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# Impact of a Health Information Technology Intervention on the Follow-up Management of Pulmonary Nodules

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**Abstract** Lung cancer is the leading cause of cancer deaths in the USA. The most common abnormalities suspicious for lung cancer on CT scan include pulmonary nodules. Recommendations to improve care for patients with pulmonary nodules require follow-up management. However, transitions in care, especially for patients undergoing transitions to ambulatory care sites from the emergency department (ED) and inpatient settings, can exacerbate failures in follow-up testing and compromise patient safety. We evaluate the impact of a discharge module that includes follow-up recommendations for further management of pulmonary nodules on the study outcome and follow-up management of patients with pulmonary nodules within 1 year after discharge. After IRB approval, we collected data on all patients undergoing chest or abdominal CT exams over a 12-month baseline and 12-month intervention period at an academic medical center. The inpatient discharge module was implemented in November 2011; the ED module was implemented in May 2012. Multivariable logistic regression was performed to account for care setting, imaging modality, recommendations, and patient demographics. Implementation of a discharge module resulted in improved follow-up of patients with pulmonary nodules within 1 year after discharge (OR = 1.64, $p = 0.01$); the ED implementation resulted in better follow-up compared to the inpatient module (OR = 2.24, $p < 0.01$). Twenty-seven percent of patients with pulmonary nodules received follow-up management, which, although significantly improved from the 18% baseline, remains low. An electronic discharge module is associated with improved follow-up management of patients with pulmonary nodules, and may be combined with interventions to further improve management of these patients.

**Keywords** Solitary pulmonary nodule · Multiple pulmonary nodules · Patient discharge · Follow-up studies

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## Introduction

Lung cancer is the leading cause of cancer deaths in the USA and worldwide [1]. The dismal survival rate attributed to lung cancer is partly due to the inability to detect the disease at an earlier stage when cure is possible [2]. Recently, low-dose CT scan has been demonstrated to improve survival by screening and early lung cancer detection [2, 3]. The most common abnormalities suspicious for lung cancer on CT scan are pulmonary nodules.

A pulmonary nodule is a nodular opacity within the lung tissue that can measure up to 3 cm in diameter [4, 5]. Guidelines for management of pulmonary nodules have been developed based on nodule characteristics (e.g., size) and patient history (e.g., smoking history) [5–7]. In a previous study, we were able to track patients with incidental pulmonary nodules detected on CT and assess whether recommendations were being documented for follow-up [8]. Specifically, we assessed adherence to the "Guidelines for management of small pulmonary nodules detected on CT scans," published in 2005 by the Fleischner Society [6]. However, we have not

shown whether documented follow-up recommendations lead to improved follow-up care.

Follow-up management of pulmonary nodules during care transitions and across care settings is more challenging because responsibility for follow-up management is often unclear. Care transitions involve transfer of responsibility among acute care and ambulatory clinicians, which may exacerbate failures in follow-up testing. Studies at other institutions have documented lack of timely follow-up management of non-urgent test results in these settings [9, 10]. Missed or delayed follow-up of abnormal test results leads to additional interventions or complications, compromising patient safety [11, 12]. As expected, one reason for this follow-up omission includes focus on more urgent findings. Other reasons include workflow issues at the receiving end of the communication, such as lack of physician continuity and gaps in transition of care [9, 10, 13]. The referring physicians need an effective way to retrieve results that need further management until follow-up tests are implemented [14]. We evaluate the impact of an innovative health information technology (IT) intervention consisting of follow-up recommendations and electronic discharge modules that include follow-up recommendations for further management of pulmonary nodules in transitions of care—from the emergency department and inpatient settings to ambulatory care sites.

## Methods

### Study Setting

The study was conducted in a 793-bed adult academic medical center—a Level-1 trauma center with an emergency department (ED). Over 600,000 imaging examinations are ordered annually for inpatient, ED, and ambulatory patient care. The Institutional Review Board approved this HIPAA-compliant study and waived the requirement for informed consent.

