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Identifying regional characteristics influencing variation in the utilization of rotator cuff repair in the United States

Daniel C. Austin, MD, MS[a,*], Michael T. Torchia, MD, MS[a], Jonathan D. Lurie, MD, MS[a,b,c], David S. Jevsevar, MD, MBA[a], John-Erik Bell, MD, MS[a]

[a]*Department of Orthopaedics, Dartmouth-Hitchcock Medical Center, Lebanon, NH, USA*
[b]*Department of Medicine, Dartmouth-Hitchcock Medical Center, Lebanon, NH, USA*
[c]*The Dartmouth Institute for Health Policy and Clinical Practice, Dartmouth College, Lebanon, NH, USA*

Background: There is a lack of consensus regarding indications for surgical management of rotator cuff disease, which can lead to increased regional variation. The objectives of this study were to describe the geographic variation in rates of rotator cuff repair (RCR) in the United States over time and to identify regional characteristics associated with utilization.

Methods: The United States was divided into 306 hospital referral regions. The adjusted per capita RCR rate was calculated using procedural counts derived from the Medicare Part B Carrier File from 2004-2014. Population-weighted multivariable regression was used to identify regional characteristics independently associated with utilization in 2014.

Results: In 2014, an 8-fold difference in rates of RCR was found between regions. Between 2010 and 2014, the overall rate of RCR grew only 3.6% and regional variation decreased. Higher regional utilization of several other orthopedic procedures ($P < .02$), as well as the regional supply of orthopedic surgeons ($P = .002$), was independently associated with significantly increased utilization. The South, Southeast, and Southwest were independently associated with significantly higher utilization ($P < .001$) compared with the Northeast. A higher prevalence of resident physicians, a marker of the academic presence within a region, was independently associated with decreased utilization ($P < .001$).

Conclusion: Utilization of RCR has increased substantially over the past decade, but the rate of growth appears to be slowing. RCR remains a procedure with significant regional variation, and increased utilization across regions is associated with higher orthopedic surgeon supply and increased rates of other orthopedic procedures.

Level of evidence: Level III; Cross-Sectional Design; Epidemiology Study

Keywords: Rotator cuff tear; rotator cuff repair; geographic variation; hospital referral regions; regional characteristics; orthopaedic procedures

This study did not contain individually identifiable patient information and was exempt from institutional review board review at our institution.

*Reprint requests: Daniel C. Austin, MD, MS, Department of Orthopaedics, Dartmouth-Hitchcock Medical Center, One Medical Center Drive, Lebanon, NH 03756, USA.

E-mail address: Daniel.C.Austin@hitchcock.org (D.C. Austin).

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Geographic variation in rates of common surgical procedures is an important issue first quantified over 40 years ago in a landmark study by Wennberg and Gittelsohn[46] (1973). Substantial variation in orthopedic procedure rates in the United States has also been observed historically,[4,10,11,25,27,37,44,45] including a study demonstrating 4.7- and 6.5-fold regional differences in hip replacement and back surgery, respectively.[5] Variation is usually greatest in procedures with controversial indications and a lack of consensus on optimal treatment and can be quite significant.[43,46] This variation can indicate potential overutilization in some areas and associated increases in the cost to the health care system, as well as possible underutilization, in others, where patients may not have access to the care they desire or need.[31]

Utilization rates of rotator cuff repair (RCR), the numbers of procedures per capita, were marked by high geographic variation in a study by Vitale et al[43] that observed 9-fold differences in RCR utilization across the United States in 1992. Rotator cuff tears can be successfully treated both surgically[8,9,18,19,28-30,32,38] and nonsurgically.[14,20,28,32,38] Whereas the majority of patients are treated nonoperatively, approximately 25% will undergo surgical repair.[24] Rates of RCR in the United States have grown substantially, with growth of 141% to 238% between the 1990s and 2000s[13,16] and 30% between 2005 and 2011.[24] RCRs were historically completed in an open fashion[12] until the development and dissemination of arthroscopic techniques in the 1990s,[6-8,17,18,38,39] and use of the latter techniques has grown rapidly.[23,24] Randomized controlled trials comparing operative and nonoperative treatment have produced conflicting results,[28,29,32] and a recent meta-analysis has demonstrated clinically similar outcomes.[36] Because both operative and nonoperative treatments have proved effective, clinical practice guidelines regarding RCR provide only a weak recommendation for surgery,[34] and there is heterogeneity regarding indications for surgery among orthopedic surgeons.[15]

Although geographic variation in RCR has been studied in the past, the data are over 25 years old, and it is unknown how the rapid growth of the procedure, as well as the introduction of arthroscopic techniques, has impacted regional utilization. Therefore, the objectives of this study were to evaluate changes in RCR utilization between 2004 and 2014 in the United States, to describe the current status of geographic variation in RCR, and to identify regional characteristics associated with increased utilization rates.

