8%)
Elbow		
Arthroplasty or synovectomy	18 (4%)	23 (4%)
Shoulder		
Arthroplasty or synovectomy	25 (6%)	37 (6%)
Knee		
Arthroplasty	138 (31%)	171 (29%)
Hip		
Arthroplasty	70 (15%)	90 (15%)
Ankle and foot		
Arthrodesis, arthroplasty, or synovectomy	27 (6%)	33 (6%)

*MCP = metacarpophalangeal, IP = interphalangeal, and CMC = carpometacarpal.

wrist, and hand; and tendon repair, transfer, and tenolysis for the hand and fingers. Lower extremity procedures included arthroplasty of the hip and knee and arthrodesis, arthroplasty, and synovectomy of the ankle and foot. To identify joint and soft-tissue reconstructive surgical procedures performed for the management of rheumatoid arthritis, we only used claims with CPT codes for these procedures coded under a principal diagnosis of rheumatoid arthritis in the claims, indicating that the procedure performed was related to rheumatoid arthritis.

Patient and Provider Characteristics

We obtained baseline patient characteristics for each study subject. Age was categorized in the following groups: sixty-six to sixty-nine, seventy to seventy-four, seventy-five to seventy-nine, and eighty years and older. Race was defined as white, black, and other. Socioeconomic status was estimated from the residence zip code of the beneficiaries and the income, education, and occupation summary of the U.S. zip codes from the 2000 U.S. Census[17]. We calculated the score for comorbidities on the basis of the Elixhauser comorbidity index as an indicator of overall health condition[18,19].

To examine regional differences, we included the density of rheumatologists and of orthopaedic surgeons. To do this, we obtained the hospital referral region where each subject resided by linking their residence zip code to the *Dartmouth Atlas of Health Care* hospital referral region level data[20]. We then linked hospital referral region identifiers to the *Dartmouth Atlas* physician capacity data for the density of specialists (rheumatologists and orthopaedic surgeons) in the region of each subject's residence (the number of specialists per one million residents in the region). Finally, we included residence location, categorized as metropolitan areas versus nonmetropolitan or rural areas, into the analysis to help control for potential differences in rheumatoid arthritis care introduced by geographic variation. We did this by linking the residence zip code of each study subject to the Federal Information Processing Standards codes in the 2013 U.S. Department of Agriculture Rural-Urban Continuum Codes for Metro and Nonmetro counties[21].

Statistical Analysis

We performed univariate analysis of the data on patients undergoing rheumatoid arthritis-related surgery to assess the effect of patient and regional factors on the timing of surgery. We used the median time interval from diagnosis to surgery by patient characteristics rather than the mean time interval because of the outliers in each patient group. We specifically used the Kruskal-Wallis test, which is a nonparametric test that does not assume normal distribution and can be used in the comparison of medians[22].

To examine the factors that influence the probability of undergoing rheumatoid arthritis-related surgery among patients newly diagnosed with rheumatoid arthritis, we used survival analysis to determine receipt of initial surgery and the time to event. Patients who did not have any operation for rheumatoid arthritis were censored. We performed multivariable analyses examining the risk of receiving rheumatoid arthritis-related upper extremity surgery and lower extremity surgery, using a Cox proportional-hazards model with patient sociodemographics, comorbidity score, and density of rheumatologists and orthopaedic surgeons in the residence area as covariates to control for these factors simultaneously. Significance was set at an alpha level of 0.05.

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Results

We identified 18,037 patients who were newly diagnosed with rheumatoid arthritis between 2000 and 2005 (Table I). Patients were followed for a total of 82,767 person-years, with a mean follow-up time (and standard deviation) of 4.6 ± 2.6 years per patient. In our study cohort, age was approximately evenly

TABLE III Univariate Analysis of the Median Time Interval from the Diagnosis of Rheumatoid Arthritis to the First Extremity Surgery for Rheumatoid Arthritis Management

