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Title

Low-Volume and High-Volume Readers of Neurological and Musculoskeletal MRI: Achieving Subspecialization in Radiology

Permalink

https://escholarship.org/uc/item/8tf2n3th

Journal

Journal of the American College of Radiology, 17(2)

ISSN

1546-1440

Authors

Trinh, Brian
Calabrese, Evan
Vu, Thienkhai
et al.

Publication Date

2020-02-01

DOI

10.1016/j.jacr.2019.10.006

Peer reviewed

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Abstract

Objective:

Differentiate high versus low-volume radiologists who interpret neurological(Neuro) MRI or musculoskeletal(MSK) MRI, and measure the proportion of Neuro/MSK MRI read by low-volume radiologists.

Methods:

We queried the 2015 Medicare Physician and Other Supplier Public Use File for radiologists who submitted claims for Neuro or MSK MRI. Radiologists were classified as high-volume versus low-volume based on their work RVU(wRVU) focus and/or volume of studies interpreted using three different methodologies: (Method1) percentage of wRVU in Neuro/MSK MRI, (Method2) absolute number of Neuro/MSK MRI interpreted, and (Method3) both percentage and absolute number. Multiple thresholds with each methodology were tested, and the percent of Neuro/MSK MRI interpreted by low-volume radiologists was calculated for each threshold.

Results:

For Neuro(MSK) MRI 33%(50%) of studies were interpreted by a radiologist whose wRVU in Neuro/MSK MRI is less than 20% (Method1). With Method2, 22%(37%) of Neuro(MSK) MRI was interpreted by radiologists who read fewer than the mean number of Neuro/MSK MRI interpreted by an “average full-time radiologist” whose wRVU in Neuro/MSK MRI is approximately 20%. With

Method3, 38%(57%) of Neuro(MSK) MRI was interpreted by “low-volume” radiologists. If instead, 50% wRVU threshold is used for Methods 1/2/3, 70%/ 58%/77% (86%/80%/90%) of Neuro(MSK) MRI is read by low-volume radiologists.

Discussion:

A large number of radiologists read a low volume of Neuro or MSK MRI; these low-volume Neuro/MSK MRI radiologists read a substantial portion of Neuro/MSK MRI. It is unknown which of the methods for distinguishing low-volume radiologists, combined with which threshold may best correlate with high performing or low-performing radiologists.

Key Words:

Specialization, quality, workforce organization, methodology research

Summary Sentence:

A large number of radiologists read a low volume of Neuro or MSK MRI, and these low-volume Neuro/MSK MRI radiologists read a large portion of Neuro and MSK MRI.

Introduction:

The increasing complexity in modern diagnostic imaging has pushed for more specialization within radiology [1,2]. Specialization within radiology can take the form of either advanced training, or a increased focus or volume of one's work within a subfield. Both of these forms of specialization have been shown to result in increased diagnostic performance [3–14]. While the value of specialization has been demonstrated across a variety of radiology subfields, including musculoskeletal, neurologic, abdominopelvic, thoracic, and breast imaging, the greatest impact has been largely for more complex imaging tasks, such as MRI or oncologic imaging. We term these types of examinations for which a specialist interpretation is most valuable, "advanced imaging."

In order to understand specialization of interpretations of advanced imaging in radiology, and to be able to promote it, we need methods for measuring specialization within radiology, both on a practice by practice level and also on a national level. Large administrative datasets, such as those available from the Centers for Medicare Services (CMS) have the potential to facilitate this study of radiologist interpretive volume of advanced imaging on both of these levels. These datasets capture a detailed picture of the work patterns of radiologists nationally.

Prior work by Rosenkrantz *et al* uses this CMS data to classify radiologists' area of specialization based on their work focus within the CMS claims files [1,15,16]. These initial studies have proven useful for classifying the supply of specialized radiologists. However, they do not discriminate between studies that are more or less complex, such as ankle MRI versus ankle radiographs, and do not inform on whether specialists are interpreting the more complex imaging studies. Therefore, we set out to expand on this prior scholarship to develop methodology for measuring not just a radiologist's area of work focus, but also whether advanced imaging is interpreted by a high-volume reader in the field. We present here this methodology and apply it to neurological MRI and musculoskeletal MRI, two areas in which specialist interpretations have been demonstrated to add value [3,4,6,9].

