Do Telephone Call Interruptions Have an Impact on Radiology Resident Diagnostic Accuracy?

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Rationale and Objectives: The purpose of this study was to measure the effect of distractions, in the form of telephone call interruptions, on radiology resident diagnostic accuracy.

Materials and Methods: Radiology resident discrepancy reports and reading room telephone logs at an academic tertiary care pediatric hospital were collected over a 13-month period. Phone call times and durations were recorded. Major discrepancy shifts (defined as a call shift where at least one major discrepancy was discovered the following morning by the attending radiologist between the resident preliminary and attending final reports), and dictation time stamps for each discrepant preliminary dictation were also recorded. Telephone call volume and preliminary report time stamps were compared between "discrepancy shifts" and "no discrepancy shifts."

Results: Each call shift spanned 14 hours, during which one radiology resident was responsible for the generation of preliminary interpretations. Review of the discrepancy log data revealed 51 major discrepancies in 41 shifts, of which 39 discrepancies had documented error details and resident preliminary report time stamps. The average number of telephone calls for the "discrepancy shifts" was slightly greater than the "no discrepancy shifts" (48.59 vs. 44.02) but was not statistically significant ($P = .0575$). However, there was a statistically significant increase in the average number of phone calls in the 1 hour preceding the generation of a discrepant preliminary report versus the "no discrepancy shifts" (4.23 vs. 3.24 calls, $P = .027$). One additional phone call during the hour preceding the generation of a discrepant preliminary report resulted in a 12% increased likelihood of a resident error ($P = .017$).

Conclusions: Distractions in the form of telephone call interruptions may negatively impact on-call radiology resident diagnostic accuracy. Efforts should be made to limit distractions in the reading room.

Key Words: Interruptions; diagnostic accuracy; patient safety.

At many academic institutions, diagnostic radiology residents are often the sole practitioner responsible for after-hour radiology coverage, generating preliminary interpretations of examinations that are later reviewed and finalized by the attending radiologist. Radiology resident on-call responsibilities often require the ability to multitask, toggling between medical functions (interpreting examinations, interacting with consulting physicians and technologists, and consenting patients) and nonmedical functions (answering telephone calls and returning pages). The shifting of focus between multiple tasks has the potential to alter the resident's mind-set with the potential for the introduction of medical errors.

Research and experience in complex "knowledge-intensive service environments" have shown that interruptions in workflow create inefficiencies, introduce barriers to productivity, and can contribute to errors (1). This is also true of the medical environment, a highly complex, cognitive-rich, service environment, with a great deal of attention and effort directed toward patient safety initiatives and health care system accountability (2–6). Prior research has linked interruptions with errors in the laboratory setting (7,8) and clinical setting and the effect of interruptions on patient safety and workplace stress (3–6,9–14).

Yu et al. (15) recently described their institutional experience with on-call radiologist workflow disruptions in the form of telephone call interruptions. Their results clearly demonstrated a high rate of significant workflow interruptions and, thus, the introduction of a potential root cause for medical errors. However, the effect of these interruptions on diagnostic performance could not be determined because

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of the relative lack of major discrepancies by their attending radiologists. To our knowledge, there have been no prior studies investigating the effect of interruptions on radiologist diagnostic accuracy, let alone radiology resident performance. Therefore, the purpose of this study was to measure the effect of distractions, in the form of telephone call interruptions, on radiology resident diagnostic accuracy.

MATERIALS AND METHODS

This study protocol was reviewed and approved by our institutional review board and waived requirement for informed consent.

Data Collection

During the study period, there was a single on-call resident on duty from 6 PM to 8 AM. The faculty radiologist was absent but available for consultation during this period. All residents were in their third or fourth year of radiology residency training.

The telephone log metadata from nine unique telephone extensions in a pediatric radiology reading room at a tertiary care pediatric hospital, spanning a total of 393 days (April 2, 2012, to April 29, 2013), were collected from the hospital telecommunications center. Telephone call data from 6 PM to 8 AM the following morning were recorded; however, the data spanning from 8 AM to 6 PM were not collected as there was a faculty pediatric radiologist in house during that time. Telephone call start time, end time, and call duration for both incoming and outgoing telephone calls were collected. No telephone call content or recordings were collected.

