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PRACTICE

In comparison with other abdominal imaging modalities, which radiologists interpret abdominal MRI?

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Abstract

Purpose To assess subspecialty mix and case volumes of general and abdominal subspecialty radiologists interpreting abdominal MRI.

Methods The 2016 CMS Physician/Supplier Procedure Summary Master File was used to obtain billed counts of radiologist-interpreted abdominal fluoroscopy, US, CT, and MRI examinations. The CMS Physician and Other Supplier Public Use File was used to assess the subspecialty mix and case volume of the radiologists interpreting those examinations.

Results The fraction of all abdominal imaging examinations interpreted by generalists and abdominal subspecialty radiologists was 70.7% and 16.5% for fluoroscopy; 68.7% and 21.0% for US; 71.4% and 19.2% for CT; and 41.9% and 52.5% for MRI. In 2016, the fraction of general and abdominal radiologists interpreting > 50 fluoroscopy examinations on Medicare fee-for-service beneficiaries was 15.1% and 16.2%. For > 50 US examinations, the fraction was 61.5% and 60.5%; for > 50 CT examinations, 91.2% and 79.6%; and for > 50 MRI examinations, 4.0% and 28.5%. The fraction of abdominal imaging examinations interpreted overall by low-volume providers (those interpreting ≤ 50 examinations in 2016) was 59.5% for fluoroscopy, 17.5% for US, 6.3% for CT, and 50.6% for MRI.

Conclusion Nationally, most abdominal fluoroscopy, US, and CT examinations are interpreted by general radiologists, who have similar annual volumes of these examinations as abdominal subspecialty radiologists. In contrast, most abdominal MRI examinations are interpreted by abdominal subspecialty radiologists, who attain considerably higher volumes. These findings have implications for workforce planning and abdominal imaging fellowship design to ensure their graduates are optimally prepared to contribute to their future practices.

Keywords Abdominal radiologist · Radiologist workforce · MRI · Health policy

Introduction

Between 1994 and 2013, the utilization of abdominal MRI increased approximately 650%, in contrast to all other abdominal imaging modalities which all either decreased or increased by less than 100% [1]. Abdominal MRI represents an advanced imaging modality that has witnessed numerous hardware- and software-related technological advances, including the clinical adoption of new sequences such as DWI [2], perfusion [3], and elastography [4]. Currently abdominal MRI is most typically performed for targeted indications (e.g., hepatocellular carcinoma (HCC) screening or magnetic resonance cholangiopancreatography), and with highly focused information being sought (e.g., assessment of oncologic treatment response [5] or the subtype of a renal cell carcinoma [6]).

A prior study demonstrated added value from re-interpretation of abdominal MRI in the context of HCC screening by subspecialty-trained radiologists [7]. However, the extent to which training and experience in abdominal MRI occurs in practice for radiologists interpreting such examinations is currently unknown. Insights into abdominal MRI interpretation patterns could have implications for residency

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and fellowship curricula design, academic and private practice hiring and staffing, as well as workflow management within individual practices. We therefore conducted this study to assess the subspecialty mix and case volumes of general and abdominal subspecialty radiologists interpreting abdominal MRI in comparison with other abdominal imaging modalities.

Methods

This retrospective study using aggregate-level data sets was HIPAA-compliant and did not require institutional review board approval given that no private identifiable health information was used.

This study focused on imaging of the abdomen, which was stratified into the following examination types based on Current Procedural Terminology (CPT) codes: abdominal fluoroscopy, US, CT, CT angiography, and MRI (Table 1). We only focused on imaging performed and billed by radiologists, and thus intentionally excluded clinician ordered and interpreted (i.e., self-referred) imaging. For the purposes of this investigation, we defined abdominal imaging examinations as those targeting the abdomen alone or as part of other examinations, since it is not possible to differentiate pelvic CT and MRI performed for visceral vs. musculoskeletal indications from the data sets used. In order to support as contemporaneous an analysis as possible, we used aggregate claims for 2016 (the most recent year for which data were available for all of the used data sets).

