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Readability of radiology reports: implications for patient-centered care

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ABSTRACT

Introduction: Radiology reports, although written primarily for healthcare providers, are read increasingly by patients and their family. This study sought to assess the readability of radiology reports.

Materials and methods: From 108,228 consecutive radiology reports from a large US health system, we excluded duplicate reports, reports of research exams, and reports with missing data. For each report, we measured the numbers of words and sentences, and computed a "reading grade level" (RGL) as the mean of three readability indices: Flesch-Kincaid Grade Level, Gunning Fog index, and Simple Measure of Gobbledygook. Analysis of variance (ANOVA) evaluated the effects of modality, patient setting, examination urgency, and combinations thereof on RGL.

Results: The 97,052 reports in the study cohort had a mean (± standard deviation) of 17.6 ± 12.8 sentences and 203 ± 161 words. Patient setting, modality, and examination urgency all had significant independent effects on RGL (all with $p < 0.001$). There were 4094 reports (4.2%) at a reading grade level of 8 or lower.

Conclusion: Radiology reports often contain complex concepts and polysyllabic terms unfamiliar to lay readers. Only 4% of all radiology reports in our sample were readable at the 8th grade level, which is the reading level of the average US adult. Although radiology reports are written for physicians and other healthcare providers, radiologists might explore using simpler, more structured language to address the goals of patient-centered care.

1. Introduction

Radiology reports are written primarily for referring physicians and other healthcare providers, but patients and their family members are interested to read their radiology reports through electronic health record (EHR) "patient portals", and do so with increasing frequency [1–5]. Although radiology reports may help patients enhance the understanding of their care and achieve better health outcomes, patients cite lengthy reports and overly technical terms as barriers to comprehension [6]. Readability indices provide objective metrics that can serve as a starting point for quality improvement efforts. The current study sought to assess the readability of radiology reports, and to suggest approaches to improve the readability of radiology reports.

2. Materials and methods

We acquired all radiology reports from January 1, 2017 to February 4, 2017 (5 weeks) from our institution, a large metropolitan U.S. health system, in which approximately 60% of exams are interpreted by academic radiologists (with or without trainees) and 40% by community-based radiologists. If a patient had combined reports for two or more examinations (e.g., foot and ankle radiographs), one report was included, and the others were considered "duplicates" containing the same information and were excluded. We captured imaging modality, patient setting (inpatient, outpatient, or emergency department), and exam urgency (STAT vs. non-STAT) for each report; we excluded reports where such information was missing. We also excluded reports for research examinations that did not have a com-

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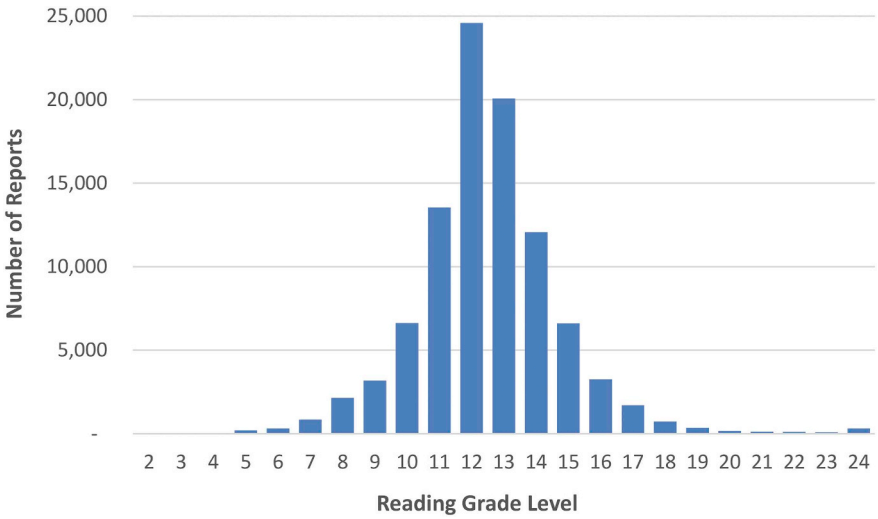

Fig. 1. Histogram of reports by reading grade level.

plete diagnostic report or an assigned radiologist. This study complied with the Health Insurance Portability and Accountability Act (HIPAA) and was approved by our Institutional Review Board; informed consent was waived.

