



**Center for Biologics Evaluation and Research
Office of Biostatistics and Epidemiology**

CBER Surveillance Program

Biologics Effectiveness and Safety Initiative

A Structured Review of Electronic Coding Algorithms for Acute Bronchitis Using Administrative Claims and Electronic Health Records

Final Report

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List of Acronyms

AFHSB	United States Armed Forces Health Surveillance Branch
AHRQ	Agency for Healthcare Research and Quality
ARI	Acute Respiratory Infection
AUROC	Area Under the Receiver Operating Characteristic Curve
BEST	Biologics Effectiveness and Safety
CBER	Center for Biologics Evaluation and Research
CDC	Centers for Disease Control and Prevention
CHEST	American College of Chest Physicians
CI	Confidence Interval
CMS	Centers for Medicare and Medicaid Services
COPD	Chronic Obstructive Pulmonary Disease
CPT	Current Procedural Terminology
DX	Diagnosis
ED	Emergency Department
EHR	Electronic Health Record
EMR	Electronic Medical Record
EMRALD	Electronic Medical Record Administrative Data Linked Database
ESSENCE	Electronic Surveillance System for Early Notification of Community-based Epidemics
FDA	Food and Drug Administration
GEM	General Equivalence Mapping
HCPCS	Healthcare Common Procedure Coding System
ICD-8	International Classification of Diseases, Eighth Revision,
ICD-9-CM	International Classification of Diseases, Ninth Revision, Clinical Modification
ICD-10-CM	International Classification of Diseases, Tenth Revision, Clinical Modification
ICD-10-TM	International Classification of Diseases, Tenth Revision, Thai Modification
ILI	Influenza-like Illness
LOINC	Logical Observation Identifiers Names and Codes
NDC	National Drug Code
NPV	Negative Predictive Value
OHIP	Ontario Health Insurance Plan
PICO	Population, Intervention, Comparator, Outcome
PPV	Positive Predictive Value
RODS	Real-time Outbreak and Disease Surveillance
RSV	Respiratory Syncytial Virus
SARI	Severe Acute Respiratory Infections
SME	Subject Matter Expert
SE	Standard Error
URI	Upper Respiratory Infection
UTI	Urinary Tract Infection

A Summary

The United States (U.S.) Food and Drug Administration (FDA) Biologics Effectiveness and Safety (BEST) Initiative conducted a structured literature review (through to June 26, 2020) to identify validated coding algorithms for ascertaining cases of acute bronchitis in large administrative healthcare databases. The studies selected for this targeted review used billing codes in claims, electronic health record (EHR), or electronic medical record (EMR) databases to derive electronic coding algorithms. Several relevant studies were reviewed, with two U.S. studies of particular relevance providing performance measures (e.g., positive predictive value [PPV], negative predictive value [NPV], sensitivity and/or specificity) for algorithms that sought to identify cases of acute bronchitis.^{1,2} Both U.S. studies employed chart review to assess the validity of the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes 466.0 (acute bronchitis) and 490 (bronchitis not otherwise specified) in EHR or claims databases. Overall, the findings indicate that these ICD-9-CM codes have moderate PPV (67–79%) and high sensitivity (88%) for identifying acute bronchitis cases.

The results of this literature review were used as the basis for developing a draft administrative claims-based outcome definition — hereafter referred to as an “algorithm” — for identifying cases of acute bronchitis. Codes were mapped from ICD-9-CM to International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) via forward–backward mapping, using General Equivalence Mappings (GEMs) for reference.ⁱ The draft algorithm was then reviewed by clinical Subject Matter Experts (SMEs) from IBM (TB, JB), FDA Center for Biologics Evaluation and Research (CBER) (JC, DT), and Acumen.

The base-case algorithm includes a proposed case definition that combines ICD-9-CM code 466.0 (acute bronchitis) and ICD-10-CM codes J20.x (acute bronchitis). We also propose including ICD-9-CM code 490 and its equivalent ICD-10-CM code J40 (bronchitis, not specified as acute or chronic) in the algorithm to provide a more inclusive algorithm, as these codes are likely to capture additional acute bronchitis cases. However, users seeking a more specific algorithm may want to exclude these more general codes which could introduce case misclassification.

As an initial step in assessing the feasibility of using the algorithm to identify acute bronchitis, the more inclusive algorithm was applied in the IBM MarketScan[®] Research Databases (Commercial and Medicare Supplemental), a collection of commercially insured individuals in the United States. Statistics describing the frequency and proportions of acute bronchitis codes included in the algorithm were generated.

B Background

Among other responsibilities, the U.S. FDA is mandated to protect public health by ensuring the safety and efficacy of drugs, biologics and medical devices.ⁱⁱ In support of this charge, the FDA Center for Biologics Evaluation and Research (CBER) has a mission to conduct policy and regulatory reviews of biologics and related products, including blood products, vaccines, allergenics, tissues, and cellular and gene therapies. CBER assesses the risks and benefits of new biologic products, as well as previously approved products that have been proposed for new indications. The CBER process emphasizes the pursuit of the maximum public benefit with the minimum risk to public safety associated with each biologic product. The BEST Initiative is a program initiated by CBER with the objective of assessing the safety and effectiveness of biologic products using large datasets of administrative healthcare data.

ⁱ Additional information about GEMs and the methodology for forward and backward mapping can be found at Centers for Medicaid and Medicare Services. (2017). 2018 ICD-10-CM and GEMs. Available at <https://www.cms.gov/Medicare/Coding/ICD10/2018-ICD-10-CM-and-GEMs>. Researchers used the following website to map ICD-9-CM codes to ICD-10-CM: <https://www.icd10data.com>.

ⁱⁱ U.S. Food and Drug Administration. What We Do. March 28, 2018. <https://www.fda.gov/aboutfda/whatwedo/>

Acute bronchitis is a lower respiratory tract infection that causes reversible bronchial inflammation.³ It is characterized by cough due to acute inflammation of the trachea and large airways without evidence of pneumonia.⁴ Cough associated with acute bronchitis typically lasts about two to three weeks. In addition to cough, common symptoms include sputum production, dyspnea, nasal congestion, headache, and fever.

Acute bronchitis is most often caused by a viral infection (the cause of up to 95% of cases), with the most commonly identified viruses being rhinovirus, enterovirus, influenza A and B, parainfluenza, coronavirus, human metapneumovirus, and respiratory syncytial virus.^{4,5} Atypical bacteria, such as *Mycoplasma pneumoniae*, *Chlamydophila* (or *Chlamydia*) *pneumoniae*, and *Bordetella pertussis*, are rare causes of acute bronchitis. Due to the typical viral etiology, antibiotics are not indicated in acute bronchitis patients without chronic lung disease.⁴ In addition to viral and bacterial causes, reports of lower respiratory tract infection, including acute bronchitis, have been reported in association with exposure to rotavirus vaccines given in conjunction with pneumococcal vaccination in infants.⁶

The diagnoses with greatest overlap with acute bronchitis are upper respiratory tract infections and pneumonia. Consequently, the primary diagnostic consideration in patients with suspected acute bronchitis is ruling out more serious causes of cough, such as asthma, exacerbation of chronic obstructive pulmonary disease (COPD), heart failure, or pneumonia.^{4,5} Laboratory testing is usually not indicated in the evaluation of acute bronchitis, although imaging (e.g., chest radiography) is used in high risk patients (e.g., presenting with tachypnea, tachycardia, or dyspnea, older than 75 years) to rule out pneumonia.^{4,5}

In the U.S., acute bronchitis is among the top ten most common illnesses observed in the outpatient setting.⁵ Each year, up to 5% of the general population experiences at least one episode of acute bronchitis, leading to more than 10 million office visits per year⁷ and an estimated \$13.5 billion in total healthcare costs.⁸ In addition, \$3.1 billion was spent on the treatment of acute bronchitis in children in 2006.⁹ Although acute bronchitis is generally uncomplicated in otherwise healthy individuals, it can progress to infectious lung diseases such as pneumonia, contributing to increased morbidity and mortality.⁵

The objective of this review was to assess and understand the validity of electronic coding algorithms using billing codes for identifying acute bronchitis from administrative claims and electronic health records (EHRs). These coding algorithms could draw on a variety of standardized code sets, including the International Classification of Diseases (ICD), the Healthcare Common Procedure Coding System (HCPCS), Current Procedural Terminology (CPT[®]), National Drug Codes (NDCs), and Logical Observation Identifiers Names and Codes (LOINC).

A structured literature review of coding algorithms for identifying potential cases of acute bronchitis using administrative claims- and EHR-based algorithms was conducted, leveraging findings from U.S. and international studies to inform the development of an algorithm. The draft algorithm was then subject to review by clinical SMEs and testing in the MarketScan Research Databases, a large collection of administrative claims data accessed via the Treatment Pathways online analytic platform. **Section C** summarizes the literature review methodology and findings; **Section D** provides a clinical case definition for acute bronchitis, which could be of value in further assessing the performance of the proposed algorithm via chart review validation studies; **Sections E** and **F** present the algorithm and its associated assumptions and decisions, respectively; **Section G** presents the results of the initial application of the algorithm to characterize the population with acute bronchitis in a claims database; and **Section H** provides discussion and concluding thoughts.

C Literature Review

C1 Methods

A literature review search strategy was developed for the BEST Initiative, based upon a Population, Intervention, Comparator, Outcome (PICO) framework. The PICO framework for this review can be summarized as follows:

- **Population:** *any population group (human)*
- **Intervention:** *any intervention or no intervention*
- **Comparator:** *any comparator, placebo*
- **Outcome:** *acute bronchitis*

The setting for eligible studies was any clinically observable environment that led an individual to seek care.

Briefly, the review process began with conducting systematic searches of existing publications available in the CBERⁱⁱⁱ and Center for Drug Evaluation and Research Sentinel^{iv} databases (no articles were retrieved from either). Next, a structured review of the academic literature was conducted, using PubMed, Medline, and Google Scholar to identify relevant resources. Only English language publications were selected for review. No restriction was imposed on publication date. The end date of the search was June 26, 2020. The PubMed search strategy is summarized below. Search terms are not case sensitive.

- **Search 1:** ("acute bronchitis" [All Fields] AND "ICD" [All Fields]): **retrieved 608 articles**
- **Search 2:** ("acute bronchitis" [All Fields] AND "ICD" [All Fields] AND "Algorithm" [All Fields]): **retrieved 118 articles**
- **Search 3:** ("acute bronchitis" [All Fields] AND "ICD" [All Fields] AND "PPV" [All Fields]): **retrieved 28 articles**
- **Search 4:** (Bronchitis AND ICD AND Validation): **retrieved 867 articles**

Targeted and *ad hoc* searches of the gray literature were conducted, including clinical guidelines and reports from organizations such as the United States Armed Forces Health Surveillance Branch (AFHSB) and the Agency for Healthcare Research and Quality (AHRQ). A snowballing technique was also applied, wherein the bibliographies of relevant studies were scanned for additional resources. Since this was not a systematic review, authors did not track the total number of abstracts screened after de-duplication.