Patient and Provider Characteristics	Upper Extremity Surgery			Lower Extremity Surgery		
	No. of Patients	Median Time *(mo)*	P Value	No. of Patients	Median Time *(mo)*	P Value
Total	158	14	—	215	25	0.02
Age (yr)			<0.001			<0.001
66-69	56	31		73	37	
70-74	39	24		74	26	
75-79	44	11		45	17	
≥80	19	1		23	13	
Sex			0.95			0.79
Male	30	9		43	23	
Female	128	14		172	25	
Socioeconomic status			0.24			0.17
Low	38	29		47	13	
Middle	35	12		64	30	
High	74	11		97	24	
Missing data	11	—		7	—	
Elixhauser comorbidity score quartile			0.04			0.01
1 (<5)	62	24		77	29	
2 (5-12)	45	12		69	26	
3 (13-21)	35	11		43	23	
4 (>21)	16	2		26	8	
Location of residence			0.87			0.42
Metropolitan area	114	18		152	26	
Nonmetropolitan area	44	10		63	21	
State assistance for Medicare premium			0.01			0.46
No	146	20		199	25	
Yes	12	2		16	18	
Density of rheumatologists (per million residents)			0.96			0.49
<10	78	14		105	28	
10-15	63	11		79	21	
>15	17	23		31	23	
Density of orthopaedic surgeons (per million residents)			0.81			0.73
<58	41	15		54	21	
58-68	42	18		89	25	
>68	75	10		72	27	

distributed among each category. The majority of the subjects were female (76%) and white (85%). Comorbid conditions were categorized using the Elixhauser method to account for the number and severity of illnesses, which were then divided into even quartiles. Regionally, 81% of the patients resided in metropolitan areas.

We captured 295 rheumatoid arthritis-related upper extremity surgeries (158 patients) and 294 lower extremity surgeries (215 patients). In our cohort, 589 procedures were performed in 360 patients, and 132 patients (37%) underwent multiple procedures. Thirteen patients had both upper extremity and lower extremity procedures. The average rates of upper and lower extremity surgery performed after a diagnosis of rheumatoid arthritis were thirty-four and thirty-six procedures per 10,000 patients per year, respectively (Table II). Among those procedures, 77% were performed during the initial rheumatoid arthritis-related operation and 23% were performed after the initial operation during the follow-up. The most common initial procedure performed was total or partial knee replacement (31%), followed by hip replacement (15%), hand arthroplasty (10%), and tendon reconstruction and/or muscle release in the hand (8%). Among hand procedures, the most commonly performed was metacarpophalangeal arthroplasty (16%), followed by metacarpophalangeal joint synovectomy (13%) and

arthrodesis of the interphalangeal joint (11%). Repair or transfer of flexor or extensor tendons comprised 15% of all hand procedures. Overall, the rate of upper extremity reconstruction was 0.9% and the rate of lower extremity reconstruction was 1.2%.

In our cohort, upper extremity procedures were performed sooner than lower extremity procedures (fourteen versus twenty-five months; $p = 0.02$). Among the patients who had at least one procedure for rheumatoid arthritis, older patients underwent surgery sooner than younger patients. For example, the median time between the diagnosis of rheumatoid arthritis and having upper extremity surgery was thirty-one months for sixty-six to sixty-nine-year-old patients and only one month for patients who were eighty years of age or older ($p < 0.001$). A greater number of comorbidities was associated with earlier upper ($p = 0.04$) and lower extremity surgery ($p = 0.01$). Finally, patients who received state assistance for their Medicare premium underwent the first upper extremity surgery earlier than did patients who did not require assistance (two months versus twenty months; $p = 0.01$) (Table III).

The multivariable analysis of factors that influenced the probability of receiving rheumatoid arthritis-related surgery during the study period is given in a table in the Appendix. Patients who were eighty years of age or older were less likely to undergo upper extremity surgery (hazard ratio [HR], 0.28; 95% confidence interval [CI]: 0.16 to 0.49) than were patients who were sixty-six to sixty-nine years old. Black patients were less likely to receive upper extremity surgery than were white patients (HR, 0.24; 95% CI: 0.07 to 0.76). Regional factors were also associated with the timing and probability of surgery. Patients who resided in regions with the greatest density of rheumatologists were less likely to undergo upper extremity surgery than were patients who lived in regions with the fewest rheumatologists (HR, 0.51; 95% CI: 0.29 to 0.89). Conversely, a higher density of orthopaedic surgeons was associated with a higher probability of receiving surgery after diagnosis (HR, 1.62; 95% CI: 1.07 to 2.47). For lower extremity surgery, patients at least eighty years of age had a lower probability of surgery (HR, 0.25; 95% CI: 0.16 to 0.41). Furthermore, patients who lived in a nonmetropolitan area had a lower rate of surgery per unit of time compared with metropolitan residents (HR, 0.67; 95% CI: 0.48 to 0.94). Finally, patients who received assistance from the state for the monthly Medicare premium had a higher probability of undergoing lower extremity surgery after the diagnosis of rheumatoid arthritis than patients who did not receive assistance (HR, 1.88, 95% CI: 1.09 to 3.23).

