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Automated extraction of incidental adrenal nodules from electronic health records

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ABSTRACT

Background: Many adrenal incidentalomas do not undergo appropriate biochemical testing and complete imaging characterization to assess for hormone hypersecretion and malignancy. With the growing availability of clinical narratives in the electronic medical record, automated surveillance using advanced data analytic techniques may represent a promising method to improve management.

Methods: A data provisioning process using a series of structured query language scripts was used to abstract all chest and abdominal computed tomography and magnetic resonance imaging reports from an academic health care system in 2018. The narratives and impressions were queried for key text relating to the identification of adrenal incidentalomas. Patients with a history of extra-adrenal malignancy undergoing staging or surveillance imaging were excluded. The prevalence and radiographic characteristics were analyzed. Patients with adrenal incidentalomas newly identified in 2018 were assessed for biochemical testing and nodule stability through August 2021.

Results: Of 36,618 patients queried, 8,557 were excluded owing to a history of extra-adrenal malignancy. Data from 447 patients were flagged by the structured query language scripts and electronically abstracted. On internal validation, 307/447 (69%) patients were correctly identified as having adrenal nodules (1.1% overall prevalence). The median patient age was 67 years, and 56% were female. The median nodule size was 1.7 (IQR 1.3–2.5) cm, 9% were bilateral, and 63% were low density (unenhanced Hounsfield units <10). Adrenal carcinoma was identified in 10 patients. In 2018, 121 patients were diagnosed with a new adrenal incidentaloma. Of 32 (27%) patients who had follow-up imaging at a median of 1.9 years, 97% of nodules were stable in size. Biochemical testing was performed in 53 patients (44%), of which 31 (26%) had complete hormonal assessment; 14 (26%) were functional nodules: 7 aldosterone-secreting, 4 cortisol-secreting, and 3 pheochromocytoma.

Conclusion: Only one-fourth of patients received appropriate biochemical testing after incidental diagnosis of an adrenal nodule, and most nodules with indeterminate imaging characteristics did not undergo follow-up imaging. Advanced data analytic techniques on electronic imaging reports may aid in the clinical identification and improved management of patients with adrenal incidentalomas.

Introduction

An incidental adrenal nodule (ie, incidentaloma) is an adrenal lesion identified on imaging performed for reasons other than the evaluation of suspected adrenal disease or a known extra-adrenal malignancy.[1] The prevalence is 1% to 6% among adults and it is rising with the increased use and sensitivity of imaging.[1–3]

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Although most incidentalomas are nonfunctioning and benign, approximately 1% to 7% are catecholamine-secreting (pheochromocytomas), 4% to 12% are cortisol-secreting, 1% to 2.5% are aldosterone-secreting (aldosteronomas), and up to 4% to 13% are primary adrenal cancers or metastases depending on the size of the nodule and indication for the imaging study.[1,3–7]

To assess for malignancy or hormone hypersecretion, guidelines recommend that all patients with a newly discovered adrenal incidentaloma undergo further evaluation with biochemical testing and follow-up imaging depending on the imaging characteristics of the lesion.[1,7–9] Complete biochemical evaluation includes cortisol and catecholamines, with the aldosterone and renin level added if the patient has hypertension. Specifically, serum cortisol levels ≥50 nmol/L (1.8 μg/dL) after a 1 mg overnight dexamethasone suppression test is considered cortisol excess, and metanephrine or normetanephrine values >2 times the reference range suggests catecholamine excess.[7] Additional/interval imaging is warranted if the lesion has suspicious features, such as high Hounsfield units (HU) on an unenhanced computed tomography (CT). Previous studies have generally reported poor compliance with guidelines, with a range of 9% to 49% of patients receiving hormonal evaluation and 15% to 76% receiving further imaging.[10–15] The underdetection of functional adrenal nodules may contribute to the development of potentially reversable comorbidities including hypertension, diabetes, osteoporosis, dyslipidemia, and cardiovascular complications.[5,16–19]

With the implementation of the electronic health record (EHR) in modern health systems, automated surveillance and alerts have made it easier and less time-intensive to identify results that require further intervention. Natural language processing (NLP) has previously been explored for the improved surveillance of postoperative complications and surgical diagnoses within the EHR.[20–24] To our knowledge, no prior studies have used advanced data analytic tools to aid in the identification and management of adrenal incidentalomas. Thus, we developed a data provisioning process to retrospectively identify incidentalomas from within electronic radiology reports. The objectives of our study were (1) to measure the prevalence and appropriateness of hormonal evaluation and (2) to determine the feasibility of prospective automated surveillance to initiate appropriate management and follow-up among a diverse population of patients at a tertiary medical center.