Materials and Methods:

The IRB approved this retrospective study under exempt review. Rosenkrantz *et al.* previously developed a system that operates in conjunction with the Neiman Imaging Types of Service (NITOS) library to map all diagnostic imaging Current Procedural Terminology (CPT) codes into one or multiple radiology subfields [15,17]. We accessed the Medicare Physician and Other Supplier Public Use File for calendar year 2015 and separately searched for all radiologists who were paid for interpreting any MRI CPT code within either the set of neuroradiology or musculoskeletal imaging studies, as defined by Rosenkrantz *et al*. Each of these groups were analyzed

separately. For each radiologist in each group, we calculated the absolute number of studies interpreted within either the Neuro or MSK MRI bundle, the associated work relative value units (wRVU) for Neuro or MSK MRI, and the total wRVU for each radiologists' Medicare studies in the year. RVU values for each CPT code were taken from the 2015 Medicare Physician Fee Schedule [18].

Within each group of Neuro MRI and MSK MRI radiologists, we defined a cohort of "average full-time radiologists," consisting of those radiologists whose total wRVU of all studies interpreted for the year fell within the 25th-75th percentile of the group. This cohort is intended to provide a point of reference to contextualize individual radiologists' work volumes. Within these cohorts of "average full-time radiologists" we formed 9 sub-cohorts based upon the percent of each radiologist's wRVU that was performed in Neuro or MSK MRI; the sub-cohorts included those radiologists within 5 percentage points of 10%, 20%, … 90% of wRVU in Neuro or MSK MRI (i.e. 10% cohort spans from 5% to 15%). The goal of the sub-cohorts of "average full-time radiologists" is to provide a reference level for average radiologists who spend about 10%/20%/…/90% of their wRVU within either Neuro or MSK MRI.

To study the robustness of the "average full-time radiologist" construct, a second group of "average full-time radiologists" that included all radiologists

in the 10th-90th percentiles was also created and used for a sensitivity analysis.

Defining low-volume radiologists of Neuro MRI or MSK MRI:

Next three different methods were proposed to differentiate radiologists as a low-volume radiologist within Neuro MRI or MSK MRI.

Method 1 defined low-volume radiologists based upon the percentage of their total wRVU that is from Neuro or MSK MRI. We tested thresholds in 10 percentage point increments from 10% to 90%.

Method 2 defined low-volume radiologists based on the absolute number of Neuro or MSK MRI studies interpreted within a calendar year. The thresholds for absolute number of MRI studies were determined by the mean number of either Neuro MRI or MSK MRI interpreted by radiologists in the 10% through 90% sub-cohorts of “average full-time radiologists.”

Method 3 is a hybrid of Method 1 and Method 2. It defined low-volume radiologists as those who interpreted less than a certain percentage of their wRVU in Neuro or MSK MRI, or fewer than the mean number of MRI interpreted by the corresponding cohort of “average full-time radiologists.” For example, when 10% was used as the threshold, a low-volume Neuro or MSK radiologist interpreted less than 10% wRVU in Neuro or MSK MRI, or

fewer than the mean of the 10% sub-cohort of “average full-time radiologists.”

Measuring Percent of MRI Interpreted by Low-Volume Versus High-Volume Radiologists:

For each of the combinations of the three methods and nine thresholds for defining “low-volume” versus “high-volume” radiologists, the percent of Neuro and MSK MRI interpreted by “low-volume” versus “high-volume” radiologists was calculated.

The database was queried with a custom Python script and statistical analysis was performed with Microsoft Excel (Redmond, WA).

Results:

In 2015, CMS recorded 14,788 radiologists who interpreted a total of 4,082,577 Neuro MRI studies, and 14,230 radiologists who interpreted a total of 2,884,593 MSK MRI studies (Table 1). The average number of Neuro MRI studies and MSK MRI studies interpreted by radiologists who read neuro MRI or MSK MRI was 276 and 203, respectively (Table 1). Histograms separately showing the distribution of number of Neuro or MSK MRI interpreted, and total wRVU of the radiologists are presented in Figure 1. The distribution of the total wRVU for the cohorts of radiologists who interpret any Neuro MRI or MSK MRI is presented in Figure 2.

Additionally, the characteristics of the cohort of “average full-time radiologists” defined as radiologists with total wRVU ranging between the 25th and 75th percentile are presented in Table 2. Table 2 also displays the data for the sub-cohorts of “average full-time radiologists.”

