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Preserving Radiology Resident Education During the COVID-19 Pandemic: The Simulated Daily Readout

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Rationale and Objectives: The educational value of the daily resident readout, a vital component of resident training, has been markedly diminished due to a significant decrease in imaging volume and case mix diversity. The goal of this study was to create a “simulated” daily readout (SDR) to restore the educational value of the daily readout.

Materials and Methods: To create the SDR the following tasks were performed; selection of cases for a daily worklist for each resident rotation, comprising a combination of normal and abnormal cases; determination of the correct number of cases and the appropriate mix of imaging modalities for each worklist; development of an “educational” environment consisting of separate “instances” of both our Picture Archive Communication System and reporting systems; and the anonymization of all of the cases on the worklists. Surveys of both residents and faculty involved in the SDR were performed to assess its effectiveness.

Results: Thirty-two residents participated in the SDR. The daily worklists for the first 20 days of the SDR included 3682 cases. An average of 480 cases per day was dictated by the residents. Surveys of the residents and the faculty involved in the SDR demonstrated that both agreed that the SDR effectively mimics a resident’s daily work on rotations and preserves resident education during the Coronavirus Disease 2019 crisis.

Conclusion: The development of the SDR provided an effective method of preserving the educational value of the daily readout experience of radiology residents, despite severe decreases in imaging exam volume and case mix diversity during the Coronavirus Disease 2019 pandemic.

Key Words: Residents; Education; Daily readout; Simulation.

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INTRODUCTION

The Coronavirus Disease 2019 (COVID-19) pandemic has dramatically changed the world of radiology (1). Most outpatient centers have restricted imaging to urgent exams that cannot be delayed and eliminated all screening examinations. A large percentage of hospital inpatient volume has consisted of chest imaging for COVID-19 patients. This has led to major disruptions to radiology resident education (2–6). In particular, the value of the daily

resident readout, a vital component of resident training, has been markedly diminished due to the significant decrease in imaging volume and breadth of pathology for the majority of resident rotations.

Several innovative strategies have been developed to compensate for these limitations and enhance the educational experience of radiology residents during the pandemic, including creating a “case of the day” for each subspecialty rotation, additional didactic conferences, virtual case conferences, and the use of teaching or rad-path files (2–6). While all of these have educational value, none successfully recreates the daily readout experience. Learning to independently interpret exams, not knowing if the exams are normal or abnormal (as opposed to reviewing teaching files), and having to clearly and concisely report findings are essential parts of radiology training (7). Although losing this experience for 1 to 2 months might not have a significant adverse effect on training, there is no guarantee

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that the world of radiology will return to “normal” in such a short time period. While some have predicted a “V” shaped rebound with imaging volumes quickly returning to normal or even increasing, others have predicted a more prolonged, “U” shaped recovery (8). Until a vaccine or an effective antiviral agent is developed or “herd” immunity occurs, patients might be reluctant to have nonurgent imaging examinations. It is also likely that with the rise in unemployment many people will lose their health insurance limiting their ability to cover the cost of imaging exams. Even for those with insurance, personal financial difficulties due to COVID-19 may limit their ability to pay their deductible and copay responsibilities.

In order to ensure that our residents would not lose the daily readout experience for an extended period, we created the “simulated” daily readout (SDR). This required the collaborative effort of both our faculty and informatics personnel. Tasks that needed to be completed included: the selection of cases for a daily worklist for each resident rotation comprising the right combination of normal and abnormal cases; the determination of the correct number of cases and the appropriate mix of imaging modalities to be interpreted by residents in different years of training; the development of an “educational” environment consisting of separate educational “instances” of both our Picture Archive Communication System (PACS) and reporting systems; the anonymization of all of the cases selected for the worklists while maintaining an identification key; the ability to access our new “educational” informatics environment either onsite or remotely; and the ability to conduct the readouts when done in-person while maintaining appropriate social distancing.

The purpose of this paper is to describe how we created the SDR and its effect on the educational experience of our residents.