Discussion

In this study of Medicare beneficiaries newly diagnosed with rheumatoid arthritis, approximately 2% of the individuals underwent upper and/or lower extremity reconstruction. The majority of patients underwent surgery within three years following diagnosis, and the most common initial rheumatoid arthritis-related reconstructive surgery was knee arthroplasty (31%). Rates of surgery declined with advancing age, even after controlling for comorbid conditions and sociodemographic factors. Upper extremity procedures were performed sooner than lower extremity procedures and were influenced by the regional density of specialists.

In our cohort, rates of surgery were low, consistent with prior studies that have demonstrated the declining rate of surgical intervention for rheumatoid arthritis-related joint deformities[23-28]. Although advances in medical treatment could explain these phenomena, this may not be true for older individuals. In our study, older individuals remained less likely to receive surgery, and elderly individuals are less likely than younger individuals to have access to outpatient clinic care for rheumatologic complaints[24,29,30]. Additionally, we found that the patients eighty years of age or older who did undergo surgery had the surgery much sooner after diagnosis than did younger patients. This trend may suggest that patients who are diagnosed later in life may either have a delay in diagnosis or have a more aggressive course[31-33]. It is possible that elderly individuals may rely on hand function, strength, and dexterity to maintain independence with activities of daily living and self-care. They may be more sensitive to declines in range of motion or pain than are younger individuals and may seek surgical intervention earlier to preserve mobility and function[34,35]. Therefore, early diagnosis of rheumatoid arthritis may improve patient outcomes because of the early initiation of medication and rehabilitation therapy.

Our study has several notable limitations. First, our findings were drawn from Medicare claims, which may be subject to coding errors inherent in administrative data. For example, it is not feasible to apply clinical guidelines, such as the American College of Rheumatology criteria, to identify newly diagnosed cases in Medicare claims data because of the lack of available clinical outcomes, laboratory findings, and self-reported symptom measures. However, a recent study comparing the reliability of diagnosis identification between office records and Medicare claims revealed a 90% correlation between these two data sources[36]. Medicare data have been widely used to examine treatment patterns, and they provide robust data owing to large, population-based samples. Compared with clinical trials or observational registries that are biased toward tertiary care centers, CMS claims data reflect real-world clinical practice[36-38]. Another limitation of our study is that, as a result of using Medicare claims data for outpatient services, we were unable to capture medication use during the study period, which may influence surgical rates. Ample evidence shows that the use of DMARDs, especially a combination of DMARDs, is effective in retarding disease progression, including joint destruction[39-42]. However, given the period from which our study cohort was drawn, we were unable to adequately determine the use of DMARDs among older patients with rheumatoid arthritis because of variation in prescription medication coverage. Although we adjusted for provider density, future studies examining the effect of medication regimens on surgical rates are warranted. Additionally, we do not have information regarding disease severity or the indications for specific surgical procedures. Although administrative data lack this granularity, future studies that incorporate patient-reported outcome and detailed clinical data may provide insight into the nuances of surgical rates

among elderly individuals with rheumatoid arthritis. Furthermore, the *Dartmouth Atlas of Health Care* data currently do not contain the density of hand surgeons in each hospital referral region as a physician capacity measure. Thus, we did not include this variable in the analysis as one of the predictors of rheumatoid arthritis-related upper extremity surgery.

Nonetheless, our study provides a new perspective on the epidemiology of surgical reconstruction for extremity disability among elderly patients with rheumatoid arthritis. DMARD use among elderly individuals is less aggressive and initiated later than for younger patients with rheumatoid arthritis[6-10], and elderly patients may have progression to debilitating joint pain and deformity more quickly than younger individuals[43-48]. Elderly patients could be considered earlier for surgical therapy in order to preserve extremity function and mobility. Surgery among the elderly is well tolerated and could potentially improve overall quality of life and the ability to complete activities of daily living and maintain independence[49,50]. Additionally, patients with profound deformities report a benefit from surgery, even with relatively modest gains in arc of motion or ulnar drift[14,51]. Furthermore, although DMARDs are associated with an increased risk of complications with lower extremity procedures, this may not be true for upper extremity procedures[52-54]. The most common complications after rheumatoid arthritis-related surgical treatments include surgical site infection and venous thromboembolism[54-57]. Other complications, such as implant dislocation, instability, and failure, occur frequently in both large and small joints and often require revision[58-62]. However, prior research on complications after rheumatoid arthritis-related hand procedures is limited compared with studies regarding the complications after lower extremity surgical procedures. Finally, unlike lower extremity reconstructive procedures, upper extremity procedures are often performed on an outpatient basis, with relatively few readmissions and low mortality rates.

