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Quantitative Metrics in Clinical Radiology Reporting: A Snapshot Perspective from a Single Mixed Academic-Community Practice

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Abstract

Quantitative imaging has emerged as a leading priority on the imaging research agenda, yet clinical radiology has traditionally maintained a skeptical attitude toward numerical measurement in diagnostic interpretation. To gauge the extent to which quantitative reporting has been incorporated into routine clinical radiology practice, and to offer preliminary baseline data against which the evolution of quantitative imaging can be measured, we obtained all clinical computed tomography (CT) and magnetic resonance imaging (MRI) reports from two randomly selected weekdays in 2011 at a single mixed academic-community practice and evaluated those reports for the presence of quantitative descriptors. We found that 44% of all reports contained at least one "quantitative metric" (QM), defined as any numerical descriptor of a physical property other than quantity, but only 2% of reports contained an "advanced quantitative metric" (AQM), defined as a numerical parameter reporting on lesion function or composition, excluding simple size and distance measurements. Possible reasons for the slow translation of AQMs into routine clinical radiology reporting include perceptions that the primary clinical question may be qualitative in nature or that a qualitative answer may be sufficient; concern that quantitative approaches may obscure important qualitative information, may not be adequately validated, or may not allow sufficient expression of uncertainty; the feeling that "gestalt" interpretation may be superior to quantitative paradigms; and practical workflow limitations. We suggest that quantitative imaging techniques will evolve primarily as dedicated instruments for answering specific clinical questions requiring precise and standardized interpretation. Validation in real-world settings, ease of use, and reimbursement economics will all play a role in determining the rate of translation of AQMs into broad practice.

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1. Introduction

Radiology thought leaders have called for an increased focus on extraction of quantitative information from clinical images and the imaging literature is replete with studies investigating new quantitative techniques, yet conventional wisdom holds that clinical radiology remains an overwhelmingly qualitative discipline. In this preliminary study attempting to characterize and understand this potential disconnection, we evaluate a sample of randomly selected clinical reports from a single mixed academic-community radiology practice for the presence or absence of quantitative metrics (QMs) and advanced quantitative metrics (AQMs), to be defined below. Our study tests the following hypotheses:

1. Despite calls for more quantitative imaging in radiology practice, prevalence of QMs and AQMs in routine clinical radiology reporting remains low.
2. Most QMs in routine clinical radiology reporting are simple descriptors of lesion size, with lower prevalence of AQMs such as perfusion parameters or apparent diffusion coefficient (ADC) values.
3. Due to the disproportionate use of QMs to describe lesion size, prevalence of QMs is higher in scans performed for assessing one or more space-occupying lesions, including cancer follow-up scans and scans performed to evaluate a mass or fluid collection.
4. Prevalence of QMs is higher for scans performed in the academic setting by subspecialty radiologists than for scans performed in the community setting by generalist radiologists.

2. Methods

2.1 Data collection and categorization

Institutional Review Board (IRB) exemption was obtained, and the informed consent requirement was waived for this purely retrospective study. Two nonholiday weekdays during 2011 (4/28/11 and 10/24/11) were randomly selected for analysis. All radiology reports from our practice for these two days were accessed from our Picture Archiving and Communication System (PACS) and were filtered to select only reports for computed tomography (CT) or magnetic resonance imaging (MRI). These data were then further filtered to remove irrelevant results including scans from outside institutions that had been archived in our PACS on those days, scans for which no report was available, scans of MRI phantoms (i.e., quality control scans), scans for CT-guided or MRI-guided biopsies, scans for which no report or only a limited report was available (e.g., for MRIs that were discontinued due to patient claustrophobia), and duplicate reports.

The remaining reports were then reviewed by a board-certified radiologist (R.A.) and were categorized across a set of parameters (Table 1), as follows:

Body part—Scans were categorized as Body, Breast, Cardiac, Musculoskeletal, Neurological, or Vascular. Body scans included all imaging of the chest, abdomen, or pelvis with the exception of dedicated musculoskeletal or vascular imaging. Breast consisted mostly of breast MRI (mammography was not included in this study). Cardiac included all dedicated CT or MRI imaging of the heart. Musculoskeletal included all extremity bone, joint, or soft tissue imaging. Neurological included brain, head/neck, and spine imaging. Vascular included all CT and MR angiography with the exception of neuroangiography, which was included in Neurological.