We first obtained from the Centers for Medicare & Medicaid Services (CMS) the 2016 Physician/Supplier Procedure Summary (PSPS) Master File [8], which contains a 100% sample of billed claims for Medicare Part B Fee-For-Service beneficiaries, aggregated by CPT code. This data set has been used as the basis of prior studies examining variation in the interpretation of medical imaging examinations by provider specialty [9–11]. Using this file, total national frequency by radiologist of each abdominal imaging examination type was determined. We also determined the subset of services

Table 1 Current procedural terminology codes included within cohort

Code	Descriptor
Abdominal fluoroscopy	
74120	Fluoroscopy pharynx
74220	Fluoroscopy cervical esophagus
74230	Fluoroscopy pharynx/esophagus with video recording
74240	Fluoroscopy upper GI
74241	Fluoroscopy upper GI with KUB
74245	Fluoroscopy upper GI with small bowel follow-through
74246	Fluoroscopy upper GI, double contrast
74247	Fluoroscopy upper GI, double contrast, with KUB
74249	Fluoroscopy upper GI, double contrast, with small bowel follow-through
74250	Fluoroscopy small bowel follow-through
74251	Fluoroscopy small bowel enteroclysis
Abdominal US	
76700	Ultrasound abdomen complete
76705	Ultrasound abdomen limited
Abdominal CT	
74150	CT abdomen without contrast
74160	CT abdomen with contrast
74170	CT abdomen with and without contrast
74176	CT abdomen & pelvis without contrast
74177	CT abdomen & pelvis with contrast
74178	CT abdomen & pelvis with and without contrast
Abdominal CTA	
74174	CT angiography abdomen and pelvis with and without contrast
74175	CT angiography abdomen with and without contrast
Abdominal MRI	
74181	MRI abdomen without contrast
74182	MRI abdomen with contrast
74183	MRI abdomen with and without contrast

of each examination type that was rendered in conjunction with a trainee in a program approved by the Accreditation Council for Graduate Medical Education (ACGME), based on the presence of a "+GC" modifier in association with the claim [12, 13].

We subsequently obtained from CMS the 2016 Provider and Other Supplier Public Use File [14], which contains a 100% sample of billed claims for Medicare Part B Fee-For-Service beneficiaries, aggregated by combinations of billing provider and CPT code. For confidentiality reasons, CMS only reports this aggregate claim information when a given provider has billed over 10 instances of a given service within the year. This data set has also been previously used in studies examining the national radiologist workforce, particularly with regard to comparisons of practice characteristics between general vs. subspecialty radiologists [15–17]. The Neiman Imaging Types of Service claims-based subspecialty classification system [18–20] was then used to classify the subspecialty of all radiologists performing abdominal imaging based on a work relative value unit- (wRVU-) weighted ratio between billed claims mapped to individual subspecialties vs. total billed claims, assigning radiologists as generalists when not fulfilling wRVU-weighted claims-based criteria for any radiology subspecialty. This system has previously been demonstrated to have an error rate of 2.9% to 4.2% in radiologist subspecialty assignments [18, 19]. Though including a larger volume of services (i.e., services billed by providers rendering 10 or fewer of the given service), the PSPS Master Files do not provide information regarding the individual providers billing for services and thus could not be used to determine radiologist subspecialty in the described fashion.

The percentage of abdominal imaging examinations interpreted by low-volume providers was determined for the various modalities at two different thresholds (≤ 10 and ≤ 50 billed examinations on Medicare fee-for-service examinations per year). The percentage of abdominal imaging examinations interpreted by generalist radiologists, abdominal subspecialty radiologists, interventional radiologists, and all other radiology subspecialists was determined for each modality. The percentage of radiologists within each subspecialty category interpreting > 10 and > 50 examinations within each modality was determined. The percentage of all included abdominal imaging examinations nationally interpreted by a trainee was determined for each modality. Analysis was performed using Excel for Windows (Microsoft Corporation; Redmond, Washington).

