ORIGINAL ARTICLE

The diagnostic course of sarcoidosis: A population-based study highlighting risk factors for a delay in diagnosis

MILES D HAGNER[1], AARON C MILLER[2,3], SOLANUS DE LA SERNA[1], ALAN T ARAKKAL[3], JOSEPH E CAVANAUGH[3], ALEJANDRO A PEZZULO, NABEEL Y HAMZEH, PHILIP M POLGREEN[1,2], ALICIA K GERKE[1]

[1]Department of Internal Medicine University of Iowa Carver College of Medicine, Iowa City, IA, USA; [2]Department of Epidemiology University of Iowa College of Public Health, Iowa City, IA, USA; [3]Department of Biostatistics University of Iowa College of Public Health, Iowa City, IA, USA.

ABSTRACT

Background and aim: Sarcoidosis is a systemic inflammatory syndrome of unknown cause characterized by granulomas, heterogeneous presentation, and variable clinical course. Diagnosis is often delayed, contributing to patient distress, increased healthcare costs, and potentially worse outcomes. Prior estimates of diagnostic delays rely largely on case-based studies, which may overestimate delays by failing to account for baseline care practices and common alternative diagnoses that may resemble sarcoidosis.

Methods: We conducted a retrospective population-based cohort study to characterize healthcare utilization before a sarcoidosis diagnosis and to identify risk factors associated with a diagnostic delay. Using longitudinal commercial, Medicare, and Medicaid healthcare insurance claims data from 2001-2022, we identified patients with sarcoidosis and evaluated diagnostic delay frequency, time to diagnosis, and potential missed opportunities for diagnosis. Secondary analysis compared diagnostic differences between pulmonary and cutaneous sarcoidosis.

Results: 87,092 sarcoidosis cases were identified, of which 56% experienced at least one healthcare visit with a symptomatically similar diagnosis before sarcoidosis was diagnosed. The mean time to diagnosis was 44 days, defined as the interval between increased baseline healthcare utilization and a sarcoidosis diagnosis. Patients had an average of 2.5 visits prior to sarcoidosis diagnosis that represented potential missed diagnostic opportunities. Pulmonary involvement was associated with longer time to diagnosis and more missed opportunities compared to cutaneous sarcoidosis. Risk factors for delays included obesity, outpatient evaluation, weekend visits, Medicaid insurance, and treatment for symptoms commonly attributable to sarcoidosis. Diagnosis was unaffected by age,

Received: 26 January 2026 | Accepted: 19 February 2026

Correspondence: Alicia K Gerke, MD / University of Iowa Hospitals and Clinics, 200 Hawkins Dr, C33-E-GH, Iowa City, IA 52242 / E-mail: alicia-gerke@uiowa.edu
ORCID: 0000-0002-8333-3403

season, or rural vs urban setting. Within Medicaid, white individuals had the highest risk for a missed diagnostic opportunity, while Black individuals had the lowest.

Conclusions: In this large population-based study, diagnostic delays in sarcoidosis were shorter than previously reported, yet substantial missed opportunities remain. Identifying patient- and system-level risk factors may help reduce delays, prevent disease progression, and improve outcomes in sarcoidosis.

Key words: sarcoidosis, diagnostic delay, diagnostic delay, case-crossover, population-based cohort, epidemiologic methods

Introduction

Sarcoidosis is systemic inflammatory syndrome of unknown cause that is characterized by granulomas, a variable presentation/disease course, and significant diagnostic delays. The majority of sarcoidosis cases involve the lungs (1), but sarcoidosis can also manifest in other organs, including the skin, eyes, and peripheral lymph nodes (2). Symptoms are often nonspecific (e.g., fatigue, shortness of breath, fever, cough). Currently, there is no definitive, diagnostic test for sarcoidosis (3). Its clinical, radiographic, and pathological features can mimic other disorders (e.g. asthma, COPD, tuberculosis or fungal infections, hypersensitivity pneumonitis, or autoimmune diseases) which may lead to diagnostic delays (4) resulting in disease progression, anxiety, and increased healthcare costs (5). Prior research has reported a wide range of estimates for diagnostic delays ranging from 6 to 24 months, with an average of 7.9 months (6). Research by Judson et al. indicates that pulmonary symptoms are linked to longer diagnostic times, and advanced pulmonary sarcoidosis is associated with greater delays compared to early-stage disease (7). Reducing diagnostic delays may help mitigate disease progression and improve patient outcomes (8). However, the wide range in existing estimates along with varying study designs makes it difficult to determine the overall burden of disease attributable to diagnostic delays. Previous studies on diagnostic delays in sarcoidosis have primarily been confined to a single or a small number of institutions or were based on local patient registries (7, 9-11). While these studies provide insights into disease characteristics, outcomes, and patient experiences, they may not be well suited to estimate the incidence of delays at a population level. These prior studies have typically used patient-reported surveys or retrospective chart reviews to infer the timing of symptom onset. Because symptoms of sarcoidosis tend to be non-specific and are often shared with other, more common diseases, these types of study design are susceptible to recall bias or confirmation bias, especially if efforts are not made to account for prior symptoms attributable to other causes. Our study aims to evaluate diagnostic delays using a large database of insurance claims data representing a broad population of commercially insured enrolees in the United States. We use an approach developed to study the incidence of diagnostic delays (12) that specifically controls for a baseline level of expected healthcare utilization when estimating the timing of symptom onset and estimates which symptomatic-visits prior to diagnosis are attributable to the disease of interest.

Study design and Methods

Data source & study population

We conducted a retrospective study utilizing longitudinal insurance claims data from the Merative MarketScan Research Databases, including Commercial/Medicare (2001-2022) and Multi-State Medicaid databases (2014-2021). Study was granted exemption by The University of Iowa Institutional Review Board (IRB201908793). These databases contain data on inpatient, outpatient, and emergency department visits, along with outpatient prescription medications and enrollment information for over 240 million

commercially insured enrollees in the US. Patients with sarcoidosis were identified using the ICD-9-CM diagnosis codes 135 and 321.4 and ICD-10-CM codes D86.XX. We defined the index diagnosis as the healthcare visit during which a patient was first diagnosed with sarcoidosis. The reported range for diagnostic delays in sarcoidosis is from 6 months to two years (13, 14); therefore, to identify the initial sarcoidosis diagnosis, we required patients to be continuously enrolled for at least two years prior to the index sarcoidosis diagnosis. Thus, patients diagnosed with sarcoidosis in the years 2001-2002 were excluded.

Statistical analysis

We define a diagnostic delay as the time interval that exceeds an accepted or reasonable standard between the onset of clinical features (such as signs or symptoms of the disease) and the establishment of the correct (index) diagnosis. We identify *potential* missed diagnostic opportunities based on healthcare visits prior to the index sarcoidosis diagnosis, where signs or symptoms of sarcoidosis were present. True missed opportunities to diagnose sarcoidosis cannot be directly observed. Some signs or symptoms occurring prior to diagnosis (e.g., fatigue, cough, chest pain, rash) may indicate the presence of underlying sarcoidosis or a coincidental disease or condition (e.g., respiratory infection). Thus, to estimate the number of missed opportunities, we utilize a two-step process that has been used in prior investigations, to study diagnostic delays (12, 15). First, we compare the expected trend to the observed pattern of diagnoses, just prior to the index sarcoidosis diagnosis. Second, we utilize a bootstrapping procedure to compute the frequency of missed opportunities and duration of diagnostic delays across individual patients. To identify potential missed diagnostic opportunities, all ICD-9/10-CM diagnosis codes identified during healthcare visits in the months before the index sarcoidosis diagnosis were reviewed for: 1) presence of signs or symptoms compatible with sarcoidosis; 2) tests ordered for illnesses with similar manifestations as sarcoidosis; or 3) diagnoses with similar presentations as sarcoidosis. If these coding features were present, these codes were deemed *clinically plausible* as potential evidence of underlying sarcoidosis. We define this set of ICD codes as *symptomatically similar diagnoses* (SSDs). Table S1 provides the complete set of ICD-9/10-CM codes used to identify potential missed diagnostic opportunities.

Frequency of missed opportunities and duration of diagnostic delays

We used a period of 1-127 days prior to the sarcoidosis diagnosis to identify missed diagnostic opportunities; we refer to this as the *diagnostic opportunity window* – time prior to the sarcoidosis diagnosis where diagnostic opportunities may occur. We identified this time frame of 128 days as the time prior to the index diagnosis when signs and symptoms of sarcoidosis were significantly elevated (see annex for details). We used the 128-730-day period prior to the sarcoidosis diagnosis as the crossover (control) period.

To estimate the expected number of SSD visits, we computed the number of patients with an SSD-associated visit each day during the period of 128-730 days prior to diagnosis. To estimate the expected trend, we fit a cubic time trend for number of days prior to diagnosis with additive effects for day of week. This trend was then extrapolated forward to estimate the expected number of SSD visits during the diagnostic opportunity window (i.e., 1-127 days prior to diagnosis). Finally, we computed the number of likely diagnostic opportunities each day prior to diagnosis as the excess number of SSD visits, defined as the difference between the observed and expected number of SSD visits during the diagnostic opportunity window.