MATERIALS AND METHODS

Subspecialty rotations included in the SDR were body, breast, cardiac, chest, musculoskeletal, neuroradiology, nuclear medicine, and pediatric radiology. Interventional radiology was excluded as it was not possible to recreate the procedural experience with the SDR, and therefore residents continued to rotate on the interventional service. Our resident rotations are 4 weeks in duration, necessitating 20 daily worklists. The SDR was the primary focus of each rotation, and residents were not involved in dictating “live” cases. Streamed didactic conferences and “cases of the day” were continued. Residents were expected to read the entire list of simulated cases each day to ensure the simulated experience resembled a “normal day” with an appropriate daily case volume. This included reviewing the imaging sequences/series for each case, formulating a differential diagnosis, dictating a complete report, and determining when findings required urgent communication of results to referring clinicians. When there were multiple residents in the same training year on the same service, each had their own worklist with identical cases so that every resident was able to review and dictate the cases independently.

Selection of Cases for SDR

Our informatics team created lists of all imaging examination reports performed by our department each week from September 1, 2019, through December 1, 2019. The lists included the medical record number and accession number of each exam, the type of examination, and the original final radiology report. The cases were filtered by modality and subspecialty. The lists were made available on a password protected HIPAA compliant institutional Share Drive. Each subspecialty section was assigned the responsibility for creating daily worklists for their rotations, which included both normal and abnormal cases and a representative modality mix pertinent to each subspecialty. Each section attempted to replicate the number of normal and abnormal cases that they felt was typical in their daily workflow based on their consensus experience. Faculty from each section spent between 20 and 30 hours preparing their daily worklists. Each section developed their own methods to create their worklists. Examples of case list creation from 3 separate sections are presented below.

Body Imaging

A mixture of normal and abnormal cases was selected such that approximately 30% of cases on each daily worklist were normal or with common incidental findings, and the remaining 70% were abnormal with imaging findings of different disease processes. All normal and abnormal cases were carefully selected to ensure each study had 1 or more salient teaching points for residents at various levels of training. Abnormal cases were examples of both common and uncommon disease processes selected to ensure resident exposure to diseases of all organ systems such as diverticulitis, initial pancreatic cancer staging, vascular disorders, and complicated postsurgical cases. Normal and abnormal cases for all imaging modalities were a mixture of inpatient, emergency department, and outpatient examinations. The selected cases were then utilized to create 20 daily worklists.

The number of cases included on each worklist depended on the year of training of the resident, and the types of exams included (Table 1).

Nuclear Medicine

The daily worklist of the nuclear medicine rotation included approximately 20% normal and 80% abnormal cases. The list for residents in the first and second years of training included a mixture of scans, including bone, ventilation-perfusion, hepatobiliary iminodiacetic acid, thyroid, renal, dopamine transporter, gastric emptying, three-phase bone, cisternograms, and parathyroid scans. Other scans, such as for cardiac amyloidosis, myocardial perfusion imaging, cerebral blood flow, lymphoscintigraphy, Iodine-123 meta-iodobenzylguanidine, octreoscans, liver mapping using macroaggregated albumin, Gallium-67, and MUGA were periodically included.

The PET/CT worklist for residents in the second, third, and fourth years of training included different

TABLE 1. Summary of Daily Resident Caseload by Year of Training for Select Resident Rotations.

		Body Imaging (daily case count)		Nuclear Medicine (daily case count)	Pediatric Radiology (daily case count)
First Year	CT	Weeks 1 and 2: 15 CT Weeks 3 and 4: 18 CT	General NM	Weeks 1 and 2: 10-14 Weeks 3 and 4: 14-18	1 MR (final week only) 3 CT 8 ultrasound 18 x-ray 2 fluoroscopy
	US	20 ultrasounds			
Second Year	All modalities except MRI	10 CT 8 ultrasounds 5 x-rays 2 fluoroscopy	General NM	Weeks 1 and 2: 12-16 Weeks 3 and 4: 16-18	2 MRI 3 CT 10 ultrasounds 24 x-rays 2 fluoroscopy
Third Year	MRI	15 MRI	PET/CT	Weeks 1 and 2: 8 Weeks 3 and 4: 8-10	3 MRI 3 CT 10 ultrasound 22 x-rays 2 fluoroscopy
	All other modalities	15 CT 10 ultrasound 5 x-rays 2 fluoroscopy			
Fourth Year	MRI	15 MRI	PET/CT	Weeks 1 and 2: 8 Weeks 3 and 4: 8-10	No fourth years on rotation
	All other modalities	18 CT 12 ultrasound 10 x-rays 2 fluoroscopy			

radiopharmaceuticals, predominantly F-18 FDG, but also included F-18 Fluciclovine and Ga-68 DOTATATE PET/CT cases. The PET/CT worklist included studies indicated for initial evaluation and detection of recurrence. Table 1 lists the number of cases included in each worklist.

