

Inappropriate Wrist MRI: Did Guidelines Have an Impact?

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The risks and benefits of MRI have been the focus of discussions over low-value care and its possible impact on initiatives to reduce unnecessary health care. Wrist pain is prevalent in approximately 19.1% of adults.¹ Although medical imaging is a useful tool for diagnosis and treatment, unnecessary imaging contributes substantially to overall health care spending, costing an estimated \$30 billion annually in the US.²

Despite published guidelines aimed at reducing advanced diagnostic imaging, MRI represents the greatest expenditure compared with other imaging studies.³⁻⁵ In 2018, the American College of Radiology (ACR) expert panel on musculoskeletal imaging released revised and more extensive appropriate imaging guidelines for wrist pain that characterize clinical scenarios in which MRI is appropriate. Guidelines were developed via a literature review of research published in peer-reviewed journals, graded on quality of evidence, supplemented by expert opinion, and reviewed annually.⁶ However, it is unclear whether the guideline development aided in reducing use and waste associated with inappropriate imaging.

It is critical to understand the impact of appropriateness criteria in reducing inappropriate advanced imaging to highlight where additional interventions are needed without compromising access and quality. This study applies the appropriateness criteria to patients presenting with multiple etiologies of wrist pain and identifies rates of inappropriate MRI use. We also evaluate the association between MRI use and patient characteristics. Additionally, we estimate the total payment and out-of-pocket (OOP) expenses associated with inappropriate studies. Lastly, we characterize the impact of ACR Appropriateness Criteria publication through an interrupted time series (ITS) analysis to compare MRI use before and after publication. We hypothesized that the rate of inappropriate use would vary by wrist pain etiology and no significant change in MRI use would occur in the postguideline period.

METHODS

Data Source and Cohort Selection

We used claims data from the IBM MarketScan Research Databases (formerly known as the Truven Health MarketScan Research

ABSTRACT

OBJECTIVES: To assess the national prevalence and cost of inappropriate MRI in patients with wrist pain prior to and following American College of Radiology (ACR) guideline publication.

STUDY DESIGN: We used administrative claims from the IBM MarketScan Research Databases to evaluate the appropriateness of wrist MRI in a national cohort of patients with commercial insurance or Medicare Advantage.

METHODS: Adult patients with a diagnosis of wrist pain between 2016 and 2019 were included and followed for 1 year. We made assessments of appropriateness based on ACR guidelines for specific wrist pain etiologies. We tabulated the total costs and out-of-pocket expenses associated with inappropriate MRI studies using weighted mean payments for facility and professional fees. We performed segmented logistic regression on interrupted time series data to identify predictors of receiving inappropriate imaging and the impact of guideline publication on MRI use.

RESULTS: The study cohort consisted of 867,119 individuals. Of these, 40,164 individuals (4.6%) had MRI, of whom 52.6% received an inappropriate study. Inappropriate studies accounted for \$44,493,234 in total payments and \$8,307,540 in out-of-pocket expenses. The interrupted time series found an approximately 1% monthly decrease in the odds of receiving an inappropriate study after guideline dissemination.

CONCLUSIONS: MRI as a diagnostic tool for wrist pain is often inappropriate and expensive. Our findings support interventions to increase guideline adherence, such as integrated clinical decision support tools.

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TAKEAWAY POINTS

- ▶ Using the American College of Radiology (ACR) Appropriateness Criteria for wrist pain, we found that 53% of patients with wrist pain who underwent MRI received an inappropriate study.
- ▶ Most commonly, imaging was inappropriate due to a lack of a preceding x-ray, suggesting MRI is potentially used as a screening tool to evaluate wrist pain.
- ▶ Results of our interrupted time series analysis found ACR guideline publication had only a subtle impact on ordering practices.
- ▶ These findings indicate that efforts to reduce inappropriate imaging should employ active strategies, such as clinical decision support in electronic health records, to lessen low-value care.

Databases) from 2015 to 2020 for this retrospective cohort study. These databases contain deidentified outpatient data for patients with employer-sponsored and Medicare Advantage or supplemental insurance.⁷ This study adheres to the Strengthening the Reporting of Observational Studies in Epidemiology reporting guidelines for cohort studies. The study cohort included adults 18 years and older with at least 12 months of continuous enrollment prior to and following a wrist pain diagnosis with an index visit between January 1, 2016, and December 31, 2019. We excluded patients who had prior claims for wrist pain management by identifying wrist pain–related claims 12 months prior to the index visit identified in the study period. Further, we excluded patients with acute fractures or traumatic injuries, as these are not captured by the appropriateness criteria. An administrative database, such as MarketScan, is advantageous for achieving the study aims because it permits a large sample size and longitudinal observation of enrollees.⁸ Although administrative databases lack detailed clinical and causal information, analysis of such data facilitates timely study of real-world practices and trend analyses.^{9–14}