On-call radiology resident preliminary reports were generated using a voice recognition system (PowerScribe; Nuance Communications Inc, Burlington, MA). Resident preliminary interpretation discrepancy logs were maintained for internal quality control and educational purposes. Each morning, major discrepancies, defined as a change in resident preliminary interpretation requiring direct communication to the ordering physician to document the change in final diagnosis, were entered into the discrepancy log. Minor discrepancies, defined as resident preliminary results that were not felt to alter patient management and were not communicated to the ordering physician, were not included in the discrepancy log. Data entered into the discrepancy log included date of the examination, type of examination, patient medical record number (MRN), and a brief description of the nature of the discrepancy. If there were no major discrepancies encountered during that shift, then the attending radiologist indicated so in the discrepancy log. The examination date and patient MRN were then used to identify the resident preliminary report and dictation time stamp in the picture archiving and communications system (PACS).

Data Analysis

The total number of calls during the study period, the total number of phone calls per shift, the total number of calls for each 1-hour block of time, and the total number of calls in the 1 hour preceding each discrepancy were recorded. The total number of calls during "discrepancy shifts" (defined as a call shift where at least one major discrepancy was discovered by the attending radiologist the following morning) was compared to the total number of calls during the "no discrepancy shifts" using the two-sample *t* test. A linear mixed-effects model was also used to compare the number of calls in the 60 minutes preceding the generation of a discrepant report with the number of calls during the 60-minute periods preceding the hour without discrepancy with each resident treated as a random effect. For these 1-hour "no discrepancy" periods, we used each 1-hour period during shifts when no discrepancies were reported (eg, 6–7 PM, 7–8 PM, and so forth). In summary, we fitted a generalized linear mixed-effects model with each resident treated as a random effect.

RESULTS

Discrepancy log entries were available for 338 shifts of the total 393 study periods (86% of shifts); the remaining 55 days had no entries in the discrepancy log and were therefore excluded from our study. There were a total of 15,504 resident preliminary reports (average of 45.9 preliminary reports per shift) resulting in 51 major discrepancies (discrepancy rate of 0.33%) during 41 total shifts (12.1% of shifts or one major discrepancy every 8.24 shifts). However, the details describing 12 of the 51 discrepancies (including a description of the error and/or the resident preliminary report time stamp) were not available and were therefore excluded from analysis. The resulting 39 major discrepancies during 33 shifts included 28 radiographs (Fig 1), eight computed tomography scans (Fig 2), and three ultrasound examinations. There were no MRI discrepancies as these examinations are primarily of the central nervous system, which are previewed by the resident but then contemporaneously reviewed and finalized by the on-call neuroradiologist. A breakdown of the total number of discrepancies by imaging modality and body region can be seen in Table 1. The most frequently encountered discrepancies were extremity fractures ($N = 8$), chest infection ($N = 5$), and pneumothorax ($N = 5$). Most discrepancies ($N = 21$ or 53.8%) occurred during the first half of the call shift (7 PM–12 AM) and an additional 10 discrepancies (25.6%) occurred during the last few hours of the shift (4–7 AM) as seen in Figure 3.

During the study period and on-call time, there were a total of 14,950 phone calls, with an average of 44.2 phone calls per shift or 3.16 calls per hour. The average telephone call length was 114.9 seconds (range, 1–2949 seconds). A total of 7875 (54.0%) phone calls were ≤1 minute, 10,867 (74.6%) phone calls were ≤2 minutes, and 13,360 (91.7%) phone calls were ≤5 minutes. Only 452 phone calls (3.1%) were ≥10 minutes.