Pediatric Radiology

Cases for the daily worklists were selected from the Share Drive list of prior cases, as well as from the section's teaching files. The percentage of selected cases that were normal exams varied between 10 and 20% based on the resident level of training and the complexity of the imaging modality. For example, more normal head, spine, and hip ultrasound exams were included for the first-year residents, but fewer were included for the second- and third-year residents. The complexity of cases was gradually increased for the second- and third-year residents. Commonly performed studies such as neonatal and cardiac intensive care unit radiographs were included for all levels of training. This exercise provided the opportunity to present uncommon pathology with high educational impact to the residents who normally would only read about such entities but would not encounter them in daily practice due to low disease prevalence.

The number of cases on each worklist varied according to the training level of the residents and the week of the rotation (Table 1). First-year residents began with 20 cases every day, which primarily consisted of radiographs with few ultrasound and CT cases and the number of cases incrementally increased by 5 per day each week of the rotation. Second-year residents began with 30 cases per day in week 1 and gradually increased to 45 cases per day in the fourth week of the rotation. The

third-year residents started week 1 with 35 daily cases and increased by 5 cases every week to reach 50 cases daily during the fourth week.

Anonymization

Utilizing our institution's high performance-computing cluster, the exam lists were used to extract the Digital Imaging and Communications in Medicine (DICOM) files through an application-programming interface from our Vendor-Neutral Archive (ACUO, Hyland Software, Westlake, Ohio), utilizing a departmentally developed DICOM anonymization tool. This process was designed to modify and preserve demographic information such as medical record numbers (MRN) and accession numbers, remove annotations and protected health information from DICOM headers, and remove secondary capture images. The anonymization tool provided an output file linking the original accession number to the anonymized accession number. This file was used to allow for multiple uniquely anonymized versions of a source exam to be used when more than 1 resident was on the same rotation in a given week. This allowed residents to read the same set of exams without causing conflicts in the PACS or reporting system. Initially, due to time constraints, relevant prior studies were only provided for mammography, but additional prior studies were added once all the primary exams for each rotation were imported.

Educational Instance of PACS and Reporting System

Separate, nonproduction instances of our PACS (Philips IntelliSpace, Philips Healthcare, Eindhoven, The Netherlands) and

our reporting system, (PowerScribe 360, Nuance Communications, Burlington, Massachusetts) were created for the SDR sessions. The PACS and reporting systems were integrated to mimic normal production reading workflows and to maintain the linking between exam and report. After each rotation week was completed, the dictated reports were removed from the reporting system. This allowed the next rotation to reuse the same set of exams for their simulated readouts.

Designated workstations were configured to allow residents and attending radiologists to alternate between the production environment and the education environment. Workstations were configured to reset themselves with every windows login to default to the normal production workflow so that the station was ready to care for patients. In order to switch back and forth between the education and production environments, batch files were employed to change the dictation server windows, registry settings and PACS client configuration files. Shortcuts to these batch files were placed on the windows desktops for all users.

Another crucial element of the SDR was maintaining social distancing between the attending and resident when co-located onsite while also allowing residents and/or faculty to work from a remote location. Access to the environment was provided using workstation virtualization and screen sharing solutions over a virtual private network. When

residents accessed the reporting system from a remote location using the virtual private network, they were unable to use speech recognition but were able to type their reports into selected templates and had full access to departmental “macros”. WebEx (Cisco Systems, Milpitas CA) was employed to allow for screen sharing, cursor/input control, and as an audio bridge between the resident and the designated teaching attending. The initial design and build of the SDR environment and the creation of the processes for gathering, anonymizing, importing and populating the exams into the SDR required a team of 7 information technology analysts and took approximately 450 hours to complete.

Evaluation of SDR

Before implementation of the SDR educational initiative, the radiology residents were asked to complete an anonymous online survey (SAP, Provo, UT) regarding their training experience during the COVID-19 crisis (Table 2). As this was defined as a quality project, this study was determined not to require Institutional Review Board (IRB) oversight.