In order to estimate the frequency of missed opportunities and duration of diagnostic delays, a bootstrapping algorithm was used to select which individual SSD-visits represented a missed diagnostic opportunity (12). Specifically, this approach works by randomly drawing which patient visits represented a missed opportunity using the estimated number of missed opportunities (outlined above) each day prior to diagnosis. Using these visits, we then compute various outcome measures of delay, including the number of patients experiencing a missed opportunity, number of missed opportunities each patient experienced, healthcare settings involved in missed opportunities, duration of diagnostic delay, and the risk-factor

models described below. We utilized the uncorrelated algorithm described in Miller et al. 2023 (12). This entire procedure was repeated 10,000 times and confidence bounds were derived using 95% percentile-based intervals.

Risk factors for experiencing a missed opportunity

Three different exploratory analyses were conducted to identify risk factors for missed diagnostic opportunities. First, we estimated a visit-level model to determine whether a patient visit resulted in a missed diagnostic opportunity (assigned a value of 1) or a correct diagnosis (assigned a value of 0). Second, we estimated a patient-level model to assess the risk of a patient experiencing at least one missed opportunity before diagnosis, labeling delayed patients as 1 and non-delayed patients as 0. Finally, we estimated the duration of diagnostic delays for patients with at least one missed opportunity, measuring the time between the first missed opportunity and their index diagnosis. This analysis was also conducted on Medicaid insurance claims, where race demographics are available, to assess the impact of race on missed diagnostic opportunities and delays.

Logistic regression was used for the visit- and patient-level models, and Weibull accelerated failure time regression, with no censoring, for the duration model. The acceleration factor (AF) from the Weibull model indicates the multiplicative effect on delay duration (i.e., survival time) from a one-unit change in covariates, with AF >1 implying increased duration of delay. Each model included patient age (categorized into <18, 18-34, 35-44, 45-54, 55-64, and ≥65 years), sex, obesity, and rurality (defined as the patient having visited a rural healthcare clinic). The visit-level model also included weekend visits as well as the month and year of the visit. The patient-level and delay duration models included month and year of the index diagnosis, and medications prescribed during the diagnostic opportunity window. Treatments evaluated include antacids or proton pump inhibitors (PPIs), antibiotics, antihistamines, cough suppressants, diuretics, inhalers, nasal sprays, and oral steroids. Each model was estimated 10,000 times using bootstrapped patient samples. We present the median of the bootstrapped effect estimates with the 95% confidence intervals (95%CI). All statistical analyses were conducted using the R programming language (12).

Secondary analysis – pulmonary versus cutaneous sarcoidosis

As a secondary analysis we explored the difference between patients with pulmonary versus cutaneous sarcoidosis. For this analysis, we stratified cases by whether a skin biopsy or respiratory procedure (e.g., bronchoscopy) was performed within 30 days of the index sarcoidosis diagnosis. Table S2 summarizes the procedure codes that were used to stratify cases. We then analyzed pulmonary and cutaneous sarcoidosis separately.

Results

We identified 87,092 index cases of sarcoidosis from 2001-2022 among patients continuously enrolled for at least two years prior to diagnosis. Baseline characteristics of the study population are provided in Table 1.

Frequency of missed opportunities

The median age was 54.0 years and 61.5% were female. Most patients were from the Commercial population (79.4%), followed by Medicare (13.5%), and Medicaid (7.1%). In the two years prior to the index sarcoidosis diagnosis, 86,261 (99.1%) patients had at least one healthcare visit for any reason and 81,211 (93.3%) had at least one SSD visit. There were a total of 1,070,892 SSD visit days in the 730-days prior to the index diagnosis. Figure 1(A) depicts the trend in the number of SSD visits over the 730-day period prior to the index sarcoidosis diagnosis, showing a dramatic increase in the frequency of SSD visits that occur in the months preceding diagnosis.

During the 128-day diagnostic opportunity window, there were 367,814 total SSD visit days among 66,455 (76.3%) patients. These visits represent "potential" missed opportunities. Figure 1(B) depicts

Table 1. Baseline characteristics of the study population

Characteristic	Number of Patients (%)
Age at Diagnosis	
<18	1,026 (1.2%)
18-34	6,104 (7.0%)
35-44	13,224 (15.2%)
45-54	24,458 (28.1%)
55-64	28,643 (32.9%)
≥65	13,637 (15.7%)
Mean (SD)	53.2 (13.4)
Median (IQR)	54.0 (16.0)
Sex	
Male	33,547 (38.5%)
Female	53,545 (61.5%)
Database Source	
Commercial	69,108 (79.4%)
Medicare	11,780 (13.5%)
Medicaid	6,204 (7.1%)
Enrollment Time Prior to Index (years)	
≤ 2 years	47 (0.1%)
≤ 3 years	24,658 (28.3%)
> 3 years	62,434 (71.7%)
Mean (SD)	5.4 (3.5)
Median (IQR)	4.2 (3.8)

the expected trend (in red) in SSD-related visits, estimated based on visits during the crossover period from 129-730 days before diagnosis. The estimated number of missed diagnostic opportunities is depicted as the area between the observed line (in black) and the expected trend (in red) during the diagnostic opportunity window (region to the right of the blue line). Figure 2 depicts the distribution of the estimated number of "potential" missed diagnostic opportunities each day prior to the index diagnosis.

From a bootstrapping approach, we estimated that 126,200 (95%CI: 119,214-134,616) of the total SSD visit days during the diagnostic opportunity window represent true missed diagnostic opportunities. Table 2 shows missed diagnostic opportunities by medical setting, where 86.3% (95%CI: 85.8-86.7%) of missed opportunities occurred in an outpatient setting, 15.5% (95%CI: 15.0-16.0) in inpatient settings, 6.3% (95%CI: 6.1-6.4) in ED settings, and 1.0% (95%CI: 0.9-1.1) in observational-stay settings.

Duration of diagnostic delays

The duration and number of missed diagnostic opportunities per individual are reported in Table 3. Approximately 56.1% (95%CI: 54.6-57.6) of patients experienced at least one missed diagnostic opportunity, with an average of 2.59 (95%CI: 2.50-2.69) visits representing missed opportunities and had an average diagnostic delay of 43.79 days (95%CI: 42.18-45.22). About 32.8% (95%CI: 31.2-34.6) had a diagnostic delay of a month or longer, and less than 1% (95%CI: 0.5-1) had delays of four months or longer.

Risk factors for missed opportunity/diagnostic delay

Results of the three exploratory risk factor analyses can be found in Tables S2-S5. Risk factors for missed opportunities included weekend visits (OR: 1.92 [95%CI: 1.85-1.99]), Medicaid insurance (OR 1.27 [95%CI: 1.21-1.33]), and obesity (OR: 1.36 [95%CI: 1.33-1.40]). Obesity was also associated with a higher risk of experiencing a diagnostic delay (OR: 1.50 [95%CI: 1.43-1.57]). Diagnostic delays were longer in those with Medicaid insurance compared to Medicare (AF: 1.12 [95%CI: 1.09-1.16]) and in those with obesity (AF: 1.08 [95%CI: 1.06-1.09]). A statistically significant difference in the odds of a missed opportunity was observed for female vs male sex (OR: 0.97 [95%CI: 0.95-0.99]). Additionally, a slight increased delay duration was observed for female sex (AF: 1.02 [95%CI: 1.01-1.04]). No particular month or season was associated with a missed opportunity, however in all months except January and February patients were more likely to experience a diagnostic delay (OR 1.06-1.15 [95%CI: 1.02-1.25]. Rural settings did not contribute to missed opportunities or delays in diagnosis. Delays were more common in the years after 2004.