The total number of calls for shifts with known discrepancies ($n = 41$) versus the number of calls for shifts without discrepancies ($n = 297$) were then compared. There

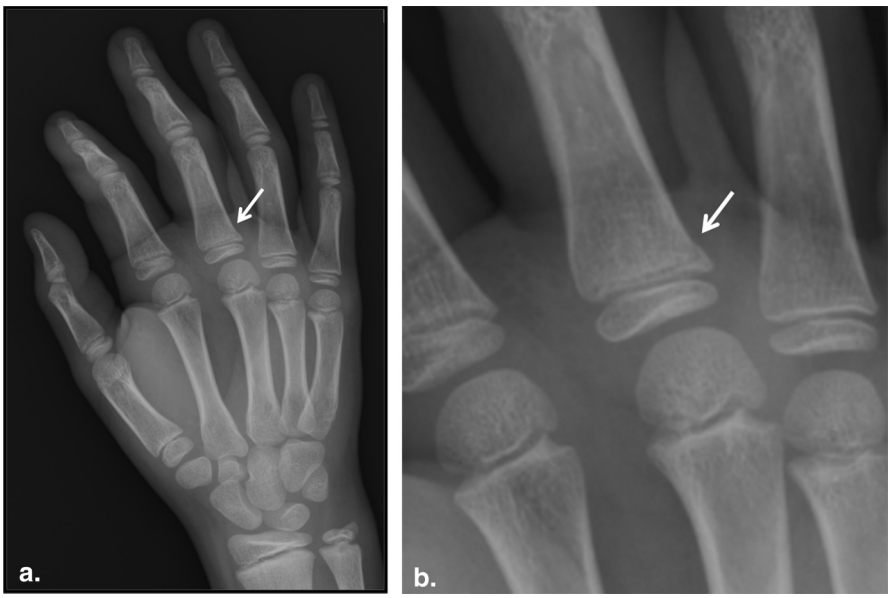

Figure 1. An 11-year-old boy with hand trauma and suspected fracture. There is a subtle cortical buckle of the proximal metaphysis of the proximal third phalanx (**a**, *white arrow*), seen best on the magnified image of the same study (magnified at the workstation [**b**, *white arrow*]) consistent with a Salter–Harris type II fracture. This fracture was not prospectively identified by the radiology resident.

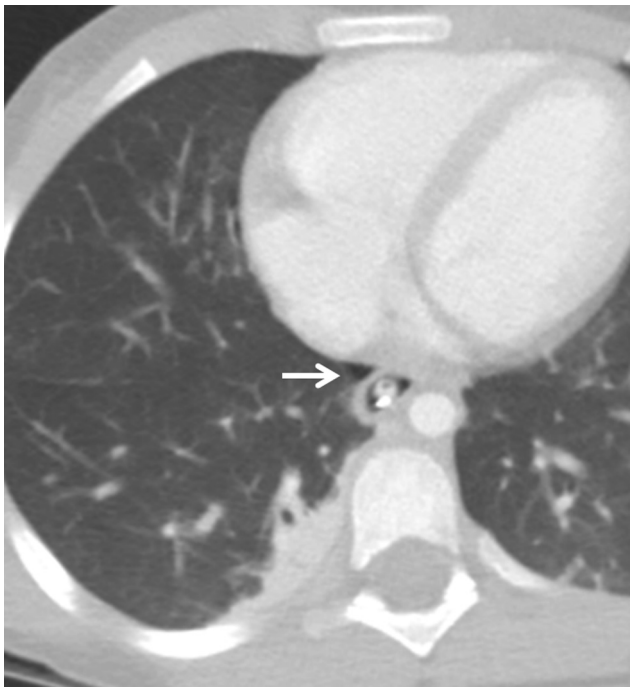

Figure 2. A 6-year-old girl's status after motor vehicle collision. There is a small right medial pneumothorax (*white arrow*) adjacent to the distal esophagus that was not prospectively identified by the radiology resident.

were on average 48.59 calls per shift (standard deviation [SD] 14.3 calls/shift or 3.47 calls/hr) during the "discrepancy shifts" versus an average of 44.02 calls per shift (SD 15.2 calls/shift or 3.14 calls/hr) on "no discrepancy shifts" or a difference of 4.57 calls per 14 hours on call shift (Fig 4). Although the "discrepancy shifts" appeared to have more telephone calls, it was not statistically significant ($P = .0575$).

