The Effect of Faster Reporting Speed for Imaging Studies on the Number of Misses and Interpretation Errors: A Pilot Study

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Abstract

Purpose: The purpose of the study was to determine if increasing radiologist reading speed results in more misses and interpretation errors.

Methods: We selected a sample set of 53 abdomen-pelvis CT scans of variable complexity performed at a teaching hospital during the study period. We classified the CT scans into 4 categories based on their level of difficulty, with level 4 representing the most-complex cases. Five attending radiologists participated in the study. We initially established an average baseline reporting time for each radiologist. Radiologists were randomly assigned a set of 12 studies, of varying complexity, to dictate at their normal speed, and a separate set of 12 studies, of similar complexity, to read at a speed that was twice as fast as their normal speed. The major and minor misses were recorded and analyzed. A χ² analysis was used to compare the results.

Results: Reading at the faster speed resulted in more major misses for 4 of the 5 radiologists. The total number of major misses for the 5 radiologists, when they reported at the faster speed, was 16 of 60 reported cases, versus 6 of 60 reported cases at normal speed; P = .032. The average interpretation error rate of major misses among the 5 radiologists reporting at the faster speed was 26.6%, compared with 10% at normal speed.

Conclusions: Our pilot study found a significant positive correlation between faster reading speed and the number of major misses and interpretation errors.

Key Words: Faster reporting speed, abdomen and pelvis CT, major misses, interpretation errors


INTRODUCTION

As the utilization of diagnostic imaging has continued to increase in recent years, the workload of radiologists has correspondingly risen. In 2006–2007, the average number of studies read annually by a radiologist increased by 7%, compared with 2002–2003 [1]. In 2006–2007, the annual relative value units (RVUs) per full-time equivalent (FTE) radiologist increased by 10%, compared with 2002–2003, and by 70%, compared with 1991–1992 [1]. Radiologists are under pressure to increase productivity by increasing workload volume. Studies have shown that a decrease occurs in both the accuracy of radiologic interpretation and the detection of pathology as the volume of interpreted studies increases and the viewing time per study decreases [2-4]. The purpose of this pilot study is to determine if faster reporting speed, for radiologists reading abdomen-pelvis CT imaging studies, results in more misses and interpretation errors.

Methods

This study was approved by the local institutional review board and was HIPAA compliant. Five board-certified attending radiologists volunteered to participate in the study, which was conducted at a tertiary-care teaching hospital. We used attending radiologists to eliminate inexperience as a factor in the results. The 5 radiologists had completed their fellowships in various subspecialties: 1 each in neuroradiology, interventional radiology,
musculoskeletal imaging, body imaging, and women’s imaging and ultrasound. The specialist in women’s imaging and ultrasound has >15 years of experience; the neuroradiologist and the interventional radiologist have >10 years of experience; the body radiologist has >5 years of experience; and the musculoskeletal radiologist has 2 years of experience.

The body radiologist reads abdomen-pelvis CT scans more often on the daily reading room schedule. The body radiologist, however, works part time and does not take calls. The other radiologists read abdomen-pelvis CTs on a daily basis, and they perform on-call readings as part of their responsibilities. Therefore, all the radiologists participating in the study read a substantial number of abdomen-pelvis CTs annually.

For this study, we selected a sample set of abdomen-pelvis CT scans, which included outpatient and inpatient studies performed at our institution between November 2013 and February 2014. The set consisted of a total of 53 noncontrast or contrast-enhanced abdomen-pelvis CTs of variable complexity, each categorized into 1 of 4 levels of complexity. A board-certified radiologist who had completed a fellowship in body imaging and had >25 years of experience selected the studies to be included in the sample set, and the level of complexity assigned to each examination.

Level 1 included noncontrast CTs with normal or noncomplex findings, without a prior comparison examination. Normal examinations were included to assess whether faster interpretation would lead to a greater rate of false positives, which could result in unnecessary and inappropriate treatment recommendations. Level 2 included contrast-enhanced CTs with no complex findings and without prior comparison. Level 3 consisted of contrast-enhanced and noncontrast CTs of moderate complexity that required comparison with prior studies. Level 4 consisted of contrast-enhanced and noncontrast CTs with significant complex findings that required comparison with prior studies.

