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A Novel Radiology Communication Tool to Reduce Workflow Interruptions: Clinical Evaluation of RadConnect

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Abstract

Despite the importance of communication, radiology departments often depend on communication tools that were not created for the unique needs of imaging workflows, leading to frequent radiologist interruptions. The objective of this study was test the hypothesis that a novel asynchronous communication tool for the imaging workflow (RadConnect) reduces the daily average number of synchronous (in-person, telephone) communication requests for radiologists. We conducted a before-after study. Before adoption of RadConnect, technologists used three conventional communication methods to consult radiologists (in-person, telephone, general-purpose enterprise chat (GPEC)). After adoption, participants used RadConnect as a fourth method. Technologists manually recorded every radiologist consult request related to neuro and thorax CT scans in the 40 days before and 40 days after RadConnect adoption. Telephone traffic volume to section beepers was obtained from the hospital telephone system for the same period. The value and usability experiences were collected through an electronic survey and structured interviews. RadConnect adoption resulted in 53% reduction of synchronous (in-person, telephone) consult requests: from 6.1 ± 4.2 per day to 2.9 ± 2.9 ($P < 0.001$). There was 77% decrease ($P < 0.001$) in telephone volume to the neuro and thorax beepers, while no significant volume change was noted to the abdomen beeper (control group). Survey responses (46% response rate) and interviews confirmed the positive impact of RadConnect on interruptions. RadConnect significantly reduced radiologists' telephone interruptions. Study participants valued the role-based interaction and prioritized worklist overview in the survey and interviews. Findings from this study will contribute to a more focused work environment.

Keywords Communication · Informatics · Workflow interruption · Clinical evaluation

Introduction

Effective stakeholder communication is a crucial responsibility of radiologists, as it directly impacts appropriate use of imaging services, patient safety, and diagnostic quality. Radiology departments can choose from a plethora of communication methods, such as beeper, telephone, face to face, and chat tools that are standalone or baked into other solutions. An integrated communication experience that streamlines communication with and within the radiology service is currently missing.

Various types of conversations are taking place with and within the radiology department. Nurses contact radiologists for questions about protocols, technologists contact them for questions about acquisition and image quality, and referrers contact them for questions about clarifications, among many other interactions. Depending on the context and the nature of the question, it may require an immediate and real-time ("synchronous") response, e.g., by telephone or in person. This causes the receiver to stop the current task and focus on the question, creating an interruption [1–3]. Workflow interruptions often result in complete disengagement [4] and are associated with longer report turnaround times [5], increased diagnostic errors [6, 7], and higher mental workload [8].

Merlijn Sevenster and Kenneth Hergaarden contributed to the work equally.

Summary Sentence A novel radiology communication tool (RadConnect) significantly reduced radiologist workflow interruptions caused by technologists over phone and in person.

