Determining Adherence to Follow-up Imaging Recommendations

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Abstract

Purpose: Radiology reports often contain follow-up imaging recommendations. However, these recommendations are not always followed up by referring physicians and patients. Failure to comply in a timely manner can lead to delayed treatment, poor patient outcomes, unnecessary testing, lost revenue, and legal liability. Therefore, the primary objective of this research was to determine adherence rates to follow-up recommendations.

Methods: We extracted radiology examination–related data, including report text, for examinations performed between January 1, 2010, and February 28, 2017, from the radiology information system at an academic institution. The data set contained 2,972,164 examinations. The first 6 years were used as the period during which a follow-up recommendation was to be detected, allowing for a maximum of 14 months for a follow-up examination to be performed.

Results: At least one recommendation for follow-up imaging was present in 10.6% of radiology reports. Overall, the follow-up imaging adherence rate was 58.14%. Mammography had the highest follow-up adherence rate at 69.03%, followed by MRI at 67.54%. Of the modalities, nuclear medicine had the lowest adherence rate at 37.93%.

Conclusions: This study confirms that follow-up imaging adherence rates are inherently low and vary by modality and that appropriate interventions may be needed to improve compliance to follow-up imaging recommendations.

Key Words: Medical informatics applications, follow-up imaging, follow-up imaging adherence, radiology reports

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INTRODUCTION

Radiology reports often contain follow-up imaging recommendations for monitoring the stability of potentially malignant findings, for ensuring resolution of potentially serious disease, or for further diagnostic characterization [1]. However, failure to comply with imaging follow-up recommendations in a timely manner is common and can lead to delayed treatment, poor patient outcomes, complications, unnecessary testing, lost revenue, and legal liability [1-3].

Follow-up recommendation detection in radiology reports has been an active area of research recently. However, much of the focus has been on identifying recommendations associated with specific incidental findings [4,5], modalities [2], or critical findings [6] or a specific type of finding, such as pulmonary nodules [7] or adrenal masses [8]. For follow-up detection algorithms to be useful in routine practice, there is an opportunity to make algorithms more scalable and generic so that recommendations can be identified from all radiology reports.

Despite modest adherence to follow-up recommendations being an important safety concern that requires urgent attention [9], very few attempts, if any, have been made to automatically determine if a follow-up examination has been performed. There have been some research initiatives to improve follow-up recommendation

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adherence rates where institution-specific workflows have been implemented. For instance, by asking radiologists to dictate certain phrases into the reports, tracking systems can automatically extract follow-up recommendations that contain these phrases with an explicit follow-up interval and create alerts when a follow-up examination is due [10]. Similarly, an explicit score can be assigned to indicate the degree of suspicion for lesion malignancy and the need for follow-up [11]. Rule-based tracking systems have also been used to automatically identify patients who have missed their follow-up examinations when the follow-up interval is known [12].

Although certain interventions such as direct verbal communication of findings and recommendations by a radiologist or technologist have been shown to improve compliance [13], generalizable techniques to automatically detect follow-up recommendation compliance are needed. To address some of these existing limitations, we developed natural language processing and machine learning–based algorithms that can reliably determine the most likely follow-up examination, if any, from a given list of candidate radiology reports for the same patient [14]. In this article, we describe an application of this automated follow-up detection and matching technology to determine adherence to follow-up imaging recommendations using a large production data set that covers 7 years of studies.

METHODS

Data Set

We extracted data for radiology examinations performed between January 1, 2010, and February 28, 2017, from the University of Washington radiology information system. The data set contained 2,972,164 examinations performed across multiple network hospitals. For each examination, the data set contained the report text as well as several metadata fields, including medical record number, examination code, examination date, radiology subspecialty, patient setting (inpatient, outpatient, or emergency), and modality. The human subjects division at the University of Washington approved this project as minimal risk. All data were stored on an encrypted machine within one of the secure data centers at the University of Washington Medical Center with restricted user access.

Because the follow-up interval for some imaging recommendations can be 12 months or longer, we used January 1, 2010, to December 31, 2015, as the period during which a follow-up recommendation was to be detected in the initial radiology reports, and we used January 1, 2010, to February 28, 2017, as the period during which the follow-up imaging should have occurred, allowing up to 14 months for the follow-up examination to be performed.

Previous Work: Follow-up Detection

In previous research, we developed natural language processing–based algorithms that could be used to detect follow-up recommendation sentences in radiology reports [14]. A report can contain one or more follow-up recommendations. Although recommendations in radiology reports can be categorized into several classes (eg, imaging recommendations, clinical or therapy follow-up, tissue sampling or biopsy, and so on), and the algorithm distinguishes between nine different types of follow-up recommendations, the focus of the current work was on follow-up imaging recommendations only.

The follow-up detection algorithm first parses the radiology report to extract sections (eg, "Clinical Indication," "Findings," and "Impression," which are common headers in most radiology reports), paragraph headers within each section if any (eg, "Abdomen" and "Pelvis"), and the sentences within the paragraphs. The algorithm then evaluates the sentences within the "Findings" and "Impression" sections as well as any addenda, to determine if a sentence contains a follow-up recommendation (eg, "Given history of malignancy, follow-up CT chest in 3 months is recommended"). Follow-up detection is performed using key word searches and other heuristics. The output of this first step is a list of follow-up recommendation sentences (along with metadata, such as whether it is a negated sentence—eg, "no further follow-up is necessary"). Using 532 reports annotated by three board-certified radiologists (including author MG) as the ground truth, the detection algorithm was evaluated to have 93.2% positive predictive value (95% confidence interval [CI]: 89.8%-94.5%), 99.5% negative predictive value (95% CI: 98.4%-99.9%), and 97.9% accuracy (95% CI: 96.2%-98.5%) [15]. The algorithm was subsequently improved based on detection errors identified in the test set so that 100% accuracy was achieved on the annotated data set.

Previous Work: Follow-up Matching

To build a system for automatic tracking and auditing of examinations that have been followed up as a result of follow-up recommendations, we developed algorithms for automated matching of imaging recommendations to subsequently performed examinations for the same