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Influence of Radiology Report Format on Reading Time and Comprehension

Elizabeth A. Krupinski · E. Tyler Hall · Stacy Jaw · Bruce Reiner · Eliot Siegel

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Abstract This study examined whether radiology report format influences reading time and comprehension of information. Three reports were reformatted to conventional free text, structured text organized by organ system, and hierarchical structured text organized by clinical significance. Five attending radiologists, five radiology residents, five internal medicine attendings, and five internal medicine residents read the reports and answered a series of questions about them. Reading was timed and participants reported reading preferences. For reading time, there was no significant effect for format, but there was for attending versus resident, and radiology versus internal medicine. For percent correct scores, there was no significant effect for report format or for attending versus resident, but there was for radiology versus internal medicine with the radiologists scoring better overall. Report format does not appear to impact viewing time or percent correct answers, but there are differences in both for specialty and level of experience. There were also differences between the four groups of participants with respect to what they focus on in a radiology report and how they read reports (skim versus read in detail). There may not be a “one-size-fits-all” radiology report format as individual preferences differ widely.

Keywords Radiology reporting · Workflow · Communication

E. A. Krupinski (✉) · E. T. Hall · S. Jaw
Department of Radiology, University of Arizona,
1609 N Warren Bldg 211 Rm 112,
Tucson, AZ 85724, USA
e-mail: krupinski@radiology.arizona.edu

B. Reiner · E. Siegel
Department of Radiology, University of Maryland,
College Park, MD, USA

Introduction

The radiology report is generally the key point of contact between radiology and other medical specialties. Clinicians are demanding faster report turn-around times [1], and there are calls for reporting standards to help insure appropriate and accurate communication of findings [2–6]. Towards this end, there are a variety of projects being conducted to improve the quality of reports by structuring them either by providing specific structure guidelines or by automating processes for generating reports or reformatting them for interpretation [7–10]. Methods for modeling the reporting and interpretation process [11], methods for evaluating the quality [12, 13] of reports, and the impact of reporting methods of communication efficiency [14] have all received increased attention in recent years.

Some studies have surveyed general clinicians regarding their expectations and preferences for the content and format of radiology reports. Plumb et al. [15] examined preferences for ultrasound reports, with the first section asking about satisfaction with reports and what types of details they wanted to be included. The second part presented them with two formats, prose versus tabular with little versus more details, and had them rank their preferences. The results indicate that at least for this type of exam, the clinicians preferred more detail in the reports for both normal and abnormal exams. In terms of structure, 43% preferred the tabular form for normal reports and 51% preferred it for abnormal reports. This study did not examine whether report format impact comprehension or speed with which the reports were read. A follow-up study [16] with general physicians from 19 different specialties confirmed the initial results.

A study by Dogan et al. [17] also found that clinicians from both university and public hospitals (surgery and internal medicine) preferred reports that had more details.

They also found that standardized formats with complete sections reporting on clinical information, technique, findings, conclusion, and a recommendation were preferred. This study also did not examine the actual report reading process and whether format affected speed or comprehension. In a similar study, McLoughlin et al. [18] surveyed 100 physicians about chest radiograph and abdominal sonogram reports and whether they preferred reports with no description, a brief description or a detailed description of findings. They found that for the chest reports that were normal, the most popular report format was the briefest one simply stating that it was normal. For abnormal chest reports, the majority preferred a more detailed description of the findings and diagnosis. For the sonogram results, the majority preferred detailed reports for both normal and abnormal exams. Again, however, there was no study of the impact of report format/detail on comprehension or speed of reading.

Report clarity was studied by Johnson et al. [19], comparing structured reporting with conventional dictation. This study examined whether reports generated by radiology residents using the structured format had greater clarity than those using free-text format for reporting out cranial MR exams for suspicion of stroke. The reports were sent to various attending physicians from a variety of subspecialties for rating of the clarity of a randomly selected sample of the total set of reports. These ratings did not differ significantly for structured versus free-text format. Two neuroradiology fellows also rated all of the reports and they rated the clarity of the structured reports significantly lower than that of the free-text reports. Their conclusion was that level of experience may affect the clarity ratings. Although this study examined report clarity, it still did not examine impact of report format on compression of the information in the report.