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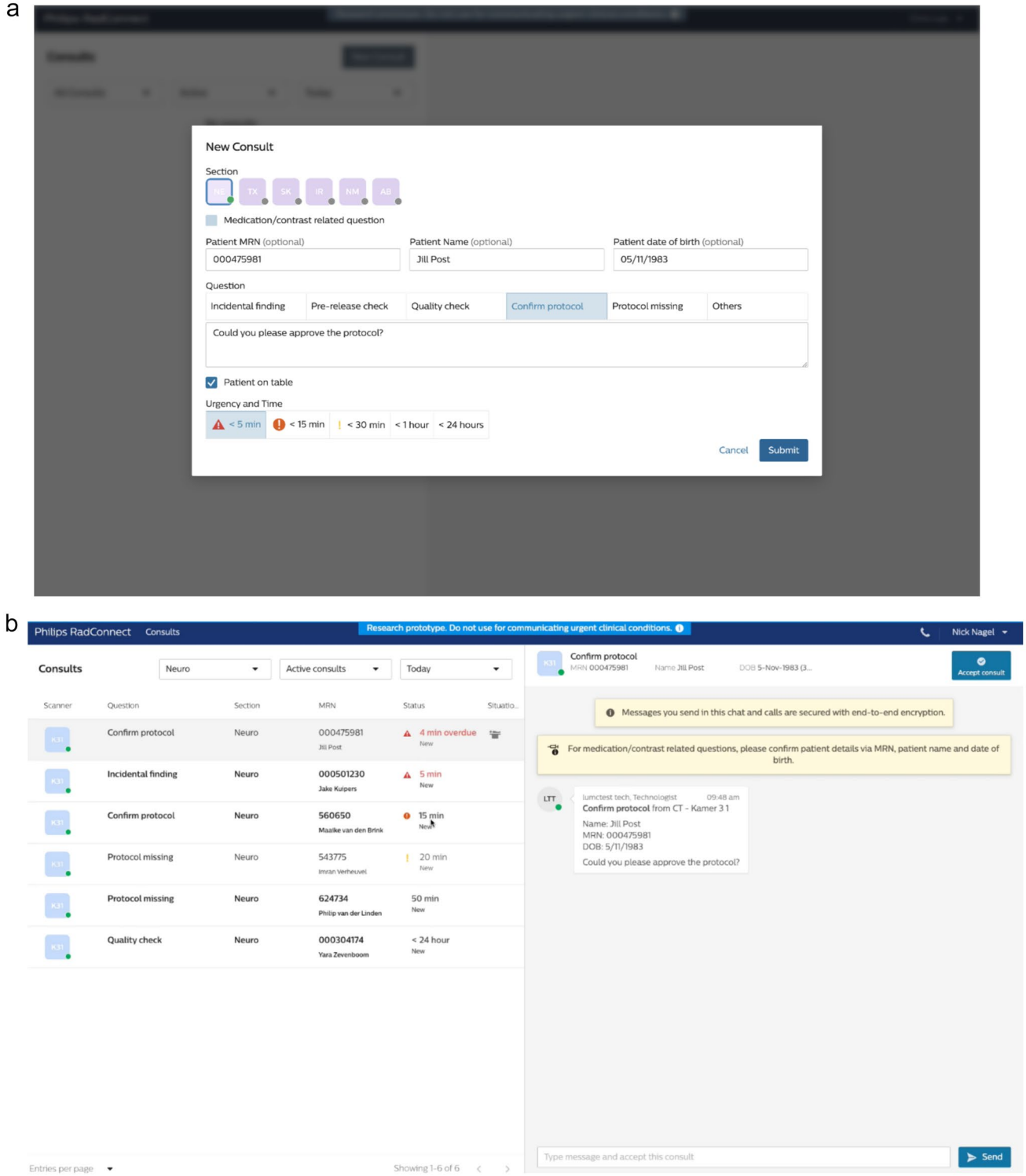

Fig. 1 **a** Sending a consult request ticket in RadConnect. The tickets are sent to a radiology section account, not to a specific individual. Note that in the study, only the neuro and thorax sections could be selected. The ticket form contains information to identify the patient. Filling out these fields is optional, but obligatory for contrast use and medication questions. Further, the technologist selects the question category, upon which the question box is filled with a pre-determined editable statement. Finally, the technologist selects the requested response time. Patient data in this figure is fictitious. RadConnect was a research prototype that was not commercially available. **b** Consult requests worklist. Consult requests are prioritized by patient status and shortest due time, i.e., requested response time minus time to submission. When a radiologist accepts a consult request, a chat channel with the technologist appears (righthand side). Whenever the question was satisfactorily answered, either user could close the ticket and it disappeared from the worklist of open tickets. Radiologists were able to push a question back to the worklist, for instance, when they had to step away from the workstation. Patient data in this figure is fictitious. RadConnect was a research prototype that was not commercially available

Unnecessary workflow interruptions should therefore be minimized [9], while not adversely impacting efficiency of the radiology service. Most questions do not require immediate and real-time responses though and can be dealt with in between tasks. This presents an opportunity for shaping an asynchronous and streamlined communication experience that is tailored to radiology.

As a first iteration, a communication tool was developed for collaboration between technologists and radiologists (RadConnect) [10]. We report on a clinical study that tested the hypothesis that RadConnect reduces the daily average number of synchronous (in-person, telephone) communication requests for radiologists, which are known to cause workflow interruptions [11]. We compared RadConnect against communication alternatives.