Complex findings included entities such as postoperative states, known malignancies, free air, intra-abdominal abscess, recurrent neoplasm, and metastatic disease. Some of the sample studies (level-3 and level-4 studies) had prior studies available (eg, body CTs, MRI, or ultrasound), and required comparison to the older examinations for accurate interpretation.

We limited the study sample to CT scans of the abdomen and pelvis. These studies are among the exams most frequently ordered and interpretation errors may have a significant impact on patient care. CT scans of the abdomen and pelvis are the most common examinations performed in our department and are interpreted on a daily basis by all staff radiologists regardless of fellowship training. All the selected sample studies were previously read and had final reports available; however, the reporting times of the original interpretation were not recorded, making it difficult to use the original studies and their miss rate as a real-life control. Each of the radiologists established a baseline, average reading speed by direct, self-measurement of reporting time, based on 12 read results of abdomen-pelvis CT scans at normal reporting speed. These reads were conducted during the course of regular working days, on studies that were not part of the sample set.

The study was performed in 2 stages, after the baseline reading speeds were established. In week 1, two radiologists were randomly assigned to read a set of 12 studies at “fast speed” (twice as fast as their baseline reading speed, or in one half their normal reporting time); the other 3 radiologists were instructed to report at their normal reading speed. The set of 12 studies randomly included studies of variable complexity, with 3 classified into each of the 4 levels.

In week 3, the radiologists were assigned a different set of 12 studies, with a similar mix of level-1, level-2, level-3, and level-4 studies, but they switched their reading speed (eg, the radiologists who read fast the first week, read at their normal speed in week 3, and vice versa). The set of 12 studies was different from that in week 1, to exclude recall bias. A stopwatch was used to keep track of the reporting time. Per our study design, if any interruptions occurred, the stopwatch was paused; however, most reports were not interrupted.

The radiologists reported in the same environment as in everyday practice, under identical viewing conditions. The CT scans were reviewed using a McKesson version of a PACS. The readings were reported via the same dictation software normally used by this radiology practice on a daily basis (Nuance Powerscribe 360, Burlington, Massachusetts). Most studies were reported after normal work hours, with a minority reported during the normal workday. All studies and reports were reviewed by a separate board-certified radiologist with 10 years of work experience, who had fellowship training in MRI, to establish the major and minor misses. Additionally, patient outcome (eg, discharge, hospital admission, or surgery and pathology reports) was confirmed with electronic medical records to support the category of the major or minor miss findings. Finally, the reports were analyzed, and the misses and interpretation errors were recorded.

We categorized misses and interpretation errors into major and minor misses. The major miss category included findings with the potential to have a clinically
significant impact on patient management and outcome (eg, resulted in treatment, hospital admission, or surgery). Failure to compare the findings with prior imaging studies, resulting in incomplete evaluation and incomplete reports, was considered an additional major miss (Table 1). The minor-miss category included benign or stable lesions, with no significant impact on patient care. A $\chi^2$ analysis was used to compare the results.

### RESULTS

All 5 radiologists completed all study stages. The mean regular reading time for all 5 radiologists was 10 minutes, 9 seconds; the average fast speed reading time was 5 minutes, 5 seconds. The total number of major misses for the 5 radiologists, when they reported at fast speed, was 16 of 60 reported studies, as opposed to 6 of 60 at their normal speed; $P = .032$. The average number of major misses among the 5 radiologists when they reported at fast speed was 3.2 of 12 reported studies (26.6% interpretation-error rate), as opposed to 1.2 of 12 studies (10% interpretation-error rate) reported at normal speed (Table 2).

Radiologist 1 had a baseline average reporting time of 9 minutes, 0 seconds, with a resultant fast speed reading time of 4 minutes, 30 seconds. When reporting at normal speed, radiologist 1 had 1 of 12 (8.3%) major misses, compared with 4 of 12 (33.3%) when reporting at fast speed. The 1 major miss reported at normal speed included the study with level-2 complexity versus 4 major misses reported at fast speed at complexity levels 1, 2, 3, and 4. There were 2 of 12 (16.6%) minor misses at normal reporting speed, versus 3 of 12 (25%) at fast speed.

Radiologist 2 had a baseline average reporting time of 9 minutes, 36 seconds, with a resultant fast speed reading time of 4 minutes, 48 seconds. At normal speed, radiologist 2 had 1 of 12 (8.3%) major misses, compared with 3 of 12 (25%) at fast speed. The 1 major miss reported at normal speed included a study with complexity-level 4, versus 3 major misses at fast speed at complexity levels 1, 3, and 4. There were 4 of 12 (33.3%) minor misses at normal reporting speed, versus 4 of 12 (33.3%) at fast speed.