There was an average of 4.23 calls (standard error = 0.46) in the 1 hour preceding each documented discrepancy (based on the 39 discrepancies with known error details and preliminary report time stamps) compared to an average of 3.24 (standard error = 0.13) calls in the 1 hour preceding the hour without discrepancy or a difference of 0.99 calls per hour (Fig 5). Despite the overlap in phone call volume range, this difference was statistically significant ($P = .027$). In the 1 hour preceding the generation of a discrepant resident preliminary report, a single additional phone call above the average baseline increased the odds of a major discrepancy by 12% ($P = .017$).

DISCUSSION

The patient safety movement has shed light on the significance of medical errors and their contribution to negative patient outcomes, with medical errors thought to contribute to an estimated 98,000 deaths and over 1 million injuries (2,3). As a result, patient safety initiatives and national safety goals have become a health care industry priority (2–6). Medical imaging remains a staple of health care, with imaging utilization rapidly expanding over the past decade, particularly in the hospital inpatient and emergency department settings (16). There is emerging evidence that increasing workplace demands can contribute to increased levels of burnout and physician dissatisfaction (17,18), with many of the fatiguing factors unrelated to the practice of medicine (19). In a recent study published in the Journal of the American College of Radiology, radiologists only spent 36.4% of their time on image interpretation, and the proportion of time spent on noninterpretive tasks was 43.8%, some of which could be handled by a nonphysician (20). These noninterpretive responsibilities contribute to a significant

TABLE 1. Discrepancies by Imaging Modality and Body Region

Imaging Modality	Chest	Abdomen	Extremity	Genitourinary Tract	Spine	Pelvis	Total
Film	13	7	7	0	1	0	28
Computed tomography	3	2	1	0	1	1	8
Ultrasound	0	0	0	3	0	0	3
Total	16	9	8	3	2	1	39

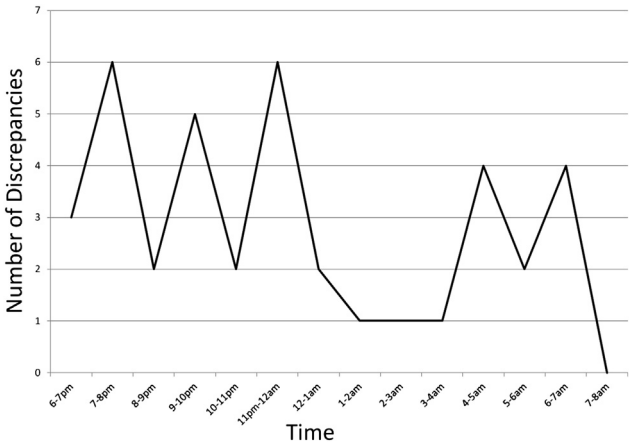

Figure 3. Timing of major discrepancies.

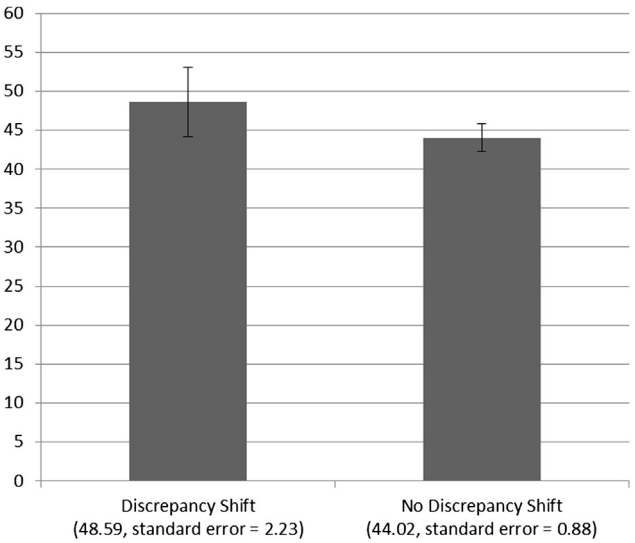

Figure 4. Average telephone calls per shift: discrepancy versus no discrepancy shifts (+/− 2 standard error; *P* = .0575).