Table 4 presents the results from the patient-level and delay duration models for the various treatments of potential symptoms of sarcoidosis. Treatments for sarcoidosis-related symptoms, such as antibiotics,

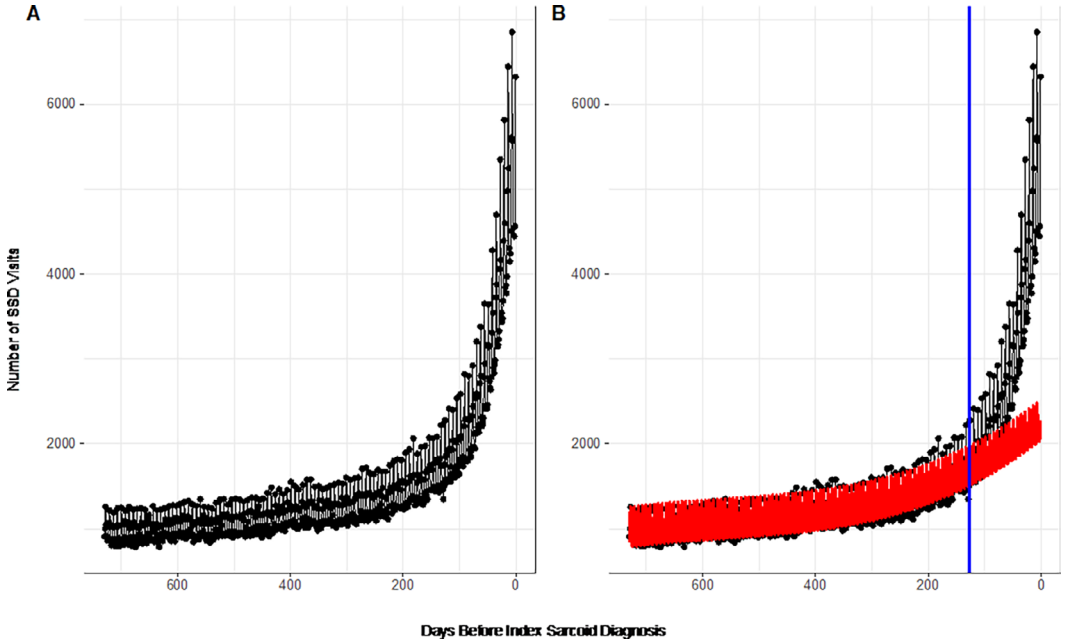

Figure 1. Trends in SSD-related healthcare visits in the 730 days prior to the index sarcoid diagnosis. (A) Raw SSD visit counts for each day prior to the index sarcoid diagnosis. (B) Expected trendline (in red) estimated from visits between 128-730 days prior to the index sarcoid diagnosis, with the estimated change point (in blue) beginning 128 days prior to the index diagnosis, marking the start of the diagnostic opportunity window. *Abbreviation*: SSD=Symptomatically Similar Diagnoses.

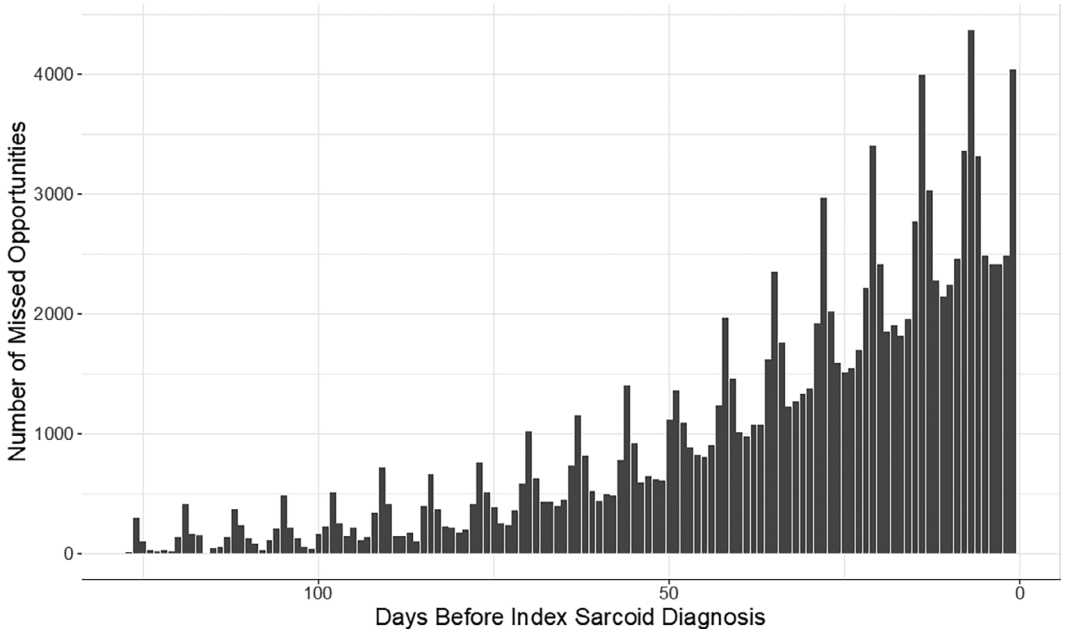

Figure 2. Estimated number of missed diagnostic opportunities each day prior to the index sarcoid diagnosis**.** Estimates are based on the excess number of SSD-associated healthcare visits, computed as the difference between the observed and expected values in Figure 1. *Abbreviation*: SSD=Symptomatically Similar Diagnoses.

Table 2. Index diagnosis visits and simulation results of missed diagnostic opportunities by setting

	Number of Index Visits[a]	*Potential* Missed Opportunities (SSD visit during opportunity window)	Estimated Number of Missed Opportunities (95%CI)[b]	Percent of Missed Opportunity Visit Days (95%CI)[c]
Outpatient	82,263	314,534	108,907 (102,633-116,202)	86.25% (85.79-86.71%)
Inpatient[d]				
Inpatient Day	8,736	59,178	19,521 (18,199-21,223)	15.46% (14.96-15.95%)
Inpatient Visit	8,736	10,948	7,647 (7,351-8,037)	-
ED	4,846	23,834	7,928 (7,426-8,556)	6.28% (6.11-6.44%)
Observational Stay	813	3,484	1,239 (1,113-1,376)	0.98% (0.91-1.05%)

[a] Multiple settings may be associated with an index visit date (i.e., we are unable to order the timing of visits from claims on the same day), thus the total number exceeds the number of individuals in the study population. [b] Multiple settings may occur on a given visit day (i.e., we are unable to order the timing of visits from claims on the same day), thus the total number exceeds the total estimated potential missed diagnostic opportunities. [c] The percent of all missed opportunities was computed across visit-days where an estimated missed opportunity occurred; thus, a percent of all visit days is not computed for inpatient visits (which include multiple days). [d] Inpatient stays were analyzed at both a visit-day- (i.e., individual day during a stay) and visit-level. Potential opportunities and estimated missed opportunities represent either a visit-day where an SSD was recorded or across a stay where an SSD was recorded across all days in a stay. *Note*: the difference in the number of missed opportunities between inpatient visits and inpatient days reflects multiple missed opportunity days occurring within a given stay.

inhalers, and oral steroids were linked to higher odds and longer durations of diagnostic delays, while antihistamines and nasal sprays were not.

Pulmonary vs cutaneous sarcoidosis

As a secondary analysis, we investigated two additional factors – differences in diagnostic delays for pulmonary vs. cutaneous sarcoidosis and risk factors associated with race from Medicaid insurance data. Baseline characteristics and diagnostic comparisons for cases of pulmonary and cutaneous sarcoidosis, are found in Tables 5 and 6, respectively. We identified 10,380 pulmonary and 3,267 cutaneous sarcoidosis cases. Pulmonary cases were more likely to experience a missed opportunity (93.7% vs 61.8%) and had longer delays (49 days vs 28.5 days) compared to cutaneous sarcoidosis cases.

Racial differences

Medicaid insurance claims show a higher risk of a missed diagnostic opportunity in white individuals (OR: 0.83 [95%CI: 0.77-0.91]) or Hispanic patients (OR: 0.78 [95%CI: 0.61-0.99]) compared to Black patients. The risk of diagnostic delays is lowest amongst Black individuals (OR: 0.77 [95%CI: 0.67-0.88]), however the delay duration was the same among races (Tables S6-S8).

Discussion

We found that around 56% of patients with sarcoidosis experience a healthcare visit for a symptomatically similar diagnosis prior to an index diagnosis of sarcoidosis, representing a potential missed opportunity to diagnose or diagnostic delay of sarcoidosis. Of those patients who experienced a delay, the mean duration of delay was around 43.8 days and involved around 2.6 missed opportunities. Less than 1% of sarcoidosis cases had a delay greater than 4 months. In the subset of patients with identified pulmonary or cutaneous involvement, we found that cases of pulmonary sarcoidosis were around 1.5 times more likely to

Table 3. Simulation results of number/duration of delayed visits per patient with sarcoidosis[a]

Metric	Number of Patients (% of All Patients)[b]	95% CI
Number of missed opportunities per patient		
≥ 1	48,818 (56.1%)	47,565-50,153 (54.6-57.6%)
≥ 2	29,047 (33.4%)	27,634-30,598 (31.7-35.1%)
≥ 3	17,455 (20.0%)	16,237-18,861 (18.6-21.7%)
≥ 4	10,459 (12.0%)	9,532-11,571 (10.9-13.3%)
≥ 5	6,316 (7.3%)	5,645-7,137 (6.5-8.2%)
Mean number of missed opportunities per patient	2.59	2.50-2.69
Median number of missed opportunities per patient	2.00	2.00-2.00
Duration of delayed visits		
≥ 7 days	44,506 (51.1%)	43,183-45,901 (49.6-52.7%)
≥ 14 days	39,489 (45.3%)	38,138-40,927 (43.8-47.0%)
≥ 21 days	34,760 (39.9%)	33,379-36,255 (38.3-41.6%)
≥ 30 days	28,603 (32.8%)	27,166-30,150 (31.2-34.6%)
≥ 60 days	14,134 (16.2%)	12,729-15,491 (14.6-17.8%)
≥ 90 days	5,861 (6.7%)	4,975-6,543 (5.7-7.5%)
≥ 120 days	681 (0.8%)	438-936 (0.5-1.1%)
Mean delay duration (days)	43.79	42.18-45.22
Median delay duration (days)	36.83	35.00-39.00

[a] Units in counts (or % of all patients) unless otherwise specified. [b] The distribution and mean number of potential missed diagnostic opportunities each patient experienced along with the distribution and mean and median duration of diagnostic delays (in days) are presented. Potential missed diagnostic opportunities represent healthcare visits in which sign/symptoms were present, but sarcoid was not diagnosed. Delay duration was defined as the time between the earliest potential missed diagnostic opportunity a patient experienced and their index diagnosis.