All abstracts were reviewed, and 29 articles were reviewed in full text. Of these, 25 were retained for extraction and informed algorithm design. A Microsoft[®] Excel spreadsheet was developed to extract relevant data. The data elements collected are provided in **Table 1**. A relevance ranking was assigned based on the judgement of the reviewer and the available information on study location ("Country"), the algorithm specifications ("Algorithm"), and the measures of validity and diagnostic accuracy (e.g., PPV and NPV). Relevance rankings were assigned based on the following criteria:

- **Ranking 1:** U.S. validation study (i.e., reporting measures of validity and diagnostic accuracy)
- **Ranking 2:** U.S. study that reported a claims-based definition but no independent validation OR a non-U.S. validation study
- **Ranking 3:** Non-U.S. study that reported a claims-based definition but no independent validation

ⁱⁱⁱ U.S. Food and Drug Administration. Innovation and Regulatory Science. July 10, 2020. <https://www.fda.gov/vaccines-blood-biologics/science-research-biologics/innovation-and-regulatory-science>

^{iv} Sentinel. Publications and Presentations. <https://www.sentinelinitiative.org/communications/publications>

Table 1. Data elements recorded in the extraction spreadsheet.

Data Element
Author
Publication Year
Article Relevance (Ranking 1-3)
Full Citation
Country of Study
Data Source
Years Included
Population Eligibility Criteria
Validation Method
Disease Definition
Algorithm Incidence Rules
ICD-9/ICD-9-CM Codes
ICD-10/ICD-10-CM Codes
Other Codes
PPV % (95% Confidence Interval [CI])
NPV % (95% CI)
Other Performance Measures
Comments

Abbreviations: ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification; ICD-10-CM, International Classification of Diseases, Tenth Revision, Clinical Modification; PPV, Positive Predictive Value; NPV, Negative Predictive Value; 95% CI, 95% Confidence Interval

C2 Results

Following title and abstract screening and full-text review, 25 publications were identified as being particularly relevant (**Appendix A**). Each publication reported either measures of diagnostic accuracy associated with EHR- or EMR-based algorithms (i.e., acute bronchitis codes derived from billing codes of admission or discharge medical records) or claims-based coding algorithms (i.e., acute bronchitis codes derived from administrative insurance claims databases). Additional publications identified in the literature review applied a coding algorithm to identify cases of acute bronchitis in administrative claims or EHR/EMR data without validation. Of the 25 publications, 19 studies were from the U.S., three studies were from Canada, and there was one study each from Thailand, Germany, and New Zealand. Publication dates for these studies ranged from 1998 to 2020. Across the selected studies, ICD diagnosis codes were the primary code sets used to identify acute bronchitis cases.

Overall, claims- and EHR/EMR-based studies with validation and several additional studies without validation identified in this literature review indicate that the approach of using ICD-9-CM 466.0 (acute bronchitis) alone or in combination with 490.0 (bronchitis not otherwise specified) was consistently used for identifying acute bronchitis cases.

We summarized literature below with respect to the data source from which each coding algorithm was derived (i.e., claims or EHRs), validation with medical charts (i.e., yes or no), and the location of the study (i.e., U.S. or international).

2.a Claims-based Algorithms with Validation

A single study was identified that reported on the diagnostic accuracy associated with an administrative claims-based algorithm for acute bronchitis in a U.S. population. Maselli and colleagues sought to assess

the accuracy of administrative claims data in seven Colorado managed care organizations for measuring antibiotic prescribing behavior conducted a stratified randomized medical record review of office visits by children with pharyngitis and adults with acute bronchitis to primary care physicians in Colorado in 1998.² A total of 9,439 patients aged 18 years and older were identified by acute bronchitis ICD-9-CM codes 466.0 and 490, with 535 charts randomly selected and abstracted for bronchitis. Among the 535 medical records reviewed for adult bronchitis, 497 (97%) specified a principal diagnosis. Of these 497 patients, the claims-based diagnosis of acute bronchitis was verified as correct in 79% of medical records reviewed.

Two studies that reported on diagnostic accuracy associated with administrative claims codes for acute bronchitis in non-U.S. populations were identified.^{10,11} Two Canadian studies by Cadieux and colleagues assessed patient medical records and physician billing claims.^{10,11} In a pilot study of nine primary care practices in Montreal, Cadieux and colleagues evaluated the accuracy of diagnostic codes in physician claims for identifying ARI.¹⁰ Among 729 patients, the diagnosis was abstracted from medical charts for 3,526 visits and researchers compared the medical chart diagnosis to the ICD-9 code on the corresponding physician claims. For ICD-9 code-specific performance measures, the study reported following performance measures for acute bronchitis (466): PPV: 72% (95% CI 67–78%), NPV: 99% (95% CI 98–99%), sensitivity: 52% (95% CI 46–59%), and specificity: 99% (95% CI 99–99%).

In the subsequent study of a random sample of 3,600 primary care physicians from a population-based registry of insured persons and claims for all physician visits in Quebec, Cadieux and colleagues reported the accuracy of five syndrome definitions (fever, gastrointestinal, neurological, rash, and respiratory including influenza-like illness) based on diagnostic codes from a sample of physician claims in comparison to clinical information in the corresponding medical chart (n=1,098 physicians completed the chart review for 10,669 corresponding visits).¹¹ The authors reported performance measures (PPV), for individual ICD-9 codes selected for each of the four respiratory disease-related syndromes: influenza-like illness (ILI) large-group (sensitive) [466.0, acute bronchitis (85%); 490.0, bronchitis not otherwise specified (0%)], ILI small group (specific) [no ICD-9-CM codes directly relevant to acute bronchitis], Real-time Outbreak and Disease Surveillance (RODS)-Respiratory [466.0, acute bronchitis (81%); 490.0, bronchitis not otherwise specified (0%)], and Centers for Disease Control and Prevention (CDC)-Department of Defense Electronic Surveillance System for Early Notification of Community-based Epidemics (ESSENCE)-Respiratory [466.0, acute bronchitis (90%); 490.0, bronchitis not otherwise specified (0%)].

2.b Medical Records-based Algorithms with Validation

Two studies were identified that reported on diagnostic accuracy associated with EHR-based algorithms, for acute bronchitis in U.S. populations.^{1,12} A study by Linder and colleagues sought to determine the accuracy of diagnoses and antibiotic prescribing in EHR for acute infections in a primary care setting by performing a study of ARI and urinary tract infection (UTI) visits in a practice-based research network of nine clinics in the greater Boston area.¹ Among the 65,285 visits identified with a primary diagnosis of ARI or UTI in the EHR, 1,000 visits were randomly selected for chart review, and 827 visits were included in the analysis (421 ARI visits, 406 UTI visits). Of the 421 ARI visits, authors sought to identify those with a diagnosis possibly related to acute bronchitis defined on the basis of (1) the use of ICD-9-CM codes 466.0 (acute bronchitis) and 490 (bronchitis not otherwise specified), and (2) blinded chart review. A bronchitis diagnosis (acute or unspecified) derived from billing codes was reported in 54 (12.8%) visits. Based on chart review the authors reported a PPV of 67%, a sensitivity of 88%, and a specificity of 98% associated with a bronchitis diagnosis (ICD-9-CM 466.0 or 490) from billing codes. In a subsequent publication from the same study setting, Renati and Linder used several ICD-9-CM codes (e.g., not-specified upper respiratory infection, influenza, etc.) to identify 500 new ARI-related visits.¹² For acute bronchitis, the authors selected primary diagnosis codes ICD-9-CM codes 466.0 and 490 and reported a PPV for all new ARI visits of 88%. Performance measures for ICD-9-CM 466.0 and 490 were not reported separately.

In an analysis of EMR data from a military syndromic electronic surveillance system, Betancourt and colleagues identified ICD-9-CM 466.0 as the sixth most frequently used code and ICD-9-CM 490 as the tenth most frequently used code included in a respiratory syndrome group that comprised a total of 138 ICD-9-CM codes.¹³ The authors reported the following measures of diagnostic validity for the respiratory syndrome group as whole across three sites: PPV: 81.3%, NPV: 90.4%; sensitivity: 65.7%, and specificity: 95.6%. Performance measures for ICD-9-CM 466.0 and 490 were not reported separately.

Two international studies were also identified that reported on EMR-based algorithms for acute bronchitis.^{14,15} In a study conducted in Canada, Hwee and colleagues analyzed data from Electronic Medical Record Administrative Data Linked Database (EMRALD).¹⁴ This data source contains clinically relevant information from EMRs that can be linked to physician billing records within administrative databases for Ontario residents less than 18 years of age who were under the care of family physicians who share their practice's EMR data with EMRALD. Among the 2,139 randomly sampled patients included in the analysis, performance measures were reported for a group of infection-related diagnosis codes in the Ontario Health Insurance Plan (OHIP), which is a truncated version of International Classification of Diseases, Eighth Revision (ICD-8) and ICD-9. OHIP codes representing respiratory infections that included 466.0 for acute bronchitis were associated with the following performance measures: PPV: 85% (95% CI 81–88%), NPV: 94% (95% CI 92–95%), sensitivity: 77% (95% CI 73–81%), and specificity: 96% (95% CI 95–97%). Performance measures for ICD-9 466.0 were not reported. Finally, a study conducted in Thailand by Sukanya described an approach for assessing the validity of principal diagnoses given in discharge summaries compared to a medical record review for various ICD-10-Thai Modification (TM) codes.¹⁵ A total of 23,202 patients were included in the respiratory system group, which included J20.9. The validity of the principal diagnosis given in the discharge summaries based on comparison with the medical record reviews for ICD-10-TM code J20.9 included PPV: 15.1% (95% CI 13.8–16.5%); NPV: 97.8% (95% CI 97.7–97.8%); sensitivity: 12.2% (95% CI 11.0–13.4%); and specificity: 98.3% (95% CI 98.2–98.3%).

2.c Algorithm Application without Validation

Five U.S. studies were found that utilized ICD-9-CM codes 466.0 and 490 to identify acute bronchitis cases in EMR, EHR, patient charts, or surveys.¹⁶⁻²⁰ These studies utilized national patient samples¹⁷⁻¹⁹ or were from a single site.^{16,20}

Additional studies utilizing a different combination of codes to identify acute bronchitis cases were also identified, including ICD-9-CM 466.0 and ICD-10-CM J40 (bronchitis, not specified as acute or chronic) in an EMR database²¹ and ICD-9-CM codes 466 or 465.9 (upper respiratory infection [URI]) in patient charts.²² Authors also identified several U.S. studies that utilized only ICD-9-CM code 466.0 to identify acute bronchitis cases in EMR, EHR, patient forms, surveys, and administrative claims databases.²³⁻²⁸

Two studies of U.S. military personnel that utilized ICD-9-CM and ICD-10-CM diagnosis codes to identify acute bronchitis cases were found. A study conducted by the AFHSB reported trends in rates of COPD and allied conditions.²⁹ The authors used ICD-9-CM codes 490–496 (chronic airway obstruction, not elsewhere classified) to identify relevant respiratory diagnoses in a medical surveillance database of administrative claims; for acute bronchitis relevant codes included ICD-9-CM code 490. In the other study of U.S. military personnel, clinical encounters for acute bronchitis relevant codes included ICD-9-CM code 466.0 and ICD-10-CM code J20.9 (acute bronchitis, unspecified).³⁰

In addition to these U.S. studies, we identified two international studies that used ICD-10 codes to identify acute bronchitis cases in EMR databases but did not report measures of diagnostic validity. A study from New Zealand³¹ utilized ICD-10 code J20 (acute bronchitis) and a study from Germany utilized ICD-10 codes J40 and J20.³²

D Acute Bronchitis Clinical Case Definition

Acute bronchitis is characterized by inflammation of the bronchi, with the most common symptom, a cough, typically lasting about two to three weeks. In addition to cough, common symptoms include sputum production, dyspnea, nasal congestion, headache, and fever. Given such a broad array of symptoms, the diagnoses with greatest overlap with acute bronchitis include upper respiratory tract infections and pneumonia. The primary diagnostic consideration in patients with suspected acute bronchitis is ruling out more serious causes of cough, such as asthma, exacerbation of COPD, heart failure, or pneumonia. Laboratory testing is usually not indicated in the evaluation of acute bronchitis, although imaging (e.g., chest radiography) is used in high-risk patients (e.g., presenting with tachypnea, tachycardia, or dyspnea, older than 75 years) to rule out pneumonia.