A recent study by Bosmans et al. [20] asked referring clinicians to freely suggest ways to improve radiology reports. The results revealed a number of common themes that have been found previously. They want clinical information and a clinical question, a conclusion, structuring, completeness, integration of images or reference to images, mentioning of relevant findings in addition to answering the clinical question, mention of a diagnosis or differential diagnosis, concise reporting, and more direct communication.

Sistrom and Honeyman-Buck [21] have examined the impact of radiology report format on both comprehension and speed. In this study, senior medical students were given either free text or structured reports in a web-based test format. Following each report, they were asked a series of questions regarding the report content. Number of correct answers, time per case, and efficiency (number correct/minute) were assessed. The results revealed no statistically significant differences in any of the three outcomes as a function of report format. The conclusion was that structured reporting is at least as efficient and accurate for reporting as free text. Although this study examined both comprehension and speed with the two report formats, it was limited by that fact that there were two sets of readers for each report format—no one read both types of reports. The readers were also medical students and not practicing clinicians which might have influenced the results as well since the medical students had little experience in general with any type of report format.

The present study examined three commonly promoted report formats in an effort to further our understanding of what type of report format is the most conducive for reading efficiency and comprehension of the information contained in the report. To overcome the limitations of previous studies, we used internal medicine clinicians and radiologists (faculty and residents) as our readers and tested their comprehension and speed of reading the reports. The inclusion of radiologists is rather unique as no studies to date seem to have included them as subjects. The overall hypothesis was that the format of radiology reports (conventional free text, structured text organized by organ system, hierarchical structured text organized by clinical significance) will influence the time it takes for someone to read the report and will influence their comprehension of the information described within the report.

Materials and methods

This study was IRB approved. Three radiology reports (CT exams) were reformatted to three common formats: conventional free text, structured text organized by organ system, hierarchical structured text organized by clinical significance by a board-certified radiologist. All patient identifiers were removed. The reports contained the same information across all three formats and word count was maintained to within 10% of each other. A second board-certified radiologist reviewed the reports to insure content accuracy. One report was on CT abdomen/pelvis with contrast with cholelithiasis as the key finding. The second was CT abdomen/pelvis without contrast and ureteral calculus was the key finding. The third exam was a CT abdomen/pelvis without contrast and UPJ stenosis was the key finding. The three report formats for the UPJ stenosis case are in Appendix 1.

A set of ten true/false questions was generated for each of the three core reports by the initial board-certified radiologist and checked for accuracy by the second. The questions asked about specific content in the reports. The questions for the UPJ stenosis case are in Appendix 2. The text was Arial 12-point bold and all reports fit into a single page (black text, white background). The reports were embedded into a PowerPoint presentation for portrait mode presentation during the study. The reports were displayed on Dell Ultra Sharp 1908 WFP Flat Panel display with

1,440×900 native resolution and 1,000:1 contrast ratio. The study took place in a typical office where reports would likely be read by a clinician. Ambient light level (overhead fluorescents) was 47.6 Ft-cd. The subjects read each report and when they indicated they were finished, it was removed from the screen and replaced by a grid pattern. Reading time was recorded with a stopwatch. Once the grid pattern was displayed, the subjects answered the ten questions (which were randomized for each report format). The subjects also filled out a short demographic survey.

Five attending radiologists and five radiology residents participated in a single 20 to 30 min session. Five internal medicine faculty and five internal medicine residents also participated. The reports were randomized for each subject with the restriction that a given base report and format could not occur sequentially.

The reading times were analyzed using repeated measures analysis of variance, with report format, radiology/internal medicine (specialty), and attending/resident (level) as independent variables. The percent correct answers on the true/false questions were analyzed in the same manner.

Results

The radiology subjects included seven males (four attending, three residents) and three females (one attending, two residents). Average age of the male residents was 32.67 (sd=2.52, range=30–35) and for the females was 29.50 (sd=2.12, range=28–31). The average age of the male attendings was 76.50 (sd=6.03, range=68–82) and the female was 52. The internal medicine subjects included six males (three attending, three residents) and four females (three attending, one resident). Average age of the male residents was 37.67 (sd=5.51, range=32–43) and the female was 28.00. The average age of the male attendings was 41.67 (sd=20.21, range=30–65) and for the females was 40.33 (sd=15.95, range=27–58).