Results

The study sample included 739,831 fluoroscopy, 1,786,641 ultrasound, 5,879,065 CT, 236,889 CT angiogram, and 374,624 MRI examinations of the abdomen performed by radiologists for Medicare fee-for-service beneficiaries in 2016. Among radiologists interpreting > 10 examinations of each modality, the median number of examinations interpreted per year was 32 for fluoroscopy, 67 for US, 208 for CT, 19 for CTA, and 29 for MRI. Figure 1 visually compares the annual caseload for abdominal CT and MRI among radiologists interpreting > 10 examinations per year. For MRI, there was a sharp initial peak of radiologists interpreting 11 or 12 MRI examinations per year with a subsequent abrupt drop-off resulting in very limited numbers of radiologists achieving high annual case volumes. In comparison, for CT, no drop-off in case volume was observed within the depicted range of up to 200 examinations per year.

The fraction of examinations interpreted by low-volume providers at the ≤ 10 examination threshold was 33.7% of fluoroscopy, 5.5% of ultrasound, 5.0% of CT, 39.0% of CTA, and 25.1% of MRI (Table 2). The fraction of examinations interpreted by low-volume providers at the ≤ 50 examination threshold was 59.5% for fluoroscopy, 17.5% for US, 6.3% for CT, 78.4% for CTA, and 50.6% for MRI (Table 2).

The fraction of examinations interpreted by general radiologists and abdominal subspecialty radiologists was 70.7% and 16.5% for fluoroscopy; 68.7% and 21.0% for US; 71.4% and 19.2% for CT; 48.5% and 20.2% for CTA, and 41.9% and 52.5% for MRI (Table 3). Interventional radiologists interpreted 21.3% of CTA. Otherwise, the fraction of examinations interpreted by interventional radiologists or by other subspecialists was $\leq 10.3\%$ for all modalities.

The fraction of general and abdominal subspecialty radiologists interpreting > 10 examinations was 53.5% and 40.8% for fluoroscopy; 91.0% and 81.2% for US; 97.1% and 88.0% for CT; 21.1% and 26.0% for CTA; and 24.8% and 49.3% for MRI (Table 4). The fraction of general and abdominal subspecialty radiologists interpreting > 50 examinations was 15.1% and 16.2% for fluoroscopy; 61.5% and 60.5% for US; 91.2% and 79.6% for CT; 1.2% and 4.5% for CTA; and 4.0% and 28.5% for MRI.

The fraction of all examinations nationally that were reported as performed with trainees in ACGME-approved programs was 10.5% for CTA, 11.5% for MRI, and 4.1%-6.4% for the other modalities (Table 5).

Discussion

Using two separate national Medicare fee-for-service aggregate claims data sets, we assessed the annual case mix and case volumes of general and subspecialized radiologists interpreting a spectrum of abdominal imaging examinations. The majority of the nation's abdominal imaging examinations (approximately 70% for fluoroscopy, US, and CT) is interpreted by generalist radiologists, rather than by abdominal subspecialty radiologists. In addition, generalists and

