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# Impact of Follow-Up Imaging Recommendation Specificity on Adherence

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Abstract. Radiology reports often contain follow-up imaging recommendations, but failure to comply with them in a timely manner can lead to delayed treatment, poor patient outcomes, complications, and legal liability. Using a dataset containing 2,972,164 exams for over 7 years, in this study we explored the association between recommendation specificity on follow-up rates. Our results suggest that explicitly mentioning the follow-up interval as part of a follow-up imaging recommendation has a significant impact on adherence making these recommendations 3 times more likely (95% CI: 2.95 – 3.05) to be followed-up, while explicit mentioning of the follow-up modality did not have a significant impact. Our findings can be incorporated into routine dictation macros so that the follow-up duration is explicitly mentioned whenever clinically applicable, and/or used as the basis for a quality improvement project focussed on improving adherence to follow-up imaging recommendations.

**MeSH/keywords.** radiology information system, radiology follow-up recommendations, follow-up compliance, quality improvement.

## 1. Introduction

Radiology reports often contain follow-up imaging recommendations to monitor stability of potentially malignant findings, to ensure resolution of potentially serious disease, or for further diagnostic characterization. However, failure to comply with imaging follow-up recommendations in a timely manner is common, with overall adherence rates under 40% [1]. Non-adherence can be due to various reasons, such as a clinician determining that follow-up is unnecessary, especially when a follow-up recommendation is made non-applicable by clinical findings that were not available to the radiologist at the time of recommendation. Other reasons can include the referring physicians missing the recommendations or losing track while addressing a more acute illness, loss of information during care-team handover, and the patient failing to schedule or show-up for follow-up appointment.

Despite various factors that may affect follow-up imaging adherence, one area where radiologists have room for improvement is in the quality and clarity of follow-up imaging recommendations. Referring physicians, especially primary care physicians who may not

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be as familiar with latest imaging guidelines, value more explicit follow-up imaging recommendations by radiologists [2]. A recent study found that imaging follow-up rate dropped from 78.8% for no conditional language to 43.8% when conditional language was present [3]. Based on the hypothesis that referring physicians prefer more explicit recommendations for follow-up imaging, in this paper we explore the association between follow-up imaging recommendation specificity on actual adherence.

### 2. Methods

# 2.1. Previous work: Follow-up detection and matching

In previous work, we developed a follow-up detection algorithm which parses the radiology report text to extract sections (e.g., "Findings" and "Impression" which are common headers in most radiology reports), paragraph headers (e.g., "Abdomen" and "Pelvis") and sentences within the paragraphs. The algorithm evaluates the sentences within the "Findings" and "Impression" sections to determine if a sentence contains a follow-up recommendation (e.g., "Follow-up CT chest in 3 months is recommended"). Using 532 reports annotated by three radiologists as the ground truth, the detection algorithm was evaluated to have 93.2% PPV (95% CI: 89.8-94.5%), 99.5 NPV (95% CI: 98.4-99.9%) and 97.9% accuracy (95% CI: 96.2-98.5%) [4]. Detected follow-up imaging recommendations are then processed through an automated matching module to determine if a subsequently performed exam for the same patient satisfies the clinical reason(s) for the follow-up recommendation. The algorithm uses: (1) study meta-data, (2) recommendation context (e.g., recommended modality and follow-up interval), (3) report text based similarity (e.g., similarity between impression of source report with a follow-up recommendation and reason for exam of candidate report) as well as (4) other features (such as time difference between source and candidate exams). An ensemble classifier, Extremely Randomized Trees, was selected for the final model. Algorithm development and validation was performed using 559 exams containing a follow-up recommendation that were annotated by three radiologists independently identifying whether the recommendation was followed-up, and if so, marking the specific subsequent imaging study (i.e., the true follow-up exam). Algorithm was evaluated using 50 splits of the 559 exams where model performance using a 70/30 split for training/test respectively was: Average PPV 74.4% (95% CI: 73.3-75.4%), NPV 80.7% (95% CI: 79.2-82.1%) and accuracy 76.5% (95% CI: 75.7-77.3%). Accuracy was deemed acceptable for the purposes of this study [5].

# 2.2. Specificity of recommendations

A quality improvement oversight committee composed of multiple clinical and quality stakeholders decided that explicitly mentioning the suggested follow-up duration and modality of the recommended follow-up exam is an important indication of the specificity of a follow-up imaging recommendation. For example, we hypothesize that "follow-up with a CT in 3-6 months to assess stability" will be preferred by more referring physicians compared to "follow-up to assess stability". Due to the nature of specific health conditions, explicit mentioning of time interval and modality is not always possible, and as such, achieving a reasonably high rate (e.g., 70%) will be an indication of having high specificity. Given the finite number of modalities and the

numerical nature of the duration, we used regular expressions to extract modality and time interval from a detected follow-up imaging recommendation. This included capturing various ways of referring to time intervals (e.g., follow-up in *three* months, 6 months, 3-6 months, annually). All intervals were converted to days with a minimum and a maximum value. Both were set to be the same if only one value was specified (e.g., "follow-up in 3 months").