It has been suggested that the reconstructive sequence for rheumatoid arthritis-related joint destruction should address proximal joints prior to distal joints and lower extremity joints prior to upper extremity joints. In our cohort, knee and hip arthroplasties were among the most common initial procedures and comprised 46% of all initial procedures. Notably, over half of patients undergo upper extremity reconstruction initially for rheumatoid arthritis-related deformity[63]. Although the indications for surgery are not clear from administrative data, for elderly individuals, maintaining pain-free hand function and dexterity may be critical to activities of daily living and maintaining independence. For many patients with rheumatoid arthritis, rheumatologists provide the majority of care and direct the referral patterns for all aspects of their care. Therefore, differences in attitudes regarding the effectiveness of surgical treatment between rheumatologists and orthopaedic surgeons may explain differences in rheumatoid arthritis-related upper extremity surgery among regions with differing densities of subspecialist care[13]. Alternatively, lower rates of surgery could also be due to increased access to DMARDs to slow the progress of disease. Finally, it is possible that health behaviors regarding compliance and prevention differ geographically[64-67]. To better control for these potential differences, we included data on metropolitan and nonmetropolitan or rural residence in our measures.

Rates of extremity surgery for rheumatoid arthritis are low among elderly individuals, and this surgery is more commonly performed in the early years following diagnosis. Future studies comparing the relative effectiveness of medical and surgical therapy on the preservation of function among elderly patients with rheumatoid arthritis can inform the management of this common and challenging disease.

Appendix

eA Tables showing the adjusted hazard ratio of undergoing upper and lower extremity rheumatoid arthritis-related surgery after the diagnosis of rheumatoid arthritis and the procedure codes for upper and lower extremity surgical procedures for rheumatoid arthritis are available with the online version of this article as a data supplement at jbjs.org. ■

Jennifer Waljee, MD, MS
Lin Zhong, MD, MPH
Onur Baser, MS, PhD
David A. Fox, MD
Kevin C. Chung, MD, MS
Section of Plastic Surgery, Department of Surgery (J.W., L.Z., and K.C.C.), and Department of Internal Medicine (O.B. and D.A.F.),
University of Michigan Health System,
1500 East Medical Center Drive,
Ann Arbor, MI 48109-5340.
E-mail address for K.C. Chung: kecchung@med.umich.edu

Huseyin Yuce, PhD, MS
Department of Mathematics,
New York City College of Technology,
300 Jay Street, N826,
Brooklyn, NY 11201

References

1. Humphreys JH, Warner A, Chipping J, Marshall T, Lunt M, Symmons DP, Verstappen SM. Mortality trends in patients with early rheumatoid arthritis over 20 years: results from the Norfolk Arthritis Register. Arthritis Care Res (Hoboken). 2014 Sep;66(9):1296-301.

2. Gleason PP, Alexander GC, Starner CI, Ritter ST, Van Houten HK, Gunderson BW, Shah ND. Health plan utilization and costs of specialty drugs within 4 chronic conditions. J Manag Care Pharm. 2013 Sep;19(7):542-8.

3. Myasoedova E, Crowson CS, Kremers HM, Therneau TM, Gabriel SE. Is the incidence of rheumatoid arthritis rising?: results from Olmsted County, Minnesota, 1955-2007. Arthritis Rheum. 2010 Jun;62(6):1576-82.

4. Widdifield J, Paterson JM, Bernatsky S, Tu K, Thorne JC, Ahluwalia V, Ivers N, Butt D, Jaakkimainen RL, Tomlinson G, Bombardier C. The rising burden of rheumatoid arthritis surpasses rheumatology supply in Ontario. Can J Public Health. 2013 Nov-Dec;104(7):e450-5. Epub 2013 Oct 31.

