Text Parsing-Based Identification of Patients with Poor Glaucoma Medication Adherence in the Electronic Health Record

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• PURPOSE: To assess the feasibility of automated text parsing screening of physician notes in the electronic health record (EHR) to identify glaucoma patients with poor medication compliance.

• DESIGN: Cross-sectional study.

• METHODS: An automated EHR extraction identified a cohort of patients at the University of Michigan with a diagnosis of glaucoma, ≥40 years old, taking ≥1 glaucoma medication, and having no cognitive impairment. Self-reported medication adherence was assessed with 2 validated instruments: the Chang scale and the Morisky medication adherence scale. In tandem, a text parsing tool that abstracted data from the EHR was used to search for combinations of the following words in patient visit notes: "not," "non," "n't," "no," or "poor" accompanied by "adherence," "adherent, "adhering," "compliance," "compliant," or "complying." The proportion of patients with self-reported poor adherence was compared between the EHR extraction and text parsing identification using a Fisher exact test.

• RESULTS: Among 736 participants, 20.0% (n = 147) self-reported poor adherence and 6.1% (n = 45) had EHR documentation of poor adherence ($P < .0001$). Using text parsing as a pre-screening tool, 22 of the 45 patients (48.9%) with non-adherence identified by text parsing also self-reported poor medication adherence compared to the 20.0% by self-report overall ($P < .0001$).

• CONCLUSIONS: Text parsing physician notes to identify patients' noncompliance to their medications identified a larger proportion of patients who then self-reported poor medication adherence than an automated EHR pull alone but was limited by the small number of patients identified. Optimizing the documentation of medication adherence would maximize the utility of this automated approach to identify medication noncompliance. (Am J Ophthalmol 2021;222:54–59.

GLAUCOMA IS A DISEASE THAT DAMAGES THE OPtic nerve and causes irreversible vision loss. Glaucoma occurs in 7.4%-11.5% of whites over 75 years of age and 17.8%-28.5% of blacks over 75 years of age, metrics projected to increase dramatically in the coming decades.[1] For many patients, vision is initially lost so slowly that people are essentially asymptomatic for years until more serious vision loss sets in. Effective treatments for glaucoma exist, although a serious disconnect is often observed between treatment plans communicated by ophthalmologists and how well patients follow those plans, as up to 80% of glaucoma patients do not follow prescribed medication regimens.[2–4] Poor adherence to glaucoma medication is associated with disease progression.[5] Additionally, poor medication adherence is an issue that is present in every field of medicine. Poor adherence can lead to worse health outcomes, increased hospitalizations, and excess health care costs.[6] The National Pharmaceutical Council reports that failure to adhere to medication regimens results in up to $100 billion in excess health care and productivity costs, including $8.5 billion dollars in patient spending due to unnecessary hospital visits.[7]

It is important to be able to identify patients who have behaviors associated with negative health consequences so that they can be given additional support to improve outcomes or alter the patient's therapy. For instance, use of tobacco is assessed and made evident in the social history section of the electronic health record (EHR), so that health care professionals can encourage smoking cessation and offer support for this important behavior change. Similarly, tobacco and substance abuse have billing codes that can help providers identify patients who may benefit from extra support. However, there is no easy way to identify people who are poorly adherent to their medications in the EHR. Medication refill data are not generally available to health care providers in real time, and it is very time consuming to obtain this information by calling the pharmacy. Many patients want to please their health care provider and may not volunteer that they miss doses of their

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medication.[8] Most eye care providers do not systematically ask about use of eye drops, and patients may not volunteer the information, so there is a paucity of data available to aid in deciding who may benefit from additional disease self-management support.[9,10] If physicians do discuss medication adherence, it is not documented as a discrete data element, but rather as a part of the eye care provider's progress note in the EHR.

The aim of this study was to assess whether text parsing of the eye care provider's progress note in the EHR could identify patients who are nonadherent to their glaucoma medications compared to identification by self-report.