Clinical practice guidelines from the American College of Chest Physicians (CHEST) provide the following criteria for the diagnosis of acute bronchitis in adult patients with symptoms of acute bronchitis (i.e., cough with or without sputum production lasting no more than three weeks) in the absence of a chest radiograph:⁷

- Heart rate < 100 beats per minute
- Respiratory rate < 24 breaths per minute
- Oral body temperature < 100°F (37.8°C)
- No dyspnea, bloody sputum, or rusty sputum color
- Chest examination findings do not indicate focal consolidation, egophony, or fremitus

Should a validation study of the acute bronchitis algorithm be executed, these clinical characteristics, diagnostic considerations, and practice guidelines could be used to inform chart review and adjudication.

E Acute Bronchitis Coding Algorithm

The aim of this review was to develop an algorithm to identify cases of acute bronchitis that could be of potential interest following exposure to a biologic product. To form a comprehensive list of acute bronchitis codes for clinical consideration, all ICD codes for acute bronchitis were extracted from the articles identified in the literature review (**Appendix A**). To expand the draft code list and reflect current coding practice, ICD-10-CM diagnosis codes were generated from ICD-9-CM codes using forward-backward mapping via the Centers for Medicare and Medicaid Services (CMS) GEMs files. The expanded draft code list, which included ICD-9-CM and ICD-10-CM codes, was subsequently reviewed by clinical SMEs from IBM (TB, JB), FDA CBER (JC, DT), and Acumen.

The workgroup has sought an approach that is consistent with those reported in the published literature. This approach involved selecting the specific codes for acute bronchitis while excluding those that are expressively inclusive of conditions too general to be useful in measuring associations between a biologic exposure and acute bronchitis or do not meet the clinical definition of acute bronchitis (included in **Section D**). This approach supports alignment and comparability with past studies and reflects current coding practices. However, this focused approach may impact the performance of the algorithm (i.e., potential decrease in sensitivity) if assessed against a case definition for acute bronchitis that includes more general symptoms (e.g., cold, cough) than the CHEST clinical practice guidelines.

The proposed algorithm for identifying acute bronchitis using administrative claims codes is presented in **Table 2**. This algorithm takes a general approach to defining acute bronchitis and may need to be adjusted or tailored for specific research questions that arise in the future. Annual counts of patients with individual diagnosis codes are provided in **Appendix B**.

Specific decisions and assumptions related to construction of the algorithm are summarized in **Section F**. Overall, the clinical SMEs recommended the inclusion of additional codes or exclusion of codes from the expanded draft code list based on clinical relevance and optimizing the balance between specificity and

sensitivity. A list of excluded codes is provided in **Appendix C**. These codes were ultimately determined by the clinical SMEs to be too general and could potentially increase the risk of misclassification. As such, while they were not applied as exclusion criteria, the codes in **Appendix C** were left out of the algorithm options to identify cases of acute bronchitis

Briefly, the proposed algorithm can be summarized as follows:

INCLUDE: ANY (“either–or”) of the codes listed in **Table 2**, regardless of health care setting or coding position (only one code required).

Table 2. Acute bronchitis algorithm.

Code	Description	Code Category	Code Type
466.0	Acute Bronchitis	DX	09
490 ¹	Bronchitis not otherwise specified	DX	09
J20.0	Acute bronchitis due to <i>Mycoplasma pneumoniae</i>	DX	10
J20.1	Acute bronchitis due to <i>Hemophilus influenzae</i>	DX	10
J20.2	Acute bronchitis due to streptococcus	DX	10
J20.3	Acute bronchitis due to coxsackievirus	DX	10
J20.4	Acute bronchitis due to parainfluenza virus	DX	10
J20.5	Acute bronchitis due to respiratory syncytial virus	DX	10
J20.6	Acute bronchitis due to rhinovirus	DX	10
J20.7	Acute bronchitis due to echovirus	DX	10
J20.8	Acute bronchitis due to other specified organisms	DX	10
J20.9	Acute bronchitis, unspecified	DX	10
J40 ¹	Bronchitis, not specified as acute or chronic	DX	10

Abbreviation: DX, ICD-CM diagnosis.

¹Including Codes 490 and J40 in the algorithm provides a more inclusive approach as these codes are likely to capture additional acute bronchitis cases. However, users seeking a more specific algorithm may elect to exclude these as being too general and common, thus introducing potential risk of misclassification.

F Assumptions and Decisions

The algorithm presented in **Section E** was reviewed internally as well as with CBER stakeholders and partners. Decisions and assumptions related to algorithm construction are summarized below. Some of these assumptions may be adjusted for future research questions.

- As informed by approaches in the published literature and on the basis of clinical consultation, it was decided that methods for diagnosing and treating acute bronchitis — as would be reflected in procedural and prescription coding standards — were too variable and general to be included in the code-based definition. The proposed algorithm has therefore been restricted to ICD diagnosis codes.
- The restriction of queries based on diagnosis coding position (e.g., principal position codes only), varied across the studies reviewed. Queries presented in **Section G** did not restrict based on coding position, out of concern that queries based solely on primary-position codes could improperly exclude acute bronchitis cases. Users may adjust this approach to include primary, secondary, or unspecified position codes, but this is likely better done at the statistical planning stage, when a specific research question has been formulated.
- As informed by approaches in the published literature and on the basis of clinical consultation, it was decided that symptoms that characteristically accompany acute bronchitis (e.g., cough, dyspnea, nasal congestion, headache, fever, common cold) are too general to be included in the algorithm.

- Additional codes included in algorithm for a more inclusive approach (ICD-9-CM 490; ICD-10-CM J40) were viewed as being more likely to identify acute bronchitis cases than chronic bronchitis cases and improve the sensitivity of the algorithm. However, these codes are general and may increase risk of misclassification, so users seeking a more specific algorithm may wish to exclude these codes.
- Risk windows used to determine the association of acute bronchitis with a particular exposure should be determined on the basis of the particular research question and exposure of interest, though a prior study used a risk window of 0-6 days and 0-29 days post-vaccination for two different rotavirus vaccinations given in conjunction with pneumococcal vaccination.⁶
- To define an incident occurrence, consideration could be given to including a “washout period” (to be defined depending on the study question), wherein individuals would be excluded from the study if they had an acute bronchitis event within a certain time period (e.g., six months) prior to the exposure of interest.

G Algorithm Characterization

G1 Methods

To summarize the epidemiology of acute bronchitis among a commercially insured population in the U.S., the workgroup used the IBM MarketScan Research Databases (Commercial and Medicare Supplemental), accessed via the Treatment Pathways^v online analytic platform, to query and analyze the diagnostic codes included in the acute bronchitis algorithm (**Table 2**). To gather the broadest range of cases to support a descriptive analysis, the analyses presented herein did not require exposure to a biologic product or restrict based on the diagnosis coding position. It is recommended that the proposed algorithm undergo a validation study prior to use, though future analytical studies should also tailor the algorithm specifications according to the study question of interest.

The figures presented below have been drawn from a large patient dataset during the study period of January 1, 2014–December 31, 2018. For all analyses, authors only queried ICD-9-CM codes for January 1, 2014–September 30, 2015 and ICD-10-CM codes for October 1, 2015–December 31, 2018. This was done out of recognition of the transition to ICD-10-CM on October 1, 2015 and an effort to exclude codes that were reported in error.

Counts of individual patients that had a diagnosis code related to acute bronchitis within a given calendar year, rather than counts of acute bronchitis codes, were presented. As such, counts relate to the first diagnosed acute bronchitis event for an individual during a given surveillance period (e.g., January 1–December 31, 2014), and individuals could only be counted once per surveillance period. Since we did not estimate the incidence of acute bronchitis in the study population, no washout period was applied.

Individuals had to be continuously enrolled in any enrollment category to be included in the analysis for a particular year. For example, patients had to be continuously enrolled from January 1 to December 31, 2014, to be included in the “2014” dataset. Age is calculated in Treatment Pathways as if each individual was born on July 1 of their given year of birth. Out of concern that the minimum continuous enrollment requirement could impact the inclusion of infants (i.e., those under one year of age), this population group has been left out of two charts that depict the proportions of individuals with acute bronchitis by age. Infants under one year of age were not excluded from queries of the absolute number of patients receiving an acute bronchitis diagnosis.

^v IBM MarketScan Research. Insight for Better Healthcare. <https://marketscan.truvenhealth.com/marketscanportal/Portal.aspx>

Age- and gender-specific data on MarketScan Research Databases enrollment and counts of individuals receiving a diagnostic code for acute bronchitis were extracted. Code-specific queries described in **Section E** are summarized in **Appendix B**. In addition to the code-specific queries the authors executed queries that aggregated all ICD-9-CM codes, all ICD-10-CM codes, and all codes (ICD-9-CM and ICD-10-CM) for acute bronchitis.

G2 Results

Of the codes included in the acute bronchitis algorithm, codes for acute bronchitis (ICD-9-CM 466) and acute bronchitis, unspecified (ICD-10-CM J20.9) were the most frequently used during the study period. Of those receiving at least one acute bronchitis diagnosis between 2014 and 2018 (n=5,591,487), 36.5% (n=2,039,857) and 42.7% (n=2,385,978) had at least one ICD-9-CM 466 and ICD-10-CM J20.9 code, respectively.

Table 3 provides a summary of aggregate counts for ICD-9-CM and ICD-10-CM codes, suggesting that approximately 48.7–62.0 individuals per 1,000 individuals included in the MarketScan Research Databases received a code associated with acute bronchitis each year. Among a cohort of 46,153,898 patients that combined those continuously enrolled for at least one calendar year between January 1, 2014 and December 31, 2018, 5,591,487 individuals (12.1%) had at least one ICD-9-CM or ICD-10-CM diagnosis code for acute bronchitis.

Table 3. Counts of patients with acute bronchitis by code set and year.

Code/ Description	Year				
	2014	2015 ^a	2016	2017	2018
ICD-9-CM	1,706,215	1,012,785			
ICD-10-CM		439,631	1,268,829	1,090,306	943,538
ICD-9-CM OR ICD-10-CM	1,706,215	1,371,053	1,268,829	1,090,306	943,538
MarketScan Research Databases Enrollment	28,407,959	22,117,235	21,616,291	19,563,847	19,371,891
Proportion of Patients with Acute Bronchitis per 1,000 Enrolled Population	60.1	62.0	58.7	55.7	48.7

Abbreviations: ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification; ICD-10-CM, International Classification of Diseases, Tenth Revision, Clinical Modification.