Methods

Procedural data

In this retrospective database study, we first queried the Medicare Part B File (Carrier File) from 2004-2014 to determine procedure counts. This source provided a 40% nationwide sample in 2004-2005 and a 100% nationwide sample from 2006-2014. Procedure counts from 2004-2005 were extrapolated to the total Medicare population based on the 40% sampling rate. We accessed the Medicare Denominator File from 2004-2014 to determine the number of eligible beneficiaries annually based on the midyear population. All individuals included in the study were aged 65 years or older, as patients receiving Medicare owing to disability or dialysis were excluded. All patients with traditional Medicare were included, whereas those with Medicare Advantage were excluded. The procedure of interest, RCR, was identified using relevant Current Procedural Terminology codes: 23410 (open RCR—acute), 23412 (open RCR—chronic), and 29827 (arthroscopic RCR).

Geographic data

Hospital referral regions (HRRs) were defined across the United States using a previously described protocol developed by Wennberg and Cooper[47] and the Dartmouth Atlas.[42] In summary, the methodology involved assigning each US ZIP code to a hospital service area based on the facility used most often by its inhabitants; these areas were then aggregated into 306 HRRs centered around tertiary-care facilities. The grouping according to tertiary-care facility was based on the referral patterns for cardiac and neurosurgical procedures. Characteristics of HRRs were obtained from publicly available databases from *The Dartmouth Atlas of Health Care*.[41,42] HRR procedural rate data were available in fewer than 80% of HRRs in the years 2004 and 2005 owing to the 40% nationwide sample, precluding HRR-level analyses. HRR-level data were available in 304 regions in 2006 and in 305 regions in 2014. The 2010 US Census was used to determine the population density and mean income by region in the HRR databases. Physician densities were based on information from the American Medical Association Physician Masterfile. The rates of surgical procedures, identified by *International Classification of Diseases, Ninth Revision* codes, were derived from the Medicare MedPAR file and indirectly adjusted for the age, sex, and race distributions of the HRR.[42] The Medicare 100% Claims File was used to calculate total Medicare spending per capita, indirectly adjusted for price, age, sex, and race. When HRR data were not available for the year 2014, we used the closest year available. Accordingly, we referenced 2012 data for orthopedic procedure rates, 2001-2011 aggregate data for spinal surgery rates, and 2011 data for the supply of orthopedic surgeons and resident physicians. The presence of an academic medical center within a region was determined using the membership list of the Council of Teaching Hospitals from 2017, based on the street addresses of member hospitals.[1]

Outcomes

Crude RCR rates for each HRR were calculated by determining the number of procedures that met the inclusion criteria per year and then dividing by the midyear Medicare population of the HRR. These rates were then adjusted using the indirect method[42] for age, sex, and race; adjusted values were used for all additional analyses. Because of patient confidentiality, HRRs with fewer than 11 procedures in a given year were suppressed, whereas rates based on procedural counts of 12 to 26 annually were suppressed because of statistical imprecision owing to the small sample size. The main outcome of interest was the per capital RCR rate in each HRR.

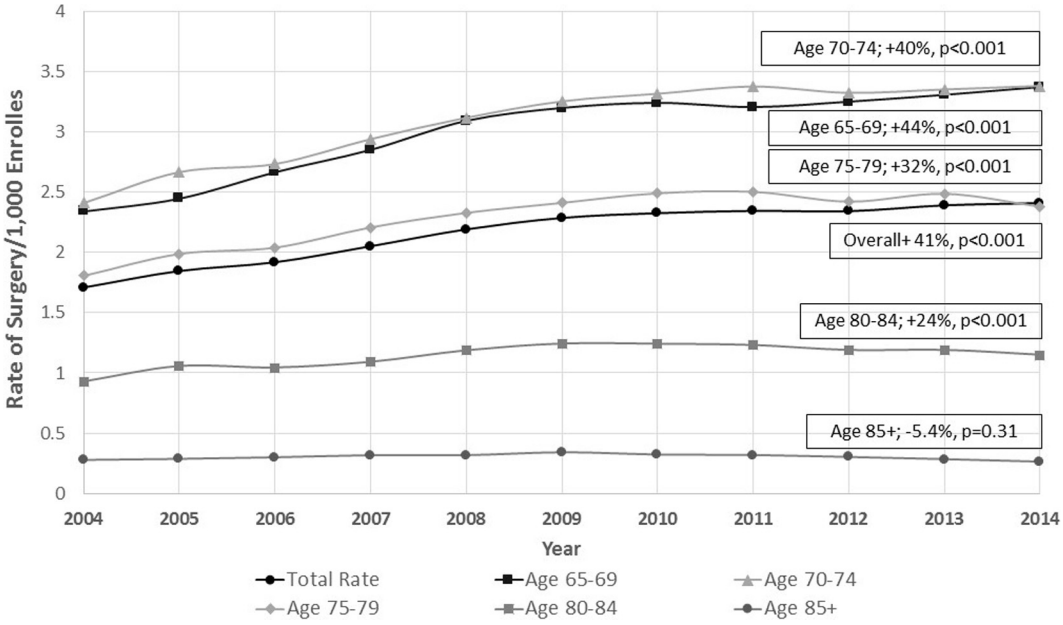

Figure 1 Rotator cuff repairs by age.