Radiologist 3 had a baseline average reporting time of 5 minutes, 0 seconds, with a resultant fast speed reading time of 2 minutes, 30 seconds. At normal speed, radiologist 3 had 3 of 12 (25%) major misses, compared with 2 of 12 (16.6%) major misses at fast speed. The 3 major misses reported at normal speed included studies of complexity levels 1, 3, and 4. The 2 major misses reported at fast speed included studies with complexity levels 3 and 4. There were 4 of 12 (33.3%) minor misses

<table>
<thead>
<tr>
<th>Major Misses</th>
<th>Radiologist 1</th>
<th>Radiologist 2</th>
<th>Radiologist 3</th>
<th>Radiologist 4</th>
<th>Radiologist 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fast</td>
<td>Normal</td>
<td>Fast</td>
<td>Normal</td>
<td>Fast</td>
</tr>
<tr>
<td>Free abdominal air and abscess collection</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pyelonephritis vs passed renal stone</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Small bowel obstruction; closed-loop</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Enteritis</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Failed to compare to prior examinations/ incomplete report</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mistook appendicolith for ureteral stone</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Failed to identify postpartum uterus</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Overall (gastric pneumatisis, colitis, pyelonephritis)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Thickened gastric wall in patient with gastric cancer</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Worsening osteoblastic bone lesions</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Worsened hydronephrosis</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

### Table 1. Major misses among radiologists reporting at fast and normal reading speed

<table>
<thead>
<tr>
<th>Radiologist</th>
<th>Normal Reporting Time (min: sec)</th>
<th>Fast Reporting Time (min: sec)</th>
<th>Major Miss at Normal Speed (%)</th>
<th>Major Miss at Fast Speed (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9:00</td>
<td>4:30</td>
<td>8.3</td>
<td>33</td>
</tr>
<tr>
<td>2</td>
<td>9:36</td>
<td>4:48</td>
<td>8.3</td>
<td>25</td>
</tr>
<tr>
<td>3</td>
<td>5:00</td>
<td>2:30</td>
<td>25</td>
<td>16.6</td>
</tr>
<tr>
<td>4</td>
<td>15:20</td>
<td>7:40</td>
<td>8.3</td>
<td>41.6</td>
</tr>
<tr>
<td>5</td>
<td>11:52</td>
<td>5:56</td>
<td>0</td>
<td>16.6</td>
</tr>
<tr>
<td>Mean or average</td>
<td>10:9</td>
<td>5:5</td>
<td>10</td>
<td>26.6</td>
</tr>
</tbody>
</table>
at normal reporting speed, versus 4 of 12 (33.3%) at fast speed.

Radiologist 4 had a baseline average reporting time of 15 minutes, 20 seconds, with a resultant fast speed reading time of 7 minutes, 40 seconds. At the normal speed, radiologist 4 had 1 of 12 (8.3%) major misses, compared with 5 of 12 (41.6%) major misses at fast speed. The 1 major miss reported at normal speed was level-4 complexity; and 5 major misses reported at fast speed included 2 studies each of level 1 and level 2, and 1 study of level 3. There were 4 of 12 (33.3%) minor misses at the normal reporting speed, versus 4 of 12 (33.3%) at fast speed.

Radiologist 5 had a baseline average reporting time of 11 minutes, 52 seconds, with a resultant fast speed reading time of 5 minutes, 56 seconds. At the normal speed, radiologist 5 had 0 of 12 (0%) major misses, compared with 2 of 12 (16.6%) major misses at fast speed. The 2 major misses reported at fast speed included studies of levels 1 and 4. There were 4 of 12 (33.3%) minor misses at normal reporting speed, versus 4 of 12 (33.3%) at fast speed.

DISCUSSION
Use of diagnostic imaging in recent years continues to increase with >1 billion radiology examinations performed each year in the United States. In 2006–2007, the average number of studies read annually by a radiologist increased by 7%, compared with 2002–2003 [1]. In 2006–2007, the annual relative value units per full-time–equivalent radiologist increased by 10%, compared with 2002–2003, and by 70%, compared with 1991–1992 [1]. Although health care services utilization per person continues to rise, radiology and other medical specialties are facing additional Medicare reimbursement reductions [5]. Decreases in Medicare per-case reimbursement have put pressure on practitioners to increase productivity by increasing workload volume. Technology improvements may help maintain productivity by increasing efficiency; however, concerns have been raised that the quality of radiology reporting may be compromised [6].