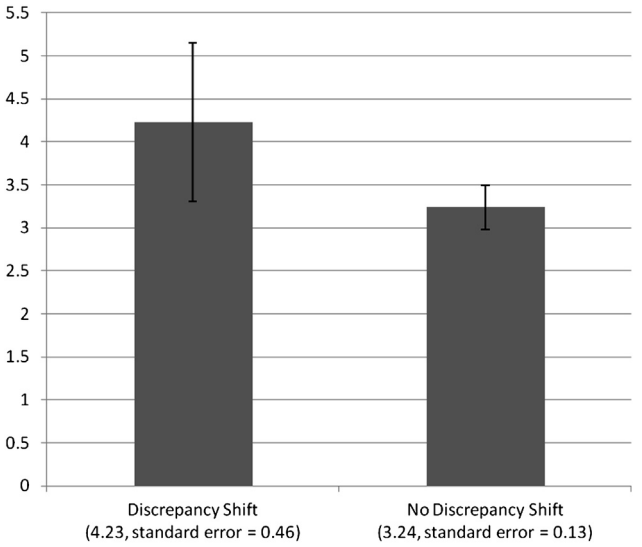

Figure 5. Average telephone calls per hour: discrepancy versus no discrepancy shifts (+/− 2 standard error; *P* = 0.027).

proportion of a radiologist's workflow, with radiology trainees not immune to these realities.

Despite the more recent trend of in-house 24/7 radiology faculty coverage, some hospitals still rely on radiology residents to provide preliminary interpretation, primarily for high-acuity inpatient and emergency department imaging examinations. The typical workflow using this model is for the resident to provide after-hour preliminary "wet reads" that are then reviewed and finalized by the staffing radiologist the next morning. There have been several prior studies investigating the discordance of resident preliminary interpretation with attending radiology final reads, most indicating a discrepancy rate of 1%–3% (21–28). At our institution, any major discrepancy resulting in a change in diagnosis requiring direct communication to the ordering provider is logged for internal quality control and educational purposes. The radiology resident overall discrepancy rate in our study was 0.33%. We suspect that our discrepancy rate is lower than reported as only major discrepancies with the potential for changing patient management requiring direct communication to the ordering provider were recorded. Other minor discrepancies not felt to negatively impact patient management were not recorded.

There have been several prior studies investigating potential factors associated with resident discrepancies, including imaging volume, imaging modalities, and on-call resident training level (21–28), but to our knowledge, there have been no studies directly measuring telephone calls as a root cause for diagnostic errors. Telephone call interruptions are one of the most frequent radiologist workflow interrupters (15), and thus, we focused on telephone calls as a potential root

cause for radiology resident diagnostic errors. In our study, a single additional telephone call above the average baseline phone call volume within 1 hour of the generation of a resident preliminary report raised the probability of the resident generating a report containing a significant error by 12% ($P = .017$). To the best of our knowledge, our research is the first to link distractions to errors in radiologic image interpretation. The conclusions of our research suggest by inference that limiting distractions could result in increased radiology resident diagnostic accuracy, although future research will be needed to address this assumption.

Although the radiology residents' primary responsibility is to render preliminary reports on imaging examinations, there are many other associated critical functions that are interwoven into the process of image interpretation, including in-person consultations, interacting with technologists to prescribe imaging protocols, answering incoming telephone calls, and returning pages. These functions are often performed simultaneously with the resident forced to toggle between tasks, frequently before the completion of the previous task. These workflow disruptions are generally not scheduled, forcing the radiologist to disengage from the current task without completing it and "forgetting" not only the specific task they were once doing but also the focused mind-set that existed before the interruption. When this type of "forgetting" occurs because of any interruption, such as receiving or initiating a telephone call, the worker must invest additional time and effort ("relearning") to return to the same mind-set and level of focus required for the task to be completed correctly (1,29). These distractions and interruptions in workflow have the potential to distract from the resident's primary function of image interpretation and insert the potential for medical error.

A recent article by Froehle and White (1) describes how increased use of technologies that were intended to make communication more streamlined in professional and knowledge-intensive service areas, such as cell phones and e-mail, has actually resulted in more interruptions and reduced productivity as a whole (1). The radiology reading room is fraught with these potential distractions and workflow inefficiencies.