Analysis

The degree of geographic variation in RCR rates between HRRs was evaluated annually using extremals (highest regional rate divided by lowest regional rate), interquartile ranges, coefficients of variation, and the systematic component of variation (SCV). The SCV was based on age-, race-, and sex-adjusted rates and reflects a measure of the nonrandom variation in rates across HRRs.[5] We used ordinary least squares linear regression to complete population-weighted multivariable analyses to evaluate associations between HRR characteristics and RCR rates in 2014. In all analyses, $P < .05$ was considered significant, and all statistical testing was completing using Stata software (version 15.0; StataCorp, College Station, TX, USA).

Results

There were 19,402 RCR procedures observed in the 40% Medicare sample in 2004 and 66,804 RCR procedures observed in the 100% Medicare sample in 2014. These counts equated to a 41% increase between 2004 and 2014 in RCR utilization as the rate shifted from 1.7 to 2.4 procedures per 1000 Medicare beneficiaries ($P < .001$). Utilization of RCR increased 41.0% nationwide from 2004-2014 ($P < .001$) but only increased 3.6% between 2010 and 2014 ($P < .001$). Between 2004 and 2014, utilization in the 65- to 69-year-old age group increased the most, with a 44% gain ($P < .001$), whereas utilization in the group aged 85 years or older did not change significantly ($P = .31$; Fig. 1). The rate in women increased by 33% ($P < .001$) whereas the rate in men increased by 48% ($P < .001$) between 2004 and 2014 (Fig. 2). The per capita rate of RCR in African American beneficiaries increased from 0.9 per 1000 in 2004 to 1.4 per 1000 in 2014, a 61% increase ($P < .001$). In non–African American beneficiaries, the rate moved from 1.8 per 1000 in 2004 to 2.5 per 1000 in 2014, a 40% increase ($P < .001$). In comparison with non–African American beneficiaries, the utilization of RCR was significantly lower in African Americans in both 2004 and 2014 ($P < .001$).

The rates of RCR ranged from a high of 5.4 per 1000 in Provo, Utah, to a low of 0.7 per 1000 in Elmira, New York, in 2006 and from a high of 5.0 per 1000 in Provo, Utah to a low of 0.7 per 1000 in Scranton, Pennsylvania, in 2014, representing a nearly 8-fold difference in per capita rates between regions (Tables I and II). The SCV, a quantifiable measure of nonrandom geographic variation, decreased slightly over the study period, with a high of 116.7 in 2006 and a low of 83.7 in 2014 (Table I). Additional measures of variation, including the extremal ratios (high to low) and interquartile ranges, did not change meaningfully during the study period. Rate maps demonstrated that utilization was generally higher in the Mountain West and Southeast whereas it was lower in the Upper Midwest and Northeast (Fig. 3).

Multivariable weighted regression analysis of 2014 data demonstrated that in comparison with regions in the bottom quartiles, HRRs in the top quartiles of either total shoulder arthroplasty (+0.35 procedures/1000 beneficiaries, $P = .006$), total knee arthroplasty (+0.48 procedures/1000 beneficiaries, $P = .001$), or spinal decompression (+0.27 procedures/1000 beneficiaries, $P = .012$) were independently associated with significantly higher RCR rates (Table III). The supply of orthopedic surgeons in a region was also independently associated with increased RCR utilization in a dose-wise fashion, with successively higher procedure rates observed in each quartile of orthopedic

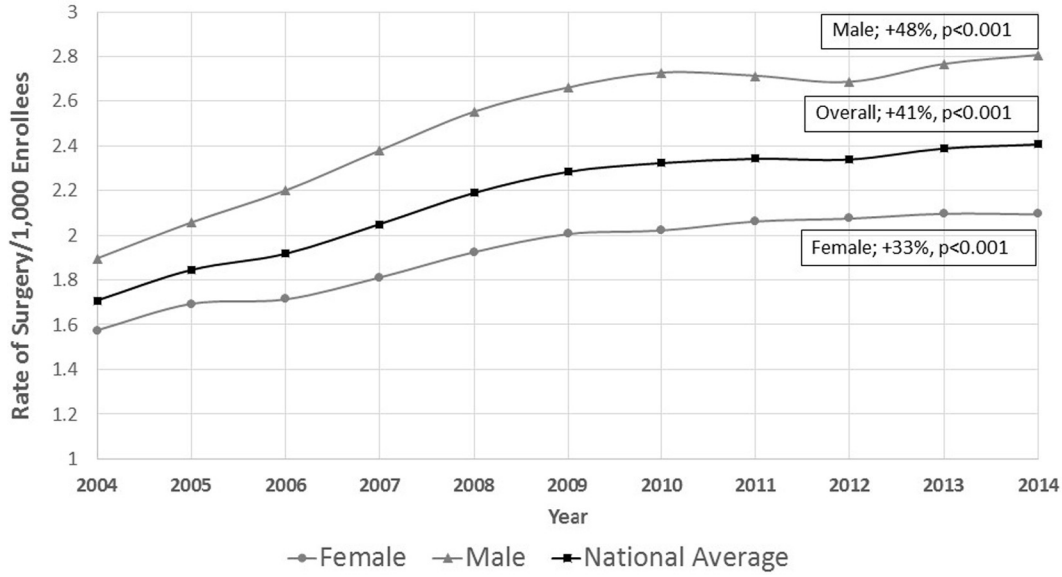

Figure 2 Rotator cuff repairs by sex.

surgeons per capita (test of trend, $P = .004$) and an associated increase of 0.35 procedures per 1000 beneficiaries in the top quartile of orthopedic surgeon supply ($P = .002$).