We identified patients with nonacute wrist pathology via *International Classification of Diseases, Ninth Revision* and *International Statistical Classification of Diseases, Tenth Revision (ICD-9 and ICD-10, respectively)* diagnosis codes and grouped them into the following categories based on etiology¹⁵: (1) scaphoid-related pathology; (2) Kienböck disease; (3) nonscaphoid malunion or nonunion; (4) inflammatory arthritis and gout; (5) neuropathic pathology; (6) posttraumatic arthritis and osteoarthritis; (7) instability, triangular fibrocartilage complex injury, sprain, and ligamentous injury; (8) cysts and soft tissue pathology; (9) muscle and tendon pathology; (10) nonspecific pain; and (11) miscellaneous. We assigned each patient to a definitive diagnosis category by the most specific diagnosis category identified throughout the 1-year follow-up, for which we applied the corresponding appropriateness criteria. Although the ACR Appropriateness Criteria guide imaging for prior scaphoid and nonscaphoid fractures in addition to suspected Kienböck disease, inflammatory arthritis, and carpal tunnel syndrome, they do not provide guidance when more than 1 of these specific etiologies are suspected. Thus, we excluded patients with diagnoses in at least 2 of the following more specific diagnosis

categories: (1) scaphoid-related pathology, (2) Kienböck disease, (3) nonscaphoid malunion or nonunion, (4) inflammatory arthritis and gout, and (5) neuropathic pathology. We did not exclude patients who had multiple diagnoses comprising multiple less specific wrist pain etiologies. In the experience of the senior author (E.D.S.), patients often present to clinic initially with a diagnosis of nonspecific wrist pain, only to have this condition represented by a more specific code at a subsequent visit. Detailed information on the *ICD-10* codes used and ACR Appropriateness Criteria can be

accessed in **eAppendix Tables 1 and 2**, respectively (eAppendix available at ajmc.com).

Outcome Variables

We applied the ACR appropriateness variants to our wrist pain categorization schema to evaluate the following MRI studies, which were identified by *Current Procedural Terminology* codes: wrist MRI without intravenous contrast, wrist MRI with and without intravenous contrast, and wrist MR arthrography (eAppendix Table 2). Among those receiving more than 1 MRI, patients were categorized into the inappropriate MRI subgroup if they received at least 1 inappropriate MRI; those with only appropriate MRI were categorized into the appropriate MRI subgroup.

We recorded the total payment and OOP expenses (coinsurance, co-payment, and deductibles) associated with each MRI claim. The total payment represents the total amount paid by the insurer plus patient OOP expenses for the claim.¹⁶ We used professional and facility fees for each MRI to calculate the weighted mean payment.¹⁷ The weighted mean spending of total payments and OOP expenses for wrist MRI was \$1522 and \$395 (including both professional and facility components), respectively. We multiplied the weighted mean spending by the number of inappropriate MRI claims to obtain the inappropriate cohort total payments and OOP expenses. All cost variables were inflation adjusted to 2020 US\$ using the Consumer Price Index for all urban consumers for medical care services.¹⁸

Explanatory Variables

We recorded sociodemographic characteristics, including sex, age at index visit, US geographic region of residence, median household income, place of residence, insurance plan type, and comorbidities. We used the metropolitan statistical area code to link to the 2019 US Census to determine median household income and place of residence.¹⁹ Insurance plan type included preferred provider organization (PPO), health maintenance organization (HMO), comprehensive, point of service, or other plan. The *other* category included basic plans, exclusive provider organization plans, consumer-driven health plans, and high-deductible health plans. As a proxy for health status, we calculated an Elixhauser Comorbidity Index score for each patient using *ICD-9/ICD-10* codes.^{20,21}

Statistical Analysis

Descriptive statistics (mean and SD for continuous variables; frequency and percentages for categorical variables) were used to characterize the study cohort. To assess significant differences between the appropriate and inappropriate MRI subgroups, we used Mann-Whitney *U* tests for continuous variables (age and comorbidity score) and Pearson χ^2 tests for categorical variables. We used bivariate analysis to assess the relationship of each explanatory variable to receiving an inappropriate MRI; relevant variables were included in multivariable models to control for confounding. We used listwise deletion to account for patients with missing plan type, which resulted in exclusion of 16,420 patients, or 1.9% of the entire cohort, from our regression models.