The number of “low-volume” readers of Neuro MRI or MSK MRI stratified by method and differing thresholds are reported in Tables 3 and 4, respectively. The corresponding number and percentage of advanced imaging studies in Neuro MRI or MSK MRI that were interpreted by these “low-volume” readers are also presented for the 10% through 90% groups in Tables 3 and 4, and graphically displayed in Figure 3.

In total, 64% of radiologists reading Neuro MRI, spent less than 20% of their wRVU in Neuro MRI (Method 1), and interpreted 33% of all Neuro MRI. With Method 2, 22% of Neuro MRI was interpreted by radiologists who read fewer than the mean number of Neuro MRI interpreted by an “average full-time radiologist” who read approximately 20% of their wRVU in Neuro MRI. With Method 3, 38% of Neuro MRI was interpreted by radiologists who spent less than 20% of their wRVU in Neuro MRI or read fewer than the mean number of Neuro MRI interpreted by an “average full-time radiologist” who spent approximately 20% of their wRVU in Neuro MRI. If instead, 50% wRVU thresholds are used, low-volume radiologists share of all Neuro MRI studies

read was 70% when calculated with Method 1, 58% when calculated with Method 2, and 77% when calculated with Method 3.

For MSK MRI, 76% of radiologists, spent less than 20% of their wRVU in MSK MRI (Method 1), and interpreted 50% of all MSK MRI. With Method 2, 37% of MSK MRI was interpreted by radiologists who read fewer than the mean number of MSK MRI interpreted by an “average full-time radiologist” whose wRVU in MSK MRI is approximately 20% of their total wRVU. With Method 3, 57% of MSK MRI was interpreted by radiologists whose wRVU in MSK MRI is less than 20% or who read fewer than the mean number of MSK MRI interpreted by an “average full-time radiologist” whose wRVU in MSK MRI is approximately 20% of their total wRVU. If instead, 50% wRVU thresholds are used, low-volume radiologists share of all Neuro MRI studies read was 86% when calculated with Method 1, 80% when calculated with Method 2, and 90% when calculated with Method 3.

A sensitivity analysis was performed to test the effect of defining “average full-time radiologists” as those whose total wRVU is within the 10th to 90th percentiles for the group instead of the 25th to 75th percentiles. Results from the sensitivity analysis are presented in Figure 4, and show the percent of Neuro MRI read by a “low-volume” radiologist is within 3 percentage points across all subgroups for Method 2, and within 1 percentage point for Method

3. For MSK MRI, it is within 5 percentage points for Method 2, and within 1 percentage point for Method 3.

Discussion:

With the increasing complexity in modern medicine, researchers have shown a trend for increased sub-specialization within radiology [1,2]. Many studies have demonstrated fellowship trained radiologists can provide significant added value to clinical care [3,5–8]. Furthermore, there is an association between higher interpretive volume and better performance metrics of mammographers [11–13]. With this knowledge, it is appropriate to ask whether complex diagnostic studies, such as neurological MRI and musculoskeletal MRI, are interpreted by radiologists, who are positioned to contribute the most value to patient care. We present here a novel analysis for how often Neuro MRI and MSK MRI are interpreted by radiologists with high versus low interpretive volumes.

Rosenkrantz et al provided a methodology for stratifying radiologists as generalist or subspecialist based on whether or not at least 50% of their wRVU was in one subspecialty [1,15]. Although this technique allows us to broadly categorize a radiologist, it does not differentiate between less complex imaging examinations and more complex imaging examinations. For example, the added value of having a subspecialist interpret a typical non-contrast CT of the brain is likely lower than the value added by the

subspecialist interpreting a brain MRI. When determining who is reading a particular type of study, such as Neuro MRI or MSK MRI, we argue it is not only important to know whether the radiologist is subspecialized, but also what percent of their time (wRVU) is spent reading that specific type of study, the total number of that kind of study they read per year, and how these numbers compare to their peers. In our study, instead of answering the question of whether or not these radiologists are subspecialized in neuroradiology or musculoskeletal radiology, we set out to answer whether or not MRI are being interpreted by radiologists with high versus low interpretive volume for and focus of work in Neuro or MSK MRI.