In comparison with regions in the bottom quartile, regions with an increased prevalence of resident physicians (all specialties), a marker of the concentration of teaching hospitals, were independently associated with significantly decreased RCR rates (Table III). The presence of an academic medical center was not associated with RCR rates ($P = .96$). When the Northeast was used as a reference, the Southeast (+0.65 procedures/1000 beneficiaries, $P < .001$), South (+0.69 procedures/1000 beneficiaries, $P < .001$), and Southwest (+0.70 procedures/1000 beneficiaries, $P < .001$) were independently associated with higher RCR utilization. The per capita supply of primary care physicians, the education or income level of the population, and the population density of HRRs did not independently influence utilization rates. The overall R^2 value of the regression model was 0.55.

Discussion

As high health care spending continues to be a concern in the United States,[33] understanding whether RCR utilization continues to increase, as well as identifying regional factors influencing utilization, is critical. The results of this study demonstrated that nonrandom geographic variation has decreased in recent years despite an essentially stable 7-fold difference in RCR rates across HRRs. This finding suggests that although outlying regional RCR rates remain generally unchanged, the RCR rates of the majority of HRRs are converging over time. This reduction in variation has occurred in the context of a 40% overall increase in RCR rates nationwide, as well as an unchanged maximum regional RCR rate, indicating that the decrease in variation is occurring because of a shift in low-utilizing HRRs upward and a general consolidation around a higher overall RCR rate. Although there has been a 40% increase in overall utilization of RCR between 2004 and 2014, there

Table I Measures of geographic variation over time

	2006 (n = 303)	2007 (n = 305)	2008 (n = 306)	2009 (n = 305)	2010 (n = 305)	2011 (n = 303)	2012 (n = 304)	2013 (n = 304)	2014 (n = 305)
Mean HRR rate* (SD)	2.07 (0.74)	2.19 (0.70)	2.33 (0.72)	2.45 (0.78)	2.46 (0.78)	2.47 (0.74)	2.44 (0.74)	2.51 (0.75)	2.50 (0.71)
Median HRR rate*	2.00	2.17	2.27	2.38	2.40	2.41	2.37	2.44	2.43
Maximum HRR rate*	5.41	5.71	5.33	5.85	6.16	5.30	5.11	5.95	5.01
Minimum HRR rate*	0.718	0.75	0.82	0.89	0.75	0.84	0.76	0.70	0.65
Extremal quotient	7.53	7.61	6.49	6.58	8.19	6.29	6.71	8.50	7.69
Interquartile ratio	1.59	1.50	1.49	1.47	1.51	1.49	1.52	1.45	1.50
Coefficient of variation	35.8	32.1	31.0	31.7	31.6	30.1	30.3	30.1	28.5
Systematic component of variation	116.7	102.4	89.5	95.5	103.6	92.0	100.5	90.9	83.7

HRR, hospital referral region; *SD*, standard deviation.