Methods

Study population and data source

The study population was derived from the EHR system of University of California Los Angeles (UCLA) Health, a large academic health care center with an extensive community clinic network. UCLA Health covers approximately 3,500 square miles within the Los Angeles metropolitan area and serves >1 million patients per year.

A data provisioning process using a series of structured query language (SQL) scripts was used to abstract all chest and abdominal CT and abdominal magnetic resonance imaging (MRI) reports between January 1, 2018, and December 31, 2018. We included chest imaging after a focus-group discussion with radiologists at our institution determined that the adrenal glands are consistently seen and reported with this imaging type. The SQL process was limited to the data extraction portion of the study and was distinct from NLP in that it did not take part in a case review portion or evaluation to determine if the patient truly had an adrenal nodule or not. This study included a single cohort with a subgroup analysis of patients with newly identified adrenal nodules discovered in 2018.

The imaging narratives and impressions were queried via the SQL for key text relating to the identification of adrenal incidentalomas. The reports that contained the following key words were flagged for inclusion: “incidental lesion,” “adrenal mass,” “adrenal adenoma,” “adrenal nodule,” “incidentaloma,” and “indeterminate nodule”. All reports with the following text were flagged for exclusion: “adrenals: unremarkable,” “adrenal glands and kidneys: unremarkable,” and “adrenals: the adrenal glands are normal.” These phrases were selected based on commonly used text within UCLA Health radiology reports when no adrenal abnormalities were present. The presence of an adrenal nodule was determined by 2 coauthors who served as human annotators. When discrepancies were encountered, the case was reviewed by the principal investigator of the study.

After the initial search flagged a high percentage of reports without adrenal nodules, the SQL was revised to additionally only include narrative reports that contained the word “adrenal” (Figure 1). This was largely a result of chest imaging reports that identified indeterminate/incidental pulmonary nodules but did not report on the adrenal glands. If an imaging report was flagged for both key inclusion and exclusion text, the patient was excluded from data abstraction. The UCLA institutional review board reviewed and approved this study.

Patients with a history of extra-adrenal malignancy undergoing staging or surveillance imaging and those with suspected adrenal pathology were excluded, as these do not represent adrenal incidentalomas. Further, we excluded all patients with adrenal gland thickening without a discrete nodule described on the radiology report. Additional data were abstracted including patient demographics (eg, age, sex, race, and ethnicity), comorbidities (eg, hypertension, type 2 diabetes mellitus, osteoporosis, and hypokalemia), radiographic findings (eg, nodule size [cm], HU, bilaterality), and biochemical lab evaluation (eg, potassium, adrenocorticotropic hormone [ACTH], catecholamines [eg, metanephrine or normetanephrine], plasma aldosterone, plasma renin activity, cortisol, and dehydroepiandrosterone sulfate [DHEAS]). In patients with new adrenal nodules, we also abstracted and reviewed all subsequent imaging reports from January 1, 2019 to August 31, 2021 to determine nodule stability. All data were abstracted in a deidentified manner.

We considered a diagnosis of pheochromocytoma when metanephrine or normetanephrine values were >2 times the reference range. Hyperaldosteronism was considered to be a plasma aldosterone-to-renin ratio (ARR) >20 and plasma aldosterone concentration >10 ng/dL, whereas those with cortisol-secreting tumors had elevated serum or salivary cortisol or 24-hour urinary cortisol and suppressed ACTH or DHEAS, when available. The laboratory reference ranges are specific to our institution’s laboratory. A complete biochemical workup consisted of cortisol and metanephrine evaluation, with the addition of ARR for patients with hypertension based on the 2002 National Institute of Health consensus statement and the 2009 American Association of Endocrine Surgeons/American Association of Clinical Endocrinologists guidelines.[8,9]

