Adoption of a Closed-Loop Communication Tool to Establish and Execute a Collaborative Follow-Up Plan for Incidental Pulmonary Nodules

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OBJECTIVE. The purpose of this study is to assess radiologists' adoption of a closed-loop communication and tracking system, Result Alert and Development of Automated Resolution (RADAR), for incidental pulmonary nodules and to measure its effect on the completeness of radiologists' follow-up recommendations.

MATERIALS AND METHODS. This retrospective study was performed at a tertiary academic center that performs more than 600,000 radiology examinations annually. Before RADAR, the institution's standard of care was for radiologists to generate alerts for newly discovered incidental pulmonary nodules using a previously described PACS-embedded software tool. RADAR is a new closed-loop communication tool embedded in the PACS and enterprise provider workflow that enables establishing a collaborative follow-up plan between a radiologist and referring provider and helps automate collaborative follow-up plan tracking and execution. We assessed RADAR adoption for incidental pulmonary nodules, the primary outcome, in our thoracic radiology division (study period March 9, 2018, through August 2, 2018). The secondary outcome was the completeness of follow-up recommendation for incidental pulmonary nodules, defined as explicit imaging modality and time frame for follow-up.

RESULTS. After implementation, 106 of 183 (58%) incidental pulmonary nodules alerts were generated using RADAR. RADAR adoption increased by 75% during the study period (40% in the first 3 weeks vs 70% in the last 3 weeks; $p < 0.001$ test for trend). All RADAR alerts had explicit documentation of imaging modality and follow-up time frame, compared with 71% for non-RADAR alerts for incidental pulmonary nodules ($p < 0.001$).

CONCLUSION. A closed-loop communication system that enables establishing and executing a collaborative follow-up plan for incidental pulmonary nodules can be adopted and improves the quality of radiologists' follow-up recommendations.

Incidental pulmonary nodules are a common finding in chest imaging, both on radiographs and CT. For example, nodules are found in approximately 16% of patients referred for lung cancer screening [1]. Although radiologists identify these nodules when 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 or her office staff. Under the typical systems of care, 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]. In addition, 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 called Result Alert and

Development of Automated Resolution (RADAR), which includes a closed-loop system for communicating follow-up recommendations, enables establishment of a collaborative follow-up plan between the radiologist and the referring provider, allows the ordering provider to schedule the follow-up, and tracks whether the follow-up study is completed. After implementation, we assessed radiologists' adoption of RADAR and its effect on the completeness of radiologists' follow-up recommendations for incidental pulmonary nodules.

Materials and Methods

Development and Implementation of RADAR

Before RADAR, the standard of care at Brigham and Women's Hospital was for radiologists to generate critical alerts for all newly discovered pulmonary nodules using a previously described PACS-embedded software tool, Alert Notification of Critical Results. RADAR was implemented within our existing Alert Notification of Critical Results system [2, 3], embedded within our PACS workflow, and integrated with the results management component of our electronic health record and e-mail 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 automated generation of the Fleischner Society recommendations for managing incidental pulmonary nodules [6] or for manual selection of a follow-up interval (Fig. 1). However, in either case, the follow-up modality and time frame are required fields to generate this alert.

RADAR is designed to establish a collaborative follow-up plan 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 e-mail notification. This e-mail 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 (collaborative follow-up plan) 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 (Fig. 2). In particular, the ordering provider may modify the follow-up interval at his or her discretion and after accounting for the patient's preference. If the provider agrees with or modifies the collaborative follow-up plan, he or she has the option to forward the alert containing the collaborative follow-up plan to the radiology department scheduling team to coordinate the follow-up imaging directly with the patient. RADAR searches the electronic health record for the collaborative follow-up plan completion, with a flag triggered if the collaborative follow-up plan is not completed by 1 month after the recommended interval (e.g., by 7 months if the follow-up is recommended in 6 months). If a collaborative follow-up plan is not performed in that time frame, RADAR escalates an alert to the ordering provider to seek clarification about whether the collaborative follow-up plan still needs to be performed or is no longer relevant (e.g., patient deceased, imaging performed outside our health care enterprise, or care transferred to another provider outside our institution). If the ordering provider stipulates that collaborative follow-up plan is still clinically relevant, the cycle of tracking for collaborative follow-up plan completion starts anew by RADAR.