For this reason, we conducted a study to determine if faster reporting when reading abdominopelvic CT scans resulted in more misses and interpretation errors. According to our data, the mean regular reading time for the 5 radiologists was 10 minutes, 9 seconds. This finding is similar to those in other studies that directly measured reporting times on various imaging modalities, and found the average reporting time on body CT scans to be 10.6 ± 0.9 minutes [7]. This range may be normal for reporting time on body CT scans for most radiologists [7]. We found that the number of major errors increased for 4 radiologists (1, 2, 4, and 5) when they reported at the faster reporting speed. Specifically, for radiologist 4, who had the longest baseline reporting time (15 minutes, 20 seconds), the percentage of major misses increased 5-fold (from 8.3% to 41.6%; Fig. 1).

Most major misses for all 5 radiologists, at the faster reporting speed, were studies at complexity level 1, followed by levels 3 and 4. We recorded 5 major misses on studies of level-1 complexity, and 4 major misses each on studies of levels 3 and 4 complexity. Therefore, most major misses involved interpretation of the more-complex cases (levels 3 and 4). The fact that 5 major misses additionally involved the interpretation of the simplest cases (level 1) suggests that not only subtle, but also obvious pathology can be easily missed when viewing time decreases. The number of minor misses did not change significantly at the faster reporting speed.

The number of major misses for radiologist 3, who had the shortest baseline reporting time (5 minutes, 0 seconds), was higher at normal reporting speed, compared with the faster reporting speed (3 of 12 [25%] versus 2 of 12 [16.6%]). The differences might be explained by the fact that the significant and obvious pathology, for some radiologists, can be detected by “flash” viewing, and the results would not change significantly with decreased viewing time, as long as the time is above a certain threshold, needed to maintain performance and interpretation accuracy. This possibility was confirmed by Kundel and Nodine [8], who demonstrated that important information can be extracted by flash viewing, with an overall high level of accuracy (70% true positive value). However, in this instance, certain types of subtle abnormalities might be missed. In our study, the most common major missed entity was pyelonephritis: 4 of 5 radiologists missed pyelonephritis at the faster reporting speed, and 1 radiologist missed it at normal reporting speed (Table 1).

![Comparison of major misses (%) among radiologists reporting at normal and fast reading speeds.](image-url)
The causes of misses and interpretation errors are multiple and may be related to faster reporting speed resulting from an increased workload, or to frequent interruptions, fatigue, inexperience, or differences of opinion. Bechtold and colleagues [3] confirmed that increasing the number of reporting examinations per day can affect the accuracy of abdominopelvic CT interpretations, as well as error rate, which almost doubled when the radiologist had to read >20 studies in 1 day. Oestmann and colleagues [4] demonstrated that performance in the detection of lung cancer degrades considerably as viewing time decreases.

The radiologic interpretation error rate has been reported to be 4% in daily practice [2]. Bechtold et al. [3] reported the overall error rate for interpretation of abdominopelvic CT scans to be 7.3%. In another study published from our department [9], the misinterpretation rate using RADPEER™ data was 2.1%. In this study, the baseline error rate was 10%, which is higher than that listed in the other papers. This result can be explained by the fact that the sample set did not consist of average daily case mix, as did the sample sets for the other studies. For purposes of this study, more complex cases were included in the sample set, because it was small, and we believe this led to a higher than average error rate. If an average daily case mix had been used, the volume of data may not have been sufficient to analyze the effect of faster reading speeds.

Kim and Radfield [10] reported that the correct diagnoses were not recognized on subsequent radiologic examinations in 196 of 656 cases (a 30% miss rate), which is significantly higher than the average error rate of 4%. They suggested that the average error rate is low (4%) because radiologists interpret normal examinations accurately, which implies that the error rate for studies with positive findings is substantially higher, consistent with our findings. A follow-up study with a larger sample set, and a case mix similar to a real-life case distribution, would be of benefit to confirm the findings of this study.