Three readability indices were measured: the Flesch-Kincaid Grade Level (FKGL) [7], Gunning Fog index (GFOG) [8], and Simple Measure of Gobbledygook (SMOG) [9,10]. The indices were chosen as they are among the most commonly used to measure readability in general, and have been applied in several studies to measure readability of health-related documents [11]. The numbers of words and sentences in each report were computed. The indices were computed using open-source PHP software (TextStatistics Project; https://github.com/DaveChild/Text-Statistics). Pairwise correlation of the readability indices was assessed using least-squares linear models. The reading grade level (RGL) was computed for each report as the mean of the three readability indices. Analysis of variance (ANOVA) was conducted to evaluate the effects of modality, patient setting, examination urgency, and combinations thereof on RGL. Statistics were performed using R version 3.4 (https://www.r-project.org/).

3. Results

Of 108,228 reports identified initially, we excluded 2946 duplicate reports, 1034 research reports, and 7196 reports with missing data. Our final cohort consisted of 97,052 reports. The mean reading grade level (± SD) for all reports was 13.0 ± 2.4. There were 4094 reports (4.2%) at or below eighth grade reading level, and 650 reports (0.7%) at or below sixth grade reading level (Figs. 1 and 2). The entire study cohort contained a mean of 17.6 sentences and 203 words; details are shown in Table 1.

Reports were created by 175 attending radiologists and 109 radiology residents and fellows; all reports written by trainees were reviewed and approved by an attending radiologist. In the study cohort, 60,079 reports were interpreted by an attending radiologist only, and 36,973 were interpreted by a trainee in conjunction with an attending radiologist. The mean number of reports per attending was 549.2 (SD, 623.5; range, 1–3326); the median was 387. There was no statistically significant difference between the mean reading grade level of attending-only reports by academic radiologists (12.68 ± 2.39, n = 32,251) and by community radiologists (12.48 ± 2.98, n = 27,828). The present study was not designed to evaluate the difference between reports created by trainees and those created by attending alone: reports by trainees included an additional attestation statement of variable length.

The three readability indices showed strong pairwise correlation, with Pearson correlation coefficient (r) of at least 0.85 for each pair of indices (Fig. 3). Patient setting, modality, and examination urgency all had significant independent effects on RGL (all with $p < 0.001$). The analysis by patient setting (emergency department, inpatient, or outpatient) also showed a small, but statistically significant difference in reading grade level (Table 2). In general, all trainees and attending radiologists interpreted inpatient, outpatient, and emergency department imaging studies. Reports generated for outpatients had more words and sentences than the mean. The 5837 STAT examination reports (6%) had fewer words and sentences than non-STAT reports, and had a lower reading grade level (Table 3). These differences were statistically significant ($p < 0.001$).

4. Discussion

Radiology reports often contain complex sentences, polysyllabic terms, and concepts that may be unfamiliar to those outside of medicine. Although radiology reports traditionally have been intended as professional communication between physicians and other healthcare providers, patients and family members are reading radiology reports with increasing frequency. Fewer than 4% of all reports in our sample were at the eighth grade reading level of the average U.S. adult. Thus, patients and caregivers may find the reports difficult to understand.

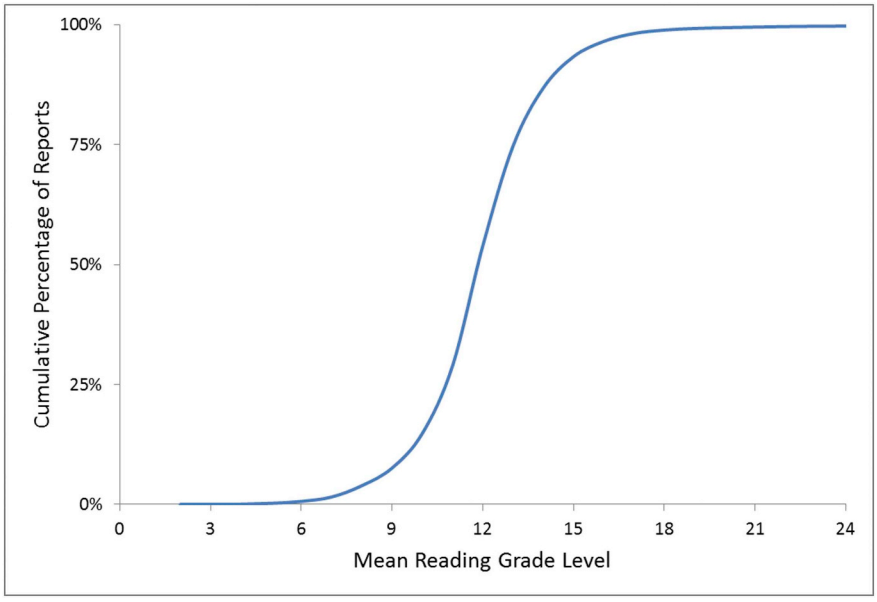

Fig. 2. Cumulative distribution of reports by reading grade level.