Two weeks after implementation of the SDR, radiology residents (Table 3) and those radiologists who served as teaching faculty received a follow-up survey (Table 4) to assess the educational value of the SDR initiative.

TABLE 2. Resident SDR Preimplementation Survey

QUESTIONS	RESPONSES
Q1. Do you feel that the COVID-19 crisis related workflow changes in the Department of Radiology have negatively impacted your education and training experience?	Definitely yes Probably yes Might or might not Probably not Definitely not
Q2. If you responded Definitely yes, Probably Yes, or Might or might not to question 1, please select the rotation(s) that you feel are impacted.	Body Breast Cardiac Chest MSK Neuroradiology Nuclear Medicine Pediatric Radiology
Q3. Which of the following have you experienced during this COVID-19 crisis with respect to your educational experience? Check all that apply.	Decreased case volume Decreased case mix Decreased procedures
Q4. With respect to your expectations of the Radiology Resident PACS Simulation Worklist Initiative, on a scale of 1 (very low) to 10 (very high), how likely do you feel this initiative has the ability to mimic your daily work on your current rotation?	1–10
Q5. With respect to your expectations of the Radiology Resident PACS Simulation Worklist Initiative, on a scale of 1 (very low) to 10 (very high), how likely do you feel this initiative will preserve your educational experience in radiology with regard to your daily work?	1–10
Q6. With respect to your expectations of the Radiology Resident PACS Simulation Worklist Initiative, on a scale of 1 (very low) to 10 (very high), how effective do you feel the required social distancing WebEx read out sessions will be?	1–10
Q7. With respect to your expectations of the Radiology Resident PACS Simulation Worklist Initiative, on a scale of 1 (very low) to 10 (very high), how effective do you anticipate the technical aspects of the PACS simulation worklist to be?	1–10

TABLE 3. Resident SDR Postimplementation Feedback Survey

QUESTIONS	RESPONSES
Q1. Do you feel that implementation of the Resident Simulation PACS Worklist (SDR) initiative has diminished the negative impact of the COVID-19 crisis-related workflow changes in the Department of Radiology on your education and training experience?	Definitely yes Probably yes Might or might not Probably not Definitely not
Q2. On a scale of 1 (very low) to 10 (very high), how closely do you feel the SDR initiative mimics daily work on a rotation?	1–10
Q3. On a scale of 1 (very low) to 10 (very high), how effective is the SDR initiative in preserving your educational experience in radiology with regard to your daily work?	1–10
Q4. How have you interacted with SDR? Choose all that apply.	On-site Remote
Q5. Which type of interaction do you feel is a more effective educational experience?	On-site Remote No difference
Q6. In an effort to maintain social distancing, read out sessions were executed using WebEx. On a scale of 1 (very low) to 10 (very high), how would you rate the effectiveness of the WebEx read out sessions compared with traditional in person read outs?	1–10
Q7. On a scale of 1 (very low) to 10 (very high), what is your overall impression of the SDR?	1–10

Statistical evaluations were performed with the support of R version 3.5 with the lme4 and epiR packages (<http://cran.r-project.org/>). The distribution of Likert scale gradings was visualized with diverging stacked bar charts. Differences between the distributions of Likert scale gradings were evaluated with 2-tailed Mann-Whitney U tests (9). *p*-values of less than 0.05 were considered statistically significant.

RESULTS

A total of 32 residents utilized the SDR. The remainder (26) of our residents was redeployed to the medical floors, rotated on the interventional service, or were on night float rotations. The daily worklists for the first 20 days of the SDR included 3682 cases.