Study outcomes

The primary outcomes included the frequency of partial and complete biochemical evaluation to assess for hormone hypersecretion among patients with adrenal incidentalomas newly identified in 2018 and the presence of functional adrenal nodules. This was determined in this subset of patients because those with nodules identified in previous years (determined by imaging reports of adrenal nodule stability or a known nodule) may have

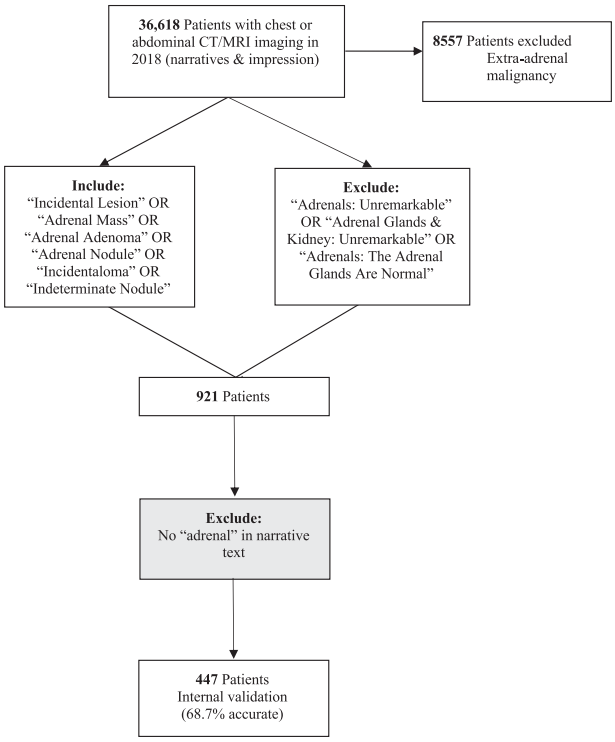

Figure 1. Structured query language script search strategy to identify patients with adrenal nodules. Initial data abstraction flagged 921 patients. After the exclusion of patients with radiology reports in which the narrative did not contain the word "adrenal," the final search strategy flagged 447 patients. *CT*, computed tomography; *MRI*, magnetic resonance imaging.

already undergone workup, which our deidentified data extraction (from Jan 2018 to Aug 2021) was unable to account for.

Additionally, our study described the prevalence and the radiographic characteristics of incidental adrenal nodules. Further outcomes included nodule stability on interval imaging (considered to be <0.5 cm of growth >90 days from initial assessment), treatment with adrenalectomy, and the prevalence of adrenal cortical carcinoma.

Statistical analysis

All data were electronically abstracted into Unified Learning Environment for Analytics & Data, a secure, cloud-based, virtual environment that allows data visualization and analysis.[25] We generated descriptive statistics for demographic and clinical variables that characterize the study population of patients with new and known incidental adrenal nodules. The continuous variables were described by median and IQR, whereas the categorical variables were represented by frequency and proportion. We used the Fisher exact test to compare the categorical variables and the Wilcoxon rank-sum test to the compare continuous variables among patients with new adrenal nodules who underwent biochemical assessment and those who did not. All tests were 2-sided, and all analyses were performed in R (R Foundation for Statistical Computing, Vienna, Austria) within the Unified Learning Environment for Analytics & Data environment.

Results

The study cohort consisted of 36,618 patients, of which 8,557 were excluded owing to a history of extra-adrenal malignancy or suspected adrenal pathology (Figure 1). Data from 447 patients were flagged by the SQL and electronically abstracted. On internal validation, 307/447 (69%) patients were correctly identified as having adrenal nodules (1.1% overall prevalence).

Patient and nodule characteristics

Patients with adrenal nodules were a median (IQR) age of 67 (60–76) years, 56% were female, and 65% White race. Of these, 89% of patients were >50 years of age, and 76% were >60 years of age. The median (IQR) nodule size was 1.7 (1.3–2.5) cm, and 27 (9%) patients had bilateral lesions. Most patients had dominant nodules between 1 and 4 cm (87.2%), whereas 15 (5.6%) nodules were ≥4 cm (Table I, which excludes the 10 patients with adrenal cortical carcinoma).