Imaging site—Ours is a multispecialty radiology practice with its primary presence at a tertiary-care academic medical center but with additional professional activity at several outpatient centers in the surrounding community. The academic medical center has separate adult and pediatric facilities. Scans were therefore categorized as Hospital-Adult, Hospital-Pediatric, or Community.

Scan indication—The primary indication for each scan was abstracted either from the submitted clinical history or from the report details. Similar indications were then grouped into high-level categories; for example, all follow-up scans for specific malignancies were grouped together as "cancer follow-up." The Appendix lists all high-level indication categories and provides examples of individual indications within each category. From this list of high-level indication categories, scans were categorized as having been performed for "cancer follow-up," "evaluate mass," or some other indication. The "evaluate mass" category included all scans for characterization of space-occupying lesions, including solid masses/nodules, fluid collections, hematomas, and aneurysms.

Presence of quantitative metrics (QMs)—Each report was categorized as either containing or not containing one or more QMs. A QM was defined as any numerical descriptor of a physical property other than quantity in either the Findings or Impression sections of the report. Examples of QMs include numerical descriptions of lesion size (e.g., diameter of a mass) or distance (e.g., distance of subfalcine herniation). Quantitative descriptors in the Technique section (e.g., scan collimation, contrast dose) were excluded. In the case of reports that implied some quantitative or semi-quantitative analysis having taking place but did not include numbers in the text, we categorized such reports as having contained QMs if it was clear that an analysis had taken place with reference to a certain numerical threshold (e.g., a Hounsfield Unit threshold in the case of characterizing an adrenal adenoma on unenhanced CT) but not if the report implied a gestalt, non-threshold-based evaluation (e.g., a lesion described as cystic-appearing due to the subjective perception of low internal attenuation on CT).

Presence of advanced quantitative metrics (AQMs)—Each report was also categorized as either containing or not containing one or more AQMs. An AQM was defined as a numerical descriptor reporting on lesion function or composition, excluding simple size or distance measurements. Examples of AQMs include perfusion parameters and ADC values. Volumetric measurements and histogram analyses were also considered AQMs.

2.2 Statistical analysis

From the above information we calculated the overall prevalence of QMs and AQMs across all CT and MR reporting for the two selected days. We then assessed the prevalence of QMs and AQMs by modality, body part, imaging site, and scan indication (i.e., prevalence of QMs and AQMs for "cancer follow-up" and "evaluate mass" indications versus all other indications).

Within each analysis, a Fisher's exact test was used to determine the association between categorical variables and the binary presence or absence of QMs and AQMs, respectively. Statistical significance was claimed at a p-value less than or equal to 0.05. For parameters with more than two categories (e.g., body part), a test was first performed for a statistically significant difference within the overall group; if the overall test was statistically significant, multiple comparisons were carried out within the group using the Bonferroni correction.

3. Results

3.1 Sample characteristics and distribution of scans

Our initial PACS query retrieved a total of 469 scans (including CT and MRI) on 4/28/2011 and 497 scans on 10/24/11, for a total of 966 scans. From this initial list, we removed 173 outside scans, 15 scans for which a report was not available, 6 MRI phantom (i.e., quality control) scans, 5 biopsy reports, 4 reports for scans that were discontinued due to patient claustrophobia, and 2 duplicate reports, leaving a final total of 761 scans for analysis.

Table 2 provides an overview of our final sample when broken down by different parameters. Our sample included 353 scans from 4/28/11 and 408 scans from 10/24/11. When broken down by modality, our sample included 511 CTs and 250 MRIs. When broken down by body part, our sample included 265 Body, 4 Breast, 8 Cardiac, 85 Musculoskeletal, 370 Neurological, and 29 Vascular scans. When broken down by imaging site, our sample included 468 Hospital-Adult, 84 Hospital-Pediatric, and 209 Community. When broken down by scan indication, our sample included 150 scans performed for “cancer follow-up,” 67 scans performed for “evaluate mass,” and 544 scans performed for other indications.