TABLE 4. Teaching Attending SDR Feedback Survey

QUESTIONS	RESPONSES
Q1. Do you feel that the COVID-19 crisis related workflow changes in the Department of Radiology have negatively impacted resident education and training experience?	Definitely yes Probably yes Might or might not Probably not Definitely not
Q2. Do you feel that implementation of the Resident Simulation PACS Worklist (SDR) initiative has mitigated the negative impact on resident education and training experience resulting from the COVID-19 crisis-related workflow changes in the Department of Radiology?	Definitely yes Probably yes Might or might not Probably not Definitely not
Q3. Which of the following has your division experienced during this COVID-19 crisis with respect to trainee education? Check all that apply.	Decreased case volume Decreased case mix Decreased procedures
Q4. On a scale of 1 (very low) to 10 (very high), how closely do you feel the SDR initiative mimics a trainee's daily work on your rotation?	1–10
Q5. On a scale of 1 (very low) to 10 (very high), how effective is the SDR initiative in preserving the educational experience in radiology with regard to daily work?	1–10
Q6. How have you interacted with SDR? Choose all that apply.	On-site Remote
Q7. Which type of interaction do you feel is a more effective educational experience?	On-site Remote No difference
Q8. In an effort to maintain social distancing, read out sessions were executed using WebEx. On a scale of 1 (very low) to 10 (very high), how would you rate the effectiveness of the WebEx read out sessions compared with traditional in person read outs?	1–10
Q9. On a scale of 1 (very low) to 10 (very high), what is your overall impression of the SDR?	1–10

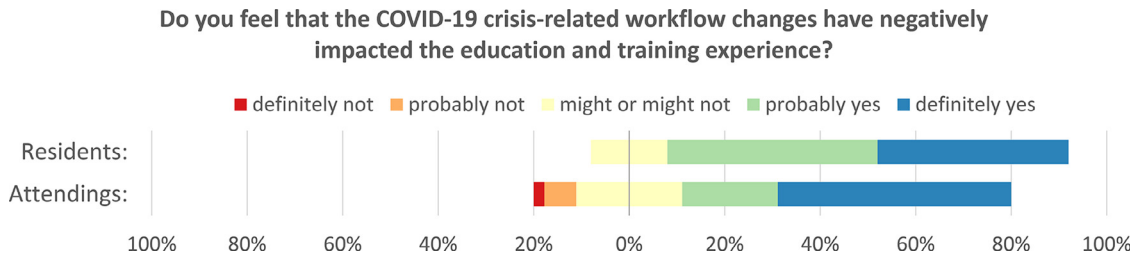


Figure 1. Diverging stacked bar charts showing the rating distributions of residents and faculty on the negative impact of the COVID-19 crisis-related workflow changes on resident education and training. Both residents and faculty felt that radiology education and training experience for residents was negatively influenced by the COVID-19 crisis. There was no statistical difference between the answer distributions of residents and faculty ($p = 0.94$) (Color version of figure is available online.)

Twenty-five of 32 residents (return rate: 78%) responded to the SDR preimplementation survey, 24/32 residents (return rate: 75%) responded to the postimplementation feedback survey, and 45/61 teaching faculty (return rate: 74%) responded to the SDR feedback survey.

Both residents and teaching faculty strongly agreed that the COVID-19 crisis-related workflow changes in the radiology department had negatively impacted the resident education and training experience (Fig. 1), without a statistically significant difference between the answer distributions of residents and faculty ($p = 0.94$). Decreased case volumes, decreased case mix, and decreased procedures contributed equally. Residents felt that the negative impact affected all rotations with the chest rotation least affected. Before implementing the SDR initiative, residents had neutral to optimistic anticipations for SDR effectiveness in preserving the educational radiology residency experience (Fig. 2).

Two weeks after implementation of the SDR, residents and teaching faculty felt strongly that the SDR initiative miti-

gated the COVID-19 negative impact on resident education (Fig. 3). There was no statistical difference between the answer distributions of residents and faculty ($p = 0.92$). Residents (Fig. 4) and teaching faculty (Fig. 5) both felt that the SDR effectively mimics a resident's daily work on rotations and preserves resident education during the COVID-19 crisis (without statistically significant differences between the answer distributions of residents and faculty ($p = 0.07$ and $p = 0.36$, respectively).

Residents and teaching faculty interfaced with the SDR both remotely from off-site locations and onsite in the department. When comparing the effectiveness of using the SDR onsite versus from a remote location, the majority of residents and faculty felt that using the SDR onsite was either more effective or equally as effective as using the SDR from a remote location. The majority of residents and teaching faculty felt that the use of WebEx as a means for socially distant readout sessions had a high to very high effectiveness. There