Multiple studies have raised the question of how a radiologist will acclimatize to new circumstances, such as a demand for faster reports. Edwards and colleagues [11] demonstrated that although radiologists could report and maintain accuracy at increasing reporting speed for short periods of time, most radiologists stated that they would not be able to sustain accuracy at this rate for longer periods of time. Studies confirmed that the diagnostic accuracy, visual accommodation, reading time, and subjective ratings of fatigue and visual strain before and after a day of clinical reading were significantly affected at the end of the work day [12]. In addition, a study evaluating interpretation time and accuracy demonstrated that a longer time spent interpreting the examination resulted in more positive findings [2].

Error rates may differ among radiologists with different areas of expertise and primary fields of training and experience [5]. Subspecialization in radiology may enhance imaging interpretation, and the preferred approach is that complex studies be interpreted by subspecialists to decrease interpretation errors (eg, cancer staging) [6]. The discrepancy rates between initial emergency CT reports by residents or general radiologists and secondary reports by specialists, have been reported to range between 6% and 27% [6]. In our study, the body radiologist did have the lowest miss rate, which would support this thesis, but a larger study is needed to confirm this finding.

The present study had a number of strengths. The study was designed to resemble real-life reporting conditions. The radiologists reported in the same environment of everyday practice, under identical viewing conditions. The radiologists used standard voice-recognition software to eliminate recording bias. The sample studies had varying levels of complexity and were randomly assigned. A different set of 12 studies was used in week 3, to eliminate recall bias.

Our study had several limitations. The study group and the number of the assigned sample cases was small, and therefore, the study should be considered a pilot. The scale of case difficulty was established by an independent board-certified radiologist who had >25 years of work experience. However, case difficulty might be considered subjective, and it was not validated by a second board-certified radiologist.

In addition, the study included a high number of cases with complex findings (50% of the cases). The higher number of complex cases does not reflect real-life conditions and resulted in an elevated error rate at the baseline reading speed (10%), which is higher than the average error rate of 4%. We included more difficult cases in our study because the sample set is small. If we had used the average case distribution of difficult cases in real-life practice, the number of interpretation errors would have been small, and determining the effect of increasing reporting speed on the error rate would have been difficult. We believe that even though the inclusion of a greater number of difficult studies does not resemble real-life reporting conditions, the data still suggest a correlation between increased reporting speed and increased error rate that deserves further study.

Lastly, in everyday practice, a radiologist may decide to put aside a difficult study and read it later, or to spend...
additional time on it. For the purpose of this study, the radiologists continued to read the assigned cases at the required speed, and therefore, this situation differs from real-life conditions. In the current environment, the ability of a radiologist to delay interpretation of a difficult study has diminished, because clinicians and hospital systems demand rapid turnaround time for radiologic examinations. Nonetheless, the lack of the option to delay does represent a limitation of the study.

We believe that the increasing level of employment of radiologists by national radiology companies, large consolidated radiology groups, and hospital systems will result in greater demand for productivity, achievable only by faster interpretation of radiologic studies. Many tele-radiologists are paid per case rather than with an annual salary, which can be an additional incentive to read more cases during a shift. In addition, our data showed that many of the increased interpretation errors at fast speed were for the easier cases (level 1), which would be unaffected even if radiologists decided to read the more complex cases at a later time. This finding suggests that the increased misinterpretation rate at faster reading rates may not be easily remedied by simply taking more time on the complex cases or saving them for a later time. However, the pressure to read faster will continue to mount. In addition, many radiologists are being employed by tele-radiology firms, hospitals, and private groups, where their reimbursement is directly based on the number of cases they read. This situation provides strong financial motivation for radiologists to read cases as quickly as they can. The findings of our study suggest that the speed of radiology interpretations may have a strong effect on the quality of patient care. A larger, multicenter study with many cases interpreted by the radiologists, and case selection similar to the average workload, would be helpful to confirm our findings and better elucidate the implications for patients’ safety of reporting at a faster rate for prolonged periods. In summary, our data found a significant positive correlation between faster reporting speed and the number of major misses and interpretation errors that occurred in radiologists’ reading of abdomen-pelvis CT scans.

**TAKE-HOME POINTS**

- The purpose of this study was to determine if increasing radiologist reading speed for abdomen-pelvis CT scans results in more misses and interpretation errors.
- Our study found a significant positive correlation between faster reading speed and the number of major misses and interpretation errors in radiologists’ reading of abdomen-pelvis CT scans.
- The findings of our study suggest that the speed of radiology interpretations may have a strong impact on the quality of patient care.

**REFERENCES**


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