We present three different methods for identifying whether or not a radiologist is a “low-volume” reader in Neuro MRI or MSK MRI. Method 1 uses a percentage of wRVU, Method 2 uses an absolute amount of Neuro or MSK MRI studies interpreted, and Method 3 combines both Methods 1 and 2. Method 1 is the least complex, and its strength is that it is easily understood. For example, a radiologist who spends 20% of their time reading Neuro or MSK MRI is on average working one full day per week in that area, while a radiologist who spends 50% of their time is on average working every other day in that area. However, Method 1’s weakness is that it does not differentiate between full-time and part time radiologists. Radiologists who only work one or two days a week may be considered a high-volume reader of Neuro MRI or MSK MRI even though in actuality they read a low total

volume of either type of study. We developed Method 2 to address this shortcoming.

Method 2 identifies low-volume readers of Neuro MRI or MSK MRI based upon a numerical threshold that is grounded in the work volume of a sub-cohort of "average full-time" radiologists. These sub-cohorts serve as an internal control and allow for an intuitive understanding of the significance of the absolute number of studies. Compared to Method 1, Method 2 requires more involved calculations. Method 2 assumes that radiologists with wRVU within the 25^{th} and 75^{th} percentile are a reliable representation of the group of "average full-time radiologists;" the results from the sensitivity analysis performed support this assumption and demonstrate that the construct of "average full-time radiologist" is robust. However, variations in relative Medicare practice composition pose a limitation for Method 2. For example, radiologists with identical total work volumes can have different Medicare and non-Medicare patients mixes. This can result in two radiologists with the same overall practice volumes of Neuro or MSK MRI appearing to have different volumes simply because one radiologist has proportionately more Medicare patients in their practice.

Method 3 was designed to combine the advantages and address the limitations of both Method 1 and 2. Method 3 uses a combination of the percentage of wRVU and the total volume threshold to identify low-volume

radiologists of Neuro MRI and MSK MRI. Method 3 is the most specific method for identifying a high-volume reader of Neuro MRI or MSK MRI.

Which method and which threshold is best for defining low-volume readers of Neuro MRI or MSK MRI remains to be determined. The underlying premise behind all three methods is the same: the more of one type of study a radiologist reads, the more adept they will be at its interpretation. However, we do not know below what volume of Neuro or MSK MRI interpreted radiologist performance may begin to decline. Further research is needed to determine which if any of these thresholds best separates higher performing from lower performing radiologists. Absent those further studies, each reader can form their own opinions and hypotheses about at what point there is a diminishing return to further increasing the focus or volume of their work in Neuro or MSK MRI. Hence, we provide an exhaustive range of thresholds for defining “low-volume readers.”

From our data, we noticed that there is a significant amount of studies being interpreted by low-volume radiologists of Neuro MRI or MSK MRI. Using the 20% threshold with Method 3, 38% of Neuro MRI and 57% of MSK MRI are interpreted by low-volume readers. If instead the 50% thresholds are used, 77% of Neuro MRI and 90% of MSK MRI are interpreted by low-volume readers. It will be important to determine if any of the thresholds proposed correlate with differences in radiologist performance.

There are several limitations to this study. First, this data is only applicable to Medicare patients, which may not accurately represent the general population. Medicare (and associated patient cost-sharing) is the payer for about 20% of US health expenditures [19]. A radiologist's practice pattern within Medicare should be fairly representative of their overall practice pattern, but, as previously discussed, there can be variation from one provider to the next of the Medicare versus non-Medicare case mix. Second, for privacy reasons, CMS only reports doctors who have billed 11 or more studies under one CPT code. Therefore, low-volume readers who interpret 10 or fewer studies within one or more CPT codes are under counted by this methodology. While it is not possible to precisely estimate the number of undercounted radiologists (and the associated study volume), due to the strong rightward skew of the distribution of studies interpreted by individual radiologists, we can infer there is a large contingent of low-volume radiologists that are undercounted. Inclusion of these undercounted radiologists would only increase the percent of Neuro and MSK MRI that are interpreted by low-volume radiologists across all three of the methods and at each of the thresholds studied. Third, we do not have outcome data to support which of our thresholds are most appropriate or clinically relevant. This is an important area that requires further research and analysis. Our methodology will provide an essential tool for performing this subsequent analysis, and our results demonstrate there remains significant opportunity

to increase the amount of Neuro and MSK MRI interpreted by high-volume readers.