5. Singh JA, Furst DE, Bharat A, Curtis JR, Kavanaugh AF, Kremer JM, Moreland LW, O'Dell J, Winthrop KL, Beukelman T, Bridges SL Jr, Chatham WW, Paulus HE, Suarez-Almazor M, Bombardier C, Dougados M, Khanna D, King CM, Leong AL, Matteson EL, Schousboe JT, Moynihan E, Kolba KS, Jain A, Volkmann ER, Agrawal H, Bae S, Mudano AS, Patkar NM, Saag KG. 2012 update of the 2008 American College of

Rheumatology recommendations for the use of disease-modifying antirheumatic drugs and biologic agents in the treatment of rheumatoid arthritis. Arthritis Care Res (Hoboken). 2012 May;64(5):625-39.

6. Schmajuk G, Schneeweiss S, Katz JN, Weinblatt ME, Setoguchi S, Avorn J, Levin R, Solomon DH. Treatment of older adult patients diagnosed with rheumatoid arthritis: improved but not optimal. Arthritis Rheum. 2007 Aug 15;57(6):928-34.

7. Schmajuk G, Trivedi AN, Solomon DH, Yelin E, Trupin L, Chakravarty EF, Yazdany J. Receipt of disease-modifying antirheumatic drugs among patients with rheumatoid arthritis in Medicare managed care plans. JAMA. 2011 Feb 2;305(5):480-6.

8. Tutuncu Z, Reed G, Kremer J, Kavanaugh A. Do patients with older-onset rheumatoid arthritis receive less aggressive treatment? Ann Rheum Dis. 2006 Sep; 65(9):1226-9. Epub 2006 Jan 13.

9. Kremers HM, Nicola P, Crowson CS, O'Fallon WM, Gabriel SE. Therapeutic strategies in rheumatoid arthritis over a 40-year period. J Rheumatol. 2004 Dec; 31(12):2366-73.

10. Fraenkel L, Rabidou N, Dhar R. Are rheumatologists' treatment decisions influenced by patients' age? Rheumatology (Oxford). 2006 Dec;45(12):1555-7. Epub 2006 May 11.

11. Solomon DH, Yelin E, Katz JN, Lu B, Shaykevich T, Ayanian JZ. Treatment of rheumatoid arthritis in the Medicare Current Beneficiary Survey. Arthritis Res Ther. 2013;15(2):R43. Epub 2013 Mar 18.

12. Jin XM, Lee J, Choi NK, Seong JM, Shin JY, Kim YJ, Kim MS, Yang BR, Park BJ. Utilization patterns of disease-modifying antirheumatic drugs in elderly rheumatoid arthritis patients. J Korean Med Sci. 2014 Feb;29(2):210-6. Epub 2014 Jan 28.

13. Alderman AK, Chung KC, Demonner S, Spilson SV, Hayward RA. The rheumatoid hand: a predictable disease with unpredictable surgical practice patterns. Arthritis Rheum. 2002 Oct 15;47(5):537-42.

14. Alderman AK, Ubel PA, Kim HM, Fox DA, Chung KC. Surgical management of the rheumatoid hand: consensus and controversy among rheumatologists and hand surgeons. J Rheumatol. 2003 Jul;30(7):1464-72.

15. Chung KC, Burns PB, Wilgis EF, Burke FD, Regan M, Kim HM, Fox DA. A multicenter clinical trial in rheumatoid arthritis comparing silicone metacarpophalangeal joint arthroplasty with medical treatment. J Hand Surg Am. 2009 May-Jun;34(5): 815-23.

16. Alderman AK, Chung KC, Kim HM, Fox DA, Ubel PA. Effectiveness of rheumatoid hand surgery: contrasting perceptions of hand surgeons and rheumatologists. J Hand Surg Am. 2003 Jan;28(1):3-11; discussion 12-3.

17. Diez Roux AV, Merkin SS, Arnett D, Chambless L, Massing M, Nieto FJ, Sorlie P, Szklo M, Tyroler HA, Watson RL. Neighborhood of residence and incidence of coronary heart disease. N Engl J Med. 2001 Jul 12;345(2):99-106.

18. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. Med Care. 1998 Jan;36(1):8-27.

19. van Walraven C, Austin PC, Jennings A, Quan H, Forster AJ. A modification of the Elixhauser comorbidity measures into a point system for hospital death using administrative data. Med Care. 2009 Jun;47(6):626-33.

20. Wennberg JE, Cooper MM. The Dartmouth atlas of health care. Chicago: American Hospital Publishing; 1996.

21. Isserman AM. In the national interest: defining rural and urban correctly in research and public policy. IRSR. 2005;28(4):465-99.