Table II High and low rates of RCR by HRR

	2006 cohort		2010 cohort		2014 cohort	
	Region	RCR per 1000	Region	RCR per 1000	Region	RCR per 1000
Highest 20 HRRs						
	UT: Provo	5.41	UT: Provo	6.16	UT: Provo	5.01
	UT: Ogden	5.25	ID: Idaho Falls	5.10	UT: Ogden	4.71
	TX: Bryan	4.44	FL: Fort Myers	4.80	ID: Idaho Falls	4.65
	OR: Bend	4.30	UT: Ogden	4.68	MT: Great Falls	4.24
	ID: Idaho Falls	4.22	GA: Rome	4.31	LA: Lake Charles	4.15
	CO: Greeley	4.01	CO: Pueblo	4.30	FL: Fort Myers	4.10
	OR: Salem	3.95	TX: Bryan	4.26	AL: Montgomery	4.08
	GA: Albany	3.95	NC: Asheville	4.17	MO: Joplin	4.07
	CA: Santa Barbara	3.84	UT: Salt Lake City	4.06	AL: Huntsville	4.03
	GA: Columbus	3.78	CO: Colorado Springs	4.05	KY: Owensboro	4.02
	MT: Missoula	3.65	AL: Huntsville	4.03	MO: Columbia	3.91
	UT: Salt Lake City	3.63	CA: San Luis Obispo	3.88	TX: Victoria	3.85
	CA: Salinas	3.62	GA: Columbus	3.86	VA: Newport News	3.79
	FL: Fort Myers	3.51	LA: Lake Charles	3.81	GA: Columbus	3.79
	MT: Billings	3.51	NE: Lincoln	3.75	UT: Salt Lake City	3.79
	FL: Panama City	3.49	CA: San Mateo County	3.73	OR: Bend	3.72
	CO: Colorado Springs	3.40	OR: Bend	3.69	TX: Abilene	3.66
	CO: Grand Junction	3.38	NC: Wilmington	3.62	NC: Asheville	3.65
	WY: Casper	3.38	MI: Muskegon	3.58	MI: Muskegon	3.61
	AL: Huntsville	3.35	PA: Lancaster	3.52	OK: Oklahoma City	3.58
Lowest 20 HRRs						
	RI: Providence	1.12	IN: Munster	1.36	IL: Aurora	1.58
	TX: Wichita Falls	1.11	AR: Texarkana	1.36	IL: Peoria	1.55
	PA: Scranton	1.10	NJ: Hackensack	1.35	NJ: Newark	1.47
	NJ: Morristown	1.09	IA: Davenport	1.35	WV: Charleston	1.41
	WV: Charleston	1.09	PA: Altoona	1.34	NJ: Paterson	1.41
	KY: Paducah	1.08	IL: Peoria	1.33	FL: Miami	1.41
	IA: Mason City	1.08	HI: Honolulu	1.33	NY: Buffalo	1.41
	NJ: Ridgewood	1.06	TX: Harlingen	1.32	PA: Sayre	1.39
	KY: Lexington	1.03	IA: Cedar Rapids	1.32	MA: Springfield	1.39
	MA: Springfield	1.00	PA: Wilkes-Barre	1.30	HI: Honolulu	1.38
	PA: Philadelphia	1.00	KY: Lexington	1.30	IL: Chicago	1.36
	NY: Buffalo	0.97	PA: Erie	1.29	KY: Lexington	1.31
	NY: Manhattan	0.93	NJ: Paterson	1.17	AR: Texarkana	1.18
	IL: Blue Island	0.92	NY: Bronx	1.14	NY: Manhattan	1.18
	NY: Bronx	0.90	NY: Manhattan	1.00	PA: Wilkes-Barre	1.06
	HI: Honolulu	0.87	WI: La Crosse	1.00	NY: Bronx	1.01
	WI: La Crosse	0.85	NJ: Newark	0.91	TX: McAllen	0.95
	IL: Chicago	0.84	IL: Chicago	0.87	WI: La Crosse	0.90
	NJ: Newark	0.81	MA: Springfield	0.81	TX: Harlingen	0.87
	NY: Elmira	0.72	PA: Scranton	0.75	PA: Scranton	0.65

HRR, hospital referral region; *RCR*, rotator cuff repair.

is evidence that this growth is slowing, with only a 3.6% increase between 2010 and 2014. Regression analysis demonstrated that several regional characteristics were independently associated with increased utilization, including higher rates of shoulder and knee arthroplasty, a greater supply of orthopedic surgeons, and a location in a southern region, highlighting that increased utilization occurs regionally across orthopedic procedures. The model also demonstrated that an increased academic presence in a region was associated with significantly lower utilization, highlighting possible differences between academic and private practice settings.

Previous studies of the general population showed a male-to-female ratio for RCR of 1.29 in 2006[13] and 1.36 in 2009,[16] which was similar to the range of 1.2 to 1.3 demonstrated in the Medicare population. Our data also showed that growth in utilization between sexes was not equal, with the rate in men increasing by 48% and the rate in women increasing by only 33%, in contrast to a previous study demonstrating that RCR procedures in women