Methods and Materials

The Internal Committee for Biomedical Experiments of Royal Philips (Amsterdam, The Netherlands) approved this study (ICBE-S-000556). It was registered at clinicaltrials.gov (NCT05540444). The regional Medical Ethics Committee of our institution waived protocol review (N22.056).

Study Design

We conducted a prospective before-after study to examine the hypothesis that a novel communication web-application, RadConnect, reduces the daily average number of synchronous (in-person, telephone) communication requests for radiologists. Synchronous consults have been associated with high rates of workflow interruptions [11] and reduction thereof may contribute to a more focused work environment. The study was conducted at Leiden University Medical Center, a single-center academic hospital in Leiden, The Netherlands. It was split in two distinct phases, each spanning 40 consecutive business days. The "before phase" (October 11–December 5, 2022) served to quantify the communication between participants in the standard situation with the conventional communication methods: in-person, telephone, and general-purpose enterprise chat (GPEC, Teams, Microsoft, Seattle, USA). In the "after phase" (May 1–June 27, 2023), participants had a personal RadConnect user account and were encouraged to use RadConnect in addition to the conventional methods, after receiving education through walk-in sessions and a video tutorial. The planning and volume of the radiology service were not changed during the study.

Before the study, RadConnect had been tested in an offline simulated setting [10], but not clinically. Therefore, participants were instructed to limit the use of RadConnect to questions about cardiothoracic (thorax) and neurological (neuro) computed tomography (CT) scans that were not medically urgent. For all other questions, participants used the three conventional methods. Technologists and radiologists were eligible for participation in the study if they were involved in the acquisition of thorax and neuro CT scans. For brevity, "technologists" also refers to nurses that support the day-to-day CT operations but have no license to operate a CT scanner. At our institution, these nurses work in the electronic medical record (EMR) to schedule same-day inpatients and ensure an approved protocol is in place before the patient arrives for a CT.

RadConnect Functionality and Deployment

In RadConnect, technologists sent a consult request to the neuro or thorax account in the form of a "ticket" that comprised various fields including requested response time and question category, e.g., "protocol missing" and "quality check" [12] (Fig. 1a). The tickets appeared on a section worklist that was prioritized by urgency (Fig. 1b). Tickets that were overdue were visually marked. To avoid patient identity confusion, patient name, birth date, and medical record number were obligatory to fill out if the question pertained to contrast or medication use. Upon opening a ticket, a chat channel was created between the technologist and the radiologist. RadConnect was a research prototype in testing phase that was not available commercially.

RadConnect was a cloud-based stand-alone solution that was accessible through a regular browser. The browser was not embedded in a third-party solution like picture archiving and communication system (PACS) or EMR. Study participants accessed RadConnect from a monitor in their standard workspace setup; no additional monitors were added.

Data Collection and Analysis

In both phases, technologists recorded every consult request for a neuro or thorax radiologist on a paper form, logging the communication method, the section, the question category, and if there was a response. No strict definitions of no response were given, but if another communication method was used to answer the same question, technologists were instructed to log the initial attempt as "no response" and the subsequent attempt as a separate consult request. RadConnect did not time out tickets after a pre-determined period. RadConnect automatically

logged anonymous meta-data of tickets. The total number of (synchronous and asynchronous) consults for the entire test group each study day was the outcome variable used for testing the hypothesis. Sample differences were tested for significance using Mann-Whitney test, while proportional before-after differences were tested using chi-squared test. P-value < 0.005 ($= 0.05/11$) was used to indicate statistical significance and Bonferroni adjustment was used to account for 11 tests. Statistical analysis was performed in R [13].

Abdomen radiologists were the control group and did not have RadConnect in either study phase. The control group served to measure the effect of possible other factors on communication behaviors than the use of RadConnect. The number of phone calls from the landline extensions at the CT scanners and the nurses' workplace to neuro, thorax, and abdomen section beepers was recorded from the telephone database. We decided against the technologists logging all communications with the abdomen section on the paper forms, as this would have been excessively laborious.

