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## Adoption of a closed loop communication tool to establish and execute a collaborative follow up plan for incidental pulmonary nodules

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### Abstract

**Purpose**—We designed a closed loop communication and tracking system (RADAR) to enable execution of a collaboratively developed care plan for follow up imaging of incidental pulmonary nodules (IPN). The system requires adoption by radiologists and referring providers. We assess radiologists' adoption of RADAR and its impact on the clarity of radiologists' follow up recommendations for IPN.

**Methods**—This Institutional Review Board-approved study was performed at a large, urban, tertiary care academic center performing 800,000 radiology examinations annually. Radiologists generate critical alerts for all newly discovered incidental pulmonary nodules using a previously described PACS-embedded software tool to track acknowledgement of receipt of critical alerts by ordering providers (i.e., usual care). RADAR (i.e., intervention) is a closed-loop communication tool, embedded in radiology PACS and enterprise provider workflow that enables establishment of a collaborative follow up plan (CFUP) between a radiologist and referring provider and helps automate the tracking and execution of CFUP. RADAR use is at the discretion of the interpreting radiologist. After implementation of RADAR for IPN in thoracic radiology (study period 3/9/2018–8/2/2018), we assessed RADAR adoption (primary outcome: #RADAR alerts for IPN/# of all alert for IPN). Secondary outcome was the clarity of follow up recommendation, defined as explicit documentation of the imaging modality and timeframe for follow up, as well as referring

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provider agreement with the recommendation. Trend over time was assessed with Cochran Armitage test.

**Results**—Post implementation, 106 of 183 (58%) IPN alerts were generated using RADAR. RADAR adoption increased by 75% during the study period (40% in first 3 weeks v 70% in last 3 weeks;  $([70\% - 40\%] / 40\% \times 100 = 75\%$ ;  $p < 0.001$  test for trend). All RADAR alerts had explicit documentation of imaging modality and timeframe for follow up, compared to 71% for non-RADAR alerts for IPNs ( $p < 0.001$ ).

**Conclusion**—Thoracic radiologists adopted a closed-loop communication system that allows for scheduling and automated tracking of pulmonary nodule follow-up recommendations. This system improved the quality of follow-up recommendations.

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## Introduction

Incidental pulmonary nodules are a common finding in chest imaging, both on radiographs and computed tomography (CT). For example, nodules are found in approximately 16% of patients referred for lung cancer screening(1). While radiologists identify these nodules upon interpreting the imaging study and commonly give management recommendations, it is typically up to the ordering physician's office to schedule any follow-up imaging and ensure that the follow-up is completed. Even with the advent of computerized closed-loop critical finding communication systems(2,3), the responsibility for scheduling and tracking the follow-up itself is left to the ordering provider and his/her office staff. Under the current system, patients may not receive the recommended follow-up because of communication breakdown or loss to follow-up(4,5).

For pulmonary nodules, additional challenges are present that make follow-up recommendations and tracking more difficult than for many incidental abdominal findings (e.g., renal mass). These include a complex set of guidelines for the follow-up interval based on nodule size and imaging characteristics as well as patient risk factors(6). Additionally, many of the follow-up intervals are quite long, up to 2 years, which makes tracking the follow-up completion difficult for ordering providers.

Follow-up communication and tracking are ideal problems for automation. Others have described systems to track the completion of follow-up recommendations in radiology reports(7,8). However, one of these was not entirely automated, and neither incorporated a provider communication system. We designed a system entitled Radiology Result Alert and Development of Automated Resolution (RADAR), which includes a closed-loop system for communicating follow-up recommendations, allows a provider to schedule the follow-up, and tracks whether the follow-up study is completed. After implementation, we assess radiologists' adoption of RADAR and its impact on the clarity of radiologists' follow up recommendations for IPN.

## Methods

### Study Design and Setting

This retrospective study was approved by the Institutional Review Board, with waiver of informed consent. It was carried out at a 753-bed tertiary academic medical center performing >650,000 imaging examinations annually.

### Development and Implementation of RADAR

RADAR was implemented within our existing critical alert system (2,3), embedded within our picture archiving and communication system (PACS) workflow, as well as integration with results management component of our EHR and email and paging systems to automate notification of the referring provider as previously described (2). Thus, the system automatically receives patient, study, and ordering physician information from PACS. The only input needed from the radiologist is the recommendation. We designed RADAR to allow for automated generation of the Fleischner Society recommendations for managing incidental pulmonary nodules(6) or for manual selection of a follow-up interval (Figure 1). However, in either case, the follow-up modality and timeframe are required fields to generate this alert.