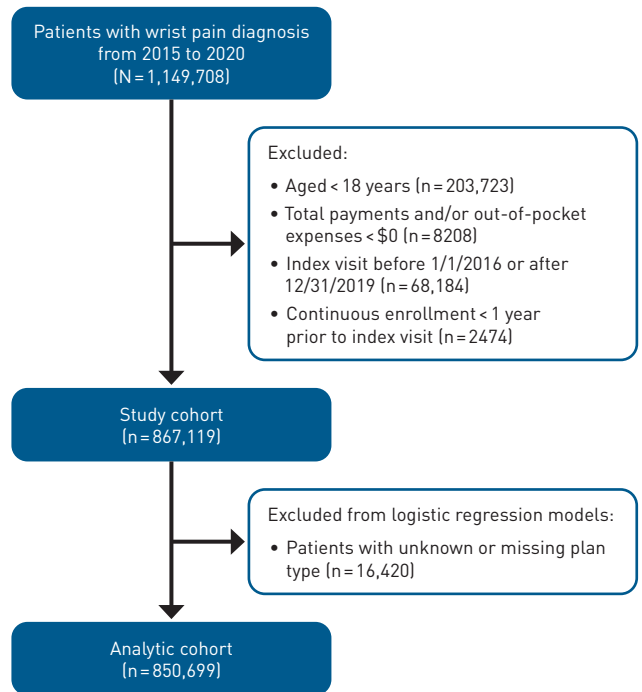
We performed segmented regression analysis of ITS data to determine the change in level and the difference in changing rates (slopes) prior to and following ACR guideline release.²² The model contained 3 time periods: preguideline (January 2016-May 2018), dissemination (June 2018-October 2018), and postguideline period (November 2018-December 2019). To account for time needed to take effect and change physician behavior, we used a 5-month dissemination period based on similar methodology.²³ We modeled the monthly rate of inappropriate MRI studies to evaluate the impact of guideline publication on inappropriate MRI use. This approach permitted us to study an appreciable gradual change in ordering practice.²⁴

The primary aim was to evaluate inappropriate MRI use before and after guideline publication in May 2018. We modeled the probability of receiving inappropriate MRI by index visit month. We performed a piecewise multivariable logistic regression to estimate the association of index visit timing (preguideline or postguideline period) with the odds and predicted probability of a patient receiving an inappropriate MRI, allowing for a 5-month dissemination period while adjusting for the covariates. We conducted a sensitivity analysis using a 3-month dissemination period. All hypothesis tests were 2-sided and used a significance level of 0.05. Statistical analyses were completed from February to September 2022 using IBM SPSS Statistics 28.0 (IBM Corporation), SAS 9.4 (SAS Institute Inc), and R 4.1.2 (R Foundation for Statistical Computing). This study was considered exempt from review by the institutional review board at the University of Michigan because of the deidentified nature of the data.

RESULTS

Our study cohort included 867,119 patients with wrist pain (Figure 1), was 37.1% male, and had a mean age of 48.6 years (Table 1). Nearly half of patients (46.2%) had 1 to 3 Elixhauser comorbidities at the index encounter. Approximately 4.6% of patients (n=40,164) received at least 1 MRI during the 12-month follow-up period after the index encounter. Of patients who received MRI, approximately half of them (52.6%) had an inappropriate study. Most commonly, imaging was deemed inappropriate because of the lack of a preceding x-ray (67.9%), and 32.1% of inappropriate MRI was due to an

FIGURE 1. Patient Flowchart



incorrect type of study obtained according to the ACR guidelines, such as MR arthrography against recommendations. Within the inappropriate-MRI subgroup, 58.3% of patients had more than 1 comorbidity compared with 50.7% of patients in the subgroup with only appropriate imaging ($P < .001$).

Total MRI use in the study cohort declined from 4.85% in the preguideline period to 4.02% in the postguideline period. Inappropriate MRI use decreased from 2.54% in the preguideline period to 2.15% in the postguideline period. The ITS found a significant decline in the predicted probability of receiving an inappropriate MRI following guideline publication (Figure 2). In the preguideline period, we observed no significant change in the odds of receiving an inappropriate MRI by month (OR, 1.000; 95% CI, 0.999-1.002; $P = .601$). In the postguideline period, the odds of receiving an inappropriate MRI decreased by approximately 1% every month (OR, 0.991; 95% CI, 0.985-0.998; $P = .007$). There was a significant difference in the slope of the preguideline period and the dissemination period and between the preguideline and postguideline periods. There was no significant difference between the dissemination and postguideline periods. Our sensitivity analysis using a 3-month dissemination period showed similar findings (eAppendix Figure). Predictors of receiving an inappropriate study are demonstrated in Table 2. Among patients who received MRI, patients older than 65 years had decreased odds of receiving an inappropriate study compared with patients aged 55 to 64 years (OR, 0.63; 95% CI,