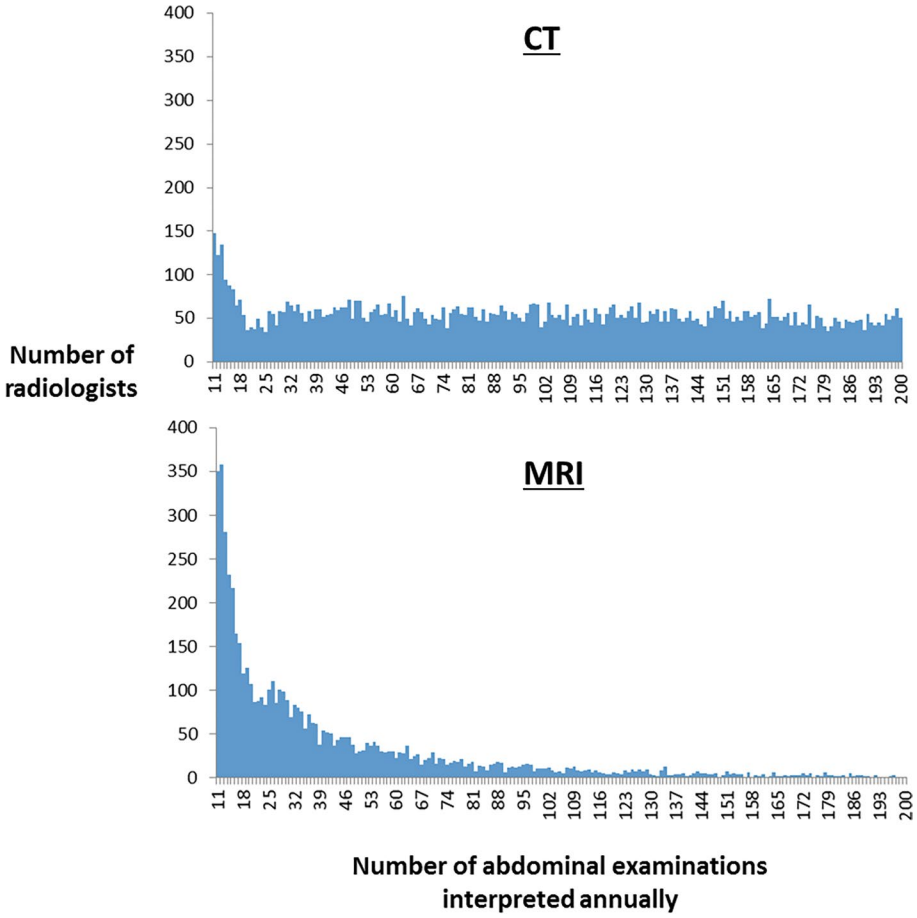

Fig. 1 Number of radiologists nationally interpreting given numbers of abdominal CT and MRI examinations annually; only annual volumes ≤ 200 displayed for illustrative purposes

Table 2 Percent of abdominal imaging examinations interpreted by low-volume providers, defined at thresholds of ≤ 10 and ≤ 50 examinations interpreted annually, stratified by modality

	≤ 10	≤ 50
Fluoroscopy (739,831)	33.7% (249,645)	59.5% (439,859)
US (1,786,641)	5.5% (97,886)	17.5% (313,101)
CT (5,879,065)	5.0% (295,755)	6.3% (369,324)
CTA (236,889)	39.0% (92,331)	78.4% (185,716)
MRI (374,624)	25.1% (93,916)	50.6% (189,476)

Numerators listed in parentheses after percentages; denominators listed in parentheses in first column

abdominal subspecialty radiologists were noted to be similar in terms of the percentage of each group interpreting > 10 and > 50 examinations for CT, fluoroscopy, and US. These observations may reflect the relatively high volumes of abdominal imaging in many practices, thus precluding their interpretation purely by subspecialists. They additionally likely reflect the extensive experience received by diagnostic radiology residents overall in abdominal imaging (e.g., not just while on dedicated abdominal imaging rotations but also on other rotations such as emergency radiology as well as on call).

Table 3 Percent of abdominal imaging examinations interpreted by different radiology subspecialties, stratified by modality

	Fluoroscopy (490,186)	US (1,688,755)	CT (5,583,310)	CTA (144,558)	MRI (280,708)
Generalist radiologist	70.7% (346,376)	68.7% (1,159,382)	71.4% (3,988,949)	48.5% (70,079)	41.9% (117,533)
Abdominal radiologist	16.5% (80,806)	21.0% (354,914)	19.2% (1,072,937)	20.2% (29,169)	52.5% (147,235)
Interventional radiologist	2.6% (12,739)	2.4% (40,512)	1.9% (107,935)	21.3% (30,863)	0.6% (1,784)
Other subspecialists	10.3% (50,265)	7.9% (133,947)	7.4% (413,498)	10.0% (14,447)	5.0% (14,156)

Computed among examinations interpreted by radiologists interpreting > 10 of the given examination

Numerators listed in parentheses after percentages; denominators listed in parentheses in first row