Table 4. Results of risk factor analysis for specific treatments received during the diagnostic opportunity window for potential symptoms of sarcoidosis

Treatment received during diagnostic opportunity window	Odds ratio estimates from patient-level risk model (i.e., multiplicative effect on odds of experiencing a diagnostic delay) (95%CI)	Acceleration factor estimates from duration model (i.e., multiplicative effect on delay duration) (95% CI)
Antacid or Proton Pump Inhibitor	1.37 (1.30-1.45)	1.08 (1.06-1.10)
Antibiotic	1.78 (1.70-1.84)	1.03 (1.02-1.05)
Antihistamine	1.08 (0.97-1.22)	1.02 (0.97-1.06)
Cough Suppressant	1.88 (1.19-3.31)	0.97 (0.83-1.11)
Diuretic	1.40 (1.31-1.50)	1.09 (1.06-1.11)
Inhaler	1.77 (1.67-1.88)	1.08 (1.06-1.10)
Nasal Spray	1.04 (0.97-1.13)	0.99 (0.96-1.02)
Oral Steroid	1.97 (1.87-2.09)	1.08 (1.06-1.10)

Table 5. Baseline characteristics for cases of pulmonary and cutaneous sarcoidosis

Characteristic	**Pulmonary Sarcoid (N = 10,380)**	**Cutaneous Sarcoid (N = 3,267)**
Age at Diagnosis		
<18	40 (0.4%)	46 (1.4%)
18-34	770 (7.4%)	215 (6.6%)
35-44	1,954 (18.8%)	470 (14.4%)
45-54	3,160 (30.4%)	986 (30.2%)
55-64	3,229 (31.1%)	1,067 (32.7%)
≥65	1,227 (11.8%)	483 (14.8%)
Mean (SD)	51.9 (12.1)	52.9 (13.0)
Median (IQR)	52.0 (16.0)	54.0 (16.0)
Sex		
Male	4,494 (43.3%)	1,075 (32.9%)
Female	5,886 (56.7%)	2,192 (67.1%)
Database Source		
Commercial	8,642 (83.3%)	2,762 (84.5%)
Medicare	1,062 (10.2%)	436 (13.3%)
Medicaid	676 (6.5%)	69 (2.1%)
Enrollment Time Prior to Index (years)		
≤ 2 years	4 (0.0%)	3 (0.1%)
≤ 3 years	2,582 (24.9%)	837 (25.6%)
> 3 years	7,798 (75.1%)	2,430 (74.4%)
Mean (SD)	5.6 (3.6)	5.4 (3.2)
Median (IQR)	4.4 (4.0)	4.3 (3.8)

Table 6. Comparison of the frequency and duration of diagnostic delays between pulmonary and cutaneous cases of sarcoidosis

Measure	**Pulmonary Sarcoidosis (95% CI)**	**Cutaneous Sarcoidosis (95% CI)**
Total Patients	10,380	3,267
Number of patients with a missed opportunity	9,726 (9,654-9,787)	2,019 (1,788-2,182)
% of patients with missed opportunity	93.7% (93.0-94.3%)	61.8% (54.7-66.8%)
Mean number of missed opportunities per patient	4.79 (4.52-5.02)	2.04 (1.76-2.34)
Mean duration of diagnostic delays	48.97 days (46.22-51.71)	28.47 days (22.32-34.43)

experience a delay, had more than twice the number of missed opportunities, and faced a delay in diagnosis around 1.7 times longer than those with cutaneous involvement. Delays in diagnosis have significant implications: particularly, pulmonary fibrosis and cardiac involvement which are major causes of death in sarcoidosis (16). A delayed diagnosis can result in incorrect diagnoses and incorrect treatments (6). In our study, we found medication prescriptions for treatment of common sarcoidosis symptoms, such as antacids/PPIs, antibiotics, cough suppressants, or oral steroids, before the sarcoidosis diagnosis, were associated with a greater likelihood of diagnostic delay. Specifically, the odds ratios for experiencing a diagnostic delay for

these treatments ranged from 1.04 to 1.97. We have found that inappropriate antibiotic use has also been associated with diagnostic delays for other diseases including tuberculosis (15), pertussis (17) and histoplasmosis (18). Inappropriate medication use associated with diagnostic delays can expose patients to unnecessary side effects, costs, and ineffective treatments. Although prior population-based studies in sarcoidosis exist, such as those using the Swedish National Patient Register and the Taiwan National Health Insurance Research Database, the studies have primarily focused on clinical features and disease course rather than diagnostic pathways (19). Our study complements this prior work by adding the healthcare utilization prior to diagnosis and by representing a broad segment of the United States population. Our approach allows us to identify diagnostic delays across regions, healthcare institutions and insurer types. We were also able to consider missed opportunities across outpatient, inpatient, and emergency department visits. To date, the largest study on delays in the diagnosis of sarcoidosis includes a meta-analysis of 1,531 cases of sarcoidosis. This study estimated the average diagnostic delay to be 7.9 months (6). In contrast, our study found significantly shorter delays of 43.8 days for all cases, and 49 or 28.5 day for the subset of pulmonary and cutaneous cases, respectively. This discrepancy can likely be attributed to differences in research approaches. For example, prior studies that employ retrospective self-reported surveys to establish timing of symptom onset such as Judson et al (7). are particularly vulnerable to recall bias as patients are unlikely to recall the exact timing of symptom onset, may overidentify unrelated symptoms to the disease (e.g., an unrelated prior respiratory infection) prior to the sarcoidosis diagnosis. Similarly, studies using chart reviews are prone to confirmation bias if efforts are not made to properly disentangle prior symptoms that might be attributable to causes other than sarcoidosis. Moreover, because many symptoms of sarcoidosis are relatively common (e.g., cough, shortness of breath, chest pain), studies that fail to account for a baseline level of expected care in absence of sarcoidosis will lead to inflated estimates of delays. Case-reports, case series, retrospective surveys and retrospective chart reviews do not account for this baseline level of expected care. In contrast, we utilize a type of case-crossover design to estimate the baseline level of care specific to our patient cohort to minimize the overidentification of diagnostic delays. Last, differences in severity and presentation across different populations may account for further variability. Interestingly, increased risk for a missed diagnosis in white individuals compared to other races may contribute to the rising mortality seen in Caucasians (20). In addition to race, we identified other risk factors associated with delays or longer times to diagnosing sarcoidosis. For example, we found that visits during weekends were associated with delays. We think that the delays in diagnosis associated with weekend visits are likely attributable to lower levels of staffing and diagnostic services during weekends compared to other days of the week. Indeed, other measures of healthcare quality appear to be affected by weekend visits (21, 22). Finally, at an individual level, the diagnosis of obesity was a risk factor for increased diagnostic delays. Obesity-related dyspnea has been found to contribute to and mask the diagnosis of other respiratory conditions such as asthma, pulmonary hypertension, and pulmonary emboli (23). Therefore, we think sarcoidosis-related symptoms, such as shortness of breath, might be mistakenly attributed to patients being overweight or obese. Our study has several limitations: 1) Diagnosis Codes were used to identify sarcoidosis cases, and these codes have limited sensitivity (24). To improve confidence in case identification, we validated our case definition using procedures such as bronchoscopy and tissue biopsy. 2) Claims Data: We relied on these data to determine visit reasons prior to diagnosis, but not all visit-related symptoms are recorded in insurance claims. 3) Race and Ethnicity: Some data (commercial and Medicare) do not include race or ethnicity, so findings associated with race may not be fully captured in these particular populations. 4) Insurance Coverage: Our dataset is largely made up of a privately insured population, so some findings may not be generalizable to uninsured individuals or those with publicly provided Medicaid or traditional Medicare. 5) Extrapulmonary Sarcoidosis: Diagnostic delays beyond cutaneous involvement were not explored, which may have important implications. For example, cardiac involvement is associated with a more severe form of sarcoidosis and interventions in the treatment of these patients, if delayed, may

have significant clinical implications. However, these cases less commonly undergo biopsy performing procedures and instead relay on clinical diagnosis (25, 26). As a result this makes the sensitivity of identifying these particular types of cases more difficult. Future studies may require datasets with more precise case definitions for subtypes of sarcoidosis. Despite these limitations, our results highlight several missed opportunities to diagnose sarcoidosis and identified risk factors linked to cognitive bias and systemic healthcare limitations. Many people with sarcoidosis experience significant diagnostic delays, which contribute to more severe presentations, exposure to inappropriate treatments, cause undue stress, and increase healthcare costs. These findings underscore the need for research into contributing factors for delay, better diagnostic biomarkers, and heightened advocacy efforts for awareness of this rare disease.