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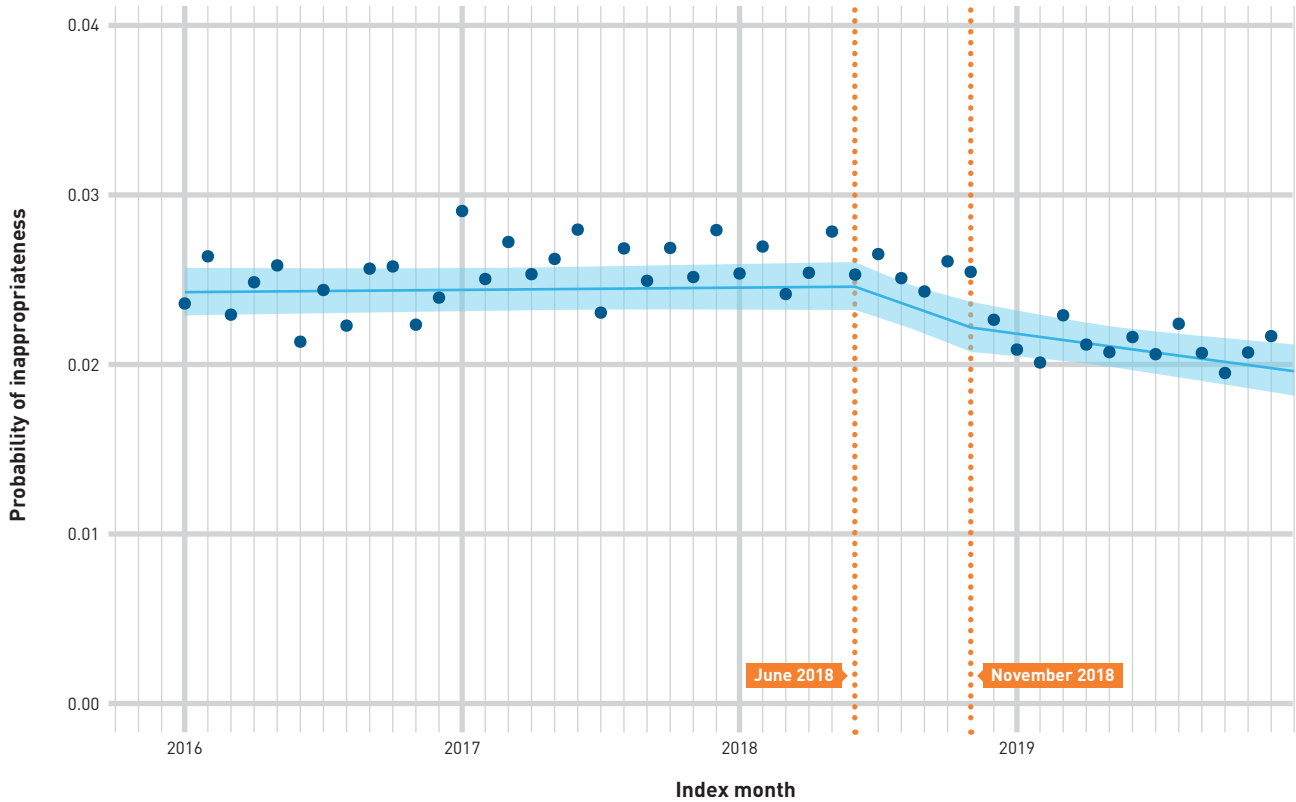
TABLE 1. Demographic Characteristics of Study Participants

Characteristic	Total cohort (n = 867,119)		Appropriate MRI subgroup (n = 19,035)		Inappropriate MRI subgroup (n = 21,129)		P ^a
	n or mean	% or SD	n or mean	% or SD	n or mean	% or SD	
Age in years, mean (SD)	48.63	16.7	41.31	14.4	46.86	14.8	<.001
Younger adults (18-39 years), n (%)	270,480	31.2%	8779	46.1%	6562	31.1%	<.001
Middle-aged adults (40-59 years), n (%)	367,086	42.3%	8218	43.2%	10,302	48.8%	<.001
Older adults (60-79 years), n (%)	196,612	22.7%	1954	10.3%	4044	19.1%	<.001
Oldest adults (≥80 years), n (%)	32,941	3.8%	84	0.4%	221	1.0%	<.001
Sex, n (%)							
Female	545,332	62.9%	10,803	56.8%	12,299	58.2%	.003
Male	321,787	37.1%	8232	43.2%	8830	41.8%	.003
Elixhauser Comorbidity Index score, mean (SD)	2.00	1.91	1.09	1.54	1.40	1.77	<.001
Elixhauser Comorbidity Index score, n (%)							
0	352,858	40.7%	9389	49.3%	8818	41.7%	<.001
1 to 3	400,226	46.2%	8133	42.7%	9805	46.4%	<.001
4 to 7	105,914	12.2%	1455	7.6%	2391	11.3%	<.001
≥8	8121	0.9%	58	0.3%	115	0.5%	<.001
US geographic region, n (%)							
Northeast	157,900	18.2%	4317	22.7%	4775	22.6%	.848
North Central	200,436	23.1%	3841	20.2%	3971	18.8%	<.001
South	370,548	42.7%	8159	42.9%	8975	42.5%	.437
West	135,790	15.7%	2667	14.0%	3357	15.9%	<.001
Unknown	2445	0.3%	51	0.3%	51	0.2%	—
Place of residence, n (%)							
Urban	670,693	77.3%	15,272	80.2%	17,091	80.9%	.014
Rural	103,071	11.9%	1976	10.4%	2037	9.6%	.014
Unknown	93,355	10.8%	1787	9.4%	2001	9.5%	—
Median household income in US\$, n (%)							
< 40,000	1544	0.2%	30	0.2%	25	0.1%	.283
≥ 40,000 and < 50,000	24,240	2.8%	485	2.5%	612	2.9%	.046
≥ 50,000 and < 60,000	179,421	20.7%	4287	22.5%	4766	22.6%	.719
≥ 60,000 and < 70,000	215,089	24.8%	4879	25.6%	5559	26.3%	.268
≥ 70,000	250,399	28.9%	5591	29.4%	6129	29.0%	.164
Unknown	196,426	22.7%	3763	19.8%	4038	19.1%	—
Insurance plan type, n (%)							
PPO	454,000	52.4%	10,586	55.6%	11,646	55.1%	.555
HMO	100,485	11.6%	1771	9.3%	1993	9.4%	.583
Comprehensive	59,824	6.9%	581	3.1%	902	4.3%	<.001
POS	78,537	9.1%	1938	10.2%	2344	11.1%	.002
Other	157,853	18.2%	3804	20.0%	3775	17.9%	<.001
Unknown	16,420	1.9%	355	1.9%	469	2.2%	—
Definitive diagnosis category, n (%)							
Scaphoid-related pathology	2633	0.3%	203	1.1%	138	0.7%	<.001
Kienböck disease	1020	0.1%	278	1.5%	114	0.5%	<.001
Nonscaphoid malunion or nonunion	199	0.0%	14	0.1%	9	0.0%	.215
Inflammatory arthritis/gout	5893	0.7%	271	1.4%	210	1.0%	<.001
Neuropathic pathology	146,489	16.9%	2302	12.1%	2189	10.4%	<.001
Osteoarthritis/posttraumatic arthritis	134,770	15.5%	199	1.0%	5722	27.1%	<.001
Instability/TFCC injury/sprain/ligamentous injury	130,109	15.0%	6956	36.5%	3977	18.8%	<.001
Cysts and soft tissue pathology	57,359	6.6%	2550	13.4%	1779	8.4%	<.001
Muscle and tendon pathology	91,345	10.5%	1304	6.9%	1242	5.9%	<.001
Nonspecific pain	291,032	33.6%	4928	25.9%	5588	26.4%	.207
Miscellaneous	6270	0.7%	30	0.2%	161	0.8%	<.001