### Cohort Selection

The hospital implemented an electronic inpatient discharge module in November 2011 and an ED discharge module in May 2012. All patients who were seen at the ED and inpatient service 1 year before (baseline) and after (intervention) implementation of these systems were included in the study. We selected all patients who received a chest or abdominal CT scan as they are a common source of pulmonary nodules discovered at imaging (Fig. 1). Our cohort consisted of 22,079 and 22,670 inpatients in the baseline and intervention periods, respectively, and 23,757 and 26,234 ED patients in the baseline and intervention periods, respectively. Radiology reports for patients with lung nodules were identified using an information retrieval toolkit, Information from Searching Content with an Ontology-Utilizing Toolkit (iSCOUT), which has been reported to accurately obtain reports with findings of pulmonary nodules in a previous study [15].

From patients with pulmonary nodules identified through iSCOUT, we included those who had findings that were reported in our critical results notification system, Alert Notification of Critical Results (ANCR) [16]. Our institutional policy requires generation of a critical result alert using the ANCR system for pulmonary nodules that are newly discovered at imaging or that require follow-up management [17].

### Manual Review

Two researchers (RP and SS) performed a manual review of a subset of radiology reports (i.e., identified through iSCOUT and ANCR) to document the presence and size of pulmonary nodules. Patients who had no lung nodules were excluded (i.e., reports incorrectly retrieved by iSCOUT), as well as imaging reports for patients in the same admission, reports in patients who have any malignancy, and reports in patients who died during the current admission. All remaining reports were included for analysis.

### Study Interventions

The health IT intervention included discharge modules for both ED and inpatient settings, which allowed access to critical findings of pulmonary nodules and recommendations for follow-up management. The online modules, described previously [18–20], enable physicians caring for patients in the ambulatory setting to access these recommendations after patients are discharged. The module for the ED was developed to replace a paper-based discharge instruction form [18]. An interdisciplinary team designed the system to improve the quality and completeness of discharge instructions, with particular attention to five specific elements—chief complaint or diagnosis, major procedures or tests performed, patient care instructions, follow-up instructions, and new/changed medications. The ED discharge module included the ability to include a list of imaging studies performed in the ED with free-text comments entered by the ED provider. A copy of the finalized radiology reports, including the presence of nodules and follow-up recommendations, could also be optionally included for patients, with a single click (Fig. 2). These features make it easier for emergency physicians to summarize findings and provide follow-up recommendations. The inpatient discharge module is available for all patients discharged from the hospital. It includes a section for discharge instructions, specifically “Instructions to PCP/Outpatient” at the bottom of the module [20]. Documentation of relevant data elements, including studies pending at discharge, was especially given priority during development. Integration with the radiology information systems enables full radiology reports to be

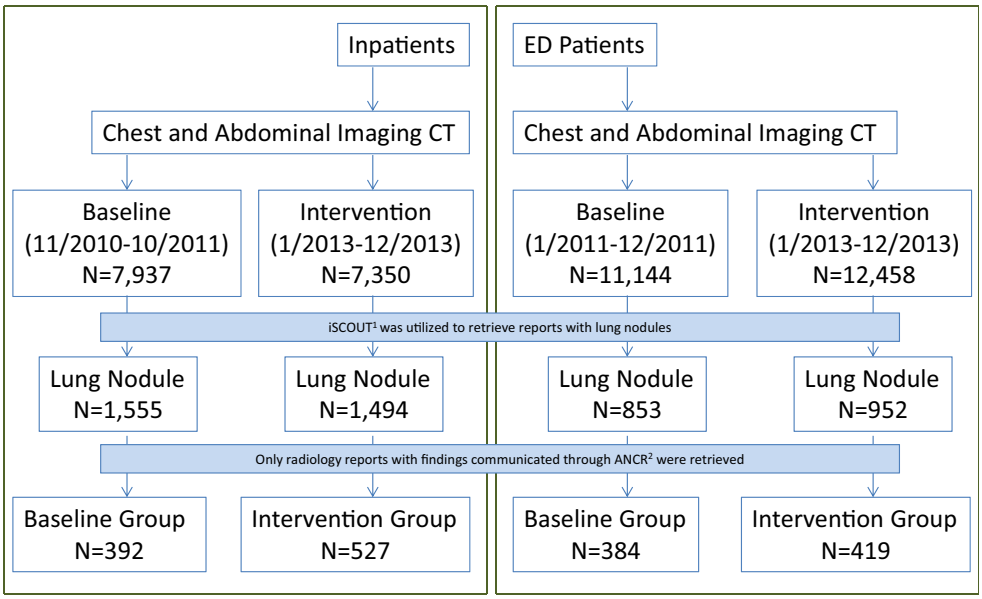


**Fig. 1** Cohort selection for baseline and intervention groups

included in the discharge summary. The two modules, although implemented separately, were both web-based and integrated with existing clinical information systems at the study institution.