METHODS

THIS STUDY WAS APPROVED BY THE UNIVERSITY OF MICHIgan Institutional Review Board and adhered to the Tenets of the Declaration of Helsinki. The University of Michigan EHR was queried to identify patients for recruitment to a larger study assessing the impact of a glaucoma coaching program on medication adherence (Support, Educate, Empower [SEE] Personalized Glaucoma Coaching Pilot Study] NCT03159247). The study included patients who received ophthalmic care at the University of Michigan between August 2012 and October 2017, had a diagnosis of glaucoma, were suspected of having glaucoma, or had ocular hypertension by ICD-9 code; or were ≥40 years old and had ≥1 prescribed glaucoma medications.[8] Patients were excluded from the study if a manual chart review identified that they had severe mental illness, cognitive impairment, did not speak English, or were deceased.[11] All potentially eligible participants were called to determine study interest and, if interested, self-reported adherence to glaucoma medications. Two validated surveys were administered to assess self-reported medication adherence over the phone, the 8-item Morisky Medication Adherence Scale (MMAS) and the Chang Adherence Assessment Tool.[12–15] The MMAS contains 8 questions asking about medication taking behaviors and is scored on a scale of 0-8, with lower scores indicating worse adherence. The Chang tool contains 1 item which asks patients to estimate the percentage of eye drops they took correctly over the past month.[12–15] Patients who scored ≤6 points on the MMAS and reported taking less than 95% of their eye drops for the past month were considered "non-adherent."[12,15]

Text parsing was used to identify participants that had any form of nonadherence documented in the EHR note at any eye visit in their history. Nonadherence was defined as any combination of the following words in the free text portion of the physician note in the EHR: "not," "non," "n't (the negative contraction)," "no," or "poor" accompanied by "adherence," "adherent," "adhering," "compliance," "compliant," or "complying." References to these terms were searched with and without hyphenation, no spaces, and double spaces between words. Patients in whom text parsing did not identify terms consistent with noncompliance were categorized as adherent. Text parsing was performed using R version 3.6.2 software (R Foundation, Vienna, AU).

Characteristics of the participant sample were summarized with descriptive statistics including means, standard deviations (SD), frequencies, and percentages. The χ^2, Student *t*-, and Wilcoxon tests were performed to test for group differences. Identification of nonadherent patients was compared between self-report and text-parsing methods. The rate of nonadherence identified by self-report (the number of participants who were "nonadherent" on both surveys of self-report divided by the total number of participants screened) and the rate of nonadherence identified through text parsing (the number of participants text parsing found nonadherence documented in the EHR divided by the total number of participants screened). Then the rate of nonadherence was calculated when first using text parsing as a pre-screening tool (the number of participants text parsing found non-adherence in the physician EHR note and who were "nonadherent" on both surveys of self-report divided by the total number of patients where text parsing identified non-adherence in the EHR notes). A χ^2 test was used to compare the rates of identifying nonadherent subjects. Second, agreement was assessed between the 2 methods with respect to identifying nonadherent patients. Discordance of adherence status between self-report and text parsing the EHR was tested by using the McNemar test. Statistical analyses were performed using SAS version 9.4 software (SAS Institute, Cary, North Carolina, USA).

RESULTS

WE IDENTIFIED 3,996 PATIENTS IN THE EHR WHO WERE OVER the age of 40, had a diagnosis of glaucoma, and were taking at least 1 glaucoma medication. There were 736 participants who met eligibility criteria and were contacted by phone (Figure). Table 1 displays demographic information of the participant sample overall and by adherence status. Overall, participants were on average 68.6 years old (±10.4 years); 54.2% were male; and 77.5% were white. The average number of progress notes per participant in the EHR was 17.6 ± 12.6 with a range of 1-97, covering an average of 4.0 years (±1.5 years; range = 0.03-5.2 years). The average number of years between the date of nonadherence identification in the EHR visit notes and the date patients were surveyed about adherence was 1.4 ± 1.4 years. There were no significant differences between patients who were identified as nonadherent and those who were adherent as determined by text parsing the EHR documentation with respect to years of follow-up or number of