HMO, health maintenance organization; POS, point of service; PPO, preferred provider organization; TFCC, triangular fibrocartilage complex.

^aBolded P values represent a significant difference between appropriate MRI and inappropriate MRI cohorts at the α level of 0.05.

FIGURE 2. Temporal Trends in Frequency of Inappropriate MRI and the Estimated Piecewise Probability Trajectory of Inappropriate MRI Use by Index Visit Month (5-Month Dissemination Period)^a



^aTemporal trends in frequency of inappropriate MRI and adjusted probability of receiving an inappropriate MRI. The first vertical dotted line in June 2018 corresponds to the start of the American College of Radiology guideline dissemination period, and the second vertical dotted line in November 2018 corresponds to the end of the dissemination period. The dark blue dots represent observed monthly rate of inappropriate MRI use by index visit month. The output of our multivariable logistic regression model for patient of average initial probability of an inappropriate MRI is depicted as a blue line with a 95% CI in the blue shaded area.

0.53-0.76; $P < .001$). Patients enrolled in comprehensive and HMO health plans had decreased odds of inappropriate MRI compared with patients in PPO plans (OR, 0.82; 95% CI, 0.76-0.88; $P < .001$; and OR, 0.82; 95% CI, 0.78-0.86; $P < .001$, respectively). Patients with 4 to 7 comorbidities had increased odds of inappropriate imaging compared with patients with fewer (1-3) comorbidities (OR, 1.09; 95% CI, 1.04-1.14; $P < .001$) (Table 2).

Between 2016 and 2020, inappropriate MRI use resulted in \$44,493,234 in total payments and \$8,307,540 in OOP expenses. Patients with inappropriate MRI incurred a mean OOP expense of \$495.11 compared with \$219.08 in patients without MRI for wrist pain-related care during the 1-year period after index visit. During this period, patients with inappropriate MRI incurred a mean total payment of \$2497.52 compared with \$1028.61 in patients without MRI.

DISCUSSION

MRI is overused in many musculoskeletal conditions,²⁵⁻²⁹ but its extent in patients with wrist pain was not previously characterized.

We found that despite evidence-based guidelines endorsed by numerous medical societies,^{6,30} more than half (52.6%) of patients with wrist pain who received MRI had at least 1 inappropriate study. Most commonly, MRI was inappropriate due to lack of a preceding x-ray (67.9%). We found that patients in HMO plans were significantly less likely to receive inappropriate imaging compared with patients in PPO plans. Patients with multiple (4-7) comorbidities also were more likely to receive inappropriate imaging compared with patients with fewer or no comorbidities. The ITS analysis demonstrates a small significant decrease (by 1% per month) in inappropriate MRI use to evaluate wrist pain after guideline publication. Inappropriate imaging accounted for \$44,493,234 in total payments and \$8,307,540 in OOP expenses over the study period. Collectively, these findings suggest high prevalence of low-value MRI use for wrist pain.