22. Kruskal WH, Wallis WA. Use of ranks in one-criterion variance analysis. J Am Stat Assoc. 1952;47(260):583-621.

23. Weiss RJ, Ehlin A, Montgomery SM, Wick MC, Stark A, Wretenberg P. Decrease of RA-related orthopaedic surgery of the upper limbs between 1998 and 2004: data from 54,579 Swedish RA inpatients. Rheumatology (Oxford). 2008 Apr;47(4):491-4. Epub 2008 Feb 22.

24. da Silva E, Doran MF, Crowson CS, O'Fallon WM, Matteson EL. Declining use of orthopedic surgery in patients with rheumatoid arthritis? Results of a long-term, population-based assessment. Arthritis Rheum. 2003 Apr 15;49(2):216-20.

25. Massardo L, Gabriel SE, Crowson CS, O'Fallon WM, Matteson EL. A population based assessment of the use of orthopedic surgery in patients with rheumatoid arthritis. J Rheumatol. 2002 Jan;29(1):52-6.

26. Nikiphorou E, Carpenter L, Morris S, Macgregor AJ, Dixey J, Kiely P, James DW, Walsh DA, Norton S, Young A. Hand and foot surgery rates in rheumatoid arthritis have declined from 1986 to 2011, but large-joint replacement rates remain unchanged: results from two UK inception cohorts. Arthritis Rheumatol. 2014 May; 66(5):1081-9.

27. Shourt CA, Crowson CS, Gabriel SE, Matteson EL. Orthopedic surgery among patients with rheumatoid arthritis 1980-2007: a population-based study focused on surgery rates, sex, and mortality. J Rheumatol. 2012 Mar;39(3):481-5. Epub 2012 Jan 15.

28. Momohara S, Ikari K, Mochizuki T, Kawamura K, Tsukahara S, Toki H, Hara M, Kamatani N, Yamanaka H, Tomatsu T. Declining use of synovectomy surgery for patients with rheumatoid arthritis in Japan. Ann Rheum Dis. 2009 Feb;68(2):291-2.

29. Leon L, Jover JA, Loza E, Zunzunegui MV, Lajas C, Vadillo C, Fontsere O, Rodriguez-Rodriguez L, Martinez C, Fernandez-Gutierrez B, Abasolo L. Health-related quality of life as a main determinant of access to rheumatologic care. Rheumatol Int. 2013 Jul;33(7):1797-804. Epub 2013 Jan 11.

30. Yazdany J, Gillis JZ, Trupin L, Katz P, Panopalis P, Criswell LA, Yelin E. Association of socioeconomic and demographic factors with utilization of rheumatology subspecialty care in systemic lupus erythematosus. Arthritis Rheum. 2007 May 15;57(4):593-600.

31. Shanmuganandan K, Arunachalam R. Late onset rheumatoid arthritis. Indian J Rheumatol. 2009;4(2):56-60.

32. Lard LR, Visser H, Speyer I, vander Horst-Bruinsma IE, Zwinderman AH, Breedveld FC, Hazes JM. Early versus delayed treatment in patients with recent-onset rheumatoid arthritis: comparison of two cohorts who received different treatment strategies. Am J Med. 2001 Oct 15;111(6):446-51.

33. Lard LR, Huizinga TW, Hazes JM, Vliet Vlieland TP. Delayed referral of female patients with rheumatoid arthritis. J Rheumatol. 2001 Oct;28(10):2190-2.

34. Nicholls EE, van der Windt DA, Jordan JL, Dziedzic KS, Thomas E. Factors associated with the severity and progression of self-reported hand pain and functional difficulty in community-dwelling older adults: a systematic review. Musculoskeletal Care. 2012 Mar;10(1):51-62. Epub 2012 Jan 31.

35. Park DC, Hertzog C, Leventhal H, Morrell RW, Leventhal E, Birchmore D, Martin M, Bennett J. Medication adherence in rheumatoid arthritis patients: older is wiser. J Am Geriatr Soc. 1999 Feb;47(2):172-83.

36. Katz JN, Barrett J, Liang MH, Bacon AM, Kaplan H, Kieval RI, Lindsey SM, Roberts WN, Sheff DM, Spencer RT, Weaver AL, Baron JA. Sensitivity and positive predictive value of Medicare Part B physician claims for rheumatologic diagnoses and procedures. Arthritis Rheum. 1997 Sep;40(9):1594-600.