Among patients with complete imaging characterization (n = 252, 85%), benign adrenal adenomas were suspected in 158 patients (62.7%) based on low-density nodules (HU <10 on unenhanced CT, homogenous, or with signal loss on MRI), whereas 78 (31%) were considered indeterminate. Myelolipoma was reported in 9 patients (3.6%) based on the presence of macroscopic fat, 4 nodules (1.6%) were described as hyperintense/hyper-enhancing, and 2 nodules (0.8%) were suspected hematomas. Adrenal carcinoma was identified in 10 patients (3.3%), of which 8 (80%) underwent adrenalectomy. Two patients did not undergo resection due to metastatic/unresectable disease. Overall, 27 (8.8%) patients underwent adrenalectomy.

Newly identified adrenal nodules (2018)

In 2018, 121 patients were found to have a new incidental adrenal nodule. The demographics were similar to the overall cohort; patients had a median (IQR) age of 67 (60–75), 50% were female, and 69% were White. Most had dominant nodules between 1 and 4 cm (92, 91.1%), whereas 3 (3.0%) patients had dominant nodules ≥4 cm.

Interval imaging was performed in 32 (26.7%) of these patients, of which 14 (43.8%) had studies performed specifically for the indication of adrenal nodule follow-up. At a median (IQR) of 1.9 (0.9–2.5) years from initial nodule characterization, 30 (97%) were stable in size and 1 (3%) enlarged from 1.3 to 2.4 cm in a patient with an adenoma. One patient was suspected to have adrenal gland thickening after a 1.2-cm adenoma was reported on the initial scan (Figure 2). In the 88 patients without interval imaging, 42 (47.7%) were characterized as low-density lesions, 21 (23.9%) were indeterminate, 4 (4.5%) were hyperintense/heterogenous, and 1 (1.1%) was a suspected pheochromocytoma. The remaining 19 patients (21.6%) had adrenal nodules that were uncharacterized. Through the study period, 4 (3.3%) patients with newly identified adrenal nodules in 2018 underwent adrenalectomy: 3 with pheochromocytoma and 1 with elevated ARR.

Hormonal evaluation

Biochemical testing was performed in 53 patients (44%) for the evaluation of hyperaldosteronism, hypercortisolism, or pheochromocytoma, of which 31 (26%) received complete hormonal workup. Aldosterone levels were examined in 32 (26.4%) patients, and ARR was calculated in 29 (90.6%) of those patients. Some form of cortisol evaluation was performed in 47 (38.8%) patients, with 24 (51%) also assessed for ACTH and 8 (6.6%) assessed for DHEAS. Metanephrine or normetanephrine levels were measured in 40 (33.1%) patients.

Patients who did not receive any biochemical testing were more likely to have low-density nodules (HU <10 or signal loss on MRI) compared to those with any hormonal evaluation (39 [70.9%] vs 15 [39.5%], P < .01). No other differences were observed in