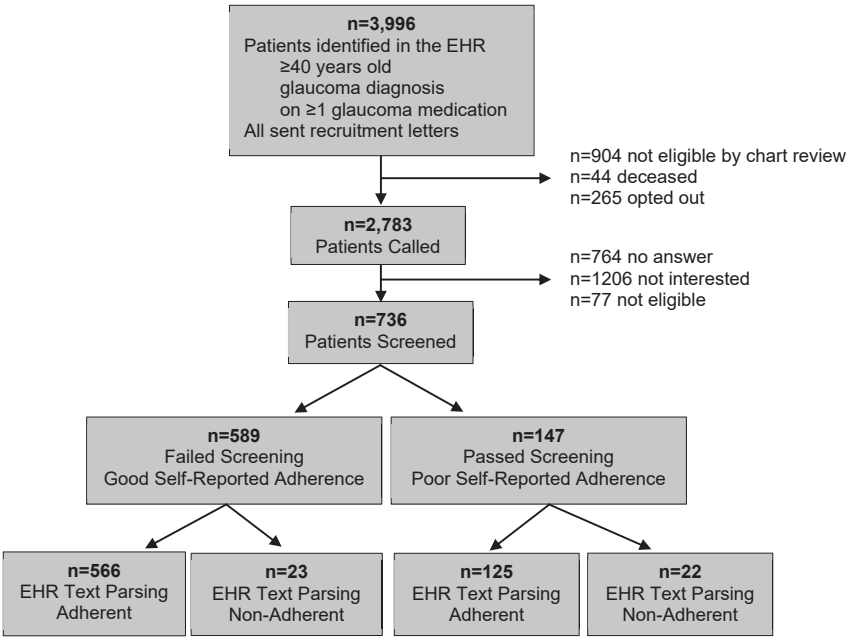

FIGURE. Results of self-reported adherence and EHR text parsing. The figure shows the method used in this study to determine self-reported adherence to glaucoma medication and the results of patient medication adherence classification in health care provider notes in the EHR. EHR = electronic health record.

progress notes ($P = .919$ and $P = .984$, respectively). Of the 736 participants, Table 2 shows that 20.0% (n = 147) self-reported medication nonadherence on both the Morisky and the Chang scales, whereas text parsing identified just 6.1% of patients (n = 45) as nonadherent ($P < .0001$). Of the 45 patients who were nonadherent identified by text parsing the EHR, 22 patients (48.9%) also self-reported poor medication adherence. Thus, 48.9% of EHR pre-screened patients would have screened into the larger study compared to the 20.0% who screened in solely by self-report ($P < .0001$). There was agreement in adherence status between self-report and text parsing in 79.9% of patients (588 of 736 patients), including 566 patients adherent by both methods and 22 nonadherent by both methods. There were 125 of 736 patients (17.0%) who had poor adherence by self-report but when text parsing found no indication of nonadherence, and 23 of 736 patients (3.1%) who self-reported good adherence but had poor adherence identified by text parsing ($P < .0001$).

DISCUSSION

ALTHOUGH TEXT PARSING HAD A LOWER OVERALL RATE OF identifying glaucoma patients with poor medication adherence than surveying all patients, when used as a prescreening tool, text parsing demonstrated more than double the rate of identifying poor medication adherence among glaucoma patients compared to surveying all patients. Text parsing first to identify patients more likely to screen as non-adherent on survey measurements, as opposed to screening all patients using self-report surveys, could serve as a much less resource-intensive way of identifying patients with poor glaucoma medication adherence. Text parsing could represent an automated way to identify glaucoma patients who need additional self-management support to improve their outcomes from glaucoma. However, the small overall number of participants with poor adherence identified by text parsing limits its clinical utility: only 45 patients were identified as poorly adherent by text parsing of which 22 also self-reported poor adherence, compared to 147 patients identified as poorly adherent by calling all glaucoma patients and screening via surveys alone. An important limitation of text parsing is that it can only identify nonadherence if the provider comments on it in the EHR. The lack of commentary on medication adherence by health care providers greatly limited the utility of text parsing in our sample.

Certain behaviors, such as drug, tobacco, and alcohol abuse, are well-documented within the EHR through discrete data elements with checkboxes to remind health care providers to input these data. This makes this behavioral data easily accessible for physicians and researchers. In contrast, medication adherence is a behavior that is poorly documented and difficult to quantify, as there is no billing code to identify poor medication adherence. The inclusion of a discrete data element, like a check box system, would remind providers to assess medication adherence at each encounter and enable automated identification and

TABLE 1. Demographic Characteristics

Demographics	Overall (N = 736)	EHR Text Parsing Adherent (n = 691)	EHR Text Parsing Nonadherent (n = 45)	*P* Value[a]	Self-Reported Surveys Adherent (n = 589)	Self-Reported Surveys Nonadherent (n = 147)	*P* Value[a]
Mean ± SD age	68.6 ± 10.4	68.7 ± 10.4	65.6 ± 9.9	.061	69.5 ± 10.0	64.5 ± 11.0	<.001
Sex							
n-missing	3	1	2	.823	0	3	.093
Males	397 (54.2)	317 (45.9)	19 (44.2)		261 (44.3)	75 (52.1)	
Females	336 (45.8)	373 (54.1)	24 (55.8)		328 (55.7)	69 (47.9)	
Race							
n-missing	9	7	2	<.001	4	5	<.001
White	564 (77.5)	546 (79.8)	18 (41.9)		474 (81.0)	90 (63.4)	
Black	125 (17.2)	102 (14.9)	2 (4.6)		86 (14.7)	39 (27.5)	
Other	38 (5.2)	36 (5.3)	23 (53.5)		25 (4.3)	13 (9.2)	
Glaucoma severity worse eye							
n-missing	88	85	3	.291	66	22	.485
Suspect	66 (10.2)	64 (10.6)	2 (4.8)		53 (10.1)	13 (10.4)	
Mild	143 (22.1)	136 (22.4)	7 (16.7)		118 (22.6)	25 (20.0)	
Moderate	180 (27.8)	169 (27.9)	11 (26.2)		150 (28.7)	30 (24.0)	
Severe	259 (40.0)	237 (39.1)	22 (52.4)		202 (38.6)	57 (45.6)	
Mean ± SD number of progress notes	17.6 ± 12.6	17.5 ± 12.8	17.6 ± 9.3	.984	18.0 ± 12.5	15.8 ± 12.6	.053
Mean ± SD y of follow-up	4.0 ± 1.4	4.0 ± 1.4	4.0 ± 1.4	.919	4.1 ± 1.4	3.7 ± 1.6	.012