Table 3 provides an overview of the most common scanning indications (using high-level indication categories) by modality, body section, and imaging location. Important indications in our sample ($n > 10$ within an imaging site) included cancer follow-up, trauma, joint pain, sinusitis, spondylosis/back pain, demyelinating disease (including multiple sclerosis), “evaluate mass,” and acute chest and abdomen symptoms. Hospital scans were slightly skewed toward more acute presentations, while community scans were slightly skewed toward more chronic disease.

3.2 Overall prevalence and nature of QMs and AQMs

The overall prevalence of QMs in our sample was 43.8% (95% confidence interval: 40.3 – 47.3%) (Table 4). As detailed in Table 5, most of the QMs found in our sample were size measurements of solid mass lesions, nodules, pathologic lymph nodes, or foci of abnormal enhancement.

The overall prevalence of AQMs in our sample was 2.0% (1.2 – 3.2%) (Table 6). AQMs found in our sample included CT Hounsfield Unit (HU) attenuation values, CT coronary calcium scores, MRI-derived cardiac functional measurements, and a single description of percent enhancement of a breast lesion over baseline on MRI (Table 7).

3.3 Prevalence of QMs and AQMs by date

Prevalence of QMs was 43.9% (38.8 – 49.1%) on 4/28/11 and 43.6% (38.9 – 48.5%) on 10/24/11; this was not a statistically significant difference (p = 0.9417).

Prevalence of AQMs was 2.0% (1.0 – 4.0%) on 4/28/11 and 2.0% (1.0 – 3.8%) on 10/24/11; this was not a statistically significant difference (p > 0.9999).

3.4 Prevalence of QMs and AQMs by modality

Prevalence of QMs was 46.0% (41.7 – 50.3%) for CT and 39.2% (33.4 – 45.4%) for MRI; this was not a statistically significant difference (p = 0.0869).

Prevalence of AQMs was 1.2% (0.6 – 2.5%) for CT and 3.6% (1.9 – 6.7%) for MRI; this was a statistically significant difference (p = 0.0471).

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3.5 Prevalence of QMs and AQMs by body part

Prevalence of QMs was 66.0% (60.1 – 71.5%) for Body, 100% (47.8 – 100%) for Breast, 100% (60.4 – 100%) for Cardiac, 42.4% (32.4 – 53.0%) for Musculoskeletal, 25.4% (21.2 – 30.1%) for Neurological, and 55.2% (37.4% – 71.7%) for Vascular. Prevalence of QMs was significantly higher for Body ($p < 0.0001$) and Cardiac ($p = 0.0013$) than for other body parts. Prevalence of QMs was significantly lower for Neurological ($p < 0.0001$) than for other body parts.

Prevalence of AQMs was 2.3% (1.1 – 5.1%) for Body, 25% (5.3 – 71.6%) for Breast, 100% (66.3 – 100%) for Cardiac, 0% (0 – 4.2%) for Musculoskeletal, 0% (0 – 1.0%) for Neurological, and 0% (0 – 11.6%) for Vascular. Prevalence of AQMs was significantly higher for Cardiac ($p < 0.0001$) than for other body parts. Prevalence of AQMs was significantly lower for Neurological ($p = 0.0001$) than for other body parts.

3.6 Prevalence of QMs and AQMs by imaging site

Prevalence of QMs was 45.7% (41.3 – 50.3%) for Hospital-Adult, 31.0% (22.1 – 41.5%) for Hospital-Pediatric, and 44.5% (37.9 – 51.3%) for Community. Prevalence of QMs was significantly lower for Hospital-Pediatric ($p = 0.0141$) than for other imaging sites.

Prevalence of AQMs was 2.1% (1.2 – 3.7%) for Hospital-Adult, 0% (0 – 4.2%) for Hospital-Pediatric, and 2.4% (1.1 – 5.5%) for Community. There was not a statistically significant difference among the group ($p = 0.5397$).