Previous research shows that MRI is a low-value screening tool for many upper extremity conditions.^{4,5,31,32} Policy experts have considered several system-level strategies to reduce low-value care.^{33,34} For instance, targeting health insurance plan features, such

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TABLE 2. Multivariable Logistic Regression of Receipt of Inappropriate MRI

Variables	OR (95% CI)	P
Time (in months) before guidelines	1.000 (0.999-1.002)	.601
Time (in months) in dissemination period	0.979 (0.968-0.991)	<.001
Time (in months) after guidelines (postdissemination period)	0.991 (0.985-0.998)	.007
Age group in years		
18-34	1.21 (1.16-1.27)	<.001
35-44	1.44 (1.37-1.50)	<.001
45-54	1.33 (1.28-1.39)	<.001
55-64	1 (reference)	—
65 and older	0.63 (0.53-0.76)	<.001
Sex		
Female	1 (reference)	—
Male	1.21 (1.17-1.24)	<.001
Elixhauser Comorbidity Index score		
0	0.95 (0.92-0.98)	.001
1-3	1 (reference)	—
4-7	1.09 (1.04-1.14)	<.001
≥8	0.84 (0.69-1.02)	.072
Geographic region		
South	1 (reference)	—
Northeast	1.27 (1.23-1.32)	<.001
North Central	0.86 (0.83-0.89)	<.001
West	1.02 (0.98-1.07)	.263
Unknown	0.85 (0.65-1.13)	.264
Insurance plan type		
PPO	1 (reference)	—
Comprehensive	0.82 (0.76-0.88)	<.001
HMO	0.82 (0.78-0.86)	<.001
POS	1.04 (0.99-1.09)	.165
Other	0.97 (0.93-1.00)	.079
Wrist pain category		
Nonspecific pain	1 (reference)	—
Scaphoid-related pathology	2.46 (2.06-2.94)	<.001
Kienböck disease	6.22 (5.08-7.60)	<.001
Nonscaphoid malunion or nonunion	2.45 (1.25-4.79)	.009
Inflammatory arthritis/gout	1.98 (1.72-2.28)	<.001
Neuropathic pathology	0.91 (0.87-0.96)	.001
Osteoarthritis/posttraumatic arthritis	2.67 (2.57-2.78)	<.001
Instability/TFCC injury/sprain/ligamentous injury	1.54 (1.48-1.61)	<.001
Cysts and soft tissue pathology	1.57 (1.49-1.66)	<.001
Muscle and tendon pathology	0.70 (0.66-0.74)	<.001
Miscellaneous	1.38 (1.17-1.62)	<.001

HMO, health maintenance organization; POS, point of service; PPO, preferred provider organization; TFCC, triangular fibrocartilage complex.

as patient cost-sharing or prior authorization requirements, could deter overuse.^{35,36} Rosenthal et al studied insurance plan type and receipt of 6 health care services deemed unnecessary by the Choosing Wisely campaign, which was an initiative to reduce ordering of diagnostic tests, imaging, and medical treatments unlikely to change patient health or clinical management.³⁶ The authors found that enrollment in an HMO insurance plan was associated with decreased likelihood of receiving early imaging in low back pain.³⁶ Enrollment in a high-deductible health plan was also a negative predictor of early imaging, but to a lesser extent.³⁶ Consistent with this, we found that patients with HMO plans were nearly 20% less likely to obtain inappropriate imaging for wrist pain compared with patients with PPO plans. Altogether, these findings suggest that managed care plans may contain mechanisms—such as prior authorization or utilization review—to support guideline-adherent use of diagnostic imaging.

Another system-level strategy to reduce low-value care is through physician and hospital participation in accountable care organizations (ACOs), in which reimbursement is tied to care quality and cost reduction. Analysis of both the Medicare Pioneer ACO Model and Oregon's Medicaid ACO model found modest reductions in low-value services, including advanced imaging use for nonspecific back pain and uncomplicated headaches.^{37,38} Similarly, given that many patients with wrist pain in our study were referred for MRI without an initial x-ray, we propose that advanced imaging for nonspecific wrist pain could be a suitable service category that ACOs should consider discouraging in the future.

Although we observed that patients with more comorbidities had greater odds of receiving imaging, previous research has found that such patients receiving MRI for musculoskeletal pain were less likely to receive surgery.³⁹ The value of these studies in these patients is low if patients are ultimately ineligible for or not amenable to surgical intervention. As such, an upper extremity surgeon should guide imaging decisions for patients with wrist pain. To ensure high-value care, physicians should preemptively consider whether advanced imaging will change management, such as surgical or pharmaceutical intervention, which may not be appropriate for patients with high disease burden.^{39,40} Furthermore, inappropriate imaging may have greater downstream consequences.⁴¹ Jacobs et al found that patients with injudicious MRI for musculoskeletal conditions incurred higher costs, rates of surgery, and opioid use.²⁶ Similarly, we found that patients with an inappropriate MRI had higher wrist pain-related OOP expenses and total payments compared with patients without any MRI studies.

