The Radiologist's Workflow Environment: Evaluation of Disruptors and Potential Implications

John-Paul J. Yu, MD, PhD[a], Akash P. Kansagra, MD, MS[a], John Mongan, MD, PhD[a]

Workflow interruptions in the health care delivery environment are a major contributor to medical errors and have been extensively studied within numerous hospital settings, including the nursing environment and the operating room, along with their effects on physician workflow. Less understood, though, is the role of interruptions in other highly specialized clinical domains and subspecialty services, such as diagnostic radiology. The workflow of the on-call radiologist, in particular, is especially susceptible to disruption by telephone calls and other modes of physician-to-physician communication. Herein, the authors describe their initial efforts to quantify the degree of interruption experienced by on-call radiologists and examine its potential implications in patient safety and overall clinical care.

Key Words: Patient safety, quality assurance, interruptions, workplace disruptions

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INTRODUCTION

The Institute of Medicine's seminal report *To Err Is Human* [1] has been widely credited with bringing about the modern patient safety movement. In an increasingly complex health care delivery environment with medical errors leading to upward of 98,000 deaths and >1 million injuries [1,2], patient safety has come to the fore with a wide array of efforts to ensure the safety of patients, ranging from the integration of electronic health records into routine clinical practice [3-5] to the establishment of national safety goals and initiatives to make patient safety a health care priority [6]. The Institute of Medicine's report garnered much attention both within the health care industry and among the public at large [7] and without a doubt has spurred intensive research into patient safety.

One particular area of research has focused on the health care work environment, specifically the link between frequent interruptions and patient safety. Interruptions are a pervasive element of complex work environments [8-13]. Controlled laboratory experiments on cognition have linked interruptions to errors [14,15], and interruptions are often to the detriment of complex tasks involving high cognitive loads that are particularly sensitive to interference and interruptions [16-18]. Within the health care delivery environment, the role of interruptions and their effects on patient safety have been extensively studied in numerous hospital settings, including the nursing environment [2,7,19-21] and the operating room [22], along with their effects on physician workflow [23-26].

Less understood, though, is the role of interruptions in other highly specialized clinical domains and subspecialty services, such as diagnostic radiology. The workflow of the on-call radiologist, in particular, is especially vulnerable to disruption by telephone calls and other modes of physician-to-physician communication. On-call radiologists handle multiple responsibilities, including examination protocoling, contrast and nuclear medicine injections, ultrasound scanning, clinical consultations, and the communication of imaging findings to referring clinicians, as well as their primary responsibility of interpreting all imaging studies in a timely manner. As a result, noninterpretative responsibilities now occupy an outsized role in the workflow of on-call radiologists and, in many instances, consume far more time and effort than the actual practice of radiologic image interpretation.

Radiologists, especially radiology residents at academic institutions, experience frequent disruptions while on call. Numerous studies from residency training programs have examined the overall rate of discordance of initial study interpretation to the final attending read [27-37], with a preponderance of studies showing the overall rate of major discordance to be approximately 1% to 2% and relatively constant. And although many of these studies examining concordance and discordance rates have examined potential factors for these discrepancies (including imaging volume, training level of

[a]Department of Radiology and Biomedical Imaging, University of California, San Francisco, San Francisco, California.

Corresponding author and reprints: John-Paul J. Yu, MD, PhD, University of California, San Francisco, Department of Radiology and Biomedical Imaging, 505 Parnassus Avenue, M-391, Box 0628, San Francisco, CA 94143-0628; e-mail: jp.yu@ucsf.edu.

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on-call residents, and types of studies done), no study to date has explored other possible root causes for discrepant findings, including extrinsic factors such as the role of interruptions in a highly disruptive on-call work environment. With telephone calls as one of the most frequent interruptions to the workflow of on-call radiologists, we sought to quantitatively ascertain the experience of on-call radiologists at our academic institution by analyzing the absolute time and frequency they spend on the phone to better understand this phenomenon and its potential implications.