RADAR is a web-based application installed on a computer (ProLiant DL380 G5, HP) with two 3.00-GHz physical central processing units and 8 GB of RAM, running a Windows server (2003 R2, standard ×64 edition, Microsoft) as the operating

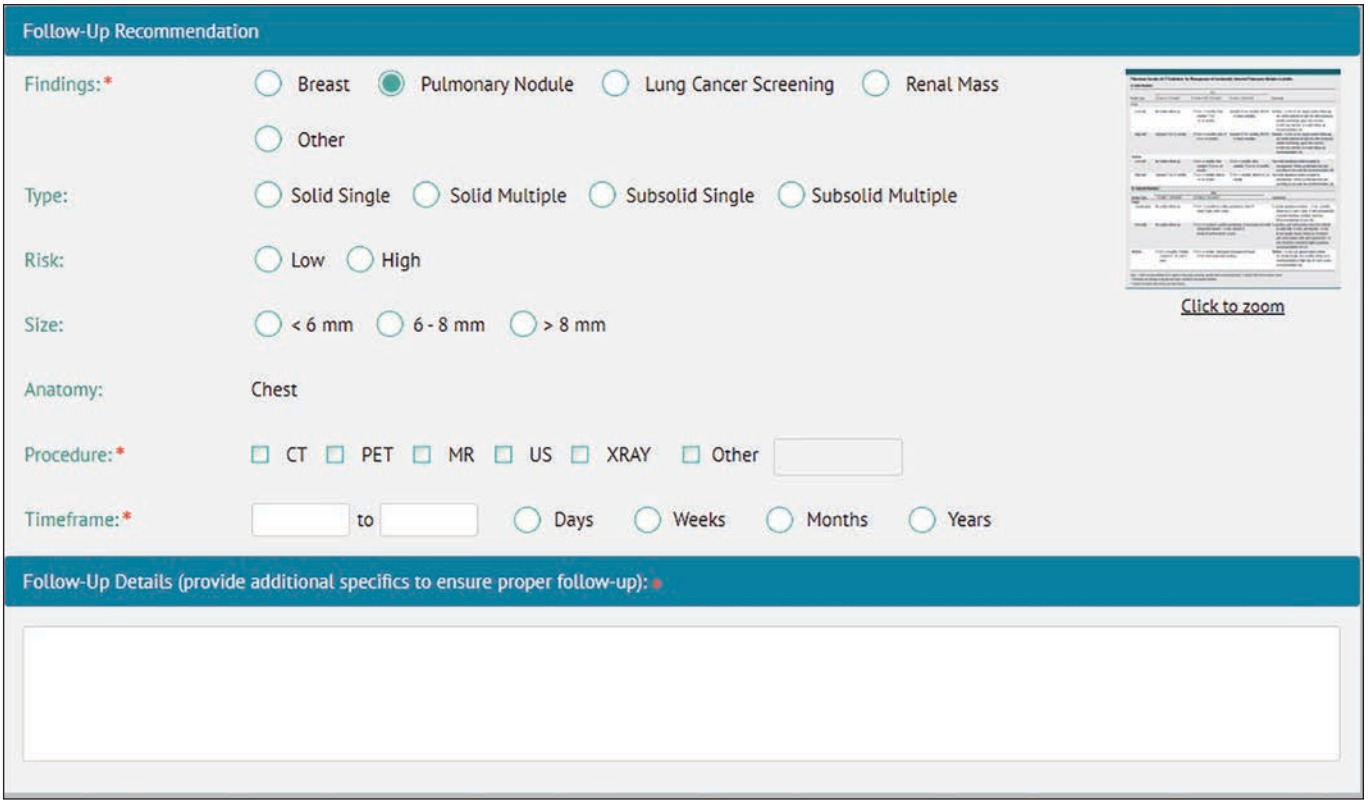

Fig. 1—Screen shot of Result Alert and Development of Automated Resolution (RADAR) system, as seen by radiologist. Radiologist may specify pulmonary nodule characteristics to generate Fleischner Society recommendations automatically or manually specify follow-up imaging modality and time frame.