Studies have demonstrated that high-volume radiologists perform better than low-volume radiologists, and the methodology we report here will give the field of radiology the tools to assess how effective it is at having high-volume radiologists interpret advanced imaging, such as Neuro and MSK MRI. Results from this analysis demonstrate that a large number of radiologists read a low volume of Neuro or MSK MRI, and these low-volume Neuro/MSK MRI radiologists read a large portion of Neuro and MSK MRI. Future studies should aim to further refine these thresholds and possibly validate unique thresholds for different types of studies based on clinical outcome data. This methodology can be used to track specialization within radiology over time and to study trends in individual radiologist's degree of specialization throughout their career. It also can be expanded to measure specialization within entire radiology practices with the objective of understanding the characteristics of radiology practices that are associated with higher degrees of specialization.

Take-Home Points:

- We have developed methodology to use administrative databases to measure "low-volume" readers within radiology, and we applied this

methodology to study specialization within neurological and musculoskeletal MRI.

- A large number of radiologists read low volume of Neuro and MSK MRI annually.
- Our method to identify “low-volume” readers can be extended to other imaging studies and used to track how frequently advanced diagnostic imaging examinations are interpreted by “low-volume” versus “high-volume” readers in the respective field.

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Figures:

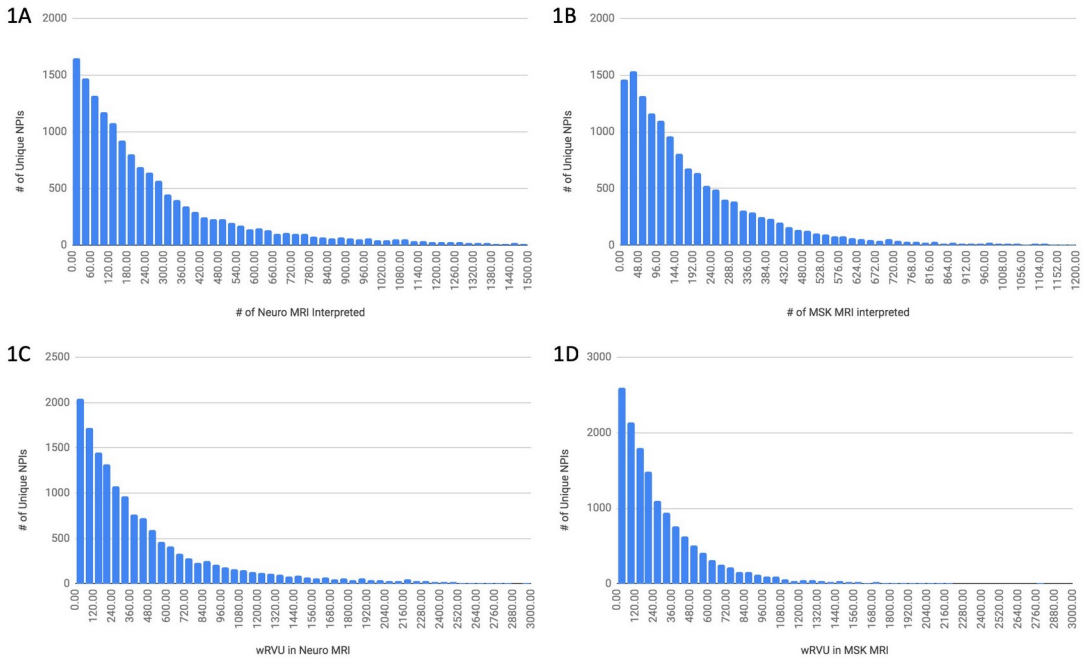

Fig. 1. Histograms of the distribution of number of and wRVU in Neuro MRI (Fig 1a, 1c) and MSK MRI (Fig 1b, 1d) by number of radiologists. wRVU=work relative value unit