^a In 2015, queries combining ICD-9-CM and ICD-10-CM codes returned lower patient counts than when codes were queried individually. This is because of cases in which both ICD-9-CM and ICD-10-CM codes were reported for the same individual, in the January–September and October–December timeframe, respectively.

^b Proportions were calculated using the counts in the “ICD-9-CM OR ICD-10-CM” row.

The workgroup assessed whether the 2015 transition to ICD-10-CM and any associated changes in coding practices resulted in notable shifts in the frequency of acute bronchitis. **Figure 1** illustrates the proportion of the enrolled population with an acute bronchitis diagnosis and suggests that the transition did not result in a substantial change to the proportion of individuals receiving an acute bronchitis diagnosis, though the proportion of patients receiving an acute bronchitis diagnosis decreased since 2016. This decrease may be attributable in part to changes in the coding process following the transition from ICD-9-CM to ICD-10-CM codes. The utilization of ICD-10-CM codes, which can account for specific etiologic factors, may have resulted in the identification of more relevant acute bronchitis cases. Independent analyses also indicated a decrease in the proportion of patients receiving a diagnosis for Bell's palsy, COPD, acute respiratory distress syndrome and pneumonia for the same time period. Therefore, this decrease may also be due to incomplete data capture in the MarketScan Research Databases for the most current year available (2018).

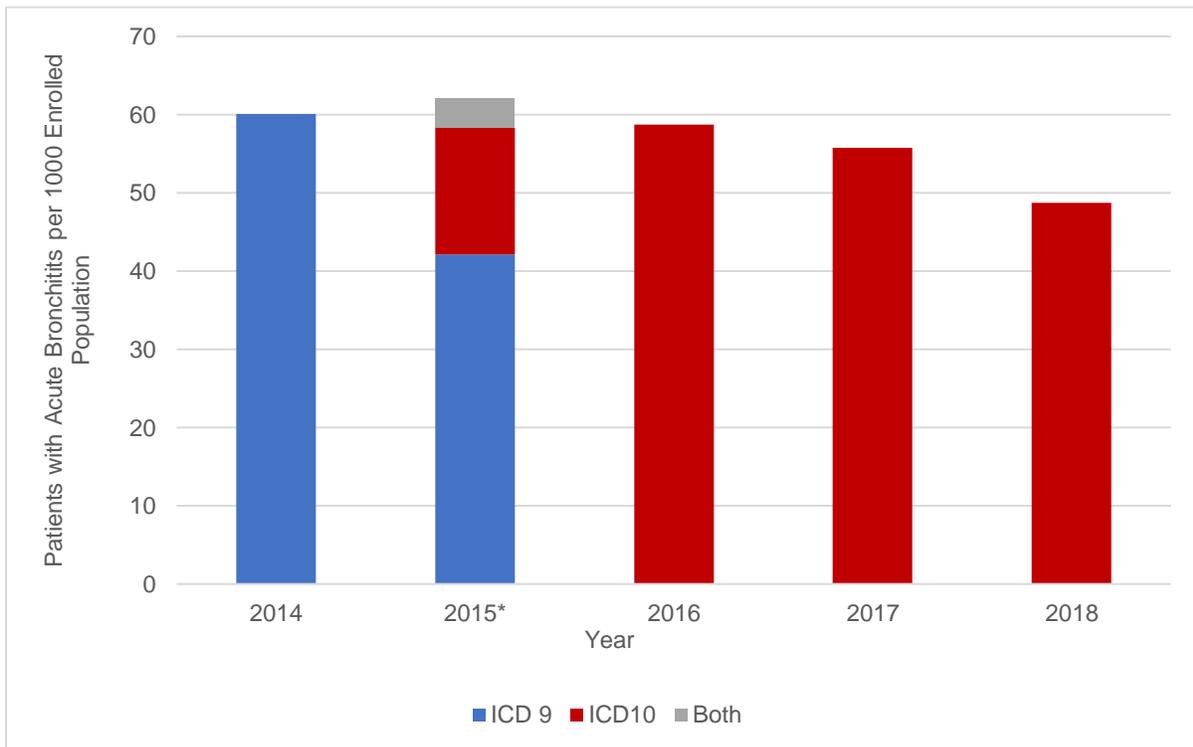


Figure 1. Proportion of patients with acute bronchitis per 1,000 enrolled, by year (2014–2018).

Note: In 2015, a patient could receive both an ICD-9-CM and an ICD-10-CM diagnosis, in the January–September and October–December timeframe, respectively.

Figure 2 presents counts of patients with an acute bronchitis diagnosis (ICD-9-CM codes 466.0 and 490) stratified by age group. Counts were calculated for the timeframe of January 1, 2014 to September 30, 2015 among the cohort of 33,216,843 patients who were continuously enrolled for at least one calendar year between January 1, 2014 and December 31, 2015. There were 2,668,721 (8.0%) with at least one diagnosis for acute bronchitis during this period, with an average age at first diagnosis of 42 years.

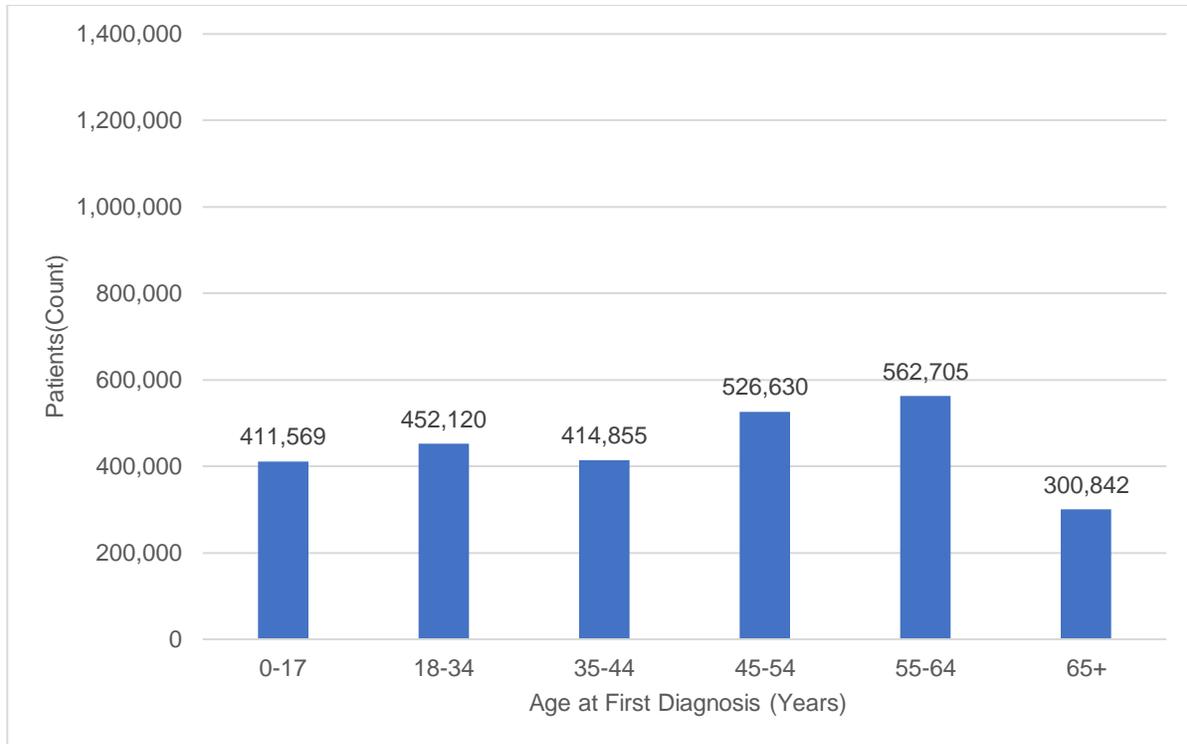


Figure 2. Patients with at least one diagnosis code for acute bronchitis (ICD-9-CM codes 466.0 and 490), January 1, 2014–September 30, 2015, stratified by age.

Figure 3 presents counts of patients with acute bronchitis (ICD-10-CM J20.X, J40) stratified by age group. Counts were drawn from a cohort of 35,337,738 patients who were continuously enrolled for at least one calendar year between October 1, 2015 and December 31, 2018 (i.e., January 1–December 31 for at least one of 2015, 2016, 2017, or 2018). Among 3,478,122 individuals (9.8%) with at least one diagnosis for acute bronchitis during this time period, the average age at first diagnosis was 42 years.

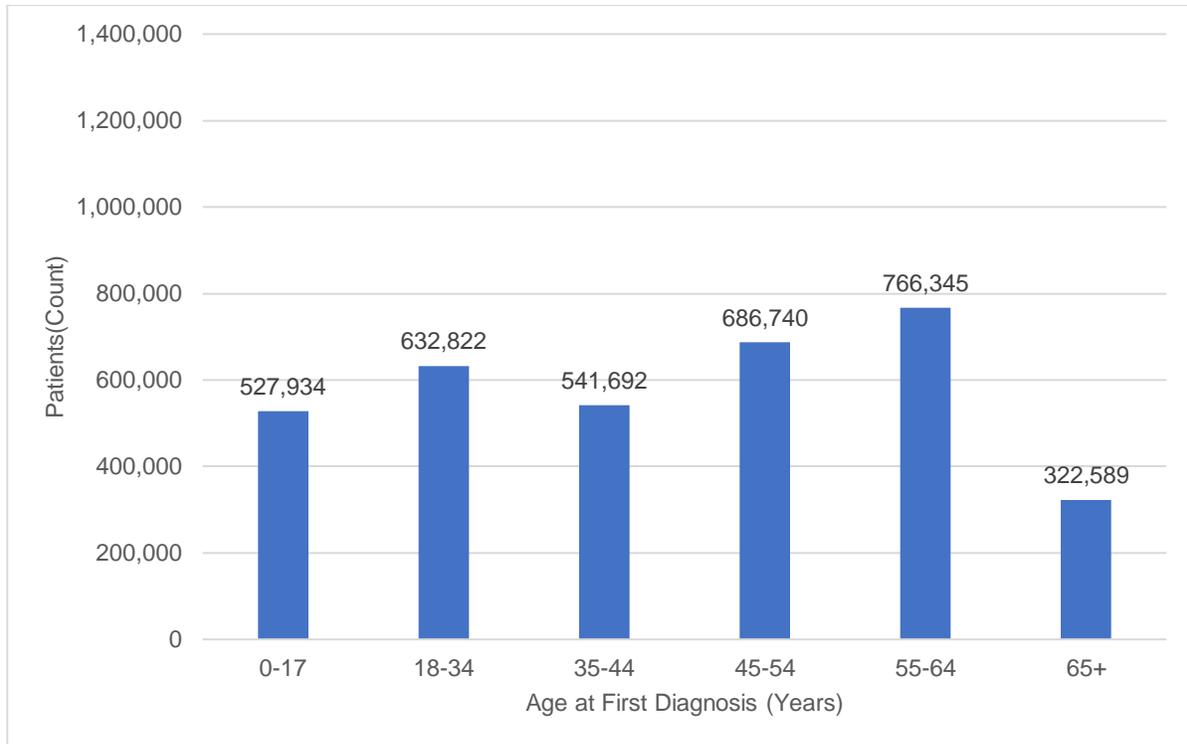


Figure 3. Patients with at least one diagnosis code for acute bronchitis (ICD-10-CM codes listed in Table 2), October 1, 2015–December 31, 2018, stratified by age.