As previously mentioned, institutional policy requires the generation of a critical result alert at the study institution for newly diagnosed lung nodules. While ANCR alerts are not visible in the discharge modules, radiology reports that have findings communicated through ANCR include documentation that the report was communicated to the ordering provider through ANCR. In addition, radiologists at the study institution voluntarily use the Fleischner Society guidelines for follow-up management of pulmonary nodules. They are able to embed standardized text from the guidelines using the speech recognition system, which are documented in the radiology reports.

## Data Collection and Outcomes

In addition to the discharge modules, other factors collected in the study included the presence of radiologists' recommendations for follow-up, presence of discharging clinicians' recommendations for follow-up, imaging modality (e.g., chest CT scan), nodule size, and patient demographics. Patient-specific variables relevant to pulmonary nodule follow-up were collected including age, race, and sex. Age was analyzed as a continuous variable, and the others as categorical variables. The reported size of the largest nodule in each individual report was used to classify size, and was analyzed both as a continuous and a categorical variable. Categories were defined as (1) ≤4 mm, (2) >4–6 mm, (3) >6–8 mm, and (4) >8 mm, consistent with categories for lung nodule follow-up in the Fleischner Society guidelines [6]. Radiologist and

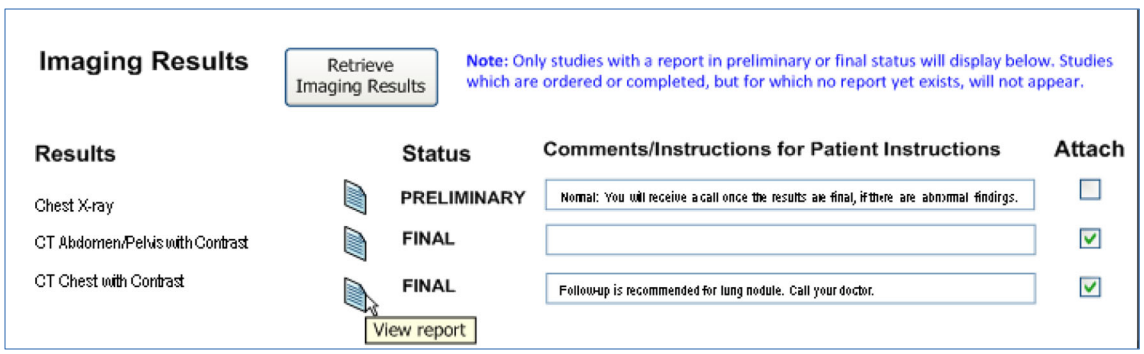


**Fig. 2** Emergency department discharge module

imaging modality characteristics were evaluated by classifying reports into abdominal CT compared to thoracic CT scans.

We analyzed the impact of the health IT intervention on the primary outcome, follow-up management of patients with pulmonary nodules within 1 year after discharge, and secondarily, the presence of documented discharge recommendations in the discharge module. Follow-up was limited to repeat CT scan or biopsy within 1 year after discharge.

### Statistical Analysis

Descriptive statistics were calculated for patient demographics and key factors. Unadjusted analysis was performed using chi-square test to assess the impact of the discharge modules on pulmonary nodule follow-up management. In addition, multivariate analysis was performed using logistic regression (R 3.2.2 software, Vienna, Austria). Backward stepwise variable selection method was utilized to identify factors independently associated with the outcome. The dependent variable in the model was binary (completed follow-up), with "0" denoting absence of follow-up. Discharge module implementation in the ED and inpatient settings was done independently and was included as a separate variable in the analysis. The categorical variable for nodule size was found to have a better fit than when formatted as a continuous variable, and was used in the final model. A second multivariable model was developed to address the secondary outcome, factors associated with follow-up documentation in the discharge module.