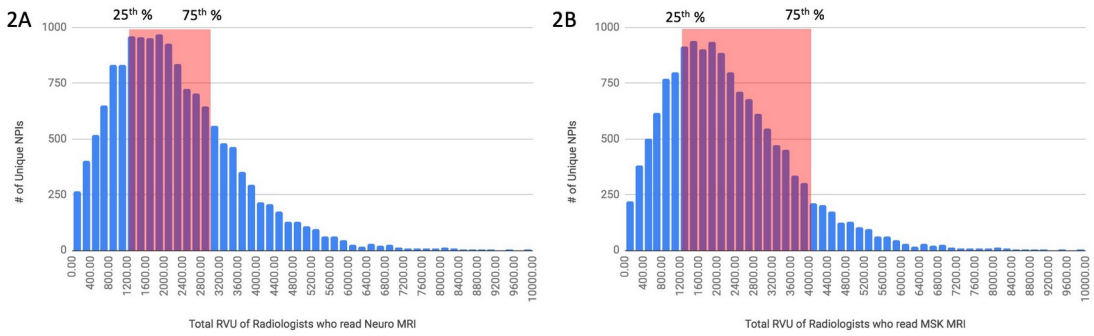

Fig. 2. Histograms of the distribution of total wRVU of all studies interpreted by number of radiologists who read any Neuro MRI (Fig 2a) or MSK MRI (Fig 2b). The red box denotes the middle two quartiles, which constitutes the cohort of “average full-time radiologists.” wRVU=work relative value unit

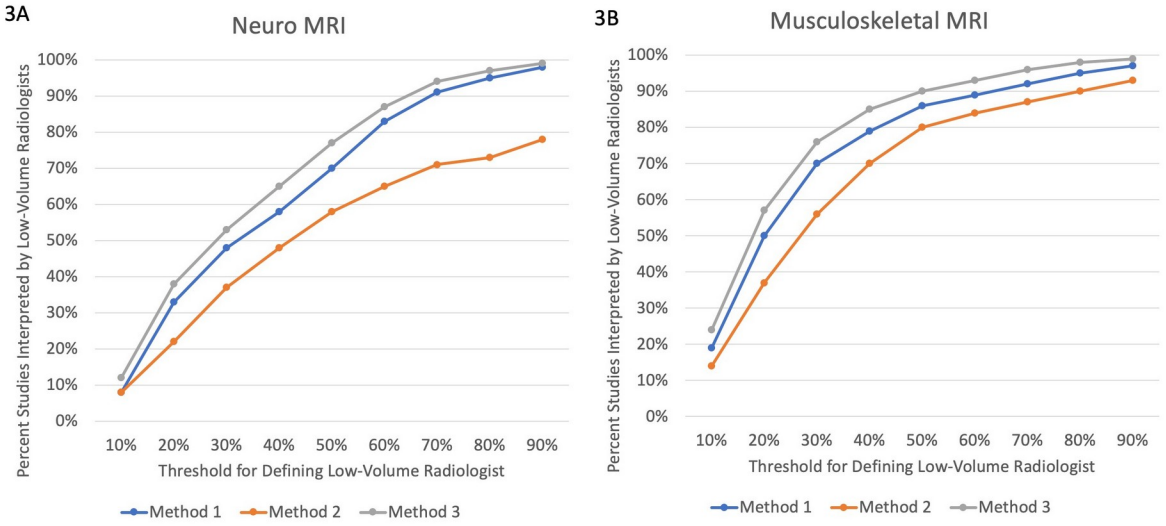

Fig. 3. Graphical representation of the percent of Neuro MRI (Fig 3a) and MSK MRI (Fig 3b) studies Interpreted by low-volume radiologists for Neuro and MSK, respectively. The percentages on the x-axis correspond to the different thresholds used to define low-volume reads of Neuro and MSK MRI.