#### 2.3. Dataset

We extracted data for radiology exams performed between 1-January-2010 and 28-February-2017 from the University of Washington radiology information system. The dataset contained 2,972,164 exams performed across multiple network hospitals. For each exam, the dataset contained the report text as well as several meta-data fields, including exam code, exam date, radiology subspecialty, patient setting (inpatient, outpatient or emergency) and modality. The Human Subjects Division determined that the study was IRB exempt as part of a quality improvement project.

Since some follow-up imaging recommendations can be up to 12-months, we used 1-January-2010 to 31-December-2015 as the period during which a follow-up recommendation was to be detected, and 1-January-2016 to 28-February-2017 as the period during which the follow-up imaging should have occurred, allowing for a maximum of 14-months for the follow-up exam to be performed.

#### 3. Results

There were 2,469,489 exams in the dataset during 2010-2015. Follow-up detection algorithm extracted 295,022 recommendation sentences corresponding to 260,972 (10.6%) reports (note that a report can contain multiple follow-up recommendations).

To determine impact of recommendation specificity on actual adherence rate, we created the 2x2 contingency tables at a recommendation level and at an exam level:

**Table 1.** 2x2 contingency table showing *recommendations* followed-up by time interval. Odds Ratio: 3.00 (95% CI: 2.95 - 3.05)

_	Time Interval Present	#Followed-up	#Not followed-up	Total
	Yes	112,765	48,176	160,941
	No	58,768	75,313	134,081
	Total	171,533	123,489	295,022

**Table 2.** 2x2 contingency table showing *recommendations* followed-up by modality. Odds Ratio: 0.97 (95% CI: 0.96 - 0.99)

Modality Present	#Followed-up	#Not followed-up	Total
Yes	91,226	66,558	157,784
No	80,307	56,931	137,238
Total	171,533	123,489	295,022

**Table 3.** Contingency table showing *exams* followed-up by time interval. Odds Ratio: 2.30 (95% CI: 2.26 – 2.33)

2.33)				
	Time Interval Present	#Followed-up	#Not followed-up	Total
	Yes	95,816	46,513	142,329
	No	56,122	62,521	118,643
	Total	151.938	109,034	260.972

Table 4. Contingency table showing exams followed-up by inodanty. Odds Ratio. 0.77 (3570 Ct. 0.76 – 0.76)				
Modality Present	#Followed-up	#Not followed-up	Total	
Yes	73,721	59,939	133,660	
No	78,217	49,095	127,312	
Total	151,938	109,034	260,972	

Table 4. Contingency table showing exams followed-up by modality. Odds Ratio: 0.77 (95% CI: 0.76 – 0.78)

## 4. Discussion

In this paper, we have discussed the impact of follow-up imaging recommendation language on follow-up adherence. Our results suggest that explicit mentioning follow-up interval as part of follow-up imaging recommendations has a significant impact on adherence, making these recommendations 3 times more likely to be followed-up (and 2.3 times more likely at an exam level). However, explicit mentioning of modality does not seem to have a significant impact as indicated in Tables 2 and 4. This result is not too surprising since the general assumption is that the follow-up modality is the same as the one with the recommendation, unless stated otherwise. The impact of including the follow-up interval is significant since this finding can be used to design appropriate interventions to improve recommendation specificity, such as implementing standardized follow-up macros to include the follow-up interval, where appropriate.

The current study has a few limitations. First, all reports were created using common dictation macros that are shared across the network hospitals and therefore the report parsing methods may not be readily generalizable to other institutions. Second, we had access only to exams that were performed within the network hospitals and therefore the study may have underestimated the true follow-up adherence rates since patients may follow-up outside of the network hospitals. Third, radiologists may use less explicit language when a follow-up is less clinically important and failure to follow-up may reflect the underlying clinical condition rather than the language used by the radiologist.

Despite the limitations, the observed result can have significant implications for quality improvement initiatives. Having standardized follow-up recommendations has been shown to increase follow-up adherence in certain settings [6]. This may help referring physicians, especially primary care physicians who may not be as familiar with latest imaging guidelines, order the correct follow-up exam at the right time which in turn will also help radiologists add more value to overall management of patient care.

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