## Results

### Population Characteristics

Our initial study population was composed of 776 patients in the baseline group (392 inpatient and 384 ED patients) and 946 patients in the intervention group (527 inpatient and 419 ED patients). After manual review, 321 and 327 patients were included in the final baseline and intervention cohorts, respectively. The majority of patients excluded during manual review (49%) were due to the presence of concurrent malignancy. Table 1 displays patient demographics and factors relevant to follow-up. Patients were mostly white and male. Majority of the patients were in the inpatient setting and had pulmonary nodules discovered in chest CT scans. Although radiologist recommendations for follow-up were indicated in 33% of reports, discharge instructions only had documentation for follow-up management in 20% of reports.

**Table 1** Demographics and relevant factors in the data set ($n$ = 648)

| Variable | Value (%) |
|---|---|
| Patient demographics | |
| Age (year) | Mean = 60.4 |
| Race | |
| White | 383/648 (59) |
| Black | 48/648 (7) |
| Hispanic | 48/648 (7) |
| Asian | 17/648 (3) |
| Unknown | 152/648 (24) |
| Gender | |
| Female | 292/648 (45) |
| Male | 356/648 (55) |
| Location of study | |
| Inpatient | 454/648 (70) |
| ED | 194/648 (30) |
| Imaging test | |
| Chest CT | 507/648 (78) |
| Abdominal CT | 141/648 (22) |
| Presence of radiologist recommendation for follow-up | 217/648 (33) |
| Presence of discharge recommendation for follow-up | 127/648 (20) |

### Primary Outcome

Descriptive statistics and results of unadjusted analysis are included in Table 2, including bivariate associations of pulmonary nodule follow-up. As shown in Table 2, only 18% of females and 26% of males had pulmonary nodule follow-up.

Using a discharge module significantly increased pulmonary nodule follow-up from 18 to 27% ($p < 0.01$). In addition, pulmonary nodule follow-up was significantly less common when patients were female ($p < 0.02$) and for patients seen in the inpatient setting. In assessing whether recommendations for follow-up and using a discharge module were significantly associated with follow-up, both factors were included in a logistic regression model. In multivariate analysis, the presence of a discharge module was significantly associated with follow-up management of patients with pulmonary nodules within 1 year after discharge ($p < 0.01$) (Table 3).

The ED setting was significantly associated with increased follow-up management, compared to the inpatient setting. Finally, females had decreased follow-up management in a subsequent year, compared to male patients.

### Secondary Outcome

In 20% of patients, the discharge modules document follow-up management at baseline, 21% post-intervention ($p = 0.50$). In a second multivariable model assessing factors associated with follow-up documentation in the discharge module, only the presence of documented radiologist recommendation for follow-up was associated with documentation of follow-up in the discharge module ($p < 0.05$).

**Table 2** Univariate analysis with chi-square *p* values

| | Pulmonary nodule follow-up (%) | Chi-square *p* value |
|---|---|---|
| Before implementation (*n* = 321) | 59/321 (18) | |
| After implementation (*n* = 327) | 88/327 (27) | <0.01* |
| Race | White 83/383 (22), black 10/48 (21), Hispanic 12/48 (25), Asian 2/17 (12) | >0.72 |
| Gender | Female 53/292 (18), male 92/356 (26) | <0.02* |
| Location of imaging study | Inpatient 83/454 (18), ED 62/194 (32) | <0.001* |
| Type of imaging study | Chest CT 128/507 (25), abdominal CT 17/141 (12) | <0.001* |
| Presence of radiologist recommendation for follow-up | 52/217 (24) | >0.49 |
| Presence of discharge recommendation for follow-up | 31/127 (24) | >0.53 |

Percentages of patients with pulmonary nodule follow-up for each category of variables are indicated in parentheses