With respect to what they focus on when they read radiology reports (impression, body, both, neither), there were significant differences (X^2=27.15, p<0.001), as can be seen in the distributions of responses in Table 1. They were also asked about what they do when previous reports are available: read the last report only, read multiple previous reports in detail, skim the last report only, skim multiple previous reports, do not read any previous reports. There were significant differences (X^2=275.18, p<0.0001) in the distribution of responses as can be seen by the distribution of responses in Table 2.

For reading time, there was no significant effect (F=1.772, p=0.1732) for format. There was a significant effect for attending versus resident (F=33.382, p<0.0001), with the residents spending an average of 20.92 s less per report than the attendings. There was also a significant effect for radiology versus internal medicine (F=12.23, p=0.0006) and an interaction effect for specialty by level (F=18.82, p<0.0001) with the radiology attendings taking the longest time to read the reports overall and the radiology residents taking the least (see Fig. 1).

For percent correct scores, there was no significant effect for report format (F=1.905, p=0.1521) or for attending versus resident (F=2.698, p=0.1023). There was a significant effect for radiology versus internal medicine (F=12.34, p=0.0006) with the radiologists (attending and residents) scoring better than the internal medicine participants (see Fig. 2).

Discussion

Overall report format does not appear to significantly impact either reading time or comprehension of the material in the reports. These findings are very similar to previous studies, especially the one most like this one by Sistrom and Honeyman-Buck [21], although they used only two formats and medical studies while we used three formats and used attendings and residents from radiology and internal medicine. What stands out more is the fact that there were significant differences in what the various groups of participants prefer to read (impression versus both body and impression) and how they read (skimming versus detailed reading of the last versus multiple reports). These results suggest that although format has little impact on time to read or comprehension of details, a one-size-fits-all or standardized report is unlikely to be very popular as there are significant individual differences and styles of reading the reports. It may however be a matter of getting used to a standardized format and that would lead perhaps to better acceptance and preferences.

Table 1 What participants said they focus on when they read radiology reports (impression, body, both, neither)

	Radiology attending	Radiology r esident	Internal medicine attending	Internal medicine resident
Impression	40%	60%	60%	60%
Body	0%	0	0	0
Both	60%	40%	40%	40%
Neither	0%	0	0	0

Table 2 What participants reported they do when previous reports are available: read the last report only, read multiple previous reports in detail, skim the last report only, skim multiple previous reports, do not read any previous reports

	Radiology attending	Radiology resident	Internal medicine attending	Internal medicine resident
Last report only	40%	80%	20%	20%
Multiple reports detail	40%	0%	0%	0%
Skim last report	0%	0%	20%	40%
Skim multiple reports	20%	20%	60%	40%
Do not read reports	0%	0%	0%	0%

It was interesting to find that in general, the attending radiologists took the longest to read the reports (even the traditional free text). This group also complained the most about the two non-traditional (structured and hierarchical) reports, saying they very much disliked them and never used them, confirming other studies on this topic [22–24]. Although it took them longer to read through them, the format did not appear impact comprehension significantly (although it did drop somewhat with the two non-traditional formats). It would be interesting and useful to carry out the same study at another institution or in a private practice environment where they do use either structured or hierarchical formats on a regular basis.

Why should we be concerned with report format beyond the core consideration of its ability to convey information in an effective and efficient manner? For one, existing reporting and IS (information services) technologies create significant workflow impediments regarding historical imaging report data extraction. These manual workflow requirements result in a great deal of relevant data being overlooked and underutilized (as if it never existed). One can only postulate the impact this has on radiologist diagnostic accuracy, degree of diagnostic confidence, and follow-up recommendations.

Existing report strategies largely leave content and formatting to the authoring radiologist; with little to no consideration of the health care provider on the receiving end of the report. Report customization options could create the potential to improve the overall perception of report quality, while tailoring content and format to the specific needs and preferences of the individual end-user. This concept of "report data customization" could also be applied to the historical report folder, which accounts for a great deal of radiologist workflow inefficiency in current practice.