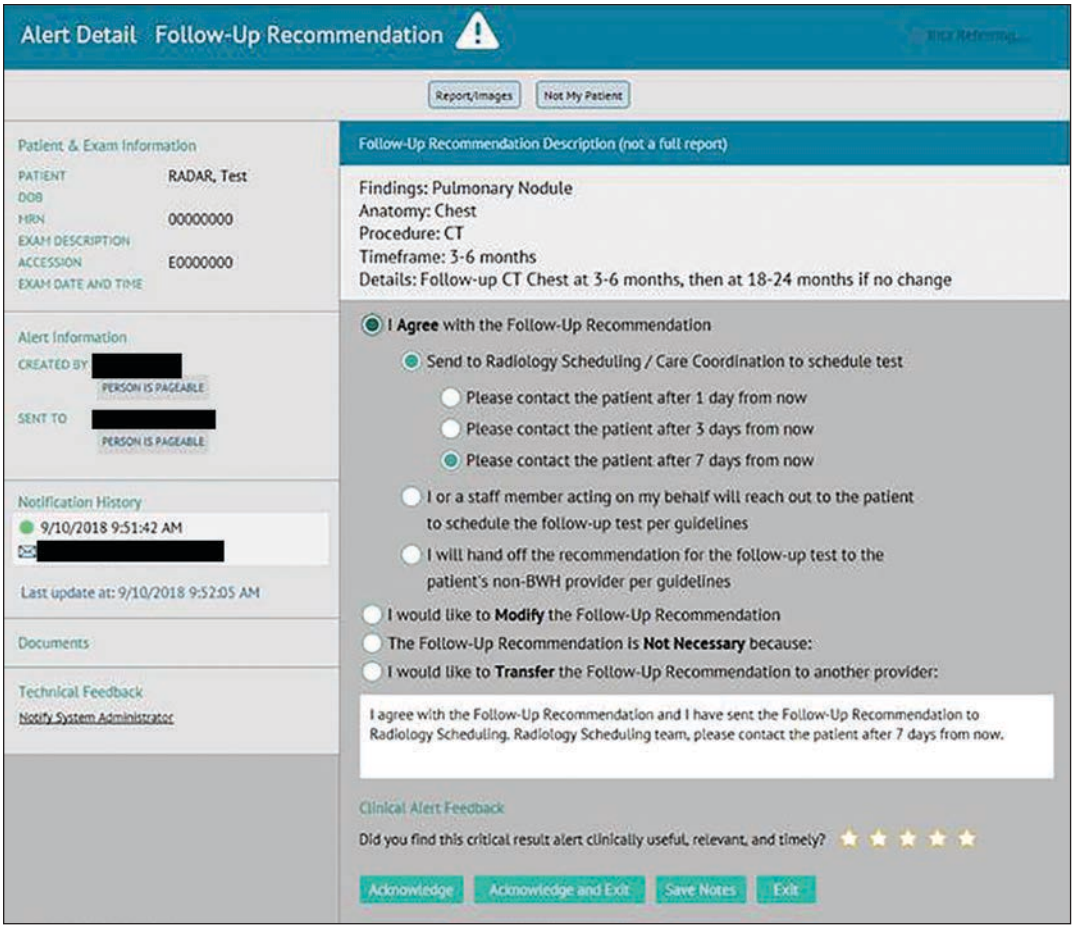

Fig. 2—Screen shot of Result Alert and Development of Automated Resolution (RADAR) system, as seen by referring provider. Provider may choose to agree with or modify recommendation, and if he or she agrees, he or she may directly refer recommendation to radiology department for scheduling.

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 simple mail transfer protocol server using e-mail. RADAR's standard query language server database stores all relevant information, including radiologist, ordering provider, primary care provider, patient, examination, result, follow-up, notification, and acknowledgment 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 e-mails 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 (Alert Notification of Critical Results).

Study Design and Setting

This retrospective study was approved by the institutional review board of Partners HealthCare, with waiver of informed consent. It was performed at a 753-bed tertiary academic medical center performing more than 600,000 imaging examinations annually.

Data Collection

We reviewed all 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 and with RADAR. Alerts were manually reviewed by a thoracic radiologist to ensure that they referred 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 completeness (presence of a follow-up time frame and an imaging modality).

Outcome Measures

The primary outcome was RADAR adoption for pulmonary nodules by thoracic radiologists (seven radiologists in the division), defined as the number of RADAR alerts for pulmonary nodules divided by the number of all alerts for pulmonary nodules during the study period. A secondary outcome was completeness of the follow-up recommendation, defined as specification of both imaging modality and time frame within the alert for pulmonary nodule follow-up. An additional secondary outcome was referring provider agreement with the follow-up recommendation generated through RADAR. This option is available only to those physicians who have opted in to the collaborative follow-up plan system, which is currently all of our referring primary care physicians ($n = 213$).