*Statistically significant findings

## Discussion

Implementation of a health IT intervention of web-based discharge modules in both inpatient and ED settings was associated with significantly improved follow-up management of patients with pulmonary nodules. The increased follow-up persisted, even in a multivariable model that accounts for patient age, sex, race, nodule size, and documented recommendation for follow-up. Twenty-seven percent of patients with pulmonary nodules received either a follow-up imaging with a chest CT scan or a biopsy with corresponding pathologic report or cytology after module implementation. This percentage, although significantly improved from baseline, remains low, considering that majority of pulmonary nodules in the intervention cohort (51%) had nodule sizes above 4 mm for which Fleischner Society guidelines recommend follow-up management [6]. Patient safety concerns will remain until appropriate follow-up management occurs because these larger nodules are more likely to be malignant. Follow-up with chest CT scan is key to detect interval nodule growth or with biopsy to detect early malignancy. For nodules below 4 mm in size, follow-up imaging is also recommended for patients at high-risk for lung cancer. Unfortunately, we did not routinely collect lung cancer risk data to quantify the added number of patients with <4-mm nodules that required further imaging follow-up.

**Table 3** Multivariate analysis with beta coefficient, odds ratio (OR), and *p* values

| Variable | Beta coefficient | OR | *p* value |
|---|---|---|---|
| Age | −0.01 | 0.99 | 0.08 |
| Gender (relative to male) | −0.52 | 0.59 | 0.01* |
| Race (relative to unknown) | | | |
| White | −0.21 | 0.81 | 0.38 |
| Black | −0.60 | 0.55 | 0.16 |
| Hispanic | −0.52 | 0.59 | 0.21 |
| Asian | −0.89 | 0.41 | 0.27 |
| ED (relative to inpatient) | 0.81 | 2.24 | <0.01* |
| Chest CT | 0.58 | 1.78 | 0.06 |
| Radiologist follow-up recommendation | 0.06 | 1.06 | 0.80 |
| Discharge recommendation | 0.22 | 1.24 | 0.43 |
| Discharge module | 0.49 | 1.64 | 0.01* |

*Statistically significant

The discharge modules in both ED and inpatient settings have dedicated fields for follow-up management, and it was our expectation that this would enhance follow-up documentation. Unfortunately, there continues to be low follow-up management documentation in discharge instructions. The role of radiologists in making recommendations for follow-up management can potentially improve documentation in patients' discharge instructions. Although the presence of discharge recommendations is not significantly associated with improved outcome, the discharge module may have improved access to the recommendations, both in the web-based discharge instruction and in access to the actual radiology report. Access to both discharge instructions and radiology reports would be possible with the discharge module, as opposed to a paper-based discharge summary that a patient is supposed to take to their follow-up ambulatory visit. Discharge summaries are often unavailable or incomplete in many cases [21–24]. Furthermore, radiology reports are likely to not be included in the printed summaries.

Two other factors were significantly associated with improved follow-up—implementation of the discharge module in the ED and male gender. The discharge modules were implemented separately in the ED and inpatient settings, and

more specific data is collected in the ED discharge module with regards to follow-up notification. A specific primary care physician (and patient-care team) can be accessed through a provider directory for notification of follow-up. More importantly, the ED module's capability to attach copies of finalized radiology reports, including the presence of nodules and follow-up recommendations, may have facilitated follow-up performance. We are unable to account for the role of gender in completing follow-up management. This is increasingly important because females who smoke are as likely as men who smoke to develop lung cancer [25]. However, better survival rates have been noted in females who have low-grade adenocarcinoma of the lungs [26]. We plan to further examine the lower rates of follow-up in females with pulmonary nodules in future studies.

### Limitations

This is a before-and-after study, and may not take into account increasing follow-up due to secular trends. However, we did not expect any significant change in follow-up management of pulmonary nodules during the study period. Radiology reports in our study setting include two key components that are critical to informing primary care providers regarding imaging results that potentially require follow-up—(1) use of a critical result communication system in conjunction with the report, and (2) standardized text from Fleischner Society guidelines for pulmonary nodule follow-up management. Although these narrative documentations are available pre- and post-intervention, the reports are more accessible in the web-based discharge modules and may have contributed to improved patient follow-up management.

## Conclusion

Access to an electronic discharge module is associated with improved follow-up management after discharge of patients with pulmonary nodules discovered in the ED and inpatient settings. Future studies should focus on the impact of more intensive interventions, in addition to health IT implementation, to further improve pulmonary nodule follow-up.

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**Compliance with Ethical Standards** The Institutional Review Board approved this HIPAA-compliant study and waived the requirement for informed consent.

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