This study (as well as those cited previously) is limited by the familiarity and practical experience readers have for the various report formats tested. In current practice, most radiologists and clinicians review and create radiology reports using free text (paragraph) formats, which have an unfair advantage over the itemized, structured formats being tested. It could be that if readers were equally experienced, the results for structured report data would likely be improved. Also, due to the limited nature of this and other research studies, the interaction effects between report content/format, context, and end-user is generally poorly evaluated and requires further investigation. As an example, one might expect that report workflow, understanding, and preferences vary in accordance with the exam type, anatomy, finding, and clinical context. When reviewing historical report data for an ICU patient who has serial portable chest reports on a daily basis, the radiologist simply concerned with interval change over the past one to

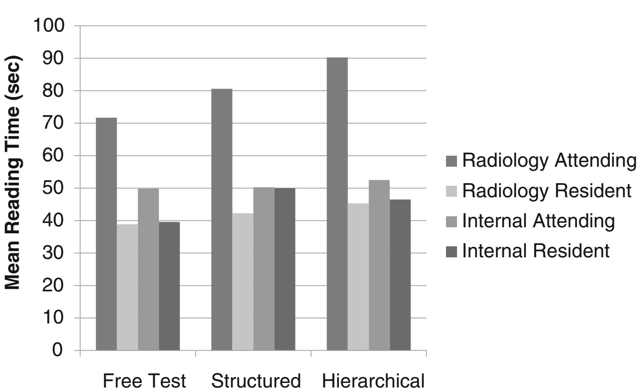

Fig. 1 Mean reading time (sec) for the three report types for the radiology and internal medicine attending and residents

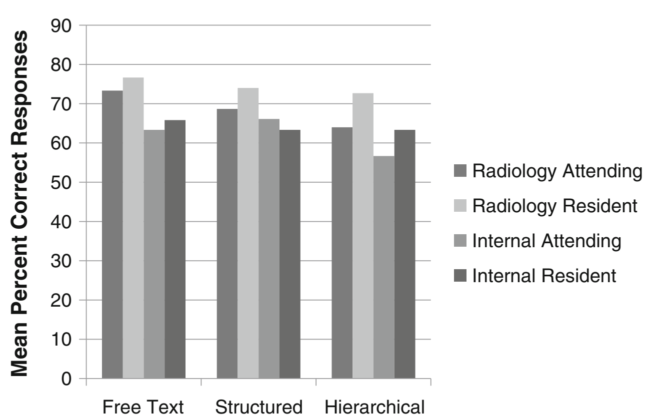

Fig. 2 Mean percent correct responses to the questions following reading of the three report types for the radiology and internal medicine attending and residents

two reports. On the other hand, if reviewing historical report data on a chest CT for a patient with a past history of surgically resected lung cancer in remission, the radiologist would like to review the report data at the time of diagnosis, post-treatment baseline, and most recent one to two surveillance exams.

Another potential limitation that could have affected the comprehension scores is that the test may have been drawing more upon the participants' ability to remember the information in the reports rather than their ability to extract necessary data. One way to address this would be to redo the study and present the readers with a specific question prior to giving them access to the report and then poll them for a response after the reading phase. Possibly related to this effect (ability to remember content) and which may in part explain some of the results, is that the radiologists were significantly older than the other groups of participants and they took the longest to read the reports. This could be an unexpected confound and could be confirmed or eliminated as a possibility in a future study.

Other potential areas for future investigation on report reading/interpretation efficiency include analyzing eye movements in hopes of better understanding the most efficient workflow and reporting patterns. Some readers may be more proficient in reviewing free-text report data (in comparison to structured report data), but in actuality, the eye movements may prove otherwise. In addition, there may be opportunity to enhance or highlight certain report features (e.g., color-coded, bold text) which have been shown to be of "high visual interest" based upon clinical context and end-user historical workflow.

Conclusion

Clinicians from different subspecialties and level of experience read radiology reports in different ways and have preferences regarding what they prefer to read first (e.g., impression), but when presented with differentially formatted radiology reports, the format has little impact on reading speed or comprehension.

Appendix 1. Three Report Formats for UPJ Example

Report #1 = Conventional Free Text

CT abdomen and pelvis without contrast

Clinical indication: Abdominal pain

Technique: Axial images were performed through the abdomen and pelvis without intravenous contrast administration.

Comparison Studies: None

Findings:

There is elevation of the right hemidiaphragm with COPD and chronic granulomatous disease.

Post-surgical changes of cholecystectomy identified.

The liver, pancreas, spleen, and adrenals are normal.