Figure 4 presents count of patients with either an ICD-9-CM or ICD-10-CM code for acute bronchitis among a cohort of 46,153,898 individuals who were continuously enrolled for at least one calendar year between 2014 and 2018. Among 5,591,487 individuals (12.1%) who received a diagnosis code for acute bronchitis between January 1, 2014, and December 31, 2018, the average age at first diagnosis was 41 years. Absolute patient counts were highest in the age group of 55–64 years, with the lowest absolute counts in the 65+ age group, though this may be due to a smaller enrolled population group as individuals move off of commercial insurance plans (as discussed in the context of **Figure 5**, below).

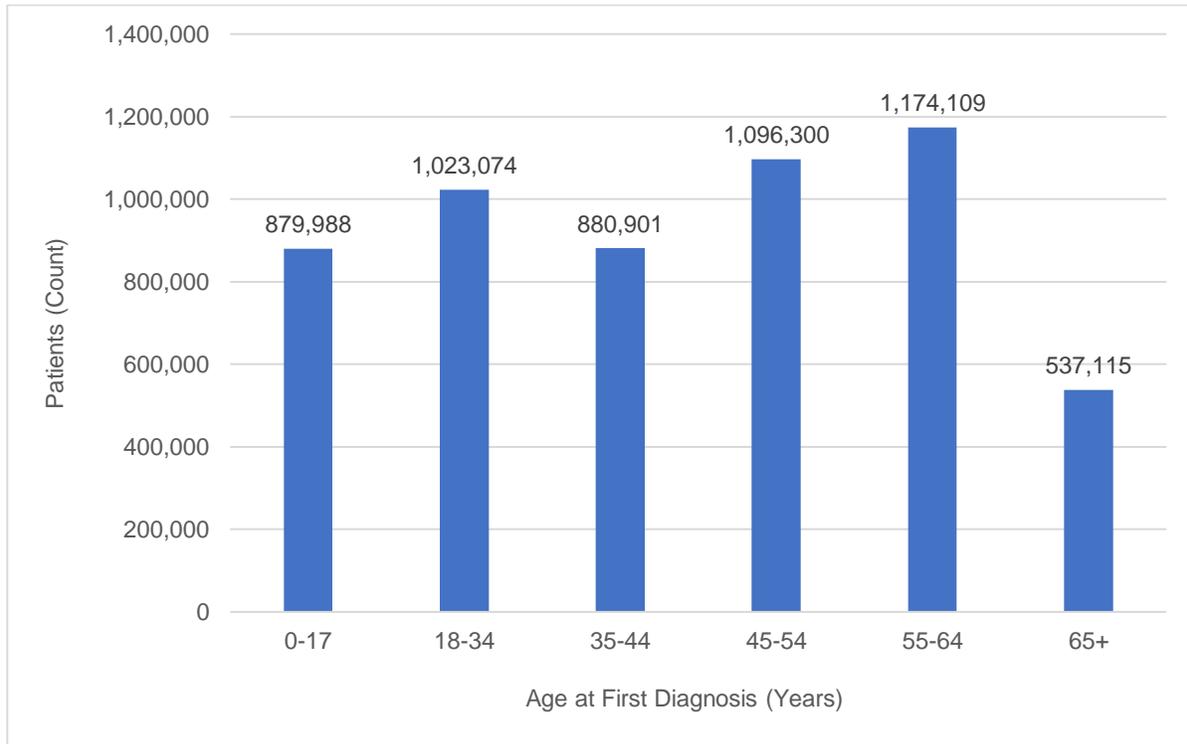


Figure 4. Patients with at least one diagnosis code for acute bronchitis (ICD-9-CM or ICD-10-CM), January 1, 2014–December 31, 2018, stratified by age.

Figure 5 summarizes the proportion of the population aged 1-85+ years with at least one ICD-9-CM or ICD-10-CM code for acute bronchitis (per 1,000 population enrolled in the MarketScan Research Databases) between January 1, 2014, and December 31, 2018, by age and gender. Patients 85 years of age and older were grouped to minimize the effect of unstable estimates due to the smaller enrolled population sizes available in this age range in the commercially insured population. The 46 million-patient cohort was used for this analysis and individuals were required to be enrolled for at least one calendar year between 2014 and 2018 but were not required to be enrolled for the full five-year period to be included in the calculations. The results suggest that the proportion of patients with acute bronchitis increases with age, with peaks in early childhood (3–5 years) and late adolescence (15–20 years) that are followed by a slow increase to about 65 years of age. At 65 years, the proportion of individuals experiencing acute bronchitis decreases sharply, though this may be due to shifts in enrollment as individuals move off of commercial insurance plans, and proportions begin to increase again after 65 years of age. In addition, the results indicate that the proportion of patients with acute bronchitis is distributed evenly between boys and girls, though a consistently higher proportion was observed in adult women aged 20-80 years old relative to men of the same age.

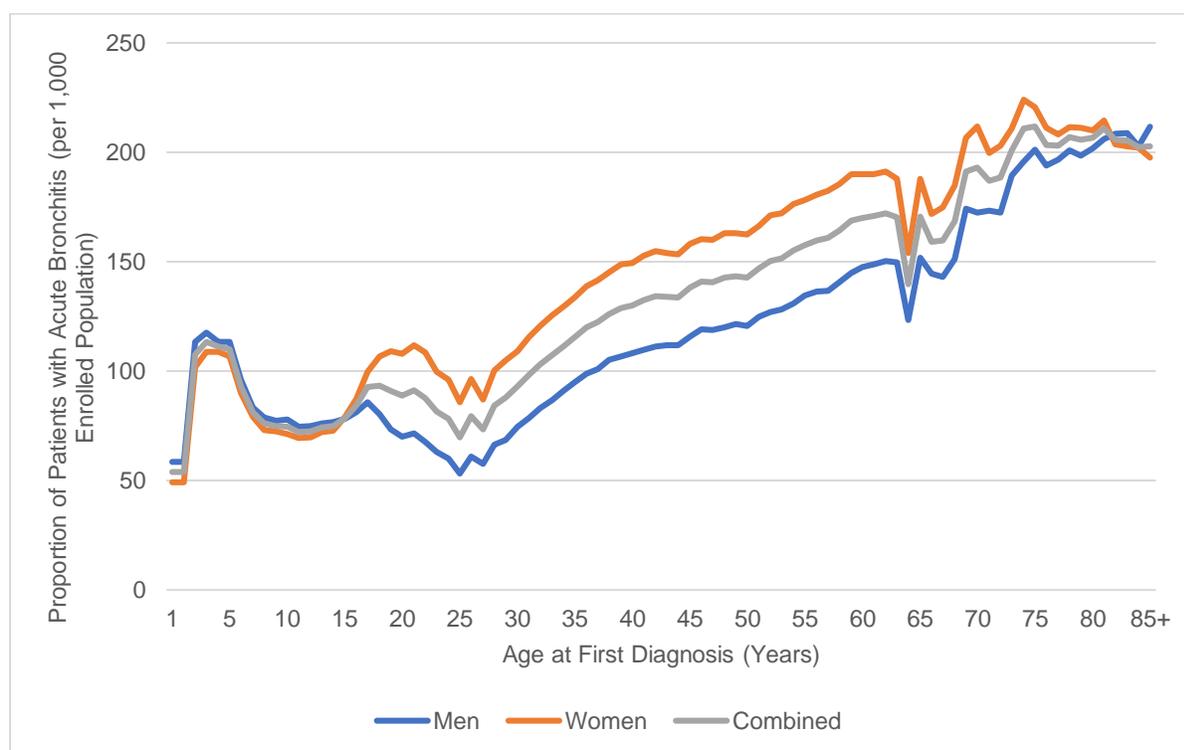


Figure 5. Proportion of patients (1–85+)* with at least one diagnosis code for acute bronchitis (ICD-9-CM or ICD-10-CM) per 1,000 population, by age and gender (January 1, 2014–December 31, 2018).

*Out of concern that the minimum continuous enrollment requirement could impact the inclusion of infants (i.e., those under 1 year old), the proportion of those under 1 year old experiencing acute bronchitis is excluded from the chart.

The workgroup also assessed whether there was a notable variation in the proportion of patients with acute bronchitis by calendar year of diagnosis. **Figure 6** presents the annual proportions of patients with a diagnosis code for acute bronchitis for ages 1–85+ years. Results suggest that proportions were consistent across calendar years, though lower proportions were observed for 2018. It should be noted that the proportions presented in **Figure 6** are substantially lower than those in **Figure 5**, where acute bronchitis encounters were queried for the entire 2014–2018 period instead of for a single year.

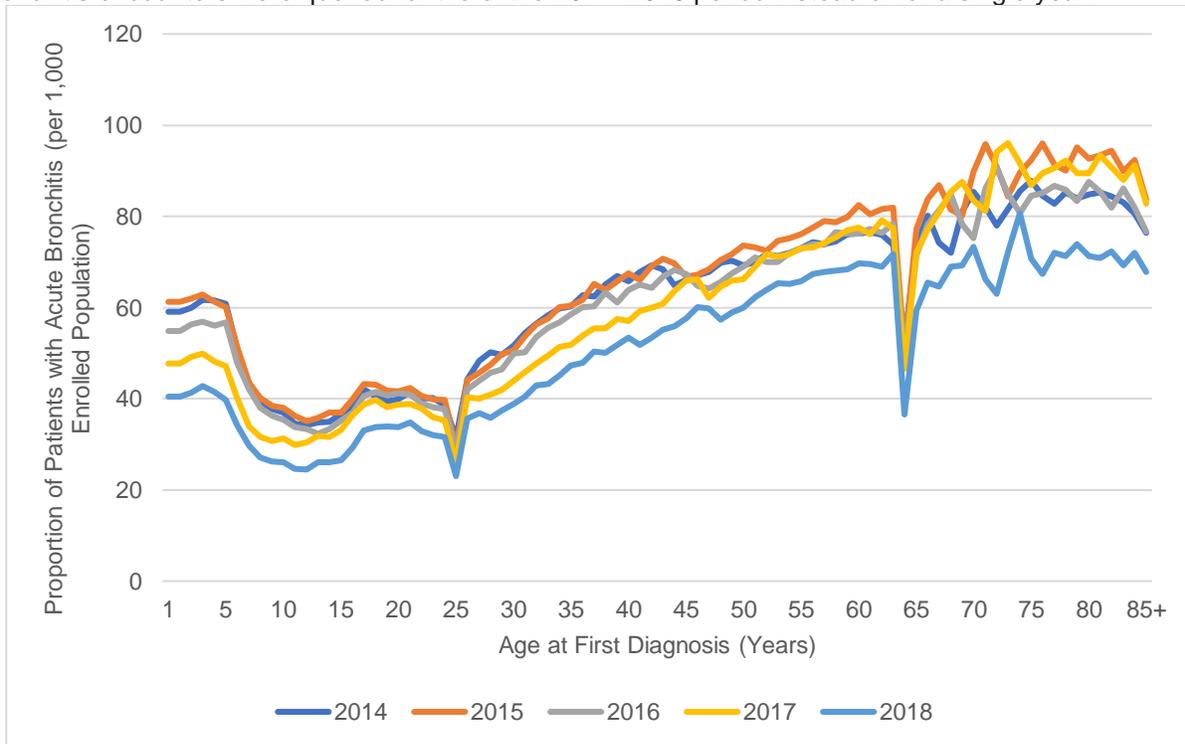


Figure 6. Proportion of patients (1–85+)* with at least one diagnosis code for acute bronchitis (ICD-9-CM or ICD-10-CM) per 1,000 population, by age and calendar year (January 1, 2014–December 31, 2018).