METHODS

Telecommunications Data

On-call radiologists at our institution assume call responsibilities in a single designated call room with 3 unique telephone extensions to the room. Through our medical center's centralized telecommunications center, an annotated list of all completed telephone encounters, including call time stamps, durations, and call origins, was analyzed. The records cover a period of 13 weeks from midnight on July 14, 2012, through 11:59 PM on October 12, 2012 (90 days). The records document the start date and time (to the nearest minute) and duration (to the nearest second) of each completed inbound and outbound call. Records falling between 8 AM and 5 PM from Monday through Friday were discarded because there is no on-call radiologist during these times. Completed telephone encounters were defined as calls (both incoming and outgoing) in which both parties were on the line at the same time, regardless of call duration. Our analysis did not include uncompleted telephone calls.

CT Imaging Volume

The total number of CT examinations corresponding to the same consecutive 90-day period between July 14, 2011, and October 12, 2012, was catalogued, with examination start times extracted from the time at which the scout image was obtained. Studies included both inpatient and outpatient examinations performed at our institution for which preliminary interpretations were rendered by an on-call radiologist. Examination metadata were queried from the radiology information system database (IDXRad version 10.6.0.999; IDX, Burlington, VT).

Statistical Analysis

Data were analyzed using the R statistical package, version 2.14 (R Development Core Team, Vienna, Austria). Average telephone call and CT study volumes were computed as arithmetic means. Spearman's rank correlation was used to test the correlation between hourly telephone call and CT study volumes. The median was selected as the measure of central tendency for intervals between calls and call durations because the distributions of these data were both non-normal and highly skewed. Probability of interruption was calculated using a subset of the data consisting of only incoming calls because outgoing calls may not constitute true interruptions. For each second of on-call time between 1 PM and 1 AM during the data collection period, the number of seconds until the next incoming call was calculated. An empirical cumulative distribution function was constructed on the basis of these intervals.

RESULTS

Overview

During the 90-day period of data collection, a total of 10,378 calls were completed during on-call hours, 5,759 (55%) of which were incoming calls. The median call duration was 57 seconds. During a typical 12-hour overnight on-call shift (8 PM to 8 AM), there was an average of 72 telephone calls, with an average total time of 108 min spent on the phone. There was an average of 19.3 CT studies during an overnight shift.

Call Frequency

Telephone call and CT volumes varied markedly depending on the hour of the day. Average telephone call volume per hour varied from 2.82 to 10.81, and average CT volume varied from 0.58 to 3.08 studies per hour over the course of the day (Fig. 1). Hourly average CT and telephone call volumes were highly correlated (Spearman's $\rho = 0.75$, $\rho \neq 0$ with $P < .001$).

Statistical Analysis

The median interval from the start of one telephone call to the start of the next ranged from 3 to 10 min, depending on the time of day. The median interval was

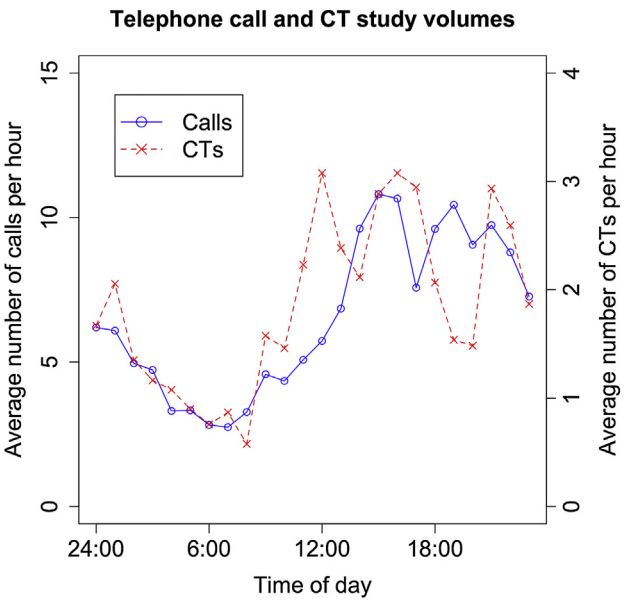

Fig 1. Average hourly volumes of telephone calls and CT studies. Times between 8 AM and 5 PM represent data from weekends only.