Following the after phase, participants were invited to complete an online structured survey to assess the value and usability of RadConnect compared against the communication alternatives. A member of the research team (S.V.) conducted a structured interview with six participants, a convenience sample of two technologists, two nurses and two radiologists.

Results

Fifty technologists, of which eight were nurses, and 29 radiologists consented to participate in the study (see Table 1). Nobody declined participation. During 1 day in the after

Table 1 Study participant information

	Technologists ($N=42$)		Non-technologist nurses ($N=8$)	Radiologists ($N=29$)	
Seniority					
	Student	5% (2/42)		Radiology resident	55% (16/29)
	Certified	95% (40/42)		Radiology fellow	7% (2/29)
				Attending radiologist	38% (11/29)
				Neuro	45% (5/11)
				Cardiothoracic	36% (4/11)
				Other specialization	18% (2/11)
Age bracket					
19 years and younger	5% (2/42)		0% (0/8)	0% (0/29)	
20–29	26% (11/42)		38% (3/8)	10% (3/29)	
30–39	31% (13/42)		0% (0/8)	62% (18/29)	
40–49	14% (6/42)		38% (3/8)	10% (3/29)	
50–59	19% (8/42)		25% (2/8)	14% (4/29)	
60 years and older	5% (2/42)		0% (0/8)	0% (0/29)	
I use messenger apps (WhatsApp, Signal, Telegram)					
Multiple times a day	100% (42/42)		100% (8/8)	93% (27/29)	
Once a day	0% (0/42)		0% (0/8)	0% (0/29)	
Once every 2 days	0% (0/42)		0% (0/8)	3% (1/29)	
Once every week	0% (0/42)		0% (0/8)	0% (0/29)	
Once every 2 weeks	0% (0/42)		0% (0/8)	0% (0/29)	
Less than once every 2 weeks	0% (0/42)		0% (0/8)	0% (0/29)	
Never	0% (0/42)		0% (0/8)	3% (1/29)	
I use communication tools (Microsoft Teams, Zoom)					
Multiple times a day	5% (2/42)		13% (1/8)	59% (17/29)	
Once a day	14% (6/42)		0% (0/8)	17% (5/29)	
Once every 2 days	5% (2/42)		63% (5/8)	3% (1/29)	
Once every week	19% (8/42)		0% (0/8)	10% (3/29)	
Once every 2 weeks	12% (5/42)		0% (0/8)	7% (2/29)	
Less than once every 2 weeks	33% (14/42)		25% (2/8)	3% (1/29)	
Never	10% (4/42)		0% (0/8)	0% (0/29)	

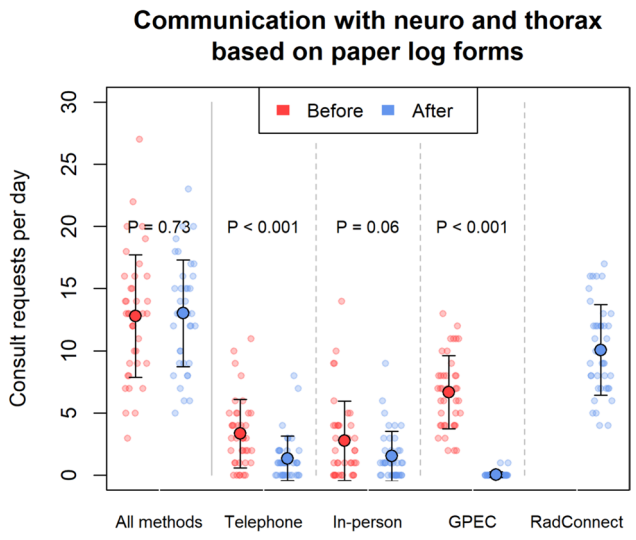

Fig. 2 Distribution of the daily number of manually logged consult requests to the neuro and thorax sections with all communication methods combined (left-most pair of samples) and broken down by method. These samples are based on the manually maintained paper log forms that record communication with the neuro and thorax sections. Sample means and standard deviations are presented per sample. *P*-values represent the significance level of testing if samples are different (Mann–Whitney's test). GPEC general-purpose enterprise chat