Acknowledgements: Author contributions: A.K.G. had full access to all data used in this study and takes responsibility for the integrity of the data and accuracy of the analysis. M.D.H., A.C.M., P.M.P., and A.K.G. designed parameters for analysis; A.C.M., P.M.P., A.T.A., and J.E.C. performed the modeling experiments and prepared figures; M.D.H. and A.K.G. revised figures for clinical context; M.D.H. and A.C.M. wrote manuscript with editing help from P.M.P., A.K.G., S.S., A.A.P., and N.Y.H.

Financial/Nonfinancial Disclosures: None.

Role of Sponsors: The sponsor had no role in the design of the study, the collection and analysis of the data, or the preparation of the manuscript.

Conflict of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

Institutional Review Board: This study was granted exemption by the University of Iowa Institutional Review Board (IRB 201908793) due to the use of de-identified data.

Declaration on the Use of AI: No artificial intelligence (AI) tools were used in the preparation of this manuscript.

References

1. Grunewald J, Grutters JC, Arkema EV, Saketkoo LA, Moller DR, Muller-Quernheim J. Sarcoidosis. Nat Rev Dis Primers. 2019;5(1):45. doi:10.1038/s41572-019-0096-x
2. Rao DA, Dellaripa PF. Extrapulmonary manifestations of sarcoidosis. Rheum Dis Clin North Am. 2013;39(2): 277-97. doi:10.1016/j.rdc.2013.02.007
3. Seve P, Pacheco Y, Durupt F, Jamilloux Y, Gerfaud-Valentin M, Isaac S, et al. Sarcoidosis: a clinical overview from symptoms to diagnosis. Cells. 2021;10(4):766. doi:10.3390/cells10040766
4. Narula N, Iannuzzi M. Sarcoidosis: pitfalls and challenging mimickers. Front Med (Lausanne). 2021;7:594275. doi:10.3389/fmed.2020.594275
5. Saketkoo LA, Russell AM, Jensen K, Mandizha J, Tavee J, Newton J, et al. Health-related quality of life (HRQoL) in sarcoidosis: diagnosis, management, and health outcomes. Diagnostics (Basel). 2021;11(6):1089. doi:10.3390/diagnostics11061089
6. Namsrai T, Phillips C, Parkinson A, Gregory D, Kelly E, Cook M, et al. Diagnostic delay of sarcoidosis: an integrated systematic review. Orphanet J Rare Dis. 2024;19(1):156. doi:10.1186/s13023-024-03152-7
7. Judson MA, Thompson BW, Rabin DL, Steimel J, Knattereud GL, Lackland DT, et al. The diagnostic pathway to sarcoidosis. Chest. 2003;123(2):406-12. doi:10.1378/chest.123.2.406
8. Gerke AK. Morbidity and mortality in sarcoidosis. Curr Opin Pulm Med. 2014;20(5):472-8. doi:10.1097/MCP.0000000000000080
9. Rodrigues MM, Coletta EN, Ferreira RG, Pereira CA. Delayed diagnosis of sarcoidosis is common in Brazil. J Bras Pneumol. 2013;39(5):539-46. doi:10.1590/S1806-37132013000500003
10. Hoogendoorn JC, Ninaber MK, Piers SRD, de Riva M, Grauss RW, Bogun FM, et al. The harm of delayed diagnosis of arrhythmogenic cardiac sarcoidosis: a case series. Europace. 2020;22(9):1376-83. doi:10.1093/europace/euaa115
11. ACCESS Research Group. Design of a case control etiologic study of sarcoidosis (ACCESS). J Clin Epidemiol. 1999;52(12):1173-86. doi:10.1016/S0895-4356(99)00142-0
12. Miller AC, Cavanaugh JE, Arakkal AT, Koeneman SH, Polgreen PM. A comprehensive framework to estimate the frequency, duration, and risk factors for diagnostic delays using bootstrapping-based simulation methods. BMC Med Inform Decis Mak. 2023;23(1):68. doi:10.1186/s12911-023-02148-w
13. Leclerc S, Myers RP, Moussalli J, Herson S, Poynard T, Benveniste O. Sarcoidosis and interferon therapy: report of five cases and review of the literature. Eur J Intern Med. 2003;14(4):237-43. doi:10.1016/S0953-6205(03)00078-5
14. Bolletta E, Mastrofilippo V, Invernizzi A, Aldigeri R, Spaggiari L, Besutti G, et al. Clinical relevance of subcentimetric lymph node biopsy in the diagnosis of ocular sarcoidosis.

Ocul Immunol Inflamm. 2022;30(3):717-20. doi:10.1080/09273948.2020.1817503
15. Miller AC, Arakkal AT, Koeneman S, Cavanaugh JE, Gerke AK, Hornick DB, et al. Incidence, duration and risk factors associated with delayed and missed diagnostic opportunities related to tuberculosis: a population-based longitudinal study. BMJ Open. 2021;11(2):e045605. doi:10.1136/bmjopen-2020-045605
16. Baughman RP, Lower EE. Who dies from sarcoidosis and why? Am J Respir Crit Care Med. 2011;183(11):1446-7. doi:10.1164/rccm.201103-0409ED
17. Evans NJ, Arakkal AT, Cavanaugh JE, Newland JG, Polgreen PM, Miller AC. The incidence, duration, risk factors, and age-based variation of missed opportunities to diagnose pertussis: a population-based cohort study. Infect Control Hosp Epidemiol. 2023;44(10):1629-36. doi:10.1017/ice.2023.31
18. Miller AC, Arakkal AT, Koeneman SH, Cavanaugh JE, Thompson GR, Baddley JW, et al. Frequency and duration of, and risk factors for, diagnostic delays associated with histoplasmosis. J Fungi (Basel). 2022;8(5).[INCOMPLETE] doi:10.3390/jof8050438
19. Arkema EV, Cozier YC. Epidemiology of sarcoidosis: current findings and future directions. Ther Adv Chronic Dis. 2018;9(11):227-40. doi:10.1177/2040622318790197
20. Mirsaeidi M, Machado RF, Schraufnagel D, Sweiss NJ, Baughman RP. Racial difference in sarcoidosis mortality in the United States. Chest. 2015;147(2):438-49. doi:10.1378/chest.14-1120
21. Becker DJ. Do hospitals provide lower quality care on weekends? Health Serv Res. 2007;42(4):1589-612. doi:10.1111/j.1475-6773.2006.00663.x
22. Attenello FJ, Wen T, Cen SY, Ng A, Kim-Tenser M, Sanossian N, et al. Incidence of "never events" among weekend admissions versus weekday admissions to US hospitals: national analysis. BMJ. 2015;350:h1460. doi:10.1136/bmj.h1460
23. Shah NM, Kaltsakas G. Respiratory complications of obesity: from early changes to respiratory failure. Breathe (Sheff). 2023;19(1):220263. doi:10.1183/20734735.0263-2022
24. Liberman AL, Newman-Toker DE. Symptom-disease pair analysis of diagnostic error (SPADE): a conceptual framework and methodological approach for unearthing misdiagnosis-related harms using big data. BMJ Qual Saf. 2018;27(7):557-66. doi:10.1136/bmjqs-2017-007032
25. Kandolin R, Lehtonen J, Airaksinen J, Vihinen T, Miettinen H, Ylitalo K, et al. Cardiac sarcoidosis: epidemiology, characteristics, and outcome over 25 years in a nationwide study. Circulation. 2015;131(7):624-32. doi:10.1161/CIRCULATIONAHA.114.011522
26. Mactaggart S, Ahmed R. The role of ICDs in patients with sarcoidosis-a comprehensive review. Curr Probl Cardiol. 2024;49(5):102483. doi:10.1016/j.cpcardiol.2024.102483

Annex

Table S1. ICD-9/10-CM codes used to identify potential missed diagnostic opportunities