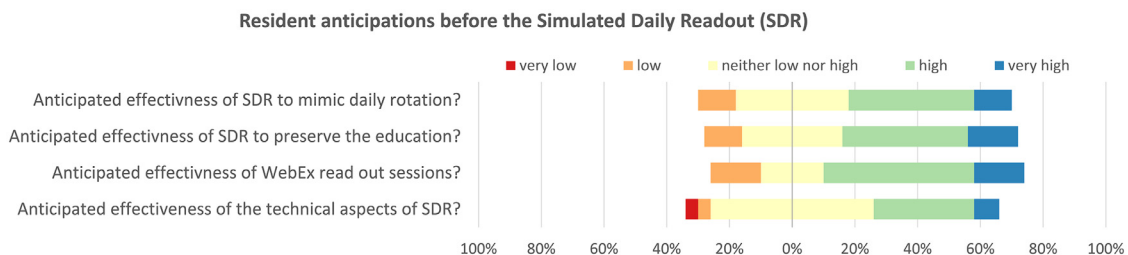


Figure 2. Diverging stacked bar charts demonstrating the rating distributions of resident anticipations before implementing the SDR (Color version of figure is available online.)

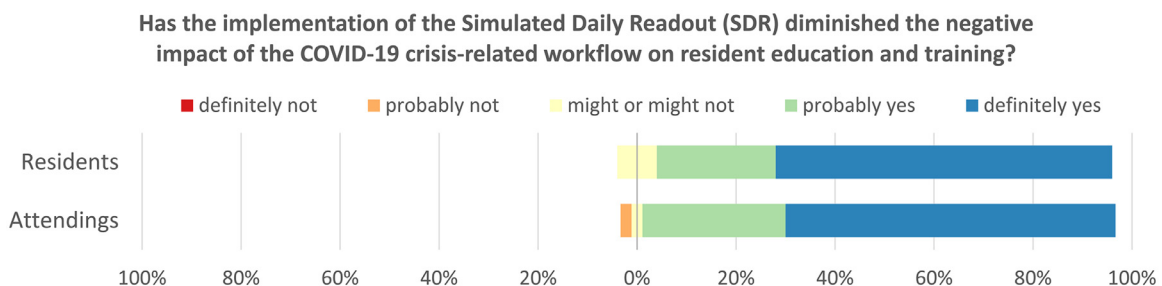


Figure 3. Diverging stacked bar charts showing the rating distributions of residents and faculty on how the SDR diminished the negative impact of the COVID-19 crisis-related workflow on resident education and training. Both residents and faculty felt strongly that SDR mitigated the negative impact of the COVID-19 induced changes on radiology education and training experience for residents. There was no statistically significant difference between the rating distributions of residents and attending physicians ($p = 0.92$) (Color version of figure is available online.)

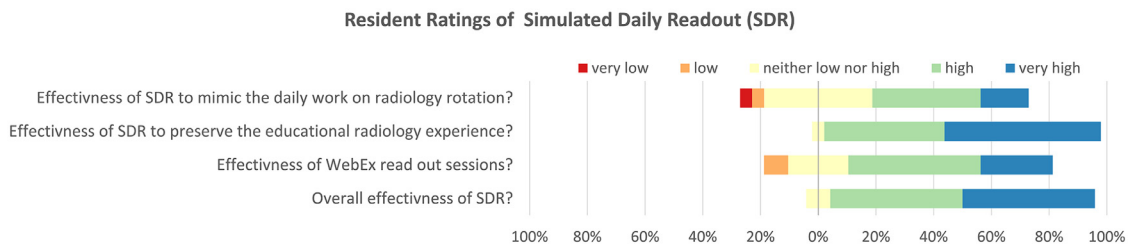


Figure 4. Diverging stacked bar charts demonstrating the rating distributions of residents after implementing the SDR (Color version of figure is available online.)

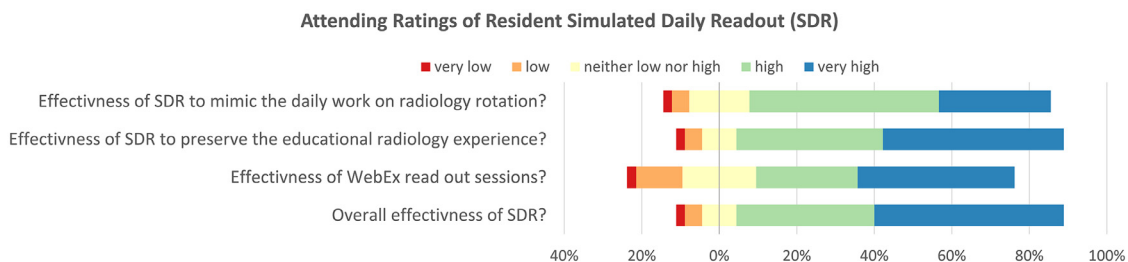


Figure 5. Diverging stacked bar charts showing the rating distributions of faculty after implementing the SDR (Color version of figure is available online.)

was no statistical difference between the answer distributions of residents and faculty ($p = 0.40$).