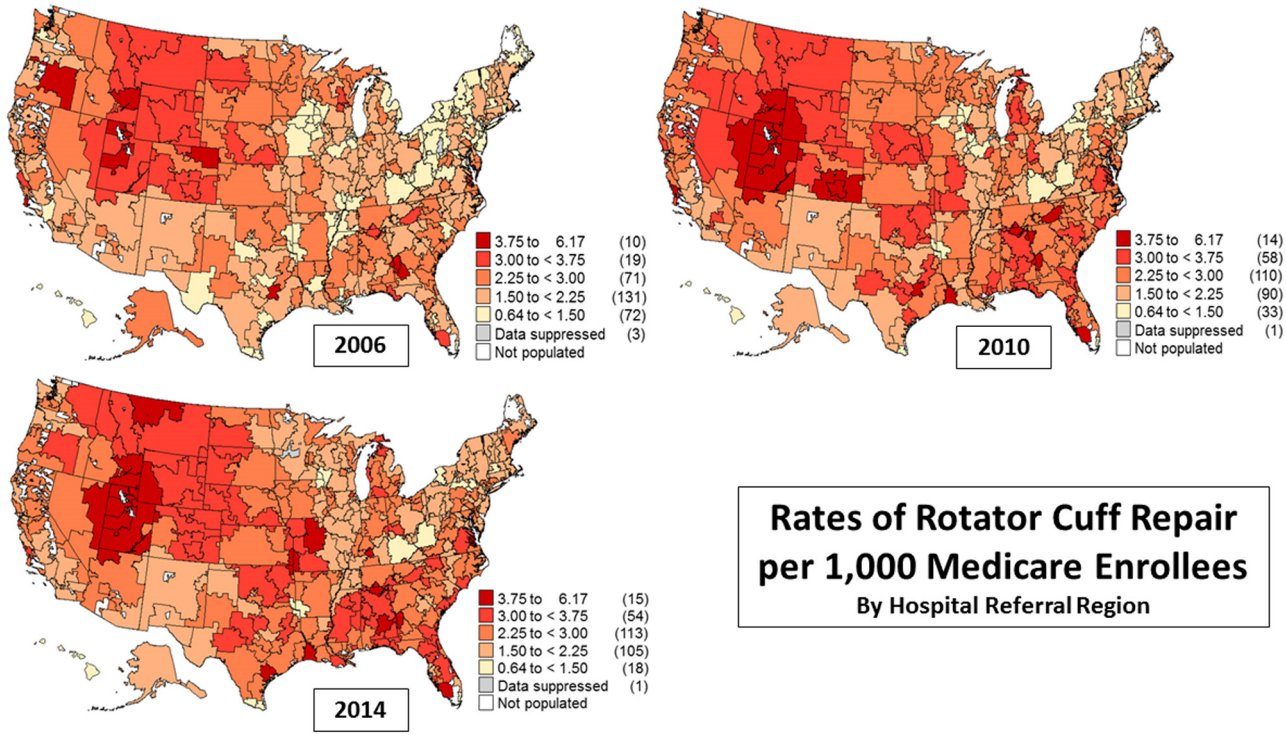

Figure 3 Maps of rotator cuff repair rates in 2006-2014.

increased twice as much as those in men between 1996 and 2006,[13] highlighting how utilization trends change over time. We also observed that utilization increased most in the 65- to 69-year-old age group (+44%) and increased less or remained stable in the older cohorts. In addition, our data demonstrated that the 2004 nationwide rate of RCR in African American patients was less than half that of non–African American beneficiaries, congruent with previous literature highlighting a similar magnitude of racial disparity in knee arthroplasty[37] and cervical spine surgery.[2] Although increased growth of RCR utilization was observed between 2004 and 2014 in the African American population, the utilization rate in non–African American patients remained 80% higher in 2014. Overall, these results demonstrate how the growth in utilization of RCR between 2004 and 2014 occurred heterogeneously in the Medicare population.

Substantial small-area geographic variation in the utilization of orthopedic surgery has been observed historically across a range of procedures including RCR,[43] total shoulder arthroplasty,[43] carpal tunnel release,[26] operative fixation of upper-extremity fractures,[4,11] lower-extremity arthroplasty,[5,37,44] and spine surgery.[44,45] Our data indicate that although geographic variation has decreased overall, it remains a high-variation procedure. The 2014 SCV value of 84 that we observed remains higher than the degree of variation reported historically with knee (SCV, 55) or hip (SCV, 67) arthroplasty and is more consistent with the amount of variation associated with spine surgery (SCV, 90-93).[44] The SCVs of all these procedures are notably higher than the SCV value of 11 for hip fracture surgical procedures,[5] an example of a low-variation procedure with little debate surrounding best practices. The small-area HRR–based high-low (extremal) ratio of 7.69 in 2014 is lower than the 9.09 value reported by Vitale et al[43] (1999) despite their use of 1992 statewide data that would have underestimated variation and suggests that overall geographic variation has likely decreased since that time. Similarly, although RCR remains a high-variation procedure, it is by no means at the top of the list, with rates of distal radial and proximal humeral fixation and total shoulder arthroplasty demonstrating 10-fold[11] or greater[4,48] differences between high- and low-utilization regions.

Previous literature has suggested that high-variation procedures are often associated with scientific uncertainty,[5,44] an observation that applies to RCR as the literature continues to provide conflicting evidence regarding the merits of operative and conservative treatments.[28,29,32,34,36] A survey-based study of orthopedic surgeons has demonstrated significant heterogeneity in the beliefs regarding the efficacy of RCR and observed that surgeons who were more optimistic completed more surgical procedures[15]—results demonstrating how clinical ambiguity can lead to variations in practice. However, differing rates of underlying RCR pathology among regions could also influence utilization rates. Indeed, a previous study of total knee arthroplasty highlighted that regions with increased utilization demonstrated higher rates of

Table III Multivariable linear regression model evaluating association between HRR characteristics and rate of RCR by HRR in 2014