The current study was limited to reports from a single radiology department, albeit one with a total of 284 practitioners (attendings and trainees) at four hospitals, and a large community-based practice. The analysis applied automated metrics to measure readability, and did not directly measure patients' comprehension of their reports. The three readability indices exhibited strong linear pairwise correlation, and averaging the three indices into a reading level score provided a tractable metric for this study. There was no structural difference in assignment of radiologists to interpret inpatient, outpatient, or emergency department examinations. The study was not designed to measure the difference of reporting between trainees and attendings.

General health literacy affects patients' comprehension of radiology reports. About 80 million adults in the U.S. have limited health literacy, which puts them at greater risk for decreased access to care and poorer health outcomes [12]. To achieve the greatest readership and comprehension of written materials, organizations have recommended that health information be written at a fourth to sixth grade level [13]. However, online health information materials—including those that describe radiology examinations and findings—are often written at a reading level that exceeds that of the average patient [14,15]. In order to evaluate health information and improve the development of patient health information materials, the use of readability formulas has become commonplace to assess how closely health information reading grade levels meet the recommended targets [11].

Changes in wording can affect report readability significantly. For example, substituting “Heart size is normal” for “The cardiomediastinal silhouette is unremarkable” reduces the RGL to 1.9 from 14.3. The

Table 1
Mean number of words, number of sentences, and reading grade level by imaging modality.

		No. of Words		No. of Sentences		Reading Grade Level	
Imaging modality	Count	Mean	SD	Mean	SD	Mean	SD
Angiography	170	446.2	234.0	31.1	13.7	14.9	1.8
CT	15,910	346.9	187.0	30.8	15.1	13.5	1.7
DEXA	1462	334.2	176.2	21.2	12.5	12.3	0.9
Fluoroscopy	2036	131.2	127.0	10.6	8.9	12.5	3.1
Interventional radiology	2284	199.8	147.2	15.8	10.6	12.8	2.0
Mammography	8380	272.7	104.9	21.1	8.1	12.7	0.6
MRI	9284	325.4	162.2	27.7	13.1	13.7	2.1
Nuclear medicine	1110	177.5	100.4	12.3	6.1	14.2	3.1
PET	125	290.1	115.9	18.7	6.9	13.8	1.3
PET-CT	1018	372.9	161.0	27.1	10.5	13.7	1.0
Radiography	42,339	91.6	43.8	9.2	4.2	12.6	2.6
SPECT	14	239.4	61.3	15.6	3.7	15.3	1.6
Ultrasound	12,920	240.9	130.0	19.8	10.5	13.2	3.0
Total	97,052	203.2	160.5	17.6	12.8	13.0	2.4