Table 4 Percent of radiologists of different subspecialties who interpret > 10 and > 50 examinations annually of different abdominal imaging modalities

	Fluoroscopy	US	CT	CTA	MRI
All radiologists (31,181)					
> 10 examinations	34.3% (10,681)	63.2% (19,720)	69.9% (21,803)	16.2% (5052)	18.3% (5715)
> 50 examinations	9.9% (3099)	39.2% (12,233)	61.7% (19,238)	1.8% (569)	5.2% (1611)
Generalist radiologists (14,757)					
> 10 examinations	53.5% (7869)	91.0% (13,429)	97.1% (14,327)	21.1% (3114)	24.8% (3662)
> 50 examinations	15.1% (2229)	61.5% (9072)	91.2% (13,461)	1.2% (170)	4.0% (592)
Abdominal radiologists (3267)					
> 10 examinations	40.8% (1332)	81.2% (2652)	88.0% (2875)	26.0% (850)	49.3% (1611)
> 50 examinations	16.2% (528)	60.5% (1977)	79.6% (2602)	4.5% (146)	28.5% (930)
Interventional radiologists (2,936)					
> 10 examinations	10.4% (305)	28.0% (821)	34.5% (1,012)	24.4% (715)	2.1% (61)
> 50 examinations	2.2% (64)	9.7% (284)	22.4% (659)	6.2% (182)	0.2% (7)
Other subspecialists (10,221)					
> 10 examinations	11.5% (1,175)	27.6% (2,818)	35.1% (3,589)	3.6% (373)	3.7% (381)
> 50 examinations	2.7% (278)	8.8% (900)	24.6% (2,516)	0.7% (71)	0.8% (82)

Numerators listed in parentheses after percentages; denominators listed in parentheses in first column

Table 5 Percentage of included abdominal imaging examinations nationally interpreted by a trainee

Modality	Percent
Fluoroscopy	6.4% (47,705/739,831)
US	4.1% (73,526/1,786,641)
CT	5.0% (292,363/5,879,065)
CTA	10.5% (24,829/236,889)
MRI	11.5% (42,964/374,624)

Numerators and denominators listed in parentheses after percentages

In contrast, MRI is the modality for which a clear distinction exists between generalists and subspecialty abdominal radiologists. This was the one modality for which a majority of examinations nationally are interpreted by abdominal subspecialty radiologists—rather than by generalists. Further, substantially higher fractions of abdominal radiologists (than of generalist radiologists) achieve high annual volumes of abdominal MRI interpretation, at both the > 10 and > 50 examination thresholds. The value of attaining high abdominal MRI volumes, as was more typical of abdominal radiologists, is highlighted by the observation that approximately 50% of abdominal MRI examinations were interpreted by low-volume providers at a ≤ 50 examination threshold, compared with only approximately 5% and 15% of abdominal CT and US examinations being interpreted by low-volume providers at the same threshold, as well as by the sharp drop-off in volumes across radiologists occurring for MRI but not for CT. Recent works have indicated that general radiologists account for a large fraction of both diagnostic and interventional radiology services rendered across the country [21, 22], overlapping with the services rendered by subspecialty radiologists. Our work indicates that such overlap does not extend in the same fashion to abdominal MRI.

The disparity in terms of abdominal CT being interpreted largely by high-volume readers of the modality regardless of subspecialty, compared with abdominal being MRI much more commonly being interpreted by low-volume readers, has implications for diagnostic radiology training pathways. Our findings support MRI expertise as a possible marketplace differentiator between subspecialty-trained and practicing abdominal radiologists vs. other radiologists. For this reason, abdominal imaging fellowships may seek to more heavily focus on MRI, both from a competitive standpoint in terms of attracting applicants as well as in terms of preparing their graduates for optimally and most uniquely contributing to their future practices. Numerous abdominal imaging fellowships currently offer a curriculum that comprises predominantly body MRI over the course of the year. But given our findings, radiology practices might prefer hiring an abdominal radiologist with specific expertise in abdominal MRI (rather than more broadly in abdominal imaging), particularly if they do not already have an individual on staff with such expertise. However, the slightly greater emphasis on MRI and CTA (vs. other abdominal imaging modalities) by radiology trainees in ACGME-approved programs suggests that this increased focus on MRI during training is already manifesting itself to some extent.