Variable	Change in RCR rate (per 1000 beneficiaries)	95% CI	*P* value
Surgical intensity			
Total shoulder arthroplasty rate[*]			
First quartile (0.4 to <1.0)	Reference	Reference	Reference
Second quartile (1.0 to <1.3)	+0.20	+0.02 to +0.39	.031[†]
Third quartile (1.3 to <1.6)	+0.20	−0.005 to +0.40	.055
Fourth quartile (1.6-2.8)	+0.35	+0.10 to +0.60	.006[†]
Knee arthroplasty rate[*]			
First quartile (3.7 to <7.6)	Reference	Reference	Reference
Second quartile (7.6 to <8.5)	+0.14	−0.04 to +0.32	.14
Third quartile (8.5 to <9.5)	+0.26	+0.06 to +0.47	.013[†]
Fourth quartile (9.5-14.7)	+0.48	+0.21 to +0.75	.001[†]
Hip arthroplasty rate[*]			
First quartile (1.5 to <3.3)	Reference	Reference	Reference
Second quartile (3.3 to <3.9)	+0.04	−0.15 to +0.23	.67
Third quartile (3.9 to <4.6)	+0.09	−0.14 to +0.32	.46
Fourth quartile (4.6-6.3)	+0.34	−0.29 to +0.28	.98
Spinal decompression rate[‡]			
First quartile (25 to <64)	Reference	Reference	Reference
Second quartile (64 to <81)	+0.12	−0.06 to +0.30	.20
Third quartile (81 to <102)	+0.26	+0.06 to +0.45	.010[†]
Fourth quartile (102-217)	+0.27	+0.06 to +0.48	.012[†]
Health care intensity			
Medicare spending per capita[§]			
First quartile (6971 to <8500)	Reference	Reference	Reference
Second quartile (8500 to <9400)	+0.22	0.01 to 0.43	.044[†]
Third quartile (9400 to <10,250)	+0.29	0.06 to 0.52	.013[†]
Fourth quartile (10,250 to <13,347)	+0.20	−0.06 to +0.45	.14
Physician intensity			
Supply of orthopedic surgeons[‖]			
First quartile (2.3 to <5.5)	Reference	Reference	Reference
Second quartile (5.5 to <6.3)	+0.19	+0.01 to +0.37	.043[†]
Third quartile (6.3 to <7.1)	+0.22	+0.03 to +0.41	.022[†]
Fourth quartile (7.1-12.3)	+0.35	+0.13 to +0.57	.002[†,‡]
Academic intensity			
Supply of resident physicians[‖]			
First quartile (3.9 to <15.0)	Reference	Reference	Reference
Second quartile (15.0 to <23.4)	−0.39	−0.60 to −0.18	<.001[†]
Third quartile (23.4 to <35.7)	−0.47	−0.70 to −0.23	<.001[†]
Fourth quartile (35.7 to <97.8)	−0.30	−0.57 to −0.03	.034[†]
Presence of academic medical center (vs. no)	−0.005	−0.18 to +0.17	.96
Socioeconomic characteristics			
% of population with college degree			
First quartile (15 to <22)	Reference	Reference	Reference
Second quartile (22 to <26)	+0.15	−0.07 to +0.37	.19
Third quartile (26 to <31)	+0.20	−0.06 to +0.45	.13
Fourth quartile (31 to <57)	+0.17	−0.14 to +0.47	.28
% of region characterized as rural			
First quartile (0 to <11)	Reference	Reference	Reference
Second quartile (11 to <28)	+0.06	−0.12 to +0.24	.52
Third quartile (28 to <41)	+0.09	−0.14 to +0.32	.44
Fourth quartile (41 to <75)	+0.19	−0.07 to +0.46	.15
Mean household income[¶]			
First quartile (41,917 to <56,700)	Reference	Reference	Reference
Second quartile (56,700 to <61,600)	−0.04	−0.27 to +0.18	.71
Third quartile (61,600 to <71,000)	+0.05	−0.21 to +0.31	.69
Fourth quartile (71,000 to <140,344)	+0.12	−0.20 to +0.45	.45

(*continued on next page*)

Table III Multivariable linear regression model evaluating association between HRR characteristics and rate of RCR by HRR in 2014 (*continued*)

Variable	Change in RCR rate (per 1000 beneficiaries)	95% CI	*P* value
Geography			
Region of United States			
Northeast	Reference	Reference	Reference
Southeast	+0.65	+0.44 to +0.87	<.001[†]
South	+0.69	+0.41 to +0.97	<.001[†]
Midwest	+0.07	−0.16 to +0.30	.53
Northwest	+0.38	−0.001 to +0.75	.051
Southwest	+0.70	+0.44 to +0.96	<.001[†]

HRR, hospital referral region; *RCR*, rotator cuff repair; *CI*, confidence interval.
The model adjusted for all variables within the table in addition to the following nonsignificant variables: supply of total physicians in 2011 (by quartile) and supply of primary care physicians in 2011 (by quartile), with an adjusted $R^2 = 0.55$.
[*] Rates are per 1000 HRR Medicare beneficiaries.
[†] $P < .05$, indicating statistical significance.
[‡] Rates are per 100,000 beneficiaries.
[§] Total Medicare spending per beneficiary in 2014.
[‖] Prevalence per 100,000 HRR inhabitants.
[¶] In USA dollars.

severe knee arthritis.[21] Similarly, studies have shown rates of proximal humeral fractures ranging from 0.43 to 5.47 per 1000 Medicare beneficiaries nationwide,[4] as well as an 8-fold variation in the rates of ankle fractures in elderly patients nationwide.[27] It is important to point out that on the basis of our results, we cannot conclude what the appropriate rate of RCR utilization should be and it is difficult to determine what the ideal RCR—or any elective surgical procedure—should be.[31] Although we have identified factors associated with utilization, we cannot determine whether higher or lower utilization is desired.