EHR = electronic health record; SD = standard deviation.

Values are mean ± SD or n (%).

The table details the participant demographics of this study, stratified by age, sex, race, glaucoma severity, number of progress notes in the EHR, and years of follow-up with their condition.

[a]A χ^2 test was performed in all categorical variables. *t*-Tests were performed for all continuous variables, except for years of follow-up where a Wilcoxon rank sum test was performed.

TABLE 2. Contingency Table of Adherence Status by Self-Report and EHR Documentation

	Self-Report		
EHR Documentation- Text Parsing	Adherent	Nonadherent	Total
Adherent	566	125	691
Nonadherent	23	22	45
Total	589	147	736

EHR = electronic health record.
Values are absolute numbers. McNemar test $P < .0001$
The table compares adherence to glaucoma medication, classified as patient self-report and health care provider notes in the electronic health record.

documentation of poor adherence in the notes section of the EHR. This may lead to the development of more nuanced text parsing queries to identify and address the unique barriers each patient faces to adherence.[16] Other potential options for supervising medication adherence exist. If pharmacies reciprocate e-prescriptions sent to them from the EHR with a notification of medication fill, then health care teams can be notified and be able to intervene if patients do not fill their scripts. Another option to assess adherence would be to record patient's self-report of their medication adherence as recommended by the National Academies of Science, Engineering, and Medicine.[17] However, the limit to self-report is that there is a bias toward under-reporting poor adherence, whereas automated metrics may provide higher accuracy.[18] As a result of this bias, even with the use of validated surveys, the accuracy of adherence levels by self-report by patients in this study cannot be verified.

Identifying patients who are not adherent to taking medication to control their chronic conditions is critical because poor medication adherence has severe consequences. Poor medication adherence is prevalent among patients with chronic conditions because the benefits of medication are less acutely apparent, leading them to question both the benefits and efficacy of the medication.[19] For glaucoma patients, nonadherence to medication was shown to be associated with progressive disease and vision loss.[20,21] For patients with both chronic obstructive pulmonary disease and heart failure, 2 common chronic conditions, poor adherence to medication is associated with a significantly increased risk of both admission to the hospital and death.[22,23] Providing an avenue to efficiently identify patients who are nonadherent to their prescribed medications, the gap in communication between health care providers and patients can be bridged to provide improved chronic disease self-management support.

Text parsing could be used in the recruitment phase of clinical trials to identify patients with poor medication adherence. Efficient strategies for identifying and recruiting patients for behavioral clinical studies are critical because an inability to effectively recruit patients results in too few patients for analysis, 45% of all study delays, and sometimes broadening the inclusion criteria, which all reduce the validity of the study results.[24,25] Text parsing could improve the efficiency of the recruitment phase of studies testing interventions to improve medication adherence, allowing results to be obtained in a more efficient manner.[26] As text parsing does not take into consideration misspelling of words, the use of natural language processing may be a useful next step in identifying even more nonadherent patients from EHR documentation. A limitation to this study was that text parsing was used to mine the entire EHR record of a patient and thus could have identified nonadherence years before the self-reported adherence was documented. In addition, these data were collected from only 1 academic center, which limits its generalizability.

As big data, supported by methods such as text parsing, continues to improve health care quality, it will be important to develop a system where patient adherence behavior is documented consistently.[27] This would facilitate the automated identification of patients who would benefit from additional support to improve their glaucoma self-management and medication adherence.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

MOHAMMED S. HAMID: INVESTIGATION, WRITING - ORIGinal draft. **Autumn Valicevic:** Methodology, Formal analysis, Data curation, Writing - review & editing. **Brianne Brenneman:** Investigation, Writing - original draft. **Leslie M. Niziol:** Conceptualization, Methodology, Formal analysis, Data curation, Writing - review & editing. **Joshua D. Stein:** Methodology, Data curation, Writing - review & editing. **Paula Anne Newman-Casey:** Resources, Methodology, Writing - original draft, Supervision, Project administration, Funding acquisition.

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