RADAR is designed to establish a collaborative follow up plan (CFUP) for imaging between the radiologist and the referring provider. Once the alert is generated by the radiologist, it is sent to the ordering physician via an email notification. This email notification includes a link to the RADAR web interface, where the provider can view the alert. The ordering provider is required to acknowledge the alert and choose a management option (CFUP) for the patient. These options include agreeing with the follow-up recommendation, modifying the follow-up interval, or disagreeing with the need for follow-up. If the provider agrees with or modifies the CFUP, he or she has the option to forward the alert containing the CFUP to the Radiology Department scheduling team to coordinate the follow up imaging directly with the patient. RADAR searches the EHR for the CFUP completion during a time-interval one month longer than the CFUP. If CFUP is not performed in that timeframe, RADAR escalates an alert to the ordering provider to seek clarification whether the CFUP still needs to be performed or is no longer relevant (e.g., patient deceased, imaging performed outside of our healthcare enterprise, care transferred to another provider outside our institution, etc.). If the ordering provider stipulates that CFUP is still clinically relevant, the cycle of scheduling, and tracking for CFUP completion starts anew by RADAR.

RADAR is a web-based application installed on a HP ProLiant DL380 G5 with two 3.00 GHz physical CPUs and 8 GB RAM, running Windows Server 2003 R2, Standard x64 Edition as the operating system. It has a directory of users, authenticated through Active Directory and updated through Paging Directory web services, with single sign-on capability for users. Alert notifications are sent via web services to the SMTP server using email. RADAR's SQL Server database stores all relevant information, including radiologist, ordering provider, primary care provider, patient, examination, result, follow-up, notification, and acknowledgement information in related tables.

RADAR was fully implemented on March 9, 2018 and was announced to the Thoracic Radiology division at our institution at that time. Adoption was encouraged by weekly emails updating the division on how frequently they were using the system and specific examples of cases in which RADAR could have been used. However, adoption was voluntary, and radiologists were still able to use the standard critical alert system.

### Data Collection

We reviewed all of the critical finding alerts sent by the Thoracic Radiology division that included the term “nodule” in the 21 weeks after RADAR implementation from March 9, 2018 through August 2, 2018. These included alerts sent with our traditional alert system as well as with RADAR. Alerts were manually reviewed by a thoracic radiologist to ensure that they did refer to pulmonary nodules for which a follow-up CT examination was recommended. Patients with recommendations for chest radiograph follow-up or biopsy were excluded. Alerts were also reviewed for clarity (presence of a follow-up timeframe and an imaging modality).

### Outcome Measures

The primary outcome was RADAR adoption for IPN by thoracic radiologists defined as # RADAR alerts for IPN/# all alerts for IPN during the study period. A secondary outcome was clarity of the follow-up recommendation, defined as specification of both imaging modality and timeframe within the alert for IPN follow up. An additional secondary outcome was referring provider agreement with the follow-up recommendation generated through RADAR. This option is only available to those physicians who have opted in to the CFUP system, which is all of our referring primary care physicians.

### Statistical Analysis

Data was initially stored in Microsoft Excel (Microsoft Corp, Redmond, WA) and analyzed with JMP Pro (SAS Institute Inc, Cary, NC). Alert dates were binned into five 3-week intervals. A Cochran Armitage test was used to evaluate trend over time, with  $\alpha$  set at 0.05. The Fisher’s exact test was used to evaluate differences in proportions.

### Results

A total of 183 alerts for pulmonary nodules were generated within the study period. Of these, 106 (58%) used RADAR, and the remaining 77 (42%) did not. In the initial three-week period after implementation, 6/15 (40%) of IPN alerts used RADAR. In the final three-week period of our study, 19/27 (70%) of IPN alerts used RADAR. Thus RADAR adoption increased by an absolute 30% (70% post- 40% pre) or relative 75% during the study period (40% in first 3 weeks v 70% in last 3 weeks;  $([70\% - 40\%] / 40\% \times 100 = 75\%$ ;  $p < 0.001$  test for trend).

All RADAR alerts (106 of 106) had explicit documentation of imaging modality and timeframe for follow up, compared to 71% (55 of 77) for non-RADAR alerts for IPNs ( $p < 0.001$ ). As discussed above, explicit documentation of follow-up modality and timeframe was required when using RADAR to generate an alert. Of the 51 RADAR alerts sent to

primary care physicians and thus eligible for tracking through the CFUP system, the referring physicians agreed with the proposed CFUP in all 51 (100%) cases.

## Discussion

We demonstrate successful implementation of a closed-loop system to communicate results about pulmonary nodules and establish and track a collaborative follow-up plan (CFUP) between radiologists and referring clinicians. The ease of use of this system is evidenced by its rapid adoption by thoracic radiologists. Additionally, the design of the system required radiologists to specify follow-up modality and timeframe, which improved the clarity of the recommendations as compared to our previously existing system.