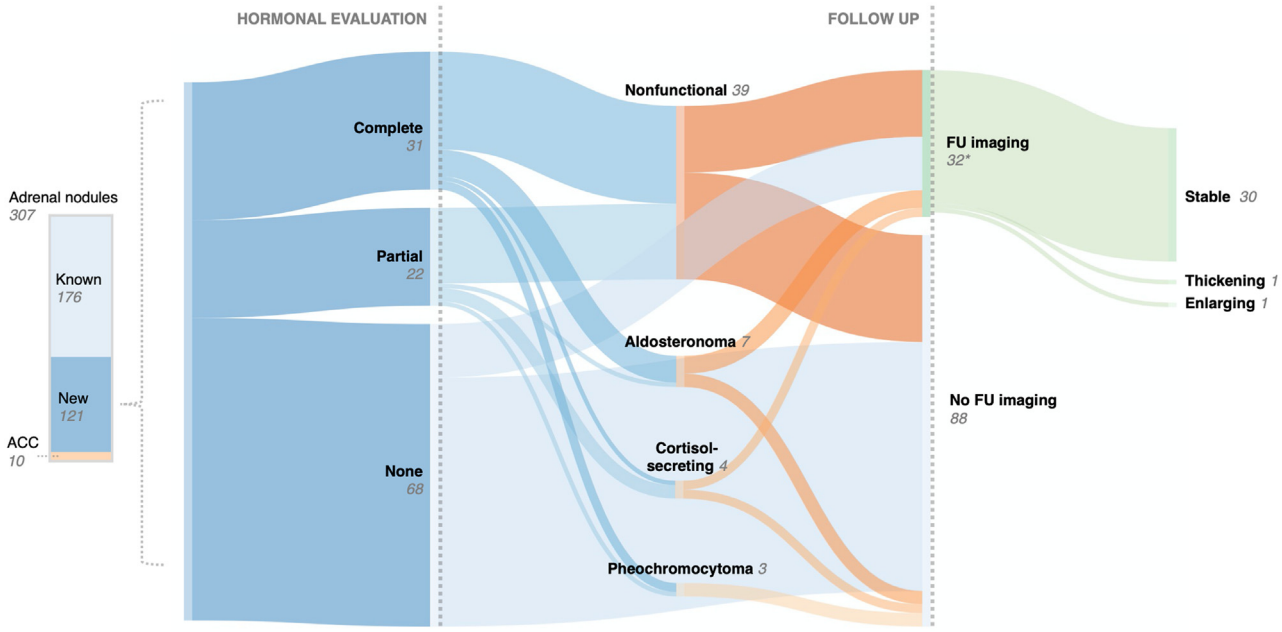

Figure 2. Sankey diagram showing the management of patients with new adrenal incidentalomas in 2018. The Sankey flow diagram includes patients with identified adrenal nodules and stratifies diagnostic management, diagnosis, and follow-up imaging by hormonal evaluation, or lack thereof, in those whom biochemical testing was not performed. A minority of patients received biochemical testing and imaging follow-up after incidental diagnosis of an adrenal nodule. *ACC*, adrenal cortical carcinoma; *FU*, follow-up.

demographic or radiologic characteristics, including age, comorbidities, or nodule size (Table II). Similar findings were observed on analysis of patients who received complete hormonal workup versus those who did not. Notably, in patients without hormonal evaluation, 48.5% had hypertension, 29.4% had diabetes, and 16.2% had osteoporosis (Table II). Of the 53 patients with biochemical workup, 14 (26.4%) had hormonal abnormalities, including 7 with elevated ARR, 4 with hypercortisolism, and 3 with elevated catecholamines (Figure 2).

Patients <50 years of age

Benign, nonfunctional incidentalomas are uncommon in patients <40 years of age. In a subanalysis of the 12 patients (9.9%) <50 years of age with adrenal nodules discovered in 2018, only 4 (33.3%) underwent hormonal evaluation and 3 (25%) had interval imaging. In the 4 patients with biochemical testing, 1 (25%) had hormonal abnormalities, 1 with pheochromocytoma. Among the 3 patients with interval imaging, 2 patients had stable nodules (1 patient with a 1.3-cm adenoma at 16-month follow-up and the other with a 2.4-cm nodule at 6-month follow-up, which was later determined to represent an adrenal metastasis). The third patient experienced adenoma growth from 1.3 cm to 2.4 cm at 3.5 years of follow-up.

Discussion

This study evaluated a data provisioning process using a series of SQL scripts that accurately identified 69% of patients with adrenal nodules undergoing CT or MRI imaging in a 1-year period within a large academic medical center. Excluding patients with a history of extra-adrenal malignancy, the overall prevalence of adrenal nodules in this cohort was 1.1%. Consistent with previous studies,[3,15,26] less than half of patients received any biochemical evaluation. Furthermore, only one-fourth of patients underwent complete guideline-recommended hormonal workup or interval cross-sectional imaging to complete nodule characterization or confirm stability in the cases of indeterminate imaging characteristics.

The guidelines from the American Association of Endocrine Surgeons/American Association of Clinical Endocrinologists and the European Society of Endocrinology recommend that all incidental adrenal nodules receive hormonal evaluation, given the potential of even low-density nodules to produce cortisol or aldosterone.[7,8] In our study, biochemical testing occurred in less than half of patients with newly discovered adrenal nodules and was more likely to occur in those with indeterminate imaging characteristics (HU >10). Although nodules with an attenuation of <10 HU are almost certainly benign,[27] a clinically significant proportion of these may still produce excess hormone,[5,28,29] highlighting a care gap and opportunity for education in optimal incidentaloma management.