3.7 Prevalence of QMs and AQMs by scan indication

Prevalence of QMs was 71.3% (63.6 – 80.0%) for “cancer follow-up,” 67.2% (55.2 – 77.2%) for “evaluate mass,” and 33.3% (29.4 – 37.3%) for all other indications. Prevalence of QMs was significantly higher for “cancer follow-up” ($p < 0.0001$) and “evaluate mass” ($p < 0.0001$) and was significantly lower for all other indications ($p < 0.0001$).

Prevalence of AQMs was 1.3% (0.4 – 4.7%) for “cancer follow-up,” 1.5% (0.4 – 7.9%) for “evaluate mass,” and 2.2% (1.3 – 3.8%) for all other indications. There was not a statistically significant difference among the group ($p = 0.9067$).

4. Discussion

To our knowledge this is the first study in the radiology literature examining the prevalence of quantitative descriptors in general clinical radiology reporting, although one recent article surveyed radiologists on rates of quantitative tumor measurements at major U.S. cancer centers. This paper does not attempt to make a value judgment on the amount of quantitative reporting in current practice, but rather seeks only to offer a snapshot “biopsy” of reporting in a single radiology group as a preliminary attempt to define the extent to which quantitative imaging has been incorporated into day-to-day radiology practice.

This study evolved from the observation of a possible disconnection between the current enthusiasm for quantitative imaging in the academic literature and the skepticism that clinical radiology has traditionally held toward numerical description. Current thought leaders have called for increased incorporation of quantitative imaging into clinical radiology, the imaging literature is replete with studies attempting to develop and validate new quantitative biomarkers, and networks comprised of researchers and industry representatives (including the Quantitative Imaging Network (QIN) and the Quantitative Imaging Biomarkers Alliance (QIBA)) have been formed to promote creation and dissemination of quantitative imaging standards. Yet many radiologists came of age hearing aphorisms such as “a radiologist with a ruler is a radiologist in trouble,” cautioning against a

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reliance on quantitative measurement at the possible expense of diagnostic accuracy and patient welfare. We undertook this study with the objectives of determining the current prevalence of QMs and AQMs in radiology reporting, characterizing the use of QMs and AQMs along different reporting parameters, and gathering baseline data against which the future evolution of quantitative imaging can be measured.

In testing our initial hypotheses, we found that nearly half of all radiology reports in our sample contained at least one QM, a result that would argue against the assertion that radiologists are averse to including quantitative descriptors in their reports. However, only 2 percent of radiology reports contained an AQM, suggesting that numerical metrics other than size and distance have been slow to translate into routine clinical practice. The few AQMs found in our sample included CT attenuation values, coronary calcium scores, and cardiac function measurements. We did not encounter a single ADC value or formal quantitative perfusion parameter, although we did find one measurement of percent enhancement of a breast lesion over baseline on MRI. Prevalence of QMs was significantly higher for Body imaging than for other body parts, probably reflecting the increased focus of Body scans on evaluation of specific space-occupying lesions. When viewed by scan indication, the prevalence of QMs was much higher for “cancer follow-up” and “evaluate mass” than for all other indications. Prevalence of QMs was roughly the same between Hospital-Adult and Community, indicating no statistically significant difference between subspecialty and generalist radiologists in use of QMs.

Why have AQMs been slow to translate into routine clinical radiology practice? We offer several possible explanations (Table 8). First, many clinical scans are clearly performed in order to gather qualitative information. Our data on high-level scanning indications (Table 4) support the contention that many diagnostic scans are performed to obtain qualitative answers to qualitative questions. However, diagnostic imaging is now undergoing a paradigm shift in which quantitative techniques are emerging to answer questions previously considered to be exclusively qualitative. This is especially true in cancer imaging, where the question of whether disease is responding or progressing can now be addressed with quantitative tumor size measurements and also by reference to a number of emerging AQMs (e.g., ADC, k_{trans}) reporting on lesion composition and/or function. Given the large amount of “follow-up cancer” imaging in our sample, the absence of these newer AQMs would seem to require further explanation.