Multiple hypo/hyperdense nodules are present within both kidneys, which are poorly evaluated in the absence of contrast. The largest hyperdense nodule measures 3.6 cm and is located within the midlateral right kidney. Additional post-contrast CT imaging is recommended.

Punctuate non-obstructing bilateral renal are identified. There is marked left hydronephrosis in a pattern of UPJ stenosis.

There is normal caliber of vascular structures and bowel with abundant stool.

The prostate is enlarged with a Foley catheter in the decompressed bladder.

A 1.9-cm sclerotic lesion is present within the left acetabular roof suggesting a benign bone island. Multilevel lumbar degenerative changes are identified.

Impression:

Multiple renal abnormalities as described above, which would warrant further evaluation with post-contrast CT.

Report Format #2 = Hierarchical Structured Text (Organized by Clinical Significance)

CT abdomen and pelvis without contrast

Clinical indication: Abdominal pain

Technique: Axial images were performed through the abdomen and pelvis without intravenous contrast administration.

Comparison Studies: None

Positive Findings:

1. Hydronephrosis (Left)

   Clinical significance: High
   Follow-up recommendations: CT with contrast
   Severity: Marked
   Diagnosis: UPJ stenosis

2. Nodular lesions

   Clinical significance: Uncertain
   Follow-up recommendations: CT with contrast
   Anatomic location: Renal, bilateral
   Size: 3.6 cm (largest lesion right mid pole)
   Diagnosis: ? Cysts

3. Calculi

   Clinical significance: Moderate
   Anatomic location: Bilateral kidneys
   Size: Punctate

4. Prostate enlargement

   Clinical significance: Low

5. Bone island

Clinical significance: Low
Anatomic location: Left acetabular roof
Size: 1.9 cm

6. COPD and chronic granulomatous disease

Clinical significance: Low

7. Osteoarthritis

Clinical significance: Low
Anatomic location: lumbar spine
Normal Anatomy:
Liver, pancreas, spleen, adrenals, blood vessels, lymphatics, biliary ducts, bladder, stomach, small bowel, and colon.
Procedures: Cholecystectomy and indwelling Foley catheter.

Report Format #3 = Structured Text (Organized by Organ System)

CT abdomen and pelvis without contrast
Clinical indication: Abdominal pain
Technique: Axial images were performed through the abdomen and pelvis without intravenous contrast administration.
Comparison Studies: None
Findings:
Lung Base:
Elevation of the right hemidiaphragm with COPD and chronic granulomatous disease
Gastrointestinal:
Normal caliber of stomach, small bowel, and colon.
Large quantity of stool present.
Genitourinary:
Marked left hydronephrosis, in pattern of UPJ stenosis.
Multiple bilateral punctuate renal calculi.
Multiple nodular lesions (hypo and hyperdense) both kidneys, largest 3.6 cm lateral mid pole right kidney. Recommend post-contrast CT.
Normal appearance of the adrenal glands.
Foley catheter in the decompressed bladder.
Enlarged prostate gland.
Biliary:
Status post cholecystectomy.
Liver, pancreas, and biliary ducts are normal.
Cardiovascular:
Patency with normal caliber of major arterial and venous structures
Lymphatic:
Spleen normal, no pathologically enlarged lymph nodes.
Musculoskeletal:
1.9 cm sclerotic lesion in the left acetabular roof? benign bone island.
Degenerative changes in the lumbar spine.
Impression:

1. Marked left hydronephrosis ? UPJ stenosis, post-contrast CT recommended.
2. Bilateral punctuate renal calculi and hypo/hyperdense nodules.

Appendix 2. Example of the Questions Asked after the Reports Were Read (UPJ Example)

Please circle true (T) or false (F) for each of the following questions regarding the report you just read.

1. The principle pathology described was left UPJ stenosis of moderate severity. (T) (F)
2. The largest nodular lesion was localized within the right kidney and measured 3.6 c (T) (F)
3. Urologic consultation was recommended. (T) (F)
4. A 1.9-cm bone island within the right acetabular roof was reported. (T) (F)
5. No pathology was reported within the inferior thorax. (T) (F)
6. The gall bladder is normal. (T) (F)
7. The liver is normal. (T) (F)
8. No catheter was reported. (T) (F)
9. The clinical indication for the study was flank pain. (T) (F)
10. No historical imaging study was available for comparison. (T) (F)

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