Furthermore, our study found that only 26% of patients received complete hormonal evaluation. The low frequency of hormonal evaluation is well characterized in the literature.[10,11,15] In a population-based study of 1,287 patients, 47.0% had some form of hormonal workup with only 15.2% having a complete workup.[3] In single-institution studies, Becker et al demonstrated that of 209 patients, 25% underwent a partial hormonal evaluation with only 18% having a complete guideline-recommended hormonal assessment,[26] whereas Kirsch et al showed even lower rates among 148 patients: 8.8% underwent hormonal evaluation, and 6.4% had complete workup.[10] Recent interventions to address this phenomenon have focused on language use in radiology reports to reduce cognitive overload, an increasing problem in the EHR era.[30] More descriptive language and explicit recommendations have been associated with increased subsequent diagnostic workup and outpatient referrals.[13,31] The inclusion of recommended diagnostic guidelines may also improve rates of testing and follow-up imaging.[12,14,32]

In addition to poor compliance with biochemical assessment, we observed that 46% of patients with initially indeterminate or uncharacterized adrenal nodules did not receive guideline-recommended interval imaging. In the 27% of patients with follow-up imaging, less than half underwent scans performed

Table I
Overall cohort demographics ($n = 297$)

Age, median (IQR), y	68 (60–75)
>50	264 (88.9)
>60	225 (75.8)
Sex, *n* (%)	
Female	166 (55.9)
Race	
White or Caucasian	193 (65.0)
Asian	28 (9.4)
Black or African American	22 (7.4)
Multiracial	4 (1.3)
Other	46 (15.5)
Ethnicity	
Hispanic or Latino	5 (18.9)
Comorbidities	
Hypertension, *n* (%)	169 (57)
Diabetes, *n* (%)	88 (30)
Osteoporosis, *n* (%)	62 (21)
Hypokalemia, *n* (%)	12 (4.0)
BMI, mean (SD)	31.2 (7.5)
Lesion size, median (IQR), cm	1.7 (1.3–2.5)
1–4 cm	232 (87.2)
>4 cm	15 (5.6)
Bilateral lesions, *n* (%)	27 (9)
Radiologic characteristics	
Low density, *n* (%)	158 (63)
Indeterminate, *n* (%)	78 (31)
Myelolipoma, *n* (%)	9 (3.6)
Hyperintense/enhancing, *n* (%)	4 (1.6)
Hematoma, *n* (%)	2 (0.8)

Low-density nodules considered to be mass attenuations of <10 HU, homogenous, or with signal loss on MRI; indeterminate, considered to be mass attenuations >10 HU or described as indeterminate; myelolipoma, based on the presence of macroscopic fat. The demographic data excludes the 10 patients with adrenal cortical carcinoma.
BMI, body mass index; *HU*, Hounsfield units.

Table II
Comparison of clinical variables among patients with and without biochemical evaluation

Clinical variables	Biochemical workup obtained		*P* value
	Yes ($n = 53$)	No ($n = 68$)	
Age, mean (SD)	64.9 (12.2)	68.2 (15.7)	.21
Sex, *n* (%)			1
Female	25 (49.0)	34 (50.0)	
Race			.35
White or Caucasian	39 (76.5)	43 (63.2)	
Asian	5 (9.8)	5 (7.4)	
Black or African American	2 (3.9)	7 (10.3)	
Other	5 (9.8)	11 (16.2)	
Multiple races	0 (0.0)	2 (2.9)	
Ethnicity			.28
Hispanic or Latino	5 (10)	13 (19.4)	
Comorbidities			
Hypertension, *n* (%)	30 (56.6)	33 (48.5)	.46
Diabetes, *n* (%)	12 (22.6)	20 (29.4)	.53
Osteoporosis, *n* (%)	9 (17.0)	11 (16.2)	1
Hypokalemia, *n* (%)	1 (1.9)	4 (5.9)	.38
BMI, mean (SD)	31.5 (8.1)	30.3 (7.0)	.34
Lesion size in cm, mean (SD)	2.2 (1.4)	1.8 (0.9)	.31
Bilateral lesions, *n* (%)	4 (7.7)	8 (11.8)	.55
Low density, *n* (%)	15 (39.5)	39 (70.9)	< .01

Biochemical workup considered to be any biochemical testing evaluation. Low-density nodules considered to be mass attenuations of <10 HU, homogenous, or with signal loss on MRI.
BMI, body mass index; *HU*, Hounsfield units; *MRI*, magnetic resonance imaging.

specifically for adrenal nodule assessment. Taken together, these findings highlighted systems-level opportunities that exist between the observed versus ideal diagnostic management of adrenal incidentalomas.