Second, even if quantitative techniques may be available to answer a clinical question, both the radiologist and the referring physician may feel that a qualitative answer is sufficient, i.e., that the increased precision resulting from quantitative interpretation would have no real effect on patient management and would therefore provide no incremental value over a qualitative description. To the extent that clinical decision-making remains qualitative and mechanistic rather than quantitative and computational, AQMs may represent a “solution in search of a problem” when applied to scenarios in which qualitative thought paradigms still predominate. Even if AQMs were presented in a radiology report, referring physicians may not know how to integrate them into their own patient care algorithms; this problem is exacerbated by each clinical subspecialty field maintaining its own dedicated literature, such that quantitative techniques validated in the imaging literature may not be quickly incorporated into the larger body of clinical knowledge. As for radiologists’ liberal use of simple size and distance metrics, we suggest that this practice traces not necessarily to the desire for increased precision in reporting, but rather to the more fundamental objective of painting a visual picture for referring physicians who may still conceive of diagnostic imaging primarily as a way of obtaining a qualitative sense of a patient’s gross pathology. Quantitative imaging techniques will likely be demanded most vocally and therefore incorporated most rapidly in those clinical setting where quantitative thought paradigms are replacing or have replaced traditional qualitative thinking.

Third, radiologists may be reluctant to incorporate quantitative reporting out of concern that an emphasis on measurement may blind the observer to other important information on the image. This objection to quantification dates back to the era of screen-film radiography, when numerical measurements had to be coaxed artificially out of analog images and the “radiologist with a ruler” risked neglecting the important qualitative answers that must be answered in a complete diagnostic interpretation. While modern digital techniques have facilitated quantitative data extraction from clinical images, one might still raise the legitimate concern that too heavy a focus on quantitative measurement might detract from the important task of making relevant qualitative observations, especially with high spatial resolution modalities where one might encounter an infinite number of possible pathologic findings and anatomic variants that might be pertinent to clinical care. It remains to be proven, not merely asserted, that AQMs can be incorporated into modern diagnostic reporting without compromising the qualitative portions of the interpretation, just as it remains to be proven that quantitative methodologies can be incorporated into modern radiology education without diluting the traditional core training in visual pattern recognition. While perhaps obvious, it is worth noting that we expect AQMs to evolve as elements of a larger, mostly qualitative clinical radiology report, rather than replacing the qualitative interpretation altogether.

Fourth, when considering a novel QM, either the radiologist or the referring physician may consider the metric as not yet having been sufficiently validated under real-life clinical conditions. For example, despite studies in the imaging literature presenting threshold ADC values for discriminating benign from malignant lesions, many clinicians consider these thresholds as either (a) not adequately tested in clinical settings outside of a controlled research environment or (b) not meeting certain requirements for accuracy including sensitivity, specificity, and area under the receiver operating characteristic (ROC) curve. In general, radiologists have been comfortable adopting newer imaging techniques on a qualitative basis (e.g., visual assessment of relative signal differences within an ADC or parametric color perfusion map) but have hesitated to incorporate the associated AQMs into their reporting. These concerns may slowly subside with increasing data and with adoption of AQMs by thought leaders both in radiology and in referring clinical fields. Imaging researchers should be cognizant of the need to validate newer techniques in environments that approximate as closely as possible to real-world clinical settings.

Fifth, radiologists may hesitate to incorporate newer QMs out of the feeling that numerical measurement is *too precise*, implying an accuracy and a certainty that may not always be present. We know from experimental data that measurement in diagnostic imaging is subject to variability and error. On a more important level, however, there is the concern that quantitative measurements could never capture the nuances and “shades of grey” inherent to as complex a system as the human body. Experienced radiologists often gently tweak the wording of their reports to convey subjective assessments of probability; consider, for example, the implied difference between “almost certainly malignant,” “possibly malignant,” “probably not malignant although malignancy cannot be entirely excluded,” and “benign in appearance.” The black-and-white nature of quantitative reporting may leave the radiologist uncomfortable with not being able to express degrees of uncertainty.