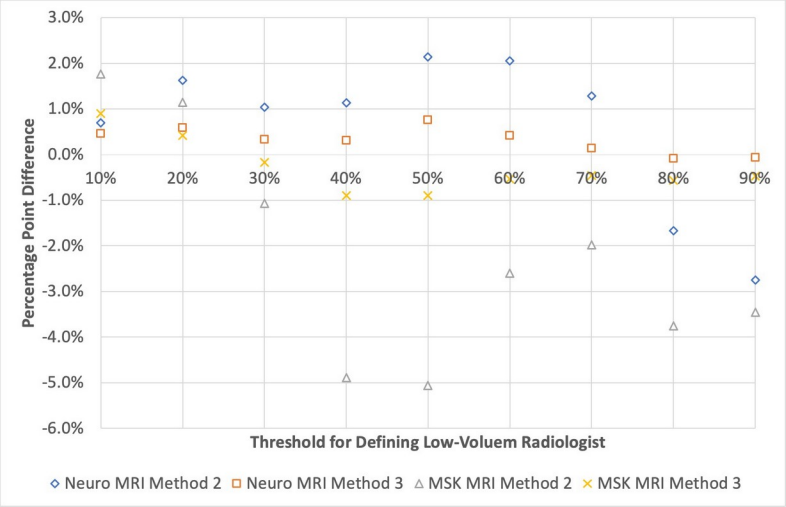

Fig. 4. Sensitivity analysis for definition of “average full-time radiologist.” Each data point represents the percentage point difference between the percent of Neuro/MSK MRI interpreted by low-volume radiologists when “average full-time radiologist” is defined as 25th to 75th percentile of total wRVU versus 10th to 90th percentile of total wRVU. Results are reported across all of the thresholds for defining low-volume radiologists. Positive numbers signify low-volume radiologists interpret more MRI when using the 10th to 90th percentiles.

Table 1. Number of Studies and wRVU Related to Neuro MRI and MSK MRI in Medicare Patients for 2015

	Neuro MRI	MSK MRI
Total # of radiologists who read studies of interest in…	14,788	14,230
Total # of studies of interest	4,082,577	2,884,539
Average # of studies of interest read per radiologist (StDev)	276 (319)	203 (243)
Median # of studies of interest read per radiologist	172	133
Average Total wRVU billed (StDev)	2236 (1397)	2258 (1404)
Average wRVU in studies of interest (StDev)	469 (549)	309 (366)
Median wRVU in studies of interest	286	202

Footnote: wRVU=work relative value unit

Table 2. Average full-time radiologists

*Representative Sub-groups	All	10%	20%	30%	40%	50%	60%	70%	80%	90%
Neuro MRI										
# of Radiologists	7,394	2,821	1,505	596	422	362	289	146	76	40
Average # of Neuro MRI Interpreted (StDev)	244 (227)	124 (47)	235 (65)	355 (96)	478 (117)	594 (152)	693 (180)	791 (206)	839 (201)	953 (298)
Median # of Neuro MRI	170	118	230	347	465	592	666	767	823	873
Average wRVU in Neuro MRI (StDev)	416 (399)	205 (78)	393 (107)	599 (157)	821 (198)	1038 (245)	1,225 (305)	1,420 (339)	1,504 (361)	1,667 (494)
Median wRVU in Neuro MRI	281	196	383	581	819	1,040	1,196	1,381	1,461	1,442
MSK MRI										
# of Radiologists	7,115	3,022	1,244	510	231	99	52	45	25	27
Average # of MSK MRI Interpreted (StDev)	185 (193)	130 (49)	256 (74)	377 (100)	507 (131)	668 (177)	759 (206)	873 (250)	1,050 (267)	1,240 (302)
Median # of MSK MRI	131	122	250	367	489	649	719	819	957	1163
Average wRVU in MSK MRI (StDev)	281 (287)	196 (75)	400 (110)	588 (152)	768 (196)	988 (257)	1,132 (289)	1,289 (351)	1,534 (355)	1,773 (426)
Median wRVU in MSK MRI	198	185	392	565	746	978	1,061	1,209	1,386	1,677

Footnotes:
*Subgroups are radiologists whose total wRVU fall within 25-75th percentile AND their percentage of wRVU in Neuro/MSK MRI studies within 5 percentage points of the subgroup label (i.e. 10% subgroup are radiologists with between 5 and 15% of wRVU in Neuro or MSK MRI, respectively).
wRVU=work relative value unit

Footnote: wRVU=work relative value unit

Table 3. Number of Neuro MRI radiologists meeting criteria for low-volume readers and number of studies interpreted by low volume readers using different thresholds and methods.