Our study was not without limitations. Of the 393 days of the study period, only 338 days (86.0%) had entries in the discrepancy log. It is impossible to know if there were or were not any discrepancies on the days when no entry was made, so we did not include the phone log data from those days. Although 100% log entry completion would have been ideal and resulted in more data points, we do not feel that these omissions affect our conclusions. In addition, although the resident preliminary report discrepancy log identified 51 discrepancies during 41 shifts, the details of only 39 of the 51 (76.5%) were available. Another limitation of our study is our focus was on only one form of a workflow distraction: telephone call interruptions. We were unable to account for other types of interruptions that may have affected the focus of the residents, such as face-to-face consultations, responding to text messages or e-mails, and so forth. Because we were unable to study the effects of these other types of distractions, it is uncertain whether telephone calls were the leading cause of error-provoking distractions, although in our experience and the experience of others (15), telephone calls are the primary reading room workflow distraction. Further research with controlled distraction variables will be required to determine if other variables are linked with an increased risk of diagnostic errors.

Another limitation was our relatively low number of discrepancy data points. There was only a 0.33% discrepancy rate in our data, although much of the literature indicates a 1%–3% error rate between radiology residents and attending radiologist final read (21–28). Multivariate analysis was hindered by this paucity of data points and was therefore unable to determine if errors are more likely to occur at certain times during the shift. There were also not enough data points to determine which imaging modality is more prone to interruption-induced errors.

Ultimately, one must ask: what can be done to minimize interruptions in the radiology reading room? The solutions to this question are beyond the scope of this article; however, potential options include the use of reading room assistants to handle nonmedical tasks (such as answering the telephone), designating a "consultation" radiologist or resident to handle radiologist-specific medical tasks, or instituting an "interruption-free zone" or "sterile cockpit zone," the likes of which have been instituted in other industries and medical fields (30). However, one must be mindful that time-sensitive consultations frequently arise and the need for radiologist interruption may outweigh the cost of temporarily decreasing overall productivity (1). In an article addressing the interactions of clinicians with the radiology department, only one factor had a significant association with overall satisfaction: the approachability of the radiology service (31). This must be taken into account when instituting policies that might limit clinician accessibility to radiologists. Ultimately, a compromise must be made that balances radiologist accessibility by consulting health care practitioners and at the same time minimizes unnecessary interruptions.

In conclusion, we have shown that distractions in the form of telephone call interruptions may negatively impact on-call radiology resident diagnostic accuracy. Efforts should be made to minimize distractions in the reading room.

REFERENCES

1. Froehle CM, White DL. Interruption and forgetting in knowledge-intensive service environments. Prod Oper Manag 2013; 23(4):704–722.
2. Kohn LT, Corrigan J, Donaldson MS, eds. To err is human: building a safer health system. Washington, District of Columbia: National Academy Press, 2000.
3. Stelfox HT, Palmisani S, Scurlock C, et al. The "To Err is Human" report and the patient safety literature. Qual Safety Health Care 2006; 15: 174–178.
4. Sittig DF, Singh H. Electronic health records and national patient-safety goals. N Engl J Med 2012; 367:1854–1860.