Our findings also have implications for radiology residents, who are required to make a decision regarding choice of fellowship early in their training (currently typically by the end of the R2 year), often prior to having sufficient exposure to abdominal MRI. However, residents considering pursuing an abdominal imaging fellowship should recognize the key role of abdominal MRI in

defining abdominal radiologists and ensure they welcome interpreting high volumes of such examinations throughout their future careers; these residents may also be well advised to seek fellowship programs with heavy emphasis on MRI, which would give a competitive advantage in the job market, whether choosing an academic or private practice. With the introduction of 'mini-fellowships,' fourth-year radiology residents now also have the unique opportunity to pursue subspecialized training in their areas of clinical interest. Trainees pursuing a non-body fellowship should consider choosing a 'mini-fellowship' in abdominal MRI, which will broaden their skills and knowledge, giving a competitive advantage over other generalists.

The observed differences in interpretation patterns for abdominal CT and MRI also have implications for practice management. Based on our findings, we believe it likely that many community practices may deem abdominal CT to represent "general" work expected of all group members, but in contrast carve out dedicated pools of their radiologists for abdominal MRI interpretations. The presence of small groups of individuals performing the majority of the latter service could be particularly relevant for groups prioritizing relative value unit (RVU) productivity or emerging quality metrics. Such workflow designs can contribute to unintended and sometimes disruptive consequences [23, 24]. For example, radiologists who are expected to read only from a narrowly defined worklist, distinct from broader lists used by their colleagues, could be placed at either an advantage or disadvantage in generating RVUs or reaching other targets, based on the composition of the given list and the sometimes idiosyncratic RVU weightings of such services. As such, potential misalignment of incentives should be carefully considered as they pertain to workload design and performance assessment of abdominal radiologists who may be more focused on MRI interpretation. As a separate consideration, generalists interpreting large volumes of abdominal imaging in their practices should consider pursuing educational opportunities in abdominal MRI, so as to help their practices manage their abdominal MRI volume while maintaining high quality as with other abdominal imaging modalities.

Abdominal CTA had some similarity to abdominal MRI in terms of generalists interpreting a minority of examinations nationally and tending to attain only low annual volumes. Unlike with abdominal MRI, however, abdominal radiologists did not show an increased tendency toward interpreting these studies. Rather, interventional radiologists had a relatively expanded role in interpretation of these examinations. Nonetheless, CTA could be an additional point of emphasis for abdominal imaging fellowship programs to help develop greater subspecialty expertise relative to generalist radiologists, thus expanding the pool of subspecialist talent in a radiologist workforce in which potential patient subspecialty access challenges exist [21, 22].

This study has a number of limitations. First, we used a data set based on services rendered only to Medicare FFS beneficiaries, and as such we did not capture examinations rendered to patients with other forms of insurance. In addition, given our use of these aggregate claims data sets, we were unable to obtain information regarding how experience or subspecialty expertise impacted the quality or outcomes from examination interpretations. Further, we did not evaluate the role of abdominal radiologists in interpreting non-abdominal imaging examinations. From prior work, it is known that abdominal imagers not uncommonly interpret examinations outside of their subspecialty domain [18, 19].

In conclusion, the bulk of abdominal fluoroscopy, US, and CT examinations nationally are interpreted by general radiologists, who had similar Medicare volumes of these examinations as abdominal subspecialty radiologists. In comparison, the majority of abdominal MRI examinations were interpreted by abdominal radiologists, who attained considerably higher annual volumes. Overall, approximately 50% of abdominal MRI vs. approximately 5% of abdominal CT examinations were interpreted by low-volume readers. These findings have implications for workforce planning and abdominal imaging fellowship design to ensure that trainees are prepared to optimally contribute to their future practices.

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