ICD Code	ICD Version	Description
7856	9	Enlargement of lymph nodes
7866	9	Swelling, mass, or lump in chest
7931	9	Lung field
79319	9	Other nonspecific abnormal finding of lung field
7823	9	Edema
79431	9	Nonspecific abnormal electrocardiogram [ECG] [EKG]
2893	9	Lymphadenitis, unspecified, except mesenteric
79902	9	Hypoxemia
7821	9	Rash and other nonspecific skin eruption
5119	9	Unspecified pleural effusion
72981	9	Swelling of limb
5183	9	Pulmonary eosinophilia
79311	9	Solitary pulmonary nodule
7842	9	Swelling, mass, or lump in head and neck
7906	9	Other abnormal blood chemistry
5180	9	Pulmonary collapse
4293	9	Cardiomegaly
7850	9	Tachycardia, unspecified
7948	9	Nonspecific abnormal results of function study of liver
V741	9	Screening examination for pulmonary tuberculosis
7822	9	Localized superficial swelling, mass, or lump
7932	9	Nonspecific (abnormal) findings on radiological and other examination of other intrathoracic organs
7892	9	Splenomegaly
7904	9	Nonspecific elevation of levels of transaminase or lactic acid dehydrogenase [LDH]
7942	9	Nonspecific abnormal results of pulmonary function study
28860	9	Leukocytosis, unspecified
2875	9	Thrombocytopenia, unspecified
42769	9	Other premature beats
78930	9	Abdominal or pelvic swelling, mass, or lump, unspecified site
4589	9	Hypotension, unspecified
5128	9	Other pneumothorax and air leak
28850	9	Leukocytopenia, unspecified
78650	9	Chest pain, unspecified
78605	9	Shortness of breath
7862	9	Cough
78079	9	Other malaise and fatigue

Table S1 (*continued*)

ICD Code	ICD Version	Description
7291	9	Myalgia and myositis, unspecified
78659	9	Other chest pain
78060	9	Fever, unspecified
7851	9	Palpitations
71947	9	Pain in joint, ankle and foot
71949	9	Pain in joint, multiple sites
7802	9	Syncope and collapse
71940	9	Pain in joint, site unspecified
78321	9	Loss of weight
78651	9	Precordial pain
78652	9	Painful respiration
7806	9	Fever and other physiologic disturbances of temperature regulation
78607	9	Wheezing
7869	9	Other symptoms involving respiratory system and chest
78630	9	Hemoptysis, unspecified
7863	9	Hemoptysis
7808	9	Generalized hyperhidrosis
78902	9	Abdominal pain, left upper quadrant
51889	9	Other diseases of lung, not elsewhere classified
78609	9	Other respiratory abnormalities
496	9	Chronic airway obstruction, not elsewhere classified
49390	9	Asthma, unspecified type, unspecified
515	9	Postinflammatory pulmonary fibrosis
1629	9	Malignant neoplasm of bronchus and lung, unspecified
51881	9	Acute respiratory failure
49121	9	Obstructive chronic bronchitis with (acute) exacerbation
49392	9	Asthma, unspecified type, with (acute) exacerbation
78600	9	Respiratory abnormality, unspecified
2357	9	Neoplasm of uncertain behavior of trachea, bronchus, and lung
2123	9	Benign neoplasm of bronchus and lung
4928	9	Other emphysema
514	9	Pulmonary congestion and hypostasis
5110	9	Pleurisy without mention of effusion or current tuberculosis
2391	9	Neoplasm of unspecified nature of respiratory system
49120	9	Obstructive chronic bronchitis without exacerbation
49320	9	Chronic obstructive asthma, unspecified
4239	9	Unspecified disease of pericardium
49310	9	Intrinsic asthma, unspecified
486	9	Pneumonia, organism unspecified
4660	9	Acute bronchitis

ICD Code	ICD Version	Description
4659	9	Acute upper respiratory infections of unspecified site
490	9	Bronchitis, not specified as acute or chronic
6826	9	Cellulitis and abscess of leg, except foot
4610	9	Acute maxillary sinusitis
4730	9	Chronic maxillary sinusitis
07999	9	Unspecified viral infection
4829	9	Bacterial pneumonia, unspecified
6869	9	Unspecified local infection of skin and subcutaneous tissue
4919	9	Unspecified chronic bronchitis
V7283	9	Other specified pre-operative examination
V7284	9	Pre-operative examination, unspecified
V7281	9	Pre-operative cardiovascular examination
6929	9	Contact dermatitis and other eczema, unspecified cause
3643	9	Unspecified iridocyclitis
3051	9	Tobacco use disorder
2382	9	Neoplasm of uncertain behavior of skin
27542	9	Hypercalcemia
V726	9	Laboratory examination
36400	9	Acute and subacute iridocyclitis, unspecified
9999	9	Other and unspecified complications of medical care, not elsewhere classified
20280	9	Other malignant lymphomas, unspecified site, extranodal and solid organ sites
6952	9	Erythema nodosum
7149	9	Unspecified inflammatory polyarthropathy
36401	9	Primary iridocyclitis
7999	9	Other unknown and unspecified cause of morbidity and mortality
V7260	9	Laboratory examination, unspecified
37730	9	Optic neuritis, unspecified
7109	9	Unspecified diffuse connective tissue disease
36410	9	Chronic iridocyclitis, unspecified
3510	9	Bell's palsy
2410	9	Nontoxic uninodular goiter
V7282	9	Pre-operative respiratory examination
79399	9	Other nonspecific (abnormal) findings on radiological and other examinations of body structure
7964	9	Other abnormal clinical findings
6861	9	Pyogenic granuloma of skin and subcutaneous tissue
36320	9	Chorioretinitis, unspecified
36402	9	Recurrent iridocyclitis
37991	9	Pain in or around eye
7099	9	Unspecified disorder of skin and subcutaneous tissue

Table S1 (*continued*)

ICD Code	ICD Version	Description
3688	9	Other specified visual disturbances
3682	9	Diplopia
7813	9	Lack of coordination
79579	9	Other and unspecified nonspecific immunological findings
V1582	9	Personal history of tobacco use
2392	9	Neoplasm of unspecified nature of bone, soft tissue, and skin
V7263	9	Pre-procedural laboratory examination
V718	9	Observation and evaluation for other specified suspected conditions
V7189	9	Observation and evaluation for other specified suspected conditions
4476	9	Arteritis, unspecified
36012	9	Panuveitis
7910	9	Proteinuria
5272	9	Sialoadenitis
37700	9	Papilledema, unspecified
71659	9	Unspecified polyarthropathy or polyarthritis, multiple sites
36283	9	Retinal edema
9953	9	Allergy, unspecified, not elsewhere classified
37900	9	Scleritis, unspecified
V725	9	Radiological examination, not elsewhere classified
36218	9	Retinal vasculitis
2290	9	Benign neoplasm of lymph nodes
08881	9	Lyme Disease
5733	9	Hepatitis, unspecified
37924	9	Other vitreous opacities
3689	9	Unspecified visual disturbance
3419	9	Demyelinating disease of central nervous system, unspecified
042	9	Human immunodeficiency virus [HIV] disease
2388	9	Neoplasm of uncertain behavior of other specified sites
V6709	9	Follow-up examination, following other surgery
37739	9	Other optic neuritis
2358	9	Neoplasm of uncertain behavior of pleura, thymus, and mediastinum
796	9	Other nonspecific abnormal findings
7969	9	Other nonspecific abnormal findings
4242	9	Tricuspid valve disorders, specified as nonrheumatic
348	9	Other conditions of brain
3488	9	Other conditions of brain
34889	9	Other conditions of brain
7909	9	Other nonspecific findings on examination of blood
79099	9	Other nonspecific findings on examination of blood
1991	9	Other malignant neoplasm without specification of site

ICD Code	ICD Version	Description
V6759	9	Other follow-up examination
7930	9	Nonspecific (abnormal) findings on radiological and other examination of skull and head
3699	9	Unspecified visual loss
5121	9	Iatrogenic pneumothorax
3698	9	Unqualified visual loss, one eye
37992	9	Swelling or mass of eye
71699	9	Arthropathy, unspecified, multiple sites
71907	9	Effusion of joint, ankle and foot
5920	9	Calculus of kidney
5921	9	Calculus of ureter
5932	9	Cyst of kidney, acquired
5849	9	Acute kidney failure, unspecified
4278	9	Other specified cardiac dysrhythmias
42789	9	Other specified cardiac dysrhythmias
4279	9	Cardiac dysrhythmia, unspecified
4139	9	Other and unspecified angina pectoris
7852	9	Undiagnosed cardiac murmurs
42781	9	Sinoatrial node dysfunction
4270	9	Paroxysmal supraventricular tachycardia
4264	9	Right bundle branch block
5178	9	Lung involvement in other diseases classified elsewhere
2891	9	Chronic lymphadenitis
4168	9	Other chronic pulmonary heart diseases
5193	9	Other diseases of mediastinum, not elsewhere classified
4940	9	Bronchiectasis without acute exacerbation
5163	9	Idiopathic interstitial pneumonia
1970	9	Secondary malignant neoplasm of lung
71690	9	Arthropathy, unspecified, site unspecified
57420	9	Calculus of gallbladder without mention of cholecystitis, without mention of obstruction
5718	9	Other chronic nonalcoholic liver disease
5738	9	Other specified disorders of liver
5739	9	Unspecified disorder of liver
47819	9	Other disease of nasal cavity and sinuses
3559	9	Mononeuritis of unspecified site
3369	9	Unspecified disease of spinal cord
34830	9	Encephalopathy, unspecified
6961	9	Other psoriasis
6983	9	Lichenification and lichen simplex chronicus
R590	10	Localized enlarged lymph nodes