Our ITS found an approximately 1% monthly decrease in inappropriate MRI use after ACR guideline implementation. Multiple possible explanations exist for this modest decrease. First, MRI is well reimbursed.⁴² This provides little economic motivation for physicians to seek higher-value diagnostic protocols first. Second, the perceived medicolegal environment of the US may contribute to increased use, as physicians who are concerned with legal risks may overrely on MRI.⁴²⁻⁴⁴ Third, insufficient guideline visibility or enforcement may

hinder adherence. Physician-level interventions such as education, appropriateness checklists, and clinical decision support have been effective at reducing inappropriate imaging use.^{25,28,45-47} Evidence suggests that a layering approach, combining multiple strategies, may lead to more substantial changes in physician practices.⁴⁸⁻⁵⁰ For example, Dudzinski et al randomly assigned attending cardiologists to an appropriate use educational intervention to promote judicious transthoracic echocardiogram ordering practices.⁴⁹ This consisted of a lecture followed by monthly emails detailing the attending's proportion of inappropriate studies with a rationale for why each echocardiogram was inappropriate based on published criteria.⁴⁹ Consistent with results of other studies,^{50,51} the authors found that scheduled feedback significantly reduced the prevalence of inappropriate studies, suggesting that active engagement is more effective for changing physician behavior than relatively passive interventions. Finally, the referral process for hand specialists can contribute to injudicious diagnostic imaging.^{4,5,52} Hartzell et al found that of patients who presented at a hand clinic, 74% had received prior testing or imaging; of this, 90% was unnecessary.⁵ Prior research suggests that hand specialists prescribe higher-value diagnostic testing.³⁹ Michelotti et al found that hand surgeons more often ordered MRI to question a specific anatomic injury compared with referring physicians, who more commonly ordered MRI for generic wrist pain; MRI for a specific injury was more likely to impact management.³⁹ Our findings support continued thoughtful MRI use by specialists, such as hand surgeons, who have better awareness of whether testing will impact patient decision-making. Taken together, our findings suggest a need for further system- and physician-level interventions to increase guideline awareness and adherence.

Limitations

This study has several limitations inherent to administrative data. First, claims data may not capture the full clinical complexity of each wrist pain etiology. Additionally, it is possible that pertinent information obtained in a physician visit was not assigned a corresponding ICD-9/ICD-10 code. Incorrect coding or failure to code all tests performed within claims data, such as a preceding x-ray, may present potential sampling bias. To mitigate this, we used a 1-year pre-index visit look-back period to verify that patients had no prior diagnosis codes or testing that would impact the appropriateness of MRI. Although it is possible that a patient did have a prior x-ray, it would be unlikely for it to occur without an associated claim. Second, our cohort is limited to patients with employer-sponsored insurance; however, in the US, private employer-sponsored insurance represents most insured patients.⁷ Third, we incorporated relevant sociodemographic and clinical factors into our regression models; however, there may be unmeasured confounders that impact our findings. Additionally, we excluded patients with missing insurance information from our regression models, which represented approximately 1.9% of our total cohort. To mitigate confounding, we ensured a similar distribution of other covariates in our study cohort before and after excluding patients with missing data.

CONCLUSIONS

This study shows the high, although gradually declining, prevalence of inappropriate MRI to evaluate wrist pain. Although establishing guidelines is necessary to address overuse, our findings suggest the need for additional interventions to systematically reduce inappropriate MRI studies. Clinical guidelines should be revised to consider patient risk factors and whether testing will impact treatment recommendations. As policy makers refine high-value care initiatives, it is essential to consider disincentivizing inappropriate advanced imaging use without compromising access to and quality of care. ■

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eAppendix Table 1. Definitive Diagnosis Wrist Pain Categorization Scheme

Wrist Pain Category	ICD-10 Code					
Scaphoid-related pathology	S62002K	S62001K	S62032K	S62021K	S62025K	S62031K
	S62024K	S62011K	S62022K	S62034K	S62009K	S62002P
	S62012K	S62015K	S62025P			
Kienböck disease	M931	M92211	M92212			
Non-scaphoid malunion or nonunion	S62152K	S62101K	S62101P	S62111K	S62111P	S62121K
	S6290XK					
Inflammatory arthritis/gout	M67331	M06832	M13832	M70032	M06831	M06031
	M67332	M12231	M12232	M70031	M05731	M06032
	M06331	M08431	M08832	M08931	M05432	M05831
	M06039	M08031	M08831	M10032	M10432	M24631
Neuropathic pathology	G5601	G5602	G5600			
Osteoarthritis/posttraumatic arthritis	M19031	M19032	M1812	M1811	M189	M19132
	M19231	M19039	M19131	M19232	M13831	M180
	M25731	M7722	M19139	M13139	M25732	M13131
	M13132	M1810	M1831	M184		
Instability/TFCC injury/sprain/ligamentous injury	S63591A	S63592A	S63501A	S63502A	S63511A	S63512A
	S638X1A	S63501D	M25331	S638X2A	S63502D	S63591D
	M25332	S63592D	S63521A	S63599A	S6391XA	S63522A
	M24231	S63002A	S63071A	S6392XA	M24232	S63001A
	S63511D	S63509A	S63512D	S63011A	S63072A	S63521D
	S63012A	S63091A	S638X2D	S63092A	S63502S	S63592S
	S63501S	S638X1D	S63522D	M25339	S63519A	S6392XD
	S63509D	S6390XA	S63522S	S63599D	S6391XD	S63511S
	S63529A	S638X9A	M25231	M25232	S63001D	S63003A
	S63031A	S63052A	S63512S	M25239	S63013A	S63509S
	S63519S	S638X1S	S638X2S	S638X9D	S6390XD	S6391XS
Cysts and soft tissue pathology	M67431	M67432	M67439	M71331	M71332	M67831
	M67832					
Muscle and tendon pathology	M654	S66912A	S66911A	S66811A	M67833	S66812A
	M67834	S66911D	S66912D	S66115A	S66119A	S66811D
	S66012A	S66319A	S66891A	S66113A	S66114A	S66211A
	S66313A	S66518A	S66812D	S66819A	S66919A	S66011A
	S66110A	S66111A	S66116A	S66118A	S66212A	S66212D
	S66312A	S66314A	S66316A	S66317A	S66319D	S66412A
	S66912S					
Nonspecific pain	M25531	M25532	M25539			
Miscellaneous	M24131	M24132	M25831	M25832	M24831	M24832
	M25631	M94231	M25632	M94232	M12832	M25839
	M12831	M24032	M24139	M87038	M24031	M25639
	M93231	M24839	M71531	M71532	M87037	M87039
	M25132	M87837	M92221	M93239		