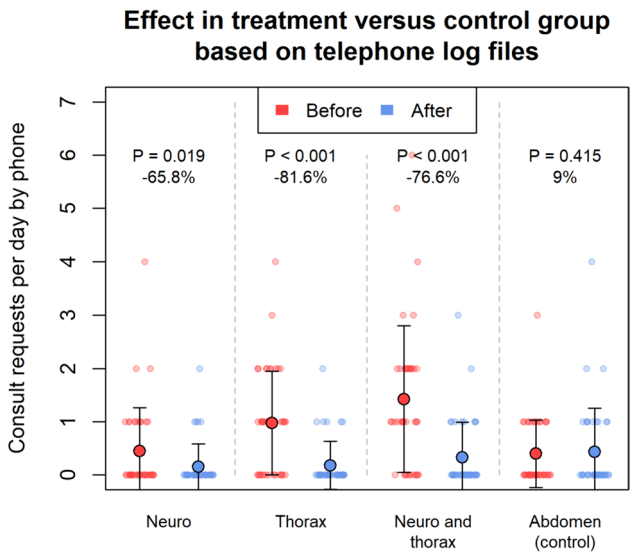

Fig. 3 Distribution of the daily number of automatically logged phone calls to the neuro, thorax, and abdomen section beepers in the before and after phases. These samples only capture communication to the section beeper extension. Phone-based communication with the respective sections to other extensions was not collected, for privacy reasons. Sample means and standard deviations are presented per sample. The before-after differences were tested for significance (Mann–Whitney test) and *P*-values were plotted. The percentages present the change of the mean number of daily calls in the after phase relative to the mean number of daily calls in the before phase

phase, some users experienced log-in difficulties. This day's data was excluded.

Of all log forms, 81% were filled out and returned. Technologists logged 517 and 507 consult requests in the before and after phases, respectively.

Adoption of RadConnect resulted in 53% reduction in synchronous (telephone, in-person) consult requests: from 6.1 ± 4.2 per day to 2.9 ± 2.9 ($P < 0.001$). Telephone-initiated requests decreased by 65%, dropping from 3.4 ± 2.7 before RadConnect to 1.4 ± 1.8 after ($P < 0.001$) (see Fig. 2). The database of the institutional telephone system showed a 77% decrease from included landline extensions to the neuro and thorax beepers ($P < 0.001$). There was a non-significant 9% increase in telephone communication from the same extensions to the abdomen section beeper, the control group (see Fig. 3). Study participants had almost entirely ceased using GPEC for thorax and neuro questions when RadConnect had become available.

Protocolling and image review questions were the most common question categories (see Table 2). The use of synchronous communication methods decreased for both question categories in the after phase. For the 399 protocolling questions before, the use of synchronous methods (telephone + in-person) accounted for 33% ([96 + 35]/399, 95% confidence interval (CI) 28–38%). For the 431 protocolling questions after, this was 13% ([32 + 25]/431, CI 10–17%). This before-after difference was statistically significant ($P < 0.001$) and shows that technologists adopted RadConnect for protocolling questions.

The no-response rate of all communication methods combined was 6% (95% confidence interval (CI) 5–9%) in the before phase and 15% (CI 12–19%) in the after phase ($P < 0.001$) (see Table 3). The synchronous communication methods had lower no-response rates than RadConnect and GPEC. Note that RadConnect's no-response rate (18%, CI 15–23%) was significantly higher than GPEC's in the before phase (10%, CI 7–14%), $P = 0.003$.

Based on the RadConnect application log files, 493 tickets were sent (of which technologists had manually logged 79% [391/493]). Radiologists accepted 80% (392/493) of consult requests; technologist had withdrawn the rest, e.g., for modifying the ticket's text, relevance timing out or following up with another communication method.