*Out of concern that the minimum continuous enrollment requirement could impact the inclusion of infants (i.e., those under 1 year old), the proportion of those under 1 year old experiencing acute bronchitis is excluded from the chart.

Analyses were also conducted to test whether there was a temporal association in the occurrence or reporting of acute bronchitis according to the time of the year, possibly as a result of an association with weather patterns or vaccination schedules. To test this, enrollment and acute bronchitis encounter data for January 1–June 30 and July 1–December 31 were queried for each year. As presented in **Table 4** and **Figure 7**, the proportion of patients experiencing acute bronchitis was lower in the second half of the year across the entire study period.

Table 4. Counts and proportions of patients experiencing acute bronchitis*, defined by ICD-9-CM and ICD-10-CM codes, stratified by time of year (2014–2018).

Description	Calendar Year				
	2014	2015	2016	2017	2018
January–June patient count	1,038,719	886,981	815,465	704,196	623,872
July–December patient count	941,032	691,669	549,457	547,922	459,290
January–June enrollment	31,110,014	24,094,695	23,531,649	21,406,675	21,225,754
July–December enrollment	30,867,380	23,759,879	23,759,879	20,866,148	20,866,232
January–June proportion (per 1,000 enrolled)	33.4	36.8	34.7	32.9	29.4
July–December proportion (per 1,000 enrolled)	30.5	29.1	23.1	26.3	22.0

* The sum of the proportions presented here exceeds those presented for full calendar years. This is because a patient can be counted in both time periods when queries are run separately, whereas they would only be counted once when the query spans the full year.

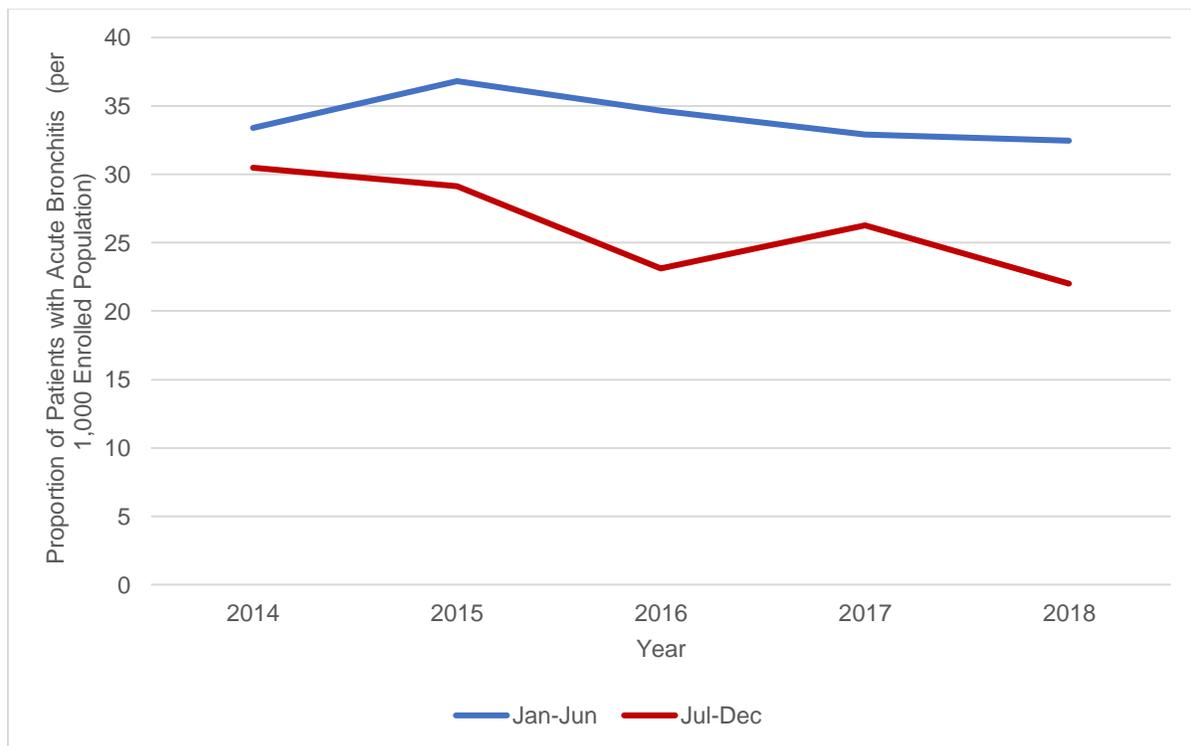


Figure 7. Proportion of patients with at least one diagnosis code for acute bronchitis (ICD-9-CM or ICD-10-CM) per 1,000 population, stratified by time of year (2014–2018).

H Discussion and Conclusion

The objective of this structured literature review was to understand and assess the validity of electronic coding algorithms for identifying acute bronchitis from administrative claims and EHRs/EMRs using billing codes.

Among the 25 publications identified, one U.S. study² and two Canadian studies^{10,11} reported validation of acute bronchitis algorithms defined in claims, two U.S. studies^{1,12} reported validation of acute bronchitis algorithms defined in EHRs, while one U.S.¹³ and two international studies^{14,15} reported performance measures for EMR-based coding algorithms. It is unclear how diagnostic code-based algorithms would perform differently in EHR compared to claims databases, beyond the differences that already occur within different databases of either EHR or claims. Validated EHR-based algorithms consisting of billing diagnosis codes were assessed for the completeness of the code lists in this report. In the two published U.S. validation studies which applied an ICD-9-CM algorithm to identify cases of acute bronchitis in EHR or administrative databases, the authors employed chart review to assess the validity of ICD-9-CM codes 466.0 and 490 in their respective databases, reporting moderate PPV (67–79%) and high sensitivity (88%).^{1,2} In addition, several U.S. studies were identified that applied billing codes to identify acute bronchitis cases using both ICD-9-CM codes 466.0 and 490.0,¹⁶⁻²⁰ or only ICD-9-CM 466.0.²³⁻²⁸ These findings — in combination with international non-validation studies — were used to develop an updated algorithm that was revised via consultation with clinical SMEs.

The algorithm was then applied in the MarketScan Research Databases, accessed via the Treatment Pathways analytic tool, to test the feasibility of algorithm use and conduct some initial analyses describing the epidemiology of acute bronchitis in a U.S. database of commercially insured patients. Findings suggest that approximately 48.7–62.0 individuals per 1,000 population experienced at least one acute bronchitis event per year between 2014 and 2018. This finding is consistent with prior research reporting a range of 44–54 cases per 1,000 population.³³ It should again be emphasized that only one case per person could be counted per query time period, and that a single individual might have experienced multiple episodes of acute bronchitis during the study period.

The average age at first diagnosis of acute bronchitis within the surveillance period was approximately 41 years. However, consistent with prior research, peaks in the proportion of patients experiencing acute bronchitis were observed in early childhood and late adolescence.³⁴ A higher average age of diagnosis may be attributable in part to a gradual increase in the proportion of patients with acute bronchitis until 65 years of age.

The proportion of patients experiencing acute bronchitis was higher among females until older age (80–85 years). Prior studies have also reported a higher frequency of female patients with acute bronchitis,^{33,35} although a literature review has reported males as being more commonly affected with lower respiratory infections.³⁶ This finding may be due in part to differences in health-seeking behavior impacting the proportion of individuals with clinically observed bronchitis. Also, the proportion of patients experiencing acute bronchitis appeared to vary substantially between the first and second halves of the calendar year, with a higher proportion of patients experiencing acute bronchitis in the first half of the year across all years of the study period. These findings are consistent with a prior study in the United Kingdom which found a peak in acute bronchitis cases in January to February and a nadir in August.³⁷ Future analysis of the MarketScan Research Databases could consider a more granular analysis of whether seasons or specific months are associated with peaks in acute bronchitis.

Strengths of this study are the development of an acute bronchitis algorithm using ICD-9-CM and ICD-10-CM code standards, based on a structured review of acute bronchitis code definitions and active engagement with clinical SMEs. To assess the plausibility of the algorithm, it was applied in a large administrative claims database to characterize acute bronchitis in the commercially insured U.S. population and generate descriptive statistics. The study also includes important limitations that should be considered in interpreting findings. First, a limited number of acute bronchitis validation studies were identified in the literature. In the two U.S. studies, PPV ranged from 67% to 79%, with a sensitivity of 88%

reported in one study.¹ The workgroup sought to optimize algorithm sensitivity by making the algorithm more inclusive and including the ICD-9-CM 490 and ICD-10-CM J40 codes for bronchitis not otherwise specified (as acute or chronic), though this approach could increase the risk of misclassification by including chronic bronchitis cases. Users seeking to prioritize specificity may want to exclude ICD-9-CM code 490 and ICD-10-CM code J40, and only use those specific to acute bronchitis (ICD-9-CM 466.0; ICD-10-CM J20.X). The analyses conducted in the MarketScan Research Databases should be viewed as exploratory and generalizable to the U.S. population that is commercially insured, and additional studies among populations with different insurance coverage would be required to validate the results and observations stemming from these queries. The algorithm is likely to capture patients with more severe acute bronchitis that requires medical attendance, but many cases of acute bronchitis are not medically attended or reported. The absence of universal diagnostic practices could also result in under-ascertainment of acute bronchitis cases, and results for the algorithm characterization analyses should be considered conservative estimates.

Besides utilizing a pre-defined algorithm consisting of a code list sometimes in combination with health care settings, diagnosis positions, and/or a time window to identify potential cases in administrative databases, predictive modelling or machine learning is another potential tool to identify the health outcome of interest when it cannot be reliably identified using the traditional code-based approach. In the case of acute bronchitis where a moderate PPV was reported in the literature using pre-defined coding algorithms, predictive modelling or machine learning approach may be considered.

I Acknowledgements

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Appendix A. Literature Review Extracted Results

Table A1 below includes a summary of the data extraction table used to extract data from papers of relevance to acute bronchitis algorithms. The 25 papers summarized in this table informed the development of the proposed acute bronchitis algorithm.

Table A1: Acute bronchitis data extraction table

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR/EMR-based Algorithm ^{vi}
Abraham, 2013	Trends in rates of chronic obstructive respiratory conditions among U.S. military personnel, 2001-2013	U.S.	Used ICD-9-CM code 490 to identify potential acute bronchitis cases in the U.S.	NA (no validation)	ICD-9-CM 490	NA (no validation)	EHR
Betancourt, 2007	Evaluation of ICD-9 codes for syndromic surveillance in the electronic surveillance system for the early notification of community-based epidemics	U.S.	Used ICD-9-CM codes 466.0 and 490 to identify potential acute bronchitis cases in the U.S.	Medical record review was used as the reference standard.	ICD-9-CM 466.0, 490 (included in respiratory syndrome group)	<u>Respiratory Syndrome group</u> PPV: 81.3% NPV: 90.4% Sensitivity: 65.7% Specificity: 95.6%	EMR

^{vi} Each publication reported on a either a claims-based (i.e., acute bronchitis codes derived from insurance reimbursement claims) or an EHR-/EMR-based (i.e., acute bronchitis codes derived from administrative medical records) algorithm.