eAppendix Table 2. Classification Scheme for MRIs Considered Inappropriate Using American College of Radiology Appropriateness Criteria Guidelines

Definitive Wrist Pain Category	Corresponding ACR AC Wrist Pain Variant
Group 1 - Scaphoid-related Pathology	Variant 11
No prior x-ray preceding MRI w/o contrast (73218 OR 73221)	
No prior x-ray preceding MRI w/ and w/o contrast (73220 OR 73223)	
Received MR Arthrography (73115 AND 73221) OR (73115 AND 73223)	Variant 8
Group 2 - Kienböck disease	
No prior x-ray preceding MRI w/o contrast (73218 OR 73221)	
Received MR Arthrography (73115 AND 73221) OR (73115 AND 73223)	Variant 11
Received MRI w/ and w/o contrast (73220 OR 73223)	
Group 3 - Non-scaphoid Malunion or Nonunion	
No prior x-ray preceding MRI w/o contrast (73218 OR 73221)	Variant 3
No prior x-ray preceding MRI w/ and w/o contrast (73220 OR 73223)	
Received MR Arthrography (73115 AND 73221) OR (73115 AND 73223)	
Group 4 - Inflammatory Arthritis / Gout	Variant 12
No prior x-ray preceding MRI w/o contrast (73218 OR 73221)	
No prior x-ray preceding MRI w/ and w/o contrast (73220 OR 73223)	
Received MR Arthrography (73115 AND 73221) OR (73115 AND 73223)	Variant 4
Group 5 – Neuropathic Pathology	
No prior x-ray preceding MRI w/o contrast (73218 OR 73221)	
Received MRI w/ and w/o contrast (73220 OR 73223)	Variant 4
Received MR Arthrography (73115 AND 73221) OR (73115 AND 73223)	
Group 6 - Osteoarthritis/Posttraumatic Arthritis/Noninflammatory Arthritis	
No prior x-ray preceding MRI w/ and w/o contrast (73220 OR 73223)	Variants 5 & 6
Received MR Arthrography (73115 AND 73221) OR (73115 AND 73223)	
Received MRI w/o contrast (73218 OR 73221)	
Group 7 - Instability/TFCC Injury/Ligamentous Injury	No prior x-ray preceding MR Arthrography (73115 AND 73221) OR (73115 AND 73223)
No prior x-ray preceding MRI w/o contrast (73218 OR 73221)	
Received MRI w/ and w/o contrast (73220 OR 73223)	Variant 9
Group 8 - Cysts / Soft Tissue Pathology	
No prior x-ray preceding MRI w/o contrast (73218 OR 73221)	
No prior x-ray preceding MRI w/ and w/o contrast (73220 OR 73223)	Variant 2
Received MR Arthrography (73115 AND 73221) OR (73115 AND 73223)	
Group 9 – Muscle and Tendon Pathology	Variant 2
No prior x-ray preceding MRI w/o contrast (73218 OR 73221)	

Received MRI w/ and w/o contrast (73220 OR 73223)	
Received MR Arthrography (73115 AND 73221) OR (73115 AND 73223)	
Group 10 - Nonspecific Pain	Variant 2
No prior x-ray preceding MRI w/o contrast (73218 OR 73221)	
Received MRI w/ and w/o contrast (73220 OR 73223)	
Received MR Arthrography (73115 AND 73221) OR (73115 AND 73223)	
Group 11 - Miscellaneous Pathology	Variant 2
No prior x-ray preceding MRI w/o contrast (73218 OR 73221)	
Received MRI w/ and w/o contrast (73220 OR 73223)	
Received MR Arthrography (73115 AND 73221) OR (73115 AND 73223)	
ACR, American College of Radiology; AC, Appropriateness Criteria	

eAppendix Figure. Inappropriate MRI Use by Index Visit Month (sensitivity analysis using 3-month dissemination period)