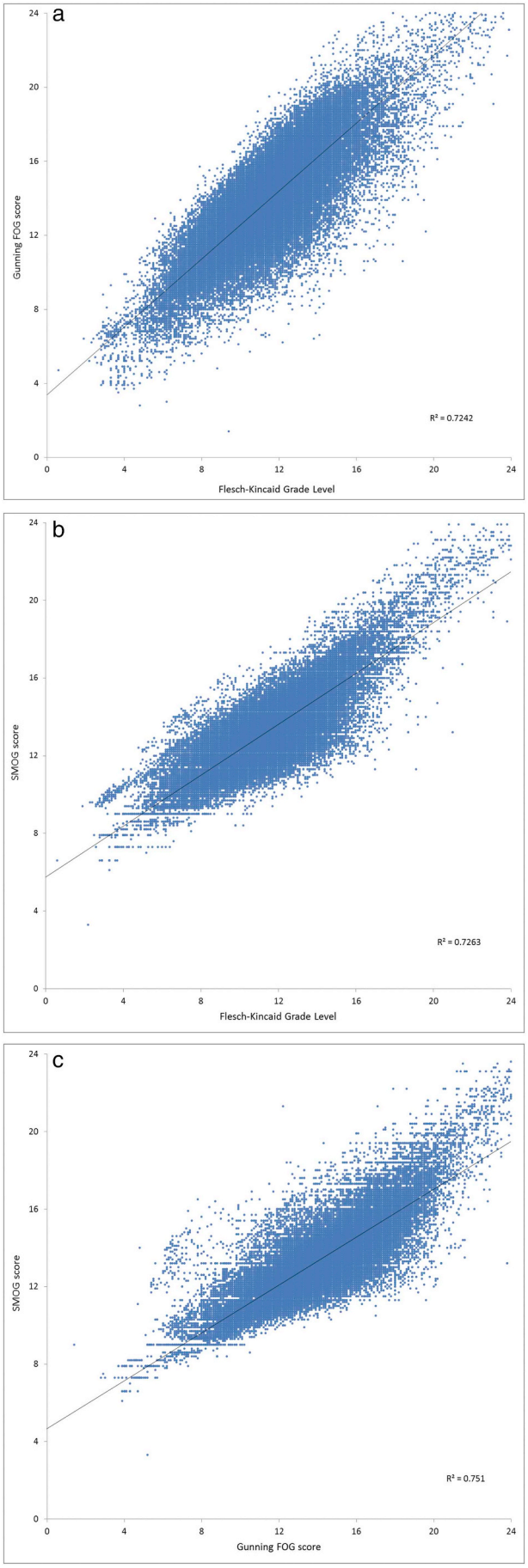

Fig. 3. Scatterplots display pairwise distributions of scores for FKGL, GFOG, and SMOG: (A) FKGL vs. GFOG, (B) FKGL vs. SMOG, (C) GFOG vs. SMOG. Trendlines are shown for the least-squares linear best fit.

primary goal of reporting is to convey the imaging finding accurately and thoughtfully to the referring provider, not necessarily to lower the RGL. In some cases, it may be necessary or clinically appropriate to use precise clinical terminology to assure clear, unambiguous communication.

As patient-centered care gains importance, radiologists are exploring approaches to better meet patients' needs. An analysis of readability of radiology reports published in 1992 found that 10,361 radiology reports in four imaging modalities (radiography, mammography, ultrasonography, and MRI) had a mean readability grade level of 10.2 [16]. A recent study of radiology reports found that patients' most common request was for a brief explanation of findings presented in non-medical language [6]. Patients also expressed concern about the complexity and length of radiology reports.

Several approaches have sought to help patients bridge the gap in understanding their radiology reports. One approach leverages the digital format of radiology reports to automatically embed hyperlinks that define radiology vocabulary in lay terms [17]. Brief radiologist training workshops can improve the readability of radiology reports [18]. Several studies have also explored a novel peer-review process which electronically requests structured, anonymous feedback from referring physicians [19,20]. This novel feedback model may enhance reporting practices, and enhance rapport with other specialties [20]. Allowing patients to access their medical records may improve doctor-patient communication, empower patients, and promote shared decision-making [21]. Concerns from radiologists about additional workflow interruptions from increased patient communication regarding their imaging results have not been substantiated [5]. Patients also want their results much sooner than is currently practiced [22].

5. Conclusion

As radiology continues to move from a volume-based to a value-based practice field, the principles of patient-centered care will be at the forefront of this shift. Although this transformation is intended to empower patients and improve health outcomes, it also highlights the radiologists' essential role in healthcare, and makes radiologists more visible to their patients [19,23]. A high-quality radiology report is one that is not only accurate, but actionable and interpretable by its end-reader [6]. Increasingly, readership of radiology reports is expanding beyond the healthcare team to include patients and their families. Providing access to healthcare information is an important first step, but patients and their family members will not necessarily comprehend that information [14,24]. As radiologists seek to accommodate the principles of patient-centered care, they should consider the patient's literacy and experience, and take steps to facilitate patients' understanding of radiology reports [25].

Table 2
Readability metrics by patient-care setting.

			No. of words		No. of sentences		Reading grade level	
Setting	Count	%	Mean	SD	Mean	SD	Mean	SD
Emergency	17,703	18%	175.8	153.8	16.7	13.2	12.9	2.5
Inpatient	20,525	21%	168.6	150.8	15.0	12.1	13.3	2.4
Outpatient	58,824	61%	223.5	162.4	18.7	12.8	12.9	2.1
Total	97,052	100%	203.2	160.5	17.6	12.8	13.0	2.4

Table 3
Readability metrics for STAT and non-STAT examinations.

			No. of words		No. of sentences		Reading grade level	
Priority	Count	%	Mean	SD	Mean	SD	Mean	SD
Non-STAT	91,215	94%	207.7	162.1	17.8	12.8	13.0	2.3
STAT	5837	6%	132.1	110.9	14.6	13.1	12.2	3.5
Total	97,052	100%	203.2	160.5	17.6	12.8	13.0	2.4

Declarations of interest

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