5. Radecki RP, Sittig DF. Application of electronic health records to the Joint Commission's 2011 National Patient Safety Goals. JAMA 2011; 306: 92–93.
6. Blendon RJ, DesRoches CM, Brodie M, et al. Views of practicing physicians and the public on medical errors. N Engl J Med 2002; 347: 1933–1940.
7. Einstein GO, McDaniel MA, Williford CL, et al. Forgetting of intentions in demanding situations is rapid. J Exp Psychol Appl 2003; 9:147–162.
8. Eyrolle H, Cellier JM. The effects of interruptions in work activity: field and laboratory results. Appl Ergon 2000; 31:537–543.
9. Meeks DW, Takian A, Sittig DF, et al. Exploring the sociotechnical intersection of patient safety and electronic health record implementation. J Am Med Inform Assoc 2014; 21:e28–e34.
10. Joint Commission Center for Transforming Healthcare, SCHA collaborate on high-reliability program. Bull Am Coll Surg 2013; 98:65.
11. McGillis Hall L, Pedersen C, Fairley L. Losing the moment: understanding interruptions to nurses' work. J Nurs Adm 2010; 40:169–176.
12. Sorensen EE, Brahe L. Interruptions in clinical nursing practice. J Clin Nur 2013; 23:1274–1282.
13. Hall LM, Ferguson-Pare M, Peter E, et al. Going blank: factors contributing to interruptions to nurses' work and related outcomes. J Nurs Manag 2010; 18:1040–1047.
14. Arora S, Hull L, Sevdalis N, et al. Factors compromising safety in surgery: stressful events in the operating room. Am J Surg 2010; 199:60–65.
15. Yu JP, Kansagra AP, Mongan J. The radiologist's workflow environment: evaluation of disruptors and potential implications. J Am Coll Radiol 2014; 11:589–593.
16. Levin DC, Rao JM, Parker L, et al. Analysis of radiologists' imaging workload trends by place of service. J Am Coll Radiol 2013; 10:760–763.
17. Rosenstein AH, Mudge-Riley M. The impact of stress and burnout on physician satisfaction and behaviors. Physician Exec 2010; 36(6):16–18. 20, 22-3.
18. Holt GR. Physician burnout: a serious concern for the medical profession. South Med J 2013; 106(5):297.
19. Shanafelt T, Dyrbye L. Oncologist burnout: causes, consequences, and responses. J Clin Oncol 2012; 30(11):1235–1241.
20. Dhanoa D, Dhesi TS, Burton KR, et al. The evolving role of the radiologist: the Vancouver workload utilization evaluation study. J Am Coll Radiol 2013; 10(10):764–769.
21. Cooper VF, Goodhartz LA, Nemcek AA, Jr, et al. Radiology resident interpretations of on-call imaging studies: the incidence of major discrepancies. Acad Radiol 2008; 15:1198–1204.
22. Flink CC, Mueller JS, Kiproff PM. Impact of resident call eligibility on major discrepancy rate. Acad Radiol 2010; 17:1299–1301.
23. Maloney E, Lomasney LM, Schomer L. Application of the RADPEER scoring language to interpretation discrepancies between diagnostic radiology residents and faculty radiologists. J Am Coll Radiol 2012; 9:264–269.
24. Miyakoshi A, Nguyen QT, Cohen WA, et al. Accuracy of preliminary interpretation of neurologic CT examinations by on-call radiology residents and assessment of patient outcomes at a level I trauma center. J Am Coll Radiol 2009; 6:864–870.
25. Ruchman RB, Jaeger J, Wiggins EF, III, et al. Preliminary radiology resident interpretations versus final attending radiologist interpretations and the impact on patient care in a community hospital. AJR Am J Roentgenol 2007; 189:523–526.
26. Ruma J, Klein KA, Chong S, et al. Cross-sectional examination interpretation discrepancies between on-call diagnostic radiology residents and subspecialty faculty radiologists: analysis by imaging modality and subspecialty. J Am Coll Radiol 2011; 8:409–414.
27. Shah NA, Hoch M, Willis A, et al. Correlation among on-call resident study volume, discrepancy rate, and turnaround time. Acad Radiol 2010; 17: 1190–1194.
28. Walls J, Hunter N, Brasher PM, et al. The DePICTORS study: discrepancies in preliminary interpretation of CT scans between on-call residents and staff. Emerg Radiol 2009; 16:303–308.
29. Altmann EM, Trafton JG, Hambrick DZ. Momentary interruptions can derail the train of thought. J Exp Psychol Gen 2014; 143(1):215–226.
30. "The Biggest Office Interruptions Are…" Available at: http://online.wsj.com/news/articles/SB10001424127887324123004579057212505053076. Accessed December 18, 2013.
31. Lindsay R, McKinstry S, Vallely S, et al. What influences clinician's satisfaction with radiology services? Insights Imaging 2011; 2(4):425–430.