A multitude of factors may contribute to physicians' failure to work up incidental adrenal nodules. When a benign pathologic diagnosis is suggested in a radiology report, a sense of physician reassurance may result in a lower rate of further workup. Furthermore, clinicians may be unfamiliar or lack awareness of current guidelines, particularly among nonspecialists.[26,33] An adrenal incidentaloma may be overlooked when managing a more acute condition, and labs and imaging studies may be ordered but never completed by the patient.

The ideal management of incidental adrenal nodules may be best achieved by more directly facilitating practice that reflects current clinical guidelines. After the introduction of a dedicated adrenal nodule protocol managed and overseen by trauma physicians at an Australian tertiary medical center, the rate of appropriate management doubled to 48%.[15] With the wide-scale adoption of EHRs, we hypothesized that an opportunity existed to leverage advanced data analytic techniques for the clinical identification and initiation of the management of incidentalomas. Similar interventions have been performed at our institution in the management of primary hyperparathyroidism[34] and are described elsewhere for surveillance of postoperative venous thromboembolism,[20] among other conditions.[22,23,35]

Our study demonstrated that automated search queries and NLP are feasible and may best facilitate prospective real-time identification of incidental adrenal nodules. With consistent and specific language use among radiologists, such as "incidental adrenal nodule," in a specific part of the radiology report, interval search queries or NLP algorithms can flag imaging reports with the key text and trigger clinical alerts. Similarly, automated population of a new adrenal nodule into a patient's "problem list," at the time of diagnosis, could also be flagged. However, with only a 69% accuracy, the current SQL system is not ready for clinical implementation, and improvements in the search strategy and alternatives are being considered. Natural language processing is a more advanced technology specifically designed to recognize clinical concepts and may provide a more robust and sensitive technique to facilitate appropriate management.[36]

The challenges of EHR-based prospective systems should also be acknowledged, including automated alert fatigue and the availability, willingness, and workflow of alerting the appropriate physician to complete the subsequent workup. We have discussed the prospective implementation of this system with endocrinologists at our institution to confirm their willingness and capacity to manage the workup of these patients. Based on our data, we expect an initiation of recommended follow-up in 10 patients monthly (121 new adrenal nodule patients in a 1-year period). Such EHR-based interventions have the potential to capture salient patient information (eg, adrenal adenoma found during CT scan of a trauma patient) and to alert the appropriate physician to complete the appropriate workup.

Our study had several limitations. This was a retrospective cohort design study that relied on medical record coding for most data extraction. We were unable to assess whether patients received biochemical evaluation or follow-up imaging at different institutions because data were only abstracted from within our institution, and abstraction was performed in a deidentified manner. Likewise, the deidentified data abstraction from 2018 to present precluded us from determining the appropriateness of biochemical evaluation in patients with adrenal nodules diagnosed before 2018 and rereading or reanalyzing reports without HU density measurements or MRI signal intensity reported before inclusion in our study, though the significant proportion of uncharacterized adrenal nodules further demonstrated the observed care

gap in optimal incidentaloma management. Furthermore, the diagnostic criteria for, and the management of, mild autonomous cortisol excess are uncertain.

Using our sets of key words, our SQL system accurately identified only 69% of patients abstracted. Several pathologies and imaging indications led to inaccurate flagging of imaging reports, including patients with indeterminate/incidental pulmonary nodules, adrenal indications for imaging (eg, "history of adrenal adenoma" or "adrenal mass protocol") with no subsequent adrenal nodule found, liver nodules/lesions, and, finally, when no adrenal nodule was reported in a way different than as described in our exclusion criteria (eg, "no adrenal mass," "no adrenal nodule," "no adrenal lesion"). Testing further iterations of the SQL with other key words may have identified more patients with adrenal nodules and improved the sensitivity and accuracy of our abstraction technique. However, this was outside the scope of our study due to the availability of and limitations in the information technology resources. Our aim was to demonstrate the feasibility of this process and to validate the future prospective use of advanced data analytics in the management of adrenal nodule patients.