The electronic survey was completed by 46% (36/79) of study participants, 15 radiologists and 21 technologists among whom were four nurses. One technologist and one radiology resident lacked firsthand experience with RadConnect. Their responses were excluded. On a five-point Likert scale, radiologists strongly agreed that calls interrupted their workflow (mean 4.7 ± 0.6) and that RadConnect avoided telephone interruptions (4.6 ± 0.5). RadConnect was voted as the least disruptive and most organized communication method and most suitable for protocolling and non-urgent

Table 2 Distribution of question categories and communication methods in the before and after phases based on the paper log forms

Before						
	Telephone	In-person	GPEC	RadConnect	Missing data	All
Protocolling	19% (96/517)	7% (35/517)	51% (263/517)	-	1% (5/517)	77% (399/517)
Image review	5% (27/517)	10% (53/517)	0% (1/517)	-	0% (0/517)	16% (81/517)
Settings	1% (4/517)	2% (9/517)	0% (0/517)	-	0% (0/517)	3% (13/517)
Allergy	0% (0/517)	0% (0/517)	0% (0/517)	-	0% (0/517)	0% (0/517)
Other	1% (5/517)	2% (12/517)	0% (0/517)	-	0% (0/517)	3% (17/517)
Missing data	0% (2/517)	0% (2/517)	1% (3/517)	-	0% (0/517)	1% (7/517)
All	26% (134/517)	21% (111/517)	52% (267/517)	-	1% (5/517)	100% (517/517)
After						
	Telephone	In-person	GPEC	RadConnect	Missing data	All
Protocolling	6% (32/507)	5% (25/507)	0% (2/507)	73% (371/507)	0% (1/507)	85% (431/507)
Image review	4% (20/507)	6% (30/507)	0% (0/507)	2% (9/507)	0% (0/507)	12% (59/507)
Settings	0% (0/507)	1% (3/507)	0% (0/507)	0% (1/507)	0% (0/507)	1% (4/507)
Allergy	0% (0/507)	0% (0/507)	0% (0/507)	0% (0/507)	0% (0/507)	0% (0/507)
Other	0% (1/507)	0% (2/507)	0% (0/507)	2% (10/507)	0% (0/507)	3% (13/507)
Missing data	0% (0/507)	0% (0/507)	0% (0/507)	0% (0/507)	0% (0/507)	0% (0/507)
All	10% (53/507)	12% (60/507)	0% (2/507)	77% (391/507)	0% (1/507)	100% (507/507)

"Missing data" applied if the consult request was logged but the question category and/or communication method was missing

GPEC general-purpose enterprise chat

questions. At the same time, it was voted the lowest for fastest to connect and considered least suitable for image review questions. There was no communication aspect where GPEC received the most votes (see Fig. 4).

Discussion

Primary Results

Clinical adoption of RadConnect significantly reduced radiology workflow interruptions caused by technologists over phone, while no reduction was seen in the control group. The effectiveness of RadConnect in reducing telephone interruptions was not only demonstrated through statistical analysis but also corroborated by the feedback of radiologists in the survey and interviews. RadConnect noticeably contributed to a work environment in which radiologists can focus on their image interpretation responsibilities. In the interviews, when asked about the top-three positive aspects of RadConnect, one resident participant said: "Most important is that [RadConnect] enables you to work more efficiently, less interrupted" (translated from Dutch).

Table 3 No-response rate per communication method in the before and after phases based on the paper log forms

	Before	After
Telephone	4% (5/134), CI 2–8%	6% (3/53), CI 2–15%
In-person	1% (1/111), CI 0–5%	3% (2/60), CI 1–11%
GPEC	10% (27/267), CI 7–14%	0% (0/2)
RadConnect	-	18% (72/391), CI 15–23%
Missing data	0% (0/5)	0% (0/1)
All	6% (33/517), CI 5–9%	15% (77/507), CI 12–19%

"Missing data" applied if the consult request was logged but the communication method was missing. 95% confidence interval (CI) was computed when the denominator $n > 10$

GPEC general-purpose enterprise chat

RadConnect was primarily used for protocolling questions and survey respondents confirmed that such questions are best managed over RadConnect. At our institution, protocolling questions are typically non-urgent and radiologists can attend to them after finishing the interpretation of a radiological examination, thus avoiding unnecessary workflow interruptions.