A recent study from Sweden observed substantial rates of otherwise undiagnosed carpal tunnel syndrome in the population and concluded that regional variation in procedures could be influenced by how these individuals interact with the medical system.[3] This idea rings true in light of our results demonstrating a clear dose-wise relationship between the supply of orthopedic surgeons in a region and the rates of utilization in that area. Although RCR generally fits the description of preference-sensitive care in which decisions made by patients and surgeons drive utilization,[31] these results highlight the role that supply has in influencing rates as well. Subspecialty referrals are generally considered an example of supply-sensitive care,[31] and it is likely that the improved access afforded by an increased supply of orthopedic surgeons could ultimately increase utilization of surgical repair. These results are in agreement with those from a study by Weinstein et al[44] (2004) that demonstrated increased utilization of hip arthroplasty and spine surgery in areas with greater supplies of orthopedic surgeons and neurosurgeons, respectively. In contrast, a study of hip and knee arthroplasty by Peterson et al[35] based on data from 1988 demonstrated no relationship between statewide utilization and surgeon supply. A study by Vitale et al[43] using data from 1992 also found that neither orthopedic surgeon density nor shoulder specialist density was independently associated with utilization of shoulder arthroplasty or RCR at the state level. These discrepancies with our findings may indicate that orthopedic surgeon supply affects utilization more than it did historically or may be a result of differences in methodology as we evaluated regional variation on a much smaller level.

In our regression model, HRRs in the Southeast, South, or Southwest were all independently associated with significantly higher utilization and proved to be the regional characteristic with the largest association with utilization. These results highlight the larger regional nature of utilization across a range of upper- and lower-extremity orthopedic procedures and are consistent with a previous study of surgical variation across a range of orthopedic, general, and vascular surgery procedures that observed that high-variation procedures often demonstrate larger regional trends of high or low utilization.[5] Rate maps of proximal humeral fracture fixation procedures in 2004-2005 showed similar trends to ours, with increased surgical rates in the South and Southwest.[4] Similarly, rate maps of distal radial fracture internal fixation surgical procedures demonstrated high use in the South and Southeast, among other regions, in 2007.[11] These results are in contrast to a recent study of variation in total shoulder arthroplasty that demonstrated increased utilization in the Mountain West and Upper Midwest but was otherwise very heterogeneous, indicating that our results do not apply to all shoulder procedures.[48] In addition, observations from a historical study of variation in hip and knee arthroplasty in 1988 demonstrated relatively decreased utilization of these procedures in the South and highlight that a shift toward increased per capita orthopedic

utilization may have occurred in these regions over the last 3 decades.[35]

Although previous studies have highlighted that lower population density is associated with increased orthopedic procedure utilization, our results did not find an association between utilization and the proportion of the region considered rural,[35,43] suggesting that these past trends may not be applicable to current practice. It is worth noting that our results demonstrate that total Medicare spending was not independently associated with RCR utilization, similarly to previous literature finding no association between hip and knee arthroplasty and regional spending.[44] Our results also noted that an increased prevalence of resident physicians, a mark of the academic presence within an HRR, was correlated with decreased utilization, a trend similar to findings in a previous study noting decreased utilization of cardiovascular procedures in academic vs. private practice settings.[22] These findings may be a result of varying treatment algorithms between treatment settings, as has been shown previously in the treatment of slipped capital epiphysis,[40] or could be a result of differing patient populations and referral patterns. Alternatively, it is possible that academic practices are less efficient and thereby less productive than private practices.

The strengths of this study include the use of a 100% sample of Medicare patients with traditional coverage during the years 2006-2014. This allowed us to accurately assess the entire population and model relevant trends using well-established methods from the Dartmouth Atlas.[42,47] Limitations of this study include those inherent to any retrospective study relying on Medicare billing data. These include having the inability to confirm the accuracy of the coding data, as well as being limited to the Medicare population aged 65 years or older. Although our methodology captured over 66,000 RCR surgical procedures in 2014 alone, it is important to note that our study includes only a portion of the RCRs completed annually in the United States as many of these procedures are completed in younger patients, with previous studies reporting the overall average age of patients to be 60 years or younger.[13,16] With this in mind, our data are important for understanding overall utilization of RCR in the Medicare population but their generalizability to patients younger than 65 years is unknown. In addition, we were unable to measure the supply of shoulder-specific surgeons in a given HRR and instead used the overall density of orthopedic surgeons for analysis. Evaluating the relationship between the supply of shoulder specialists and RCR utilization would be more ideal for understanding the relationship between the surgeon supply and utilization of a region. Finally, we have no data on the severity of the underlying rotator cuff tear or the magnitude of the corresponding surgical repair for the procedures included in our study. Although it would be very difficult to collect these data on a nationwide level, this level of detail would be helpful for further understanding regional variation in RCR utilization and for evaluating more specific trends within the overall picture of ongoing growth.

Conclusion

The utilization of RCR in the Medicare population has increased substantially between 2004 and 2014 but has slowed in recent years. Although regional differences have decreased over time, RCR remains a high-variation procedure. The results suggested that increased RCR utilization is correlated with increased rates of other orthopedic procedures and higher concentrations of orthopedic surgeons, whereas an increased regional academic presence was associated with decreased utilization.

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