Sixth, beyond wanting to be able to express uncertainty when appropriate, some radiologists may simply place more trust in holistic or gestalt paradigms than in deconstructed interpretation. Many radiologists feel that through training and experience they have developed a “sixth sense” that allows them to glance at an image and almost instantaneously know whether there is something out of place that requires further investigation. This notion – that experienced individuals may acquire the ability to subconsciously react to a stimulus very quickly and very accurately – has been addressed in the popular literature in books such as Malcolm Gladwell's *Blink*, and the field of naturalistic decision-making has arisen in an attempt to understand the effects of experience on intuitive thought. Articles in the non-radiology clinical literature have also suggested that current enthusiasm for mathematical models in medical decision-making and research may be placing traditional clinical judgment in jeopardy. In time we may be able to engage in systematic study of gestalt interpretation, pitting it against quantitative modeling for detection or characterization of particular disease entities. In the meantime, many radiologists will continue to point to gestalt interpretation as their most valuable tool, one that will not easily replaced by numbers.

Finally, there are practical workflow limitations to incorporating quantitative methods into routine radiology reporting. Some quantitative techniques can be time-consuming and resource-intensive, requiring additional expertise and training on the part of the technologist and/or radiologist. The need for specialized post-processing on a dedicated workstation can further disrupt clinical workflow and also create problems by introducing additional equipment into a crowded workspace. The relevance of these limitations may depend largely on the availability of additional economic reimbursements to offset potential interruptions in workflow. We would expect reimbursement policy to be a major determinant of the speed with which advanced quantitative imaging technologies are adopted into routine clinical practice.

Although this preliminary study captures the experience of only a single practice over two randomly selected dates, our results are thought to be somewhat generalizable to the larger radiology landscape. Ours is a fairly representative mid-to-large-scale radiology department with a volume of approximately 50,000 procedures per month. As noted previously, our practice is comprised of both subspecialists and generalists, and we maintain presence in a tertiary-care referral center (with separate adult and pediatric facilities) as well as several outpatient centers in the surrounding community.

We do note several limitations than may have affected our prevalence results. First, our department is fairly siloed with clinical and research activities taking place in separate facilities; other, more integrated academic departments may incorporate more AQMs into their clinical reporting by virtue of greater clinical access to experimental equipment and higher participation of clinical faculty in active research endeavors. Second, our volume of certain specialty procedures (e.g., prostate MRI) is probably lower than in other institutions due to our particular locoregional referral patterns. Third, our cardiology department does its own reporting for inpatient Cardiac scans, leading to possible undersampling of Cardiac AQMs in our sample. Fourth, the small sample size in this preliminary study led to wide confidence intervals especially for Breast, Cardiac, and Vascular imaging. And finally, due to our exclusive focus on CT and MR imaging, we did not measure the use of AQMs in other modalities, most notably the use of standard uptake values (SUVs) in PET imaging.

In conclusion, our findings suggest that radiologists are not inherently averse to using quantitative descriptors but that AQMs have indeed been slow to translate into routine clinical practice. We envision this study as providing useful baseline data against which the future evolution of quantitative imaging may be measured. We believe that quantitative techniques in imaging will continue to evolve, driven by the need for more precise and more standardized interpretation in support of evidence-based medicine grounded in quantitative statistics, but that QMs will develop largely as dedicated instruments for answering specific questions, with the larger radiology "toolbox" remaining primarily qualitative for the

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foreseeable future. We would expect gradual incorporation of more AQMs into radiology reporting as clinical decision-making paradigms become more quantitative and as AQMs themselves are more broadly validated and their clinical relevance and improvement over current methods is demonstrated. Vendors will face the important challenge of making AQMs easy to obtain from the scan – ideally as easy as using electronic calipers to make size and distance measurements – with software integrated into existing platforms and lesion segmentation performed automatically or with the push of a button. Finally, we expect reimbursement economics to play a large role in dictating the speed with which AQMs are translated into routine clinical practice.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Parameters used for categorization of scans

Parameter	Possible values
Date	4/28/11
	10/24/11
Modality	CT
	MRI
Body part	Body
	Breast
	Cardiac
	Musculoskeletal
	Neurological
	Vascular
Imaging site	Hospital-Adult
	Hospital-Pediatric
	Community
Scan indication	“Cancer follow-up”
	“Evaluate mass”
	Other
Presence of quantitative metrics (QMs)	Present
	Absent
Presence of advanced quantitative metrics (AQMs)	Present
	Absent