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR/EMR-based Algorithm ^{vi}
Cadieux, 2011	Accuracy of syndrome definitions based on diagnoses in physician claims	Canada	Used ICD-9 codes 466.0 and 490 to identify potential acute bronchitis cases in Canada	Medical record review was used as the reference standard.	ICD-9 466.0, 490 (included in 3 respiratory disease syndrome groups)	<u>ILI large-group</u> PPV: 466.0 (85%) PPV 490.0 (0%) <u>RODS</u> PPV: 466.0 (81%) PPV: 490.0 (0%) <u>ESSENCE</u> PPV: 466.0 (90%) PPV: 490.0 (0%)	Claims
Cadieux, 2008	Accuracy of physician billing claims for identifying acute respiratory infections in primary care	Canada	Used ICD-9 code 466.0 to identify potential acute bronchitis cases in Canada	Medical record review was used as the reference standard.	ICD-9 466.0	<u>Acute bronchitis:</u> PPV: 72% (95% CI 67-78%) NPV: 99% (95% CI 98-99%) Sensitivity: 52% (95% CI 46-59%) Specificity: 99% (95% CI 99-99%) <u>All respiratory infections</u> PPV: 93% (95% CI 91-94%) NPV: 93% (95% CI 92-94%) Sensitivity: 49% (95% CI 45-53%) Specificity: 99% (95% CI 99-100%)	Claims

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR/EMR-based Algorithm ^{vi}
Evertsen, 2010	Diagnosis and management of pneumonia and bronchitis in outpatient primary care practices	U.S.	Used ICD-9-CM code 466.0 to identify potential acute bronchitis cases in the U.S.	NA (no validation)	ICD-9-CM 466.0	NA (no validation)	EMR
Gonzales, 2013	A cluster randomized trial of decision support strategies for reducing antibiotic use in acute bronchitis	U.S.	Used ICD-9-CM codes 466.0 and 490 to identify potential acute bronchitis cases in the U.S.	NA (no validation)	ICD-9-CM 466.0, 490	NA (no validation)	EHR
Gonzales, 1998	Factors associated with antibiotic use for acute bronchitis	U.S.	Used ICD-9-CM code 466.0 to identify potential acute bronchitis cases in the U.S.	NA (no validation)	ICD-9-CM 466.0	NA (no validation)	EHR and patient forms
Groothuis, 2011	Respiratory syncytial virus hospitalization trends in infants with chronic lung disease of infancy, 1998–2008	U.S.	Used ICD-9-CM code 466.0 to identify potential acute bronchitis cases in the U.S.	NA (no validation)	ICD-9-CM 466.0	NA (no validation)	National Hospital Discharge Survey

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR/EMR-based Algorithm ^{vi}
Hall, 2003	Evaluation and treatment of acute bronchitis at an academic teaching clinic	U.S.	Used ICD-9-CM codes 456.9 and 466.0 to identify potential acute bronchitis cases in the U.S.	NA (no validation)	ICD-9-CM 465.9, 466.0	NA (no validation)	Charts
Huang, 2014	Implementing hospital-based surveillance for severe acute respiratory infections caused by influenza and other respiratory pathogens in New Zealand	New Zealand	Used ICD-10 code J20 to identify potential acute bronchitis cases in New Zealand	Medical record review was used as the reference standard.	ICD-10 J20	45.8% met the SARI case definition	EMR
Hwee, 2018	Use of physician billing claims to identify infections in children	Canada	Used OHIP code 466.0 to identify potential acute bronchitis cases in Canada	Medical record review was used as the reference standard.	OHIP 466.0 (acute bronchitis)	<u>Respiratory infection</u> PPV: 85% (95% CI 81-88%) NPV: 94% (95% CI 92-95%) Sensitivity: 77% (95% CI 73-81%) Specificity: 96% (95% CI 95-97%)	EMR
Linder, 2006	Acute infections in primary care: accuracy of electronic diagnoses and electronic antibiotic prescribing	U.S.	Used ICD-9-CM codes 466.0 and 490 to identify potential acute bronchitis cases in the U.S.	Medical record review was used as the reference standard.	ICD-9-CM 466.0, 490	<u>Bronchitis diagnosis</u> PPV: 67% Sensitivity: 88% Specificity: 98% <u>ARI</u> PPV: 96% Sensitivity: 98% Specificity: 96%	EHR

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR/EMR-based Algorithm ^{vi}
Mainous et al, 2003	Trends in antimicrobial prescribing for bronchitis and upper respiratory infections among adults and children	U.S.	Used ICD-9-CM codes 466.0 and 490 to identify potential acute bronchitis cases in the U.S.	NA (no validation)	ICD-9-CM 466.0, 490	NA (no validation)	National Ambulatory Medical Care Survey
Maselli, 2001	Measuring antibiotic prescribing practices among ambulatory physicians: accuracy of administrative claims data	U.S.	Used ICD-9-CM codes 466.0 and 490 to identify potential acute bronchitis cases in the U.S.	Medical record review was used as the reference standard	ICD-9-CM 466.0, 490	Claims-based diagnosis of acute bronchitis was verified as correct in 79% of medical records reviewed	Claims
Masseria,2015	The estimated incidence of pertussis in people aged 50 years old in the United States, 2006–2010	U.S.	Used ICD-9-CM code 466.0 to identify potential acute bronchitis cases in the U.S.	NA (no validation)	ICD-9-CM 466.0	NA (no validation)	Claims

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR/EMR-based Algorithm ^{vi}
Morgan, 2017	Patient-provider race and sex concordance: new insights into antibiotic prescribing for acute bronchitis	U.S.	Used ICD-9-CM codes 466.X and 490 to identify potential acute bronchitis cases in the U.S.	NA (no validation)	ICD-9-CM 466.X, 490	NA (no validation)	EMR
Petri, 2010	Data-driven identification of co-morbidities associated with rheumatoid arthritis in a large us health plan claims database	U.S.	Used ICD-9-CM code 466.0 to identify potential acute bronchitis cases in the U.S.	NA (no validation)	ICD-9-CM 466.0	NA (no validation)	Claims
Renati, 2016	Necessity of office visits for acute respiratory infections in primary care	U.S.	Used ICD-9-CM code 466.0 and 490 to identify potential acute bronchitis cases in the U.S.	Medical record review was used as the reference standard	ICD-9-CM 466.0, 490	PPV: 88% for new ARI visits	EHR
Rogers, 2019	Outbreak of acute respiratory illness associated with adenovirus type 4 at the U.S. Naval Academy, 2016	U.S.	Used ICD-9-CM code 466.xx and ICD-10-CM codes and J20.9 to identify potential acute bronchitis cases in the U.S.	NA (no validation)	ICD-9-CM 466.xx ICD-10-CM J20.9	NA (no validation)	EHR

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR/EMR-based Algorithm ^{vi}
Roth, 2012	Unintended consequences of a quality measure for acute bronchitis	U.S.	Used ICD-9-CM codes 466.0 and 490 to identify potential acute bronchitis cases in the U.S.	NA (no validation)	ICD-9-CM 466.0, 490	NA (no validation)	EHR
Schneider, 2005	Are ICD-10 codes appropriate for performance assessment in asthma and COPD in general practice? Results of a cross sectional observational study	Germany	Used ICD-10 code J20 to identify potential acute bronchitis cases in Germany	NA (no validation)	ICD-10 J20, J40	NA (no validation)	EMR
Smith, 2006	Acute respiratory tract infection visits of veterans with spinal cord injuries and disorders: rates, trends, and risk factors	U.S.	Used ICD-9-CM code 466.xx to identify potential acute bronchitis cases in the U.S.	NA (no validation)	ICD-9-CM 466.xx	NA (no validation)	Claims
Stone, 2000	Antibiotic prescribing for patients with colds, upper respiratory tract infections, and bronchitis: a national study of hospital-based emergency departments	U.S.	Used ICD-9-CM codes 466.0 and 490 to identify potential acute bronchitis cases in the U.S.	NA (no validation)	ICD-9-CM 466.0, 490	NA (no validation)	National Ambulatory Medical Care Survey

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR/EMR-based Algorithm ^{vi}
Sukanya, 2017	Validity of principal diagnoses in discharge summaries and ICD-10 coding assessments based on national health data of Thailand	Thailand	Used ICD-10-TM code J20.9 to identify potential acute bronchitis cases in Thailand	Medical record review was used as the reference standard	ICD-10-TM J20.9	PPV: 15.08% (95% CI 13.78-16.49%) NPV: 97.75% (95% CI: 97.72-97.78%) Sensitivity: 12.15% (95% CI 11.00-13.37%) Specificity: 98.24% (95% CI 98.17-98.32%)	EMR
Veljanovski,2018	Risk factors for respiratory hospitalizations in a population of patients with a clinical diagnosis of COPD	U.S.	Used ICD-9-CM code 466.0 and ICD-10-CM code J40 to identify potential acute bronchitis cases in the U.S.	NA (no validation)	ICD-9-CM 466.0 ICD-10-CM J40	NA (no validation)	EMR

Abbreviations: ARI: Acute respiratory infections; EHR: Electronic Health Record; EMR: Electronic Medical Record; ESSENCE: Electronic Surveillance System for Early Notification of Community-based Epidemics; ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification; ICD-10-CM, International Classification of Diseases, Tenth Revision, Clinical Modification; ICD-10-TM: International Classification of Diseases, Tenth Revision, Thai Modification; ILI: Influenza-like illness; OHIP: Ontario Health Insurance Plan; RODS: Real-time Outbreak and Disease Surveillance; SARI: Severe Acute Respiratory Infections

Appendix B. Counts of Patients with Specific Codes Proposed for the Algorithm

As an initial test of the proposed algorithm, the workgroup ran code-specific queries in a large U.S. administrative claims dataset. Researchers used the MarketScan Research Databases (Commercial, Medicare Supplemental), accessed via the Treatment Pathways online analytic platform, querying the past five full years of available data. Results are presented in **Table B1**. Because the transition between International Classification of Diseases, Ninth and Tenth Revisions, Clinical Modification (ICD-9-CM to ICD-10-CM) occurred on October 1, 2015, ICD-9-CM codes were queried for January 1, 2014–September 30, 2015, and ICD-10-CM codes were queried for October 1, 2015–December 31, 2018.

Subtotal rows and “Total” columns may be smaller than the sum of individual cells, because patients with multiple codes in a single year and with more than one of the same diagnosis codes in different years will only be counted once in these rows and columns. As a result, the sum of all “% of Total” cells in a single column may exceed 100%. However, the “Total” column could also be larger than the sum of individual years, as a result of situations where an individual is only enrolled for part of the year that they experience an acute bronchitis event but is then continuously enrolled for a separate year. For example, an individual could be continuously enrolled for a few days, weeks, or months in 2016 and experience an acute bronchitis event, then be continuously enrolled for all of 2017. This event would not be captured in the column for the 2016 (as the individual would be excluded from that cohort) but would be captured in the “Total” column.