Statistical Analysis

Data were initially stored in Excel (version 16, Microsoft) and analyzed with JMP Pro (version 14, SAS Institute). 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 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 3-week period after implementation, six of

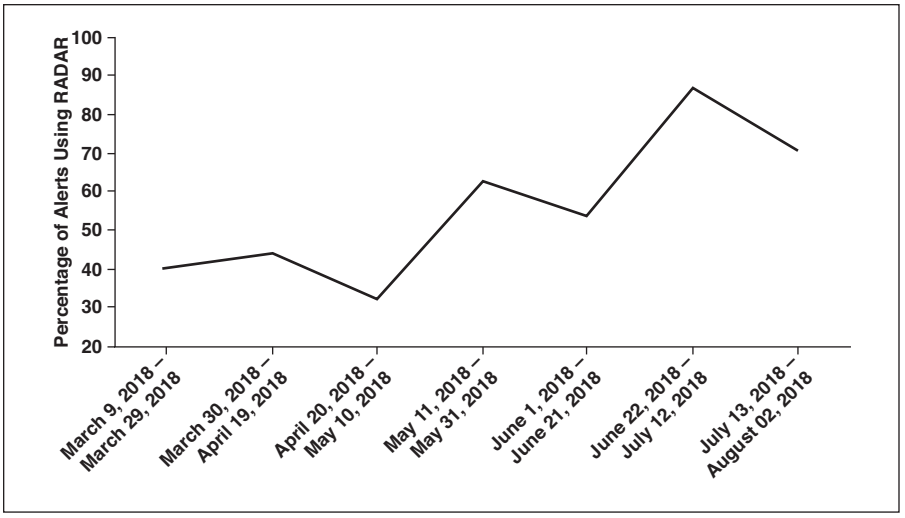

Fig. 3—Graph showing adoption of Result Alert and Development of Automated Resolution (RADAR) system over time.

15 (40%) pulmonary nodule alerts used RADAR. In the final 3-week period of our study, 19 of 27 (70%) pulmonary nodule alerts used RADAR. Thus, RADAR adoption increased by an absolute 30% or relative 75% during the study period (40% in first 3 weeks vs 70% in last 3 weeks; $p < 0.001$ test for trend) (Fig. 3).

All 106 RADAR alerts had explicit documentation of imaging modality and time frame for follow-up, compared with 71% (55 of 77) for non-RADAR alerts for pulmonary nodules ($p < 0.001$). As discussed already, explicit documentation of follow-up modality and time frame 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 collaborative follow-up plan system, the referring physicians agreed with the proposed collaborative follow-up plan in all 51 (100%) cases.

Discussion

We show successful implementation of a closed-loop system to enable the establishment and execution of a collaborative follow-up plan between radiologists and referring primary care providers. The ease of use of this system, though voluntary, is evidenced by its rapid adoption by thoracic radiologists and primary care providers. In addition, the design of the system required radiologists to specify follow-up modality and time frame, which improved the completeness of the recommendations compared with our previously existing system. Notably, 100% of referring primary care physicians agreed with the proposed follow-up plans through RADAR.

To our knowledge, no prior studies have evaluated the establishment of a collaborative follow-up plan between radiologists and referring providers. Prior studies have shown that approximately 40% of radiologists' follow-up recommendations are not adhered to by referring providers [9], though reasons are likely multifactorial and difficult to study, at least in part because of a lack of consistent documentation of reasons for disagreement in the medical record. In contrast, RADAR requires the referring provider to explicitly agree or disagree with the radiologist's follow-up recommendation before the care plan is executed. Primary care providers agreed with radiologists' recommendations for incidental pulmonary nodule follow-up 100% of the time. Future studies will be needed to assess agreement on follow-up recommendation between radiologists and non–primary care referring providers for incidental pulmonary nodules. Documentation of agreement and reasons for any disagreement between radiologists and referring providers will likely be helpful in improving the quality of recommendations and timely execution of needed care for patients.

Although others have described systems for automated tracking of follow-up recommendations [7, 8], our system combines notification, establishment of a collaborative follow-up plan with scheduling, and tracking tools into one streamlined process to enhance the probability that needed care is executed in a timely fashion. The process for establishing the collaborative follow-up plan in RADAR requires explicit electronic confirmation of receipt of the incidental nodule alert by the referrer. This closed-loop communication process is consistent with the American College of Radiology's Practice Parameter on communication of imaging findings [10]. The lack of direct (verbal) communication with referring providers has been identified as a risk factor for not completing follow-up [11]. We think 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 timely completion of follow-up.