Table 2

Distribution of scans by parameter

Parameter	4/28/11	10/24/11	Total
By modality:			
CT	230	281	511
MRI	123	127	250
By body part:			
Body	118	147	265
Breast	1	3	4
Cardiac	3	5	8
Musculoskeletal	42	43	85
Neurological	176	194	370
Vascular	13	16	29
By imaging site:			
Hospital-Adult	226	242	468
Hospital-Pediatric	25	59	84
Community	102	107	209
By scan indication:			
"Cancer follow-up"	71	79	150
"Evaluate mass"	30	37	67
Other	252	292	544
All scans	353	408	761

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Table 3

High-level scanning indications (*n*) by modality, body part, and imaging site

Body part/modality	Hospital-Adult	Hospital-Pediatric	Community	Total scans
Body – CT	Cancer follow-up (70) Acute abdomen (32) Trauma (21) Others (50)	Acute abdomen (4) Cancer follow-up (4) Trauma (4) Others (3)	Cancer follow-up (23) Acute abdomen (19) Others (28)	258
Body – MRI	Cirrhosis/HCC surveillance (2) Inflamatory bowel disease (2) Others (2)	*n/a*	Evaluate mass (1)	7
Breast – CT	*n/a*	*n/a*	*n/a*	0
Breast – MRI	*n/a*	*n/a*	Cancer follow-up (3) High risk for breast cancer (1)	4
Cardiac – CT	*n/a*	*n/a*	*n/a*	0
Cardiac – MRI	Arrhythmia (2) Cardiac valvular disease (2) Cardiomyopathy (2) Other (2)	*n/a*	*n/a*	8
MSK – CT	Postoperative (3) Joint pain (2) Trauma (1)	*n/a*	Postoperative (2) Trauma (2) Cancer follow-up (1)	11
MSK – MRI	Trauma (15) Joint pain (9) Other (10)	Scoliosis (2) Others (4)	Joint pain (21) Trauma (8) Others (5)	74
Neuro – CT	Trauma (43) Sinusitis (19) Altered mental status (12) Others (62)	Trauma (12) Evaluate mass (5) Others (22)	Spondylosis/back pain (9) Cancer follow-up (8) Others (23)	215
Neuro – MRI	Evaluate mass (20) Cancer follow-up (17) Others (41)	Evaluate mass (4) Neurodevelopmental disease (3) Seizures (3) Others (13)	Spondylosis/back pain (13) Demyelinating disease (12) Headache (7) Others (22)	155
Vascular – CT	Acute chest (14) Evaluate mass (3) Peripheral vascular disease (3) Others (5)	Visceral vascular disease (1)	Acute chest (1)	27
Vascular - MRI	Congenital heart diease (1) Evaluate mass (1)	*n/a*	*n/a*	2
All scans	468	84	209	761

Table 4

Prevalence of QMs by reporting parameter

Parameter	Prevalence (%)	95% CI	Overall comparison p-value	Multiple comparisons p-value
Overall	333/761 (43.8%)	[40.3%, 47.3%]		
By date:				
4/28/11	155/353 (43.9%)	[38.8%, 49.1%]	0.9417	
10/24/11	178/408 (43.6%)	[38.9%, 48.5%]		
By modality:				
CT	235/511 (46.0%)	[41.7%, 50.3%]	0.0869	
MRI	98/250 (39.2%)	[33.4%, 45.4%]		
By body part:				
Body	176/265 (66.0%)	[60.1%, 71.5%]	<0.0001 *	<0.0001 *
Breast	4/4 (100%)	[47.8, 100%]		0.0363
Cardiac	8/8 (100%)	[60.4%, 100%]		0.0013 *
MSK	36/85 (42.4%)	[32.4%, 53.0%]		0.8173
Neuro	94/370 (25.4%)	[21.2%, 30.1%]		<0.0001 *
Vascular	16/25 (55.2%)	[37.4%,71.7%]		0.2526
By imaging site:				
Hospital-Adult	214/468 (45.7%)	[41.3%, 50.3%]	0.0396 *	0.1760
Hospital-Pediatric	26/84 (31.0%)	[22.1, 41.5%]		0.0141 *
Community	93/209 (44.5%)	[37.9%, 51.3%]		0.8060
By scan indication:				
"Cancer follow-up"	107/150 (71.3%)	[63.6%, 80.0%]	<0.0001 *	<0.0001 *
"Evaluate mass"	45/67 (67.2%)	[55.2%, 77.2%]		<0.0001 *
Other	181/544 (33.3%)	[29.4%, 37.3%]		<0.0001 *

CI = confidence interval.