RadConnect Usability

In addition to providing an asynchronous communication experience, RadConnect had features that were specifically designed for the image acquisition workflow. At the time of the clinical study, the GPEC solution had

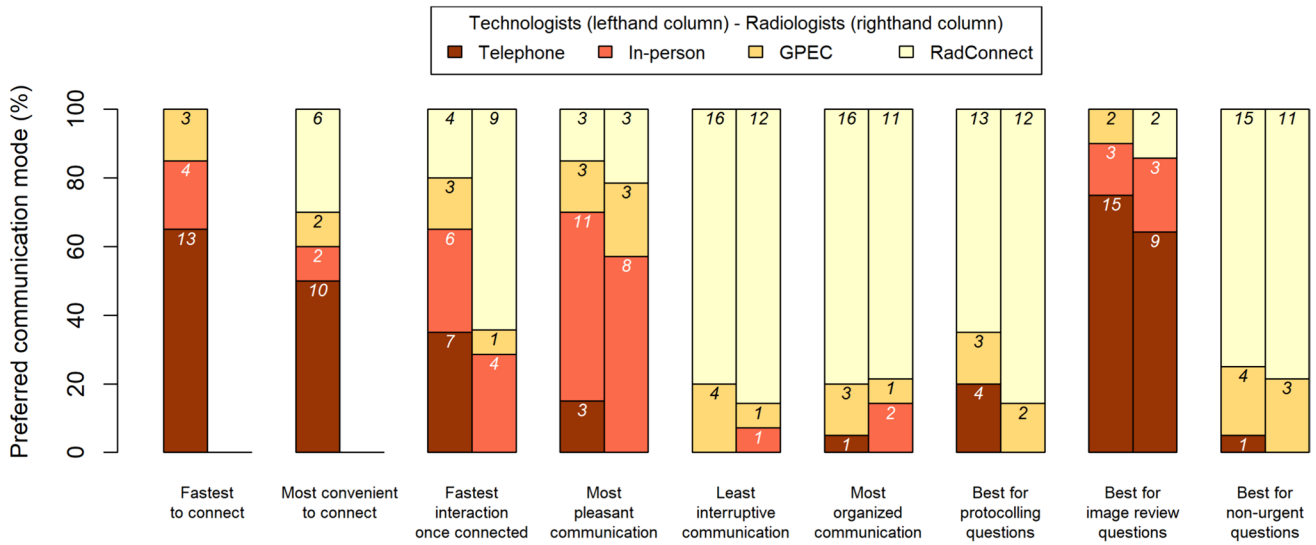

Fig. 4 The aggregated preferences of technologists (left-hand column) and radiologists (right-hand column) for nine dimensions of communication. The data labels represent the number of respondents that voted for the corresponding communication method as their preferred method. In RadConnect, only technologists could initiate discussion by sending a ticket. Radiologists could respond to incoming tickets, but they could not seek to connect with a technologist themselves. For this reason, radiologists were not polled on their connecting experiences (speed and convenience). GPEC general-purpose enterprise chat

been in use for over a year. Despite most participants being accustomed to this asynchronous tool (Table 1), RadConnect was collectively adopted and GPEC was no longer used for neuro and thorax CT questions. This suggests that RadConnect's differentiating features add a unique value that exceeds the value delivered by asynchronous communication per se. The survey corroborates this: RadConnect was preferred in various aspects of communication, while GPEC was not preferred in any (Fig. 4). When asked if RadConnect could be used instead of the current setup, one radiologist interview commented: "Yes, because the [GPEC] environment is actually not meant for [how we use it]" (translated from Dutch).

Three features differentiated RadConnect from GPEC.

- Consult requests were initiated through *tickets with an urgency indication*. The tickets exploit the standardized nature of the technologists' questions, e.g., to enter a protocol for a specific patient.
- RadConnect is *role-based* as it allows technologists to send tickets to a section and not an individual radiologist. The role-based model worked satisfactorily, except for specific image review questions that, for legal reasons, must be answered by an attending radiologist.
- RadConnect has a *prioritized worklist*, which survey respondents appreciated for providing the most organized communication experience. The interviewees shared that the worklist also gave a satisfactory sense of being up to date when it was empty.