Particular challenges exist with regard to follow-up recommendations for incidental 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 [12]. RADAR provides a streamlined system to automatically generate follow-up recommendations based on Fleischner Society guidelines with the input of nodule and patient characteristics, which may improve adherence to guidelines. In addition, RADAR requires specific imaging modality and time frame recommendations, preventing vague follow-up recommendations that are confusing for ordering providers.

The second major challenge for pulmonary nodule follow-up is the long follow-up intervals, because patients and providers may forget the need for follow-up after 1 or even 2 years. Future studies will be needed to assess whether RADAR functionality could help ensure that follow-up imaging examinations are scheduled and completed even with long time intervals.

There are several limitations to this study. First, it was conducted at a single academic radiology department with a dedicated quality and safety department with extensive experience with the creation of automated results alert systems. Systems such as RADAR may be difficult to reproduce in other institutions. Second, RADAR can automatically track only the follow-up imaging completion that is performed at our institution. However, given the success of this system within our thoracic radiology division, future studies can assess expansion of its use to nonthoracic radiologists who may discover incidental nodules on other studies (e.g., abdominal CT). The feasibility of RADAR in the emergency department and inpatient setting can also be assessed in future studies. Finally, future work is needed to evaluate the ordering physicians' use of this system and its success in ensuring that patients indeed undergo the recommended follow-up imaging.

Conclusion

In conclusion, a closed-loop communication system that enables the establishment and execution of a collaborative follow-up plan can assist radiologists in specifying follow-up for pulmonary nodules and help ensure their timely completion. By integrating this system directly within the PACS and electronic health record workflow and promoting its voluntary use, we were able to show adoption by radiologists over a relatively short time frame, with concomitant improvement in the completeness of radiology follow-up recommendations for incidental pulmonary nodules.

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References

1. Yip R, Henschke CI, Yankelevitz DF, Smith JP. CT screening for lung cancer: alternative definitions of positive test result based on the national lung screening trial and international early lung cancer action program databases. *Radiology* 2014; 273:591–596
2. Lacson R, O'Connor SD, Andriole KP, Prevedello LM, Khorasani R. Automated critical test result notification system: architecture, design, and assessment of provider satisfaction. *AJR* 2014; 203:[web]W491–W496
3. Lacson R, Prevedello LM, Andriole KP, et al. Four-year impact of an alert notification system on closed-loop communication of critical test results. *AJR* 2014; 203:933–938
4. Sloan CE, Chadalavada SC, Cook TS, Langlotz CP, Schnall MD, Zafar HM. Assessment of follow-up completeness and notification preferences for imaging findings of possible cancer. *Acad Radiol* 2014; 21:1579–1586
5. Singh H, Thomas EJ, Mani S, et al. Timely follow-up of abnormal diagnostic imaging test results in an outpatient setting: are electronic medical records achieving their potential? *Arch Intern Med* 2009; 169:1578–1586
6. MacMahon H, Naidich DP, Goo JM, et al. Guidelines for management of incidental pulmonary nodules detected on CT images: from the Fleischner Society 2017. *Radiology* 2017; 284:228–243
7. Santo EC, Dunbar PJ, Sloan CE, Cook TS, Lalevic D, Zafar HM. Initial effectiveness of a monitoring system to correctly identify inappropriate lack of follow-up for abdominal imaging findings of possible cancer. *J Am Coll Radiol* 2016; 13(12 Pt A):1505.e2–1508.e2
8. Wandtke B, Gallagher S. Reducing delay in diagnosis: multistage recommendation tracking. *AJR* 2017; 209:970–975
9. Mabotuwana T, Hombal V, Dalal S, Hall CS, Gunn M. Determining adherence to follow-up imaging recommendations. *J Am Coll Radiol* 2018; 15(3 Pt A):422–428
10. American College of Radiology (ACR). ACR practice parameter for communication of diagnostic imaging findings. ACR website. www.acr.org/-/media/ACR/Files/Practice-Parameters/CommunicationDiag.pdf. Published 1991. Updated 2014. Accessed October 8, 2018
11. Liao GJ, Liao JM, Lalevic D, Cook TS, Zafar HM. Time to talk: can radiologists improve follow-up of abdominal imaging findings indeterminate for malignancy by initiating verbal communication? *J Am Coll Radiol* 2018; 15:1627–1632
12. Lacson R, Prevedello LM, Andriole KP, et al. Factors associated with radiologists' adherence to Fleischner Society guidelines for management of pulmonary nodules. *J Am Coll Radiol* 2012; 9:468–473