Table S1 (*continued*)

ICD Code	ICD Version	Description
R918	10	Other nonspecific abnormal finding of lung field
R591	10	Generalized enlarged lymph nodes
R911	10	Solitary pulmonary nodule
R599	10	Enlarged lymph nodes, unspecified
R9431	10	Abnormal electrocardiogram [ECG] [EKG]
R938	10	Abnormal findings on diagnostic imaging of other specified body structures
R9389	10	Abnormal findings on diagnostic imaging of other specified body structures
R000	10	Tachycardia, unspecified
J90	10	Pleural effusion, not elsewhere classified
R0902	10	Hypoxemia
J9811	10	Atelectasis
I517	10	Cardiomegaly
R798	10	Other specified abnormal findings of blood chemistry
R7989	10	Other specified abnormal findings of blood chemistry
D72829	10	Elevated white blood cell count, unspecified
R748	10	Abnormal levels of other serum enzymes
R001	10	Bradycardia, unspecified
R161	10	Splenomegaly, not elsewhere classified
E871	10	Hypo-osmolality and hyponatremia
D696	10	Thrombocytopenia, unspecified
R222	10	Localized swelling, mass and lump, trunk
R221	10	Localized swelling, mass and lump, neck
J939	10	Pneumothorax, unspecified
R0602	10	Shortness of breath
R05	10	Cough
R079	10	Chest pain, unspecified
R078	10	Other chest pain
R0789	10	Other chest pain
R0600	10	Dyspnea, unspecified
R51	10	Headache
R109	10	Unspecified abdominal pain
R5383	10	Other fatigue
R509	10	Fever, unspecified
M6281	10	Muscle weakness (generalized)
R531	10	Weakness
M2550	10	Pain in unspecified joint
R55	10	Syncope and collapse
R002	10	Palpitations
R202	10	Paresthesia of skin
R21	10	Rash and other nonspecific skin eruption

ICD Code	ICD Version	Description
R0609	10	Other forms of dyspnea
R634	10	Abnormal weight loss
R4182	10	Altered mental status, unspecified
R200	10	Anesthesia of skin
R110	10	Nausea
R1084	10	Generalized abdominal pain
M549	10	Dorsalgia, unspecified
M791	10	Myalgia
R1011	10	Right upper quadrant pain
R5381	10	Other malaise
R062	10	Wheezing
R042	10	Hemoptysis
R098	10	Other specified symptoms and signs involving the circulatory and respiratory systems
R0989	10	Other specified symptoms and signs involving the circulatory and respiratory systems
M79605	10	Pain in left leg
R0781	10	Pleurodynia
R068	10	Other abnormalities of breathing
R0689	10	Other abnormalities of breathing
R072	10	Precordial pain
J449	10	Chronic obstructive pulmonary disease, unspecified
J984	10	Other disorders of lung
J45909	10	Unspecified asthma, uncomplicated
J8410	10	Pulmonary fibrosis, unspecified
J849	10	Interstitial pulmonary disease, unspecified
J9601	10	Acute respiratory failure with hypoxia
J441	10	Chronic obstructive pulmonary disease with (acute) exacerbation
J811	10	Chronic pulmonary edema
J45901	10	Unspecified asthma with (acute) exacerbation
J18	10	Pneumonia, unspecified organism
J189	10	Pneumonia, unspecified organism
J209	10	Acute bronchitis, unspecified
J069	10	Acute upper respiratory infection, unspecified
J40	10	Bronchitis, not specified as acute or chronic
J329	10	Chronic sinusitis, unspecified
B349	10	Viral infection, unspecified
G039	10	Meningitis, unspecified
Z01818	10	Encounter for other preprocedural examination
E8352	10	Hypercalcemia
F17210	10	Nicotine dependence, cigarettes, uncomplicated

Table S1 (*continued*)

ICD Code	ICD Version	Description
I888	10	Other nonspecific lymphadenitis
M064	10	Inflammatory polyarthropathy
Z01810	10	Encounter for preprocedural cardiovascular examination
H209	10	Unspecified iridocyclitis
Z2082	10	Contact with and (suspected) exposure to other viral communicable diseases
Z20828	10	Contact with and (suspected) exposure to other viral communicable diseases
Z01812	10	Encounter for preprocedural laboratory examination
F17200	10	Nicotine dependence, unspecified, uncomplicated
I429	10	Cardiomyopathy, unspecified
Z87891	10	Personal history of nicotine dependence
L929	10	Granulomatous disorder of the skin and subcutaneous tissue, unspecified
L52	10	Erythema nodosum
M797	10	Fibromyalgia
I898	10	Other specified noninfective disorders of lymphatic vessels and lymph nodes
D485	10	Neoplasm of uncertain behavior of skin
H469	10	Unspecified optic neuritis
Z48813	10	Encounter for surgical aftercare following surgery on the respiratory system
L309	10	Dermatitis, unspecified
D898	10	Other specified disorders involving the immune mechanism, not elsewhere classified
D8989	10	Other specified disorders involving the immune mechanism, not elsewhere classified
H44112	10	Panuveitis, left eye
H4710	10	Unspecified papilledema
H538	10	Other visual disturbances
H04123	10	Dry eye syndrome of bilateral lacrimal glands
H20042	10	Secondary noninfectious iridocyclitis, left eye
M25572	10	Pain in left ankle and joints of left foot
G510	10	Bell's palsy
H532	10	Diplopia
Z115	10	Encounter for screening for other viral diseases
Z1159	10	Encounter for screening for other viral diseases
M25571	10	Pain in right ankle and joints of right foot
H21513	10	Anterior synechiae (iris), bilateral
H542	10	Low vision, both eyes
H2000	10	Unspecified acute and subacute iridocyclitis
H468	10	Other optic neuritis
C411	10	Malignant neoplasm of mandible
H7090	10	Unspecified mastoiditis, unspecified ear
M359	10	Systemic involvement of connective tissue, unspecified
D360	10	Benign neoplasm of lymph nodes
H20012	10	Primary iridocyclitis, left eye

ICD Code	ICD Version	Description
H53133	10	Sudden visual loss, bilateral
H20011	10	Primary iridocyclitis, right eye
H44111	10	Panuveitis, right eye
I313	10	Pericardial effusion (noninflammatory)
H4922	10	Sixth [abducent] nerve palsy, left eye
L928	10	Other granulomatous disorders of the skin and subcutaneous tissue
I428	10	Other cardiomyopathies
M130	10	Polyarthritis, unspecified
C7951	10	Secondary malignant neoplasm of bone
L308	10	Other specified dermatitis
D71	10	Functional disorders of polymorphonuclear neutrophils
H5711	10	Ocular pain, right eye
H539	10	Unspecified visual disturbance
H20013	10	Primary iridocyclitis, bilateral
H20029	10	Recurrent acute iridocyclitis, unspecified eye
C8590	10	Non-Hodgkin lymphoma, unspecified, unspecified site
I469	10	Cardiac arrest, cause unspecified
R29810	10	Facial weakness
H44113	10	Panuveitis, bilateral
Z0001	10	Encounter for general adult medical examination with abnormal findings
R930	10	Abnormal findings on diagnostic imaging of skull and head, not elsewhere classified
R846	10	Abnormal cytological findings in specimens from respiratory organs and thorax
N12	10	Tubulo-interstitial nephritis, not specified as acute or chronic
Z862	10	Personal history of diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism
D1431	10	Benign neoplasm of right bronchus and lung
R768	10	Other specified abnormal immunological findings in serum
Z018	10	Encounter for other specified special examinations
Z0189	10	Encounter for other specified special examinations
H3091	10	Unspecified chorioretinal inflammation, right eye
N200	10	Calculus of kidney
N201	10	Calculus of ureter
N179	10	Acute kidney failure, unspecified
I472	10	Ventricular tachycardia
I499	10	Cardiac arrhythmia, unspecified
I493	10	Ventricular premature depolarization
I471	10	Supraventricular tachycardia
I442	10	Atrioventricular block, complete
J479	10	Bronchiectasis, uncomplicated

Table S1 (*continued*)

ICD Code	ICD Version	Description
M798	10	Other specified soft tissue disorders
M7989	10	Other specified soft tissue disorders
E860	10	Dehydration
K8020	10	Calculus of gallbladder without cholecystitis without obstruction
J4520	10	Mild intermittent asthma, uncomplicated
G629	10	Polyneuropathy, unspecified
G9340	10	Encephalopathy, unspecified
I889	10	Nonspecific lymphadenitis, unspecified
I2699	10	Other pulmonary embolism without acute cor pulmonale
L930	10	Discoid lupus erythematosus
L409	10	Psoriasis, unspecified
L4050	10	Arthropathic psoriasis, unspecified
L929	10	Granulomatous disorder of the skin and subcutaneous tissue, unspecified