Responsiveness

Our study revealed that radiologists' unresponsiveness is more common with asynchronous than with synchronous communication tools. While synchronous communication methods require an immediate response, asynchronous tools allow radiologists to respond when they have time. A negative aspect of asynchronous tools is that they leave the sender uncertain if and when the recipient will respond. During the study, radiologists' unresponsiveness and the workflow delays it may cause were sources of frustration among technologists who had to try another communication method to get an answer. Accordingly, when asked what required improvement in RadConnect, one technologist said: "That it gives a signal that there is an open consult that needs attention of a radiologist" (translated from Dutch).

Throughout the study and in the interviews afterwards, we identified several factors influencing radiologist responsiveness in RadConnect:

- The neuro section had agreed on the *working instruction* that only the section beeper carrying radiologist use RadConnect, thus creating a single point of failure, if this radiologist stepped away from his/her workstation. All thorax section radiologists were in principle committed to using RadConnect at the same time.
- Some radiologists struggled with *efficient application management* in the three-monitor setup of the radiologist workstation, which left no exclusive screen

space for RadConnect. Consequently, RadConnect was hidden under other applications. In addition, new or overdue message notifications appeared on only one monitor and were easily missed by concentrating radiologists. This is an important improvement area for RadConnect.

- As an *artifact of the study design*, radiologist participants used RadConnect (for CT questions) and GPEC (for non-CT questions) simultaneously, thus adding to their mental workload.

Related Work

Various studies tallied the frequency and nature of consult requests for radiologists [1, 2, 4, 5, 11]. Protocolling requests were the most common question categories measured in [5] accounting for 27% of all requests. Referring physicians and technologists most frequently reached out to radiologists. Image review and protocol requests were the most common categories for referrers and technologists, respectively [2]. One study reported that radiologists spent an average of 1 min 39 s per call [5]. We are not aware of publications that quantitatively report on the effect of adopting new communication tools in the radiology department.

Study Design and Limitations

RadConnect was developed in close collaboration with future end users from our department. We were therefore confident that RadConnect could accommodate the local question answering dynamics. However, since RadConnect was going to be used clinically for the first time, we decided to limit the study setting to one modality and two radiology sections. We opted for a physically compact setup so that issues could be addressed directly on the work floor. The reading stations of the neuro and thorax sections were next door from three of the four CT scanners. Due to the limited setup of the study, only a segment of all communication in the radiology department was in scope for RadConnect. In the interviews, participants expressed that the value of RadConnect is even greater when radiologists work remote from the modalities and when all sections are using it.

The main results were extracted from the log forms, which were maintained manually and had limitations in terms of completeness and, potentially, quality. We chose not to retrieve telephone traffic between personal extensions to respect the privacy of participants. The recorded consult events did not contain details on the duration, obtrusiveness, or effectiveness of communication. RadConnect only allowed technologists to initiate communication. So, even though radiologists were able to exchange messages with technologists, radiologists were not able to send *tickets* to technologists and we could therefore not assess if technologists benefitted from RadConnect to the extent that radiologists did.

Lastly, before-after studies are susceptible to the influence of confounding factors, which, in our study, could have involved events causing a shift in urgent communications and thus affected communication behaviors in the relevant time period. The abdomen section was the control group in both phases of the research, but it cannot be excluded that confounding factors only affected the neuro and thorax section.

Conclusion

A novel radiology communication tool (RadConnect) significantly reduced radiologist workflow interruptions caused by technologists using synchronous methods. RadConnect differentiates from a general chat application by role-based interaction and prioritized worklist overview, which was valued by study participants in the post-study survey and interviews. Our study showed that communication tooling has an effect on workflow interruptions and learnings from the study will contribute to a more focused work environment.

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Data Availability The data that support the findings of this privately-funded study are not openly available.

Declarations

Competing Interests H. Lamb serves as consultant for Royal Philips Electronics. K. Hergaarden, O. Hertgers and S. Romeijn are partly supported by non-personal grants by Royal Philips Electronics. M. Sevenster and S. Vosbergen are employees of Royal Philips Electronics. J. Foster-Dingley and D. Nguyen were employees of Royal Philips Electronics at the time of study planning and execution. M. Sevenster and S. Vosbergen own stock in Royal Philips Electronics. All other authors have no conflicts of interest.

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