Method 1									
Threshold for wRVU in Study of Interest	10%	20%	30%	40%	50%	60%	70%	80%	90%
# of Low-Volume Radiologists for Neuro MRI	4,699 (32%)	9,477 (64%)	11,229 (76%)	12,210 (83%)	13,049 (88%)	13,862 (93%)	14,268 (96%)	14,495 (98%)	14,658 (99%)
% of Studies Interpreted by Low-volume Neuro MRI Radiologists	8%	33%	48%	58%	70%	83%	91%	95%	98%
Method 2									
Threshold # of Studies to Read to Define Low-Volume Radiologist	124	235	355	478	594	693	791	839	953
# of Low-Volume Readers	5,769 (39%)	9,013 (61%)	11,126 (75%)	12,271 (83%)	13,010 (88%)	13,433 (91%)	13,761 (93%)	13,869 (94%)	14,097 (95%)
% of Studies Interpreted by Low-Volume Radiologists	8%	22%	37%	48%	58%	65%	71%	73%	78%
Method 3									
Threshold for Low-Volume Radiologist	If meet criteria from either Method 1 or Method 2								
# of Low-Volume Radiologists	6,535 (44%)	10,860 (73%)	12,439 (84%)	13,253 (90%)	13,887 (94%)	14,347 (97%)	14,613 (99%)	14,709 (99%)	14,763 (100%)
% of Studies Interpreted by Low-Volume Radiologists	12%	38%	53%	65%	77%	87%	94%	97%	99%

Table 4. Number of MSK MRI radiologists meeting criteria for low-volume readers and number of studies interpreted by low volume readers using different thresholds and methods.

Method 1

Threshold for wRVU in Study of Interest	<10%	<20%	<30%	<40%	<50%	<60%	<70%	<80%	<90%
# of Low-Volume Radiologists for MSK MRI	6,816 (48%)	10,757 (76%)	12,428 (87%)	13,102 (92%)	13,486 (95%)	13,677 (96%)	13,822 (97%	13,940 (98%)	14,036 (99%)
% of Studies Interpreted by Low-Volume MSK MRI Radiologists	19%	50%	70%	79%	86%	89%	92%	95%	97%

Method 2

Threshold # of Studies to Read to Define Low-Volume Radiologist	130	256	377	507	668	759	873	1050	1240
# of Low-Volume Readers	6,941 (49%)	10,522 (74%)	12,236 (86%)	13,168 (93%)	13,678 (96%)	13,825 (97%)	13,948 (98%)	14,048 (99%)	14,126 (99%)
% of Studies Interpreted by Low-Volume Radiologists	14%	37%	56%	70%	80%	84%	87%	90%	93%

Method 3

Threshold for Low-Volume Radiologist	If meet criteria from either Method 1 or Method 2								
# of Low-Volume Radiologists	8,355 (59%)	12,053 (85%)	13,348 (94%)	13,788 (97%)	14,002 (98%)	14,089 (99%)	14,149 (99%)	14,190 (100%)	14,218 (100%)
% of Studies Interpreted by Low-Volume Radiologists	24%	57%	76%	85%	90%	93%	96%	98%	99%

Footnote: wRVU=work relative value unit

Table 5. Sensitivity analysis for definition of "average full-time radiologists." Number of MSK MRI radiologists meeting criteria for low-volume readers and number of studies interpreted by low volume readers using different thresholds and methods.

Method 1									
Threshold for wRVU in Study of Interest	10%	20%	30%	40%	50%	60%	70%	80%	90%
# of Low-Volume Radiologists for MSK MRI	6,816 (48%)	10,757 (76%)	12,428 (87%)	13,102 (92%)	13,486 (95%)	13,677 (96%)	13,822 (97%	13,940 (98%)	14,036 (99%)
% of Studies Interpreted by Low-Volume MSK MRI Radiologists	19%	50%	70%	79%	86%	89%	92%	95%	97%
Method 2									
Threshold # of Studies to Read to Define Low-Volume Radiologist	130	256	377	507	668	759	873	1050	1240
# of Low-Volume Readers	6,941 (49%)	10,522 (74%)	12,236 (86%)	13,168 (93%)	13,678 (96%)	13,825 (97%)	13,948 (98%)	14,048 (99%)	14,126 (99%)
% of Studies Interpreted by Low-Volume Radiologists	14%	37%	56%	70%	80%	84%	87%	90%	93%
Method 3									
Threshold for Low-Volume Radiologist	If meet criteria from either Method 1 or Method 2								
# of Low-Volume Radiologists	8,355 (59%)	12,053 (85%)	13,348 (94%)	13,788 (97%)	14,002 (98%)	14,089 (99%)	14,149 (99%)	14,190 (100%)	14,218 (100%)
% of Studies Interpreted by Low-Volume Radiologists	24%	57%	76%	85%	90%	93%	96%	98%	99%

Footnote: wRVU=work relative value unit