In conclusion, only one-fourth of patients received appropriate biochemical testing after incidental diagnosis of an adrenal nodule, and most nodules with indeterminate imaging characteristics did not have follow-up imaging. Advanced data analytic techniques on electronic imaging reports may aid in the clinical identification and improved management of patients with adrenal incidentalomas.

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Conflict of interest/Disclosure

The authors have no conflicts of interests or disclosures to report.

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Discussion

Dr David Schneider (Madison, WI): I am wondering about your data provisioning system. It seems to me that you probably were not very satisfied with the 69% capture rate. There are existing natural language processing (NLP) systems where you could use the concept unique identifier, for example, a Systematized Nomenclature of Medicine code for adrenal module. It seems more straightforward than an elaborate structured query language script. Why didn't you take that approach? You're probably missing a significant amount of data that your institution has available.

Dr Max Schumm: Natural language processing was part of our initial discussion when designing this project, but it required quite a bit of expertise, time, and resources, which we were limited by. The NLP systems should be investigated and used by other institutions with the available financial and IT resources. We will be pursuing NLP in the next phase of this project.

Dr Scott Wilhelm (Cleveland, OH): Do you have a sense of how many of these patients have not been screened or have not had further workup? Simply because they know they're sending them to someone who will already do it for them.

Dr Max Schumm: Due to the deidentified nature of this study, we unfortunately could not perform a chart review or dive too much into such granular data. Radiology reports often will recommend endocrinology follow-up or consultation, but in terms of understanding the temporal relationship of biochemical testing or outside hospital follow-up, we were unable to assess for that.

Dr Dawn Elfenbein (Madison, WI): I was wondering if you were able to capture who was the specialist that ordered the exam—was it a PCP or a trauma surgeon? I think sometimes that makes a difference with what happens next. I wonder how many times you captured what the radiologist recommended as the next step.

Dr Max Schumm: Previous studies have found that several factors have a strong association with improved follow-up. For example, follow-up is increased when the radiologist recommends biochemical evaluation, follow-up imaging, or endocrinology referral. Additionally, specific terminology, such as describing the nodule as indeterminate versus benign, also increases workup. Regarding whom ordered the exam, we did not assess for that. However, an interesting finding in the literature is when scans are ordered on an outpatient basis, we see a higher rate of workup, compared to scans ordered while inpatient. I think what it comes down to, really, is ownership of the patient. When imaging is ordered as an outpatient, a clinician is likely following and established with the patient. In contrast, in the inpatient setting, the inpatient team or an ER physician is ordering the scan and then may be signing it out to the next clinician or the patient's primary care provider, and the appropriate follow-up may slip through the cracks.

Dr Mahsa Javid (Charleston, SC): I was going to go a bit further into thoughts about the role of primary care. What do you think is the role of endocrine surgeons and perhaps this society in helping to guide or educate primary care groups in doing this?

Dr Max Schumm: I think a simple solution is to improve physician education on the guideline recommended management of adrenal nodule patients. This is a common sentiment in the literature. Improved education and outreach at the institutional, regional, and even national level, such as grand rounds and society meetings, will help reinforce and disseminate the management guidelines among primary care groups.

Dr Barbra Miller (Columbus, OH): Have you thought about what language the radiologists can include to improve further evaluation of patients? Also, who is going to take care of this increased volume of patients?

Dr Max Schumm: Your question is a very important one. I think it is crucial to have a plan in place and engage the necessary stakeholders before you pursue an initiative like this. We are fortunate that our group has a study coordinator and lab manager who can champion this implementation effort and evaluate and follow these patients. But at institutions where there may be less resources or a similar kind of project champion is unavailable, it may be important to work closely with endocrinology and see if there is an endocrinologist who can actively follow these patients. In circumstances or practices with too much volume, a mid-level provider may be used. With respect to the volume, our study identified 120 new nodules in a 1-year period. So that's about 10 new patients per month. If our study underestimated this value, it is going to be a little more than that. Regardless, it's most important to have a plan in place to guide and sustain this intervention before embarking on this journey.