While others have described systems for automated tracking of follow-up recommendations(7,8), our system combines notification, scheduling, and tracking into one streamlined process. Lack of direct (verbal) communication with referring providers has been identified as a risk factor for not completing follow-up(9). We believe that our interactive system will help engage the ordering physician in the follow-up process, and also relieve some of his or her administrative burden, thus encouraging the completion of follow-up.

Particular challenges exist with regards to follow-up recommendations for pulmonary nodules. The first is the complexity of guidelines for follow-up, which depend on both nodule and patient factors. It is perhaps this complexity that leads to relatively low guideline adherence, even at academic centers(10). RADAR provides a streamlined system to generate the Fleischner follow-up recommendation automatically based on input of nodule and patient characteristics; this may improve adherence to guidelines. Additionally, RADAR requires specific imaging modality and timeframe recommendations, preventing vague recommendations that are confusing for ordering providers.

The second major challenge for pulmonary nodule follow-up is the long follow-up intervals, since patients and providers may forget the need for follow-up after 1 or even 2 years. The automation of RADAR should help ensure follow-ups are scheduled and completed even with long intervals.

Given the success of this system within Thoracic Radiology, we plan to expand use of RADAR to non-thoracic radiologists who may discover incidental nodules on other studies, e.g., abdominal CT. Future work is needed to evaluate the ordering physicians' use of this system and its success in ensuring that patients indeed receive the recommended follow-up imaging.

In conclusion, a closed-loop communication system assists radiologists in specifying follow-up for pulmonary nodules and will allow for tracking of these follow-up recommendations. By integrating this system directly within the PACS workflow, we ensured quick adoption of the system by radiologists.

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**Follow-Up Recommendation**

Findings: \*  Breast  Pulmonary Nodule  Lung Cancer Screening  Renal Mass  
 Other

Type:  Solid Single  Solid Multiple  Subsolid Single  Subsolid Multiple

Risk:  Low  High


Size:  < 6 mm  6 - 8 mm  > 8 mm

Anatomy: Chest

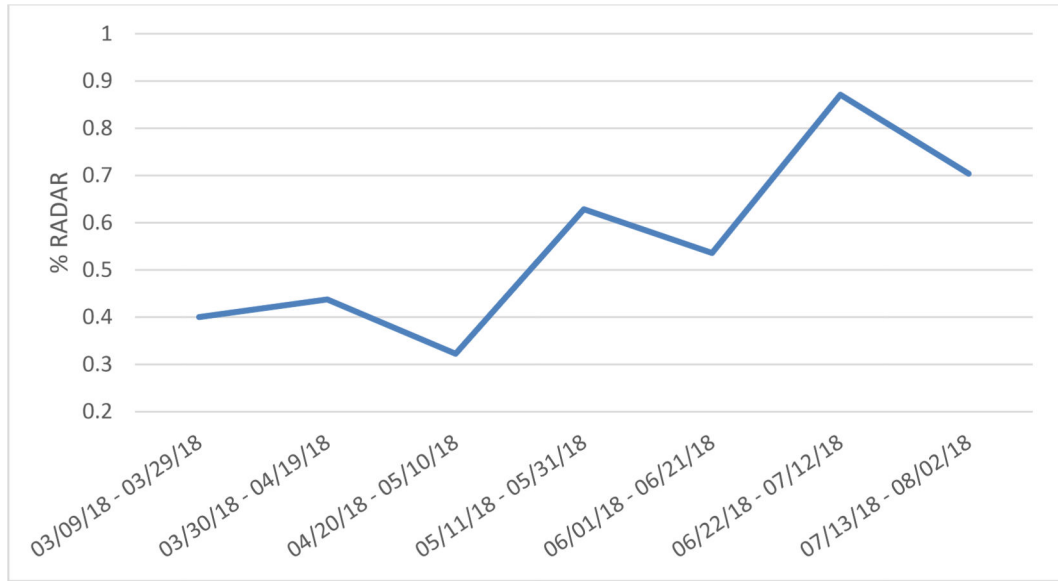
Procedure: \*  CT  PET  MR  US  XRAY  Other

Timeframe: \*  to   Days  Weeks  Months  Years

**Follow-Up Details (provide additional specifics to ensure proper follow-up): \***



**Figure 1.** Screenshot of the Radiology Result Alert and Development of Automated Resolution (RADAR) system, as seen by the radiologist. The radiologist may specify pulmonary nodule characteristics to generate the Fleischner Society recommendations automatically or manually specify a follow-up imaging modality and timeframe.



**Figure 2.** Adoption of the Radiology Result Alert and Development of Automated Resolution (RADAR) system over time