* denotes statistically significant (incorporating Bonferroni correction for multiple comparisons)

Table 5

QMs found in our sample of radiology reports

Metric	Number of reports containing metric
Size of solid mass/nodule/lymph node/abnormal enhancement	210
Size of cyst	21
Size of fluid collection/abscess/hematoma	19
Size of non-neoplastic extremity musculoskeletal pathology (intraarticular body, fracture impaction, thickness or length of tendon/cartilage tear)	17
Size of non-neoplastic spine pathology (disc extrusion, central canal stenosis, spondylolisthesis, percent loss of height of compression fracture)	13
Size or percent narrowing of vessel	12
Size of nasal bone spur/nasal septal deviation	12
Distance of brain herniation/midline shift	8
Size of renal calculus	6
Size of solid organ (e.g., spleen, prostate)	6
Diameter of hollow viscus (e.g., appendix, small bowel)	5
Other (including AQMs)	19

Note: Number of reports total greater than 333 due to some reports containing more than one type of QM

Table 6

Prevalence of AQMs by reporting parameter

Parameter	Prevalence (%)	95% CI	Overall comparison p-value	Multiple comparisons p-value
Overall	15/761 (2.0%)	[1.2%, 3.2%]		
By date:				
4/28/11	7/353 (2.0%)	[1.0%, 4.0%]	> 0.9999	
10/24/11	8/408 (2.0%)	[1.0%, 3.8%]		
By modality:				
CT	6/511 (1.2%)	[0.6%, 2.5%]	0.0471 *	
MRI	9/250 (3.6%)	[1.9%, 6.7%]		
By body part:				
Body	6/265 (2.3%)	[1.1%, 5.1%]	<0.0001 *	0.5755
Breast	1/4 (25%)	[5.3%, 71.6%]		0.0767
Cardiac	8/8 (100%)	[66.3%, 100%]		<0.0001 *
MSK	0/85 (0%)	[0%, 4.2%]		0.3864
Neuro	0/370 (0%)	[0%, 1.0%]		0.0001 *
Vascular	0/29 (0%)	[0%, 11.6%]		>0.9999
By imaging site:				
Hospital-Adult	10/468 (2.1%)	[1.2%, 3.7%]	0.5397	
Hospital-Pediatric	0/84 (0%)	[0, 4.2%]		
Community	5/209 (2.4%)	[1.1%, 5.5%]		
By scan indication:				
“Cancer follow-up”	2/150 (1.3%)	[0.4%, 4.7%]	0.9067	
“Evaluate mass”	1/67 (1.5%)	[0.4%, 7.9%]		
Other	12/544 (2.2%)	[1.3%, 3.8%]		

CI = confidence interval.

*denotes statistically significant (incorporating Bonferroni correction for multiple comparisons)

Table 7

AQMs found in our sample of radiology reports

Modality	Metric	Number of reports containing metric
CT	Hounsfield Unit (HU) attenuation value	4
	Coronary calcium score	2
MRI	Multiple cardiac function measurements (incl. stroke volume, ejection fraction, etc.)	8
	Percent enhancement of breast lesion over baseline	1

Table 8

Potential reasons for the slow translation of AQMs into routine clinical radiology practice

- Primary clinical question considered to be qualitative in nature
- Qualitative answer to the clinical question considered sufficient
- Concern that quantitative measurement may obscure important qualitative information
- Concern that quantitative techniques not adequately validated under real-life conditions
- Concern that quantitative metrics do not allow sufficient expression of uncertainty
- "Gestalt" interpretation felt to be superior to quantitative paradigms
- Practical workflow limitations to quantitative imaging