Table S2. Procedure codes used to identify pulmonary or cutaneous cases of sarcoidosis

Category	Codes
Pulmonary procedures	**31628, 31624, 31629, 3324, 31622, 31620, 31623, 31633, 31632, 3323, 3322, 31645, 31625, 88172, 3324, 10022, 76942, 32405, 38510, 38505, 3328, 38525, 3326, 4011**
Cutaneous procedures	**11100, 11101**

Table S3. Results of logistic regression model for potential missed diagnostic opportunities

Risk Factor	Odds Ratio (95%CI)
Database source	
Commercial	REF
Medicare	1.08 (1.00-1.16)
Medicaid	1.27 (1.21-1.33)
Age	
<18	REF
18-34	1.42 (1.26-1.58)
35-44	1.40 (1.25-1.56)
45-54	1.35 (1.21-1.50)
55-64	1.34 (1.21-1.50)
≥65	1.44 (1.28-1.63)
Female	0.97 (0.95-0.99)
Any obesity dx prior to index	1.36 (1.33-1.40)
Rural location	1.03 (0.94-1.11)
Weekend visit	1.92 (1.85-1.99)

Risk Factor	Odds Ratio (95%CI)
Month of visit	
January	REF
February	1.01 (0.96-1.06)
March	1.00 (0.96-1.05)
April	1.03 (0.99-1.08)
May	1.01 (0.97-1.06)
June	1.04 (0.99-1.08)
July	1.04 (1.00-1.09)
August	1.01 (0.97-1.07)
September	1.05 (1.01-1.11)
October	0.98 (0.95-1.03)
November	0.98 (0.93-1.03)
December	1.06 (1.01-1.10)
Year of visit	
2003	REF
2004	0.98 (0.88-1.10)
2005	1.10 (0.99-1.22)
2006	1.05 (0.95-1.15)
2007	1.06 (0.95-1.16)
2008	1.12 (1.00-1.22)
2009	1.12 (1.01-1.21)
2010	1.12 (1.03-1.22)
2011	1.15 (1.05-1.26)
2012	1.11 (1.01-1.21)
2013	1.10 (1.01-1.21)
2014	1.09 (1.00-1.20)
2015	1.21 (1.09-1.33)
2016	1.11 (1.00-1.23)
2017	1.15 (1.04-1.26)
2018	1.21 (1.09-1.32)
2019	1.18 (1.06-1.30)
2020	1.22 (1.10-1.34)
2021	1.11 (1.01-1.24)
2022	1.05 (0.93-1.18)

Table S4. Results of logistic regression model for delayed patient

Risk Factor	Odds Ratio (95%CI)
Database Source	
Commercial	REF
Medicare	0.92 (0.83-1.01)
Medicaid	1.02 (0.95-1.10)
Age	
<18	REF
18-34	1.68 (1.46-1.99)
35-44	1.60 (1.40-1.89)
45-54	1.44 (1.26-1.69)
55-64	1.35 (1.18-1.59)
≥65	1.49 (1.26-1.80)
Female	0.99 (0.96-1.02)
Any obesity dx prior to index	1.50 (1.43-1.57)
Rural location	1.09 (0.98-1.23)
Antacid/PPI rx during delay window	1.37 (1.30-1.45)
Antibiotic rx during delay window	1.78 (1.70-1.84)
Antihistamine rx during delay window	1.08 (0.97-1.22)
Cough suppressant rx during delay window	1.88 (1.19-3.31)
Diuretic rx during delay window	1.40 (1.31-1.50)
Inhaler rx during delay window	1.77 (1.67-1.88)
Nasal spray rx during delay window	1.04 (0.97-1.13)
Oral steroid rx during delay window	1.97 (1.87-2.09)
Month of index visit	
January	REF
February	1.06 (0.99-1.14)
March	1.10 (1.02-1.19)
April	1.09 (1.02-1.18)
May	1.13 (1.04-1.21)
June	1.15 (1.06-1.25)
July	1.13 (1.04-1.22)
August	1.14 (1.06-1.23)
September	1.11 (1.02-1.20)
October	1.10 (1.02-1.19)
November	1.12 (1.03-1.22)
December	1.13 (1.05-1.22)
Year of index visit	
2003	REF
2004	1.09 (0.93-1.28)
2005	1.32 (1.14-1.55)

Risk Factor	Odds Ratio (95%CI)
2006	1.32 (1.14-1.54)
2007	1.33 (1.16-1.52)
2008	1.48 (1.29-1.71)
2009	1.40 (1.22-1.62)
2010	1.44 (1.25-1.65)
2011	1.48 (1.30-1.69)
2012	1.44 (1.26-1.66)
2013	1.40 (1.22-1.59)
2014	1.43 (1.25-1.65)
2015	1.40 (1.21-1.61)
2016	1.33 (1.16-1.54)
2017	1.46 (1.26-1.70)
2018	1.51 (1.28-1.75)
2019	1.46 (1.24-1.68)
2020	1.52 (1.32-1.76)
2021	1.51 (1.29-1.75)
2022	1.37 (1.16-1.62)

Table S5. Results of Weibull accelerated failure time regression model for duration of delay

Risk Factor	Acceleration Factor (95%CI)
Database Source	
Commercial	REF
Medicare	1.02 (0.98-1.06)
Medicaid	1.12 (1.09-1.16)
Age	
<18	REF
18-34	0.99 (0.92-1.09)
35-44	1.02 (0.94-1.11)
45-54	1.06 (0.98-1.16)
55-64	1.09 (1.01-1.19)
≥65	1.14 (1.04-1.25)
Female	1.02 (1.01-1.04)
Any obesity dx prior to index	1.08 (1.06-1.09)
Rural location	1.03 (0.98-1.07)
Antacid/PPI rx during delay window	1.08 (1.06-1.10)
Antibiotic rx during delay window	1.03 (1.02-1.05)
Antihistamine rx during delay window	1.02 (0.97-1.06)

Table S5 (*continued*)

Risk Factor	Acceleration Factor (95%CI)
Cough suppressant rx during delay window	0.97 (0.83-1.11)
Diuretic rx during delay window	1.09 (1.06-1.11)
Inhaler rx during delay window	1.08 (1.06-1.10)
Nasal spray rx during delay window	0.99 (0.96-1.02)
Oral steroid rx during delay window	1.08 (1.06-1.10)
Month of index visit	
January	REF
February	0.96 (0.93-1.00)
March	0.97 (0.94-1.00)
April	0.97 (0.94-1.00)
May	0.97 (0.94-1.00)
June	1.00 (0.97-1.04)
July	1.01 (0.97-1.04)
August	1.01 (0.97-1.04)
September	1.00 (0.97-1.04)
October	1.00 (0.96-1.03)
November	0.99 (0.96-1.02)
December	0.99 (0.95-1.02)
Year of index visit	
2003	REF
2004	1.00 (0.92-1.10)
2005	1.02 (0.94-1.10)
2006	1.01 (0.93-1.09)
2007	1.00 (0.93-1.08)
2008	1.02 (0.95-1.10)
2009	1.05 (0.98-1.13)
2010	1.06 (0.98-1.14)
2011	1.06 (0.99-1.15)
2012	1.06 (0.99-1.14)
2013	1.07 (0.99-1.15)
2014	1.06 (0.98-1.14)
2015	1.06 (0.98-1.14)
2016	1.06 (0.98-1.14)
2017	1.07 (0.99-1.15)
2018	1.09 (1.01-1.17)
2019	1.08 (1.00-1.17)
2020	1.08 (1.00-1.17)
2021	1.10 (1.03-1.20)
2022	1.12 (1.03-1.22)

Table S6. Results of logistic regression model for potential missed diagnostic opportunities for individuals with Medicaid insurance

Risk Factor	**Odds Ratio (95%CI)**
Race	
White	REF
Black	0.83 (0.77-0.91)
Hispanic	0.78 (0.61-0.99)
Other	1.08 (0.78-1.53)
Missing/Unknown	1.00 (0.86-1.19)

Table S7. Results of logistic regression model for delayed patients with Medicaid insurance

Risk Factor	**Odds Ratio (95%CI)**
Race	
White	REF
Black	0.77 (0.67-0.88)
Hispanic	1.04 (0.63-1.78)
Other	1.10 (0.67-1.89)
Missing/Unknown	1.02 (0.78-1.32)

Table S8. Results of Weibull accelerated failure time regression model for duration of delay for individuals with Medicaid insurance

Risk Factor	**Acceleration Factor(95%CI)**
Race	
White	REF
Black	0.96 (0.92-1.00)
Hispanic	1.05 (0.89-1.21)
Other	0.99 (0.83-1.17)
Missing/Unknown	0.97 (0.89-1.05)