The overall effectiveness of SDR was rated high to very high by the majority of residents and faculty alike, exceeding the resident expectations of this educational resource. There was no statistical difference between the answer distributions of residents and faculty ($p = 0.07$).

Comments from radiology residents and teaching faculty were overwhelmingly positive when asked about the strengths and concerns of the SDR initiative. The most common positive comment about the SDR from both residents and faculty was the preservation of the resident rotation educational experience by maintaining a high volume and high-yield case mix. Both residents and faculty noted the benefit of having a dedicated daily teaching attending with no real-time clinical responsibilities, allowing for extended, in-depth dialogue focused on education and addressing gaps in resident knowledge. Resident responses described readouts with faculty as being more meaningful and not rushed. Faculty expressed increased time to review cases, correct dictations, identify gaps in resident knowledge, and provide teaching points and similar case examples to reinforce learning.

The most common shared concerns from both residents and faculty were the lack of patient history and access to prior imaging exams during SDR case dictation. Other general concerns described by residents and faculty dealt with technical matters, such as limited PACS and voice recognition functionality during remote access, and lack of an answer key to the daily case list.

DISCUSSION

Implementation of the SDR delivered several advantages for our residents' educational experience. First, the SDR

minimized the amount of time that our residents experienced low imaging volumes with a homogeneous case mix. Second, during the COVID-19 crisis, a number of our residents were deployed to assist on the inpatient units, followed by mandatory quarantine periods. During their quarantine, the ability to log in to PACS remotely allowed these residents to participate in SDR, minimizing the negative impact that the pandemic had on their radiology education. Third, the ability to provide our residents with an appropriate volume and variety of imaging examinations during their rotations ensured that the educational goals and expectations of each rotation were met, alleviating the need to consider restructuring or altering the overall rotation schedule for the next academic year. Finally, the ability to track cases read by each resident in the simulated worklist environment allowed these numbers to be added to their case logs, which was particularly important for senior residents to meet the Federal Drug Administration supervised requirement of 240 mammograms within a 6-month period during the last 2 years of training to meet graduation requirements.

Although initially intended as an educational tool during the COVID-19 pandemic, SDR can serve as an enduring teaching tool for rotation preparation, supplementation, and even assessment. Residents could use the SDR worklists to prepare for upcoming rotations and call or review previously completed rotations. SDR worklists can also supplement teaching and training on rotations when case volume may be low, when trainees are interested in greater exposure to specific modalities, or even as a means to address areas of weakness or gaps in understanding. Additionally, the SDR worklist standardizes resident exposure to cases and ensures residents' exposure to essential pathology that may not be encountered during standard rotations given low disease

prevalence. SDR could also potentially be incorporated into resident assessment at the end of their rotations, in addition to standard attending feedback and RadExam (10) tests, to assess their ability to independently interpret a series of images mimicking “real-world” practice as a radiologist.

Two of the major perceived weaknesses of the SDR were the lack of patient history and the lack of relevant prior examinations, which are integral components of the normal daily readout workflow. Both limitations were quickly addressed. Histories are now available for all cases, and relevant prior examinations are currently being imported for all cases on the worklists.

Limitations of this study include the fact that our evaluation of the effectiveness of the SDR was performed within the first month of implementation, and potential response bias. It is possible that the effectiveness and enthusiasm for the SDR might decrease if the SDR is the only means of resident education for a prolonged period of time. However, it is also possible that the effectiveness may increase over time as technical difficulties and areas of improvement continue to be addressed, and both faculty and trainees become familiar with the workflow routines. Although our survey of both faculty and residents was anonymous, it is possible that the responses were influenced by knowing that the SDR was an initiative proposed and implemented by radiology leadership.

CONCLUSION

The development of the SDR provided an effective method of preserving the educational value of the daily readout

experience of radiology residents, despite severe decreases in imaging exam volume and case mix diversity during the COVID-19 pandemic.

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