37. Zhang J, Xie F, Delzell E, Chen L, Kilgore ML, Yun H, Saag KG, Lewis JD, Curtis JR. Trends in the use of biologic agents among rheumatoid arthritis patients enrolled in the US Medicare program. Arthritis Care Res (Hoboken). 2013 Nov;65(11): 1743-51.

38. Kim SY, Servi A, Polinski JM, Mogun H, Weinblatt ME, Katz JN, Solomon DH. Validation of rheumatoid arthritis diagnoses in health care utilization data. Arthritis Res Ther. 2011;13(1):R32. Epub 2011 Feb 23.

39. Cash JM, Klippel JH. Second-line drug therapy for rheumatoid arthritis. N Engl J Med. 1994 May 12;330(19):1368-75.

40. Smolen JS, Kalden JR, Scott DL, Rozman B, Kvien TK, Larsen A, Loew-Friedrich I, Oed C, Rosenburg R; European Leflunomide Study Group. Efficacy and safety of leflunomide compared with placebo and sulphasalazine in active rheumatoid arthritis: a double-blind, randomised, multicentre trial. Lancet. 1999 Jan 23;353 (9149):259-66.

41. Fries JF, Williams CA, Morfeld D, Singh G, Sibley J. Reduction in long-term disability in patients with rheumatoid arthritis by disease-modifying antirheumatic drug-based treatment strategies. Arthritis Rheum. 1996 Apr;39(4):616-22.

42. Felson DT, Anderson JJ, Meenan RF. The comparative efficacy and toxicity of second-line drugs in rheumatoid arthritis. Results of two metaanalyses. Arthritis Rheum. 1990 Oct;33(10):1449-61.

43. Cho SK, Sung YK, Choi CB, Cha HS, Choe JY, Chung WT, Hong SJ, Jun JB, Kim J, Kim TH, Koh EM, Lee HS, Lee J, Lee SS, Lee SW, Yoo DH, Yoon BY, Bae SC; Korean Observational Study Network for Arthritis (KORONA) Investigators. Do patients with elderly-onset rheumatoid arthritis have severe functional disability? Semin Arthritis Rheum. 2012 Aug; 42(1):23-31.

44. Pawłowska J, Smoleńska Z, Daca A, Witkowski JM, Bryl E. Older age of rheumatoid arthritis onset is associated with higher activation status of peripheral blood CD4(+) T cells and disease activity. Clin Exp Immunol. 2011 Feb;163(2):157-64. Epub 2010 Dec 13.

45. Pease CT, Bhakta BB, Devlin J, Emery P. Does the age of onset of rheumatoid arthritis influence phenotype?: a prospective study of outcome and prognostic factors. Rheumatology (Oxford). 1999 Mar;38(3):228-34.

46. Ferraccioli GF, Cavalieri F, Mercadanti M, Conti G, Viviano P, Ambanelli U. Clinical features, scintiscan characteristics and X-ray progression of late onset rheumatoid arthritis. Clin Exp Rheumatol. 1984 Apr-Jun;2(2):157-61.

47. van der Heijde DM, van Riel PL, van Leeuwen MA, van 't Hof MA, van Rijswijk MH, van de Putte LB. Older versus younger onset rheumatoid arthritis: results at onset and after 2 years of a prospective followup study of early rheumatoid arthritis. J Rheumatol. 1991 Sep;18(9):1285-9.

48. Dejaco C, Duftner C, Wipfler-Freissmuth E, Weiss H, Schneider T, Schirmer M. Elderly- versus younger-onset rheumatoid arthritis: higher levels of ultrasound-detected inflammation despite comparable clinical disease activity. Arthritis Care Res (Hoboken). 2013 Feb;65(2):304-8.

49. Voskuijl T, Hageman M, Ring D. Higher Charlson Comorbidity Index Scores are associated with readmission after orthopaedic surgery. Clin Orthop Relat Res. 2014 May;472(5):1638-44. Epub 2013 Nov 26.

50. Becker DJ, Yun H, Kilgore ML, Curtis JR, Delzell E, Gary LC, Saag KG, Morrisey MA. Health services utilization after fractures: evidence from Medicare. J Gerontol A Biol Sci Med Sci. 2010 Sep;65(9):1012-20. Epub 2010 Jun 7.

51. Waljee JF, Chung KC. Objective functional outcomes and patient satisfaction after silicone metacarpophalangeal arthroplasty for rheumatoid arthritis. J Hand Surg Am. 2012 Jan;37(1):47-54.

52. Kawakami K, Ikari K, Kawamura K, Tsukahara S, Iwamoto T, Yano K, Sakuma Y, Tokita A, Momohara S. Complications and features after joint surgery in rheumatoid

arthritis patients treated with tumour necrosis factor-α blockers: perioperative interruption of tumour necrosis factor-α blockers decreases complications? Rheumatology (Oxford). 2010 Feb;49(2):341-7. Epub 2009 Dec 4.

53. Clement ND, Breusch SJ, Biant LC. Lower limb joint replacement in rheumatoid arthritis. J Orthop Surg Res. 2012;7(1):27. Epub 2012 Jun 14.

54. Jain A, Witbreuk M, Ball C, Nanchahal J. Influence of steroids and methotrexate on wound complications after elective rheumatoid hand and wrist surgery. J Hand Surg Am. 2002 May;27(3):449-55.

55. Wilson MG, Kelley K, Thornhill TS. Infection as a complication of total knee-replacement arthroplasty. Risk factors and treatment in sixty-seven cases. J Bone Joint Surg Am. 1990 Jul;72(6):878-83.

56. Hämäläinen M, Raunio P, Von Essen R. Postoperative wound infection in rheumatoid arthritis surgery. Clin Rheumatol. 1984 Sep;3(3):329-35.

57. Niki Y, Matsumoto H, Hakozaki A, Mochizuki T, Momohara S. Rheumatoid arthritis: a risk factor for deep venous thrombosis after total knee arthroplasty? Comparative study with osteoarthritis. J Orthop Sci. 2010 Jan;15(1):57-63. Epub 2010 Feb 12.

58. Ravi B, Croxford R, Austin PC, Hollands S, Paterson JM, Bogoch E, Kreder H, Hawker GA. Increased surgeon experience with rheumatoid arthritis reduces the risk of complications following total joint arthroplasty. Arthritis Rheumatol. 2014 Mar;66(3):488-96.

59. Ravi B, Croxford R, Hollands S, Paterson JM, Bogoch E, Kreder H, Hawker GA. Increased risk of complications following total joint arthroplasty in patients with rheumatoid arthritis. Arthritis Rheumatol. 2014 Feb;66(2):254-63.

60. Gschwend N, Simmen BR, Matejovsky Z. Late complications in elbow arthroplasty. J Shoulder Elbow Surg. 1996 Mar-Apr;5(2 Pt 1):86-96.

61. Torchia ME, Cofield RH, Settergren CR. Total shoulder arthroplasty with the Neer prosthesis: long-term results. J Shoulder Elbow Surg. 1997 Nov-Dec;6(6):495-505.

62. Petscavage JM, Ha AS, Chew FS. Arthroplasty of the hand: radiographic outcomes of pyrolytic carbon proximal interphalangeal and metacarpophalangeal joint replacements. AJR Am J Roentgenol. 2011 Nov;197(5):1177-81.

63. Chung KC, Pushman AG. Current concepts in the management of the rheumatoid hand. J Hand Surg Am. 2011 Apr;36(4):736-47.

64. Matlock DD, Peterson PN, Heidenreich PA, Lucas FL, Malenka DJ, Wang Y, Curtis JP, Kutner JS, Fisher ES, Masoudi FA. Regional variation in the use of implantable cardioverter-defibrillators for primary prevention: results from the National Cardiovascular Data Registry. Circ Cardiovasc Qual Outcomes. 2011 Jan 1;4(1):114-21. Epub 2010 Dec 7.

65. Arcury TA, Gesler WM, Preisser JS, Sherman J, Spencer J, Perin J. The effects of geography and spatial behavior on health care utilization among the residents of a rural region. Health Serv Res. 2005 Feb;40(1):135-55.

66. Hajjar I, Kotchen T. Regional variations of blood pressure in the United States are associated with regional variations in dietary intakes: the NHANES-III data. J Nutr. 2003 Jan;133(1):211-4.

67. Hahn RA, Heath GW, Chang MH; Behavioral Risk Factor Surveillance System State Coordinators. Cardiovascular disease risk factors and preventive practices among adults—United States, 1994: a behavioral risk factor atlas. MMWR CDC Surveill Summ. 1998 Dec 11;47(5):35-69.