Of the codes included in the acute bronchitis algorithm, codes for acute bronchitis (ICD-9-CM 466) and acute bronchitis, unspecified (ICD-10-CM J20.9) were the most frequently used during the study period. Of those receiving at least one acute bronchitis diagnosis between 2014 and 2018 (n=5,591,487), 36.5% (n=2,039,857) and 42.7% (n=2,385,978) had at least one ICD-9-CM 466 and ICD-10-CM J20.9 code, respectively. In addition, 15.1% (n=844,565) and 20.7% (n=1,155,605) received a code for bronchitis not otherwise specified (ICD-9-CM 490 and ICD-10-CM J40, respectively).

Table B1. Annual patient counts and proportions for ICD-9-CM and ICD-10-CM diagnosis codes proposed for inclusion in acute bronchitis algorithm (January 1, 2014–December 31, 2018).

Code	Code Description	Year										Total (Count)	Total (% of Total)
		2014 (Count)	2014 (% of Total)	2015 (Count)	2015 (% of Total)	2016 (Count)	2016 (% of Total)	2017 (Count)	2017 (% of Total)	2018 (Count)	2018 (% of Total)		
ICD-9-CM													
466	Acute Bronchitis	1,290,065	75.6%	746,753	54.5%							2,039,857	36.5%
490	Bronchitis not otherwise specified	508,067	29.8%	315,578	23.0%							844,565	15.1%
ICD-9-CM Subtotal		1,706,215	100.0%	1,012,785	73.9%							2,704,336	48.4%
ICD-10-CM													
J20.0	Acute bronchitis due to Mycoplasma pneumoniae			3,325	0.2%	8,458	0.7%	7,910	0.7%	6,176	0.7%	27,821	0.5%
J20.1	Acute bronchitis due to Hemophilus influenzae			572	0.0%	1,486	0.1%	1,543	0.1%	1,525	0.2%	5,393	0.1%
J20.2	Acute bronchitis due to streptococcus			1,353	0.1%	3,060	0.2%	2,979	0.3%	2,750	0.3%	10,340	0.2%
J20.3	Acute bronchitis due to coxsackievirus			98	0.0%	197	0.0%	133	0.0%	143	0.0%	627	0.0%
J20.4	Acute bronchitis due to parainfluenza virus			324	0.0%	763	0.1%	756	0.1%	750	0.1%	2,870	0.1%
J20.5	Acute bronchitis due to respiratory syncytial virus			628	0.0%	1,446	0.1%	1,720	0.2%	1,715	0.2%	6,524	0.1%
J20.6	Acute bronchitis due to rhinovirus			1,959	0.1%	4,296	0.3%	4,635	0.4%	3,648	0.4%	15,446	0.3%
J20.7	Acute bronchitis due to echovirus			73	0.0%	171	0.0%	130	0.0%	131	0.0%	567	0.0%
J20.8	Acute bronchitis due to other specified organisms			21,568	1.6%	72,179	5.7%	89,087	8.2%	84,517	9.0%	281,748	5.0%
J20.9	Acute bronchitis, unspecified			298,404	21.8%	773,506	61.0%	723,660	66.4%	609,027	64.5%	2,385,978	42.7%
J40	Bronchitis, not specified as acute or chronic			130,167	9.5%	359,201	28.3%	334,795	30.7%	297,210	31.5%	1,155,605	20.7%
ICD-10-CM Subtotal				439,631	32.1%	1,268,829	100.0%	1,090,306	100.0%	943,538	100.0%	3,487,938	62.4%

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Code	Code Description	Year										Total (Count)	Total (% of Total)
		2014 (Count)	2014 (% of Total)	2015 (Count)	2015 (% of Total)	2016 (Count)	2016 (% of Total)	2017 (Count)	2017 (% of Total)	2018 (Count)	2018 (% of Total)		
Total		1,706,215	1,371,053	100.0%	100.0%	1,268,829	100.0%	1,090,306	100.0%	943,538	100.0%	5,591,487	100.0%

Abbreviations: ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification; ICD-10-CM, International Classification of Diseases, Tenth Revision, Clinical Modification.

Appendix C. Codes Excluded from Proposed Algorithm

The diagnosis codes listed in **Table C1** are proposed for exclusion from the algorithm. These codes were initially considered for inclusion based on a literature review and their potential relation to acute bronchitis, either as an etiologically relevant pathogen (e.g., influenza) or as a condition that can sometimes accompany acute bronchitis (e.g., cough, wheezing). In consultation with clinical SMEs (TB, JB, JC, DT) these codes – which were not specific to acute bronchitis - were ultimately determined to be too general and could potentially increase the risk of misclassification. Consequently, these codes were not used to identify patients with a relevant acute bronchitis diagnosis.

Table C1. Excluded codes potentially relevant to acute bronchitis identified from the literature or GEMs mapping.

Code	Description	Code Category	Code Type
034.0	Streptococcal sore throat	DX	09
034.1	Scarlet Fever	DX	09
381.00	Acute nonsuppurative otitis media, unspecified	DX	09
381.01	Acute serous otitis media	DX	09
381.02	Acute mucoid otitis media	DX	09
381.03	Acute sanguinous otitis media	DX	09
381.04	Acute allergic serous otitis media	DX	09
381.05	Acute allergic mucoid otitis media	DX	09
381.06	Acute allergic sanguinous otitis media	DX	09
381.10	Chronic serous otitis media, simple or unspecified	DX	09
381.19	Other chronic serous otitis media	DX	09
381.20	Chronic mucoid otitis media, simple or unspecified	DX	09
381.29	Other chronic mucoid otitis media	DX	09
381.3	Other and unspecified chronic nonsuppurative otitis media	DX	09
381.4	Nonsuppurative otitis media, not specified as acute or chronic	DX	09
382.00	Acute suppurative otitis media	DX	09
382.01	Acute suppurative otitis media with spontaneous rupture of eardrum	DX	09
382.02	Acute suppurative otitis media in diseases classified elsewhere	DX	09
382.1	Chronic tubotympanic suppurative otitis media	DX	09
382.2	Chronic atticoantral suppurative otitis media	DX	09
382.3	Unspecified chronic suppurative otitis media	DX	09
382.4	Unspecified suppurative otitis media	DX	09
382.9	Unspecified otitis media	DX	09
387.0	Otosclerosis involving oval window, nonobliterative	DX	09
387.1	Otosclerosis involving oval window, obliterative	DX	09
387.2	Cochlear otosclerosis	DX	09
387.8	Other otosclerosis	DX	09
387.9	Otosclerosis, unspecified	DX	09
388.00	Degenerative and vascular disorders, unspecified	DX	09
388.01	Presbycusis	DX	09
388.02	Transient ischemic deafness	DX	09
388.10	Noise effects on inner ear, unspecified	DX	09
388.11	Acoustic trauma (explosive) to ear	DX	09
388.12	Noise-induced hearing loss	DX	09
388.2	Sudden hearing loss, unspecified	DX	09
388.30	Tinnitus, unspecified	DX	09
388.31	Subjective tinnitus	DX	09
388.32	Objective tinnitus	DX	09
388.40	Abnormal auditory perception, unspecified	DX	09
388.41	Diplacusis	DX	09

Code	Description	Code Category	Code Type
388.42	Hyperacusis	DX	09
388.43	Impairment of auditory discrimination	DX	09
388.44	Auditory recruitment	DX	09
388.45	Acquired auditory processing disorder	DX	09
388.5	Disorders of acoustic nerve	DX	09
388.60	Otorrhea, unspecified	DX	09
388.61	Cerebrospinal fluid otorrhea	DX	09
388.69	Other otorrhea	DX	09
388.70	Otalgia, unspecified	DX	09
388.71	Otogenic pain	DX	09
388.72	Referred otogenic pain	DX	09
388.8	Other disorders of ear	DX	09
388.9	Unspecified disorder of ear	DX	09
460	Acute nasopharyngitis [common cold]	DX	09
461.0	Acute maxillary sinusitis	DX	09
461.1	Acute frontal sinusitis	DX	09
461.2	Acute ethmoidal sinusitis	DX	09
461.3	Acute sphenoidal sinusitis	DX	09
461.8	Other acute sinusitis	DX	09
461.9	Acute sinusitis, unspecified	DX	09
462	Acute pharyngitis, unspecified	DX	09
463	Acute tonsillitis	DX	09
464.00	Acute laryngitis without mention of obstruction	DX	09
464.01	Acute laryngitis with obstruction	DX	09
464.10	Acute tracheitis without mention of obstruction	DX	09
464.11	Acute tracheitis with obstruction	DX	09
464.20	Acute laryngotracheitis without mention of obstruction	DX	09
464.21	Acute laryngotracheitis with obstruction	DX	09
464.30	Acute epiglottitis without mention of obstruction	DX	09
464.31	Acute epiglottitis with obstruction	DX	09
464.4	Croup	DX	09
464.50	Supraglottitis unspecified, without obstruction	DX	09
464.51	Supraglottitis unspecified, with obstruction	DX	09
465.0	Acute laryngopharyngitis	DX	09
465.8	Acute upper respiratory infection, other multiple sites	DX	09
465.9	Acute upper respiratory infection of unspecified site	DX	09
466.11	Acute bronchiolitis due to respiratory syncytial virus (RSV)	DX	09
466.19	Acute bronchiolitis due to other infectious organisms	DX	09
473.0	Chronic maxillary sinusitis	DX	09
473.1	Chronic frontal sinusitis	DX	09
473.2	Chronic ethmoidal sinusitis	DX	09
473.3	Chronic sphenoidal sinusitis	DX	09
473.8	Other chronic sinusitis	DX	09
473.9	Unspecified sinusitis (chronic)	DX	09
480.0	Pneumonia due to adenovirus convert	DX	09
480.1	Pneumonia due to respiratory syncytial virus	DX	09
480.2	Pneumonia due to parainfluenza virus	DX	09
480.3	Pneumonia due to SARS-associated coronavirus	DX	09
480.8	Pneumonia due to other virus not elsewhere classified	DX	09
480.9	Viral pneumonia, unspecified convert	DX	09
481	Pneumococcal pneumonia [Streptococcus pneumoniae pneumonia]	DX	09
482.0	Pneumonia due to Klebsiella pneumoniae	DX	09
482.1	Pneumonia due to Pseudomonas	DX	09
482.2	Pneumonia due to Hemophilus influenzae [H. influenzae]	DX	09
482.30	Pneumonia due to Streptococcus, unspecified	DX	09

Code	Description	Code Category	Code Type
482.31	Pneumonia due to Streptococcus, group A	DX	09
482.32	Pneumonia due to Streptococcus, group B	DX	09
482.39	Pneumonia due to other Streptococcus	DX	09
482.40	Pneumonia due to Staphylococcus, unspecified	DX	09
482.41	Methicillin susceptible pneumonia due to Staphylococcus aureus	DX	09
482.42	Methicillin resistant pneumonia due to Staphylococcus aureus	DX	09
482.49	Other Staphylococcus pneumonia	DX	09
482.81	Pneumonia due to anaerobes	DX	09
482.82	Pneumonia due to escherichia coli [E. coli]	DX	09
482.83	Pneumonia due to other gram-negative bacteria	DX	09
482.84	Pneumonia due to Legionnaires' disease	DX	09
482.89	Pneumonia due to other specified bacteria	DX	09
482.9	Bacterial pneumonia, unspecified	DX	09
483.0	Pneumonia due to mycoplasma pneumoniae	DX	09
483.1	Pneumonia due to chlamydia	DX	09
483.8	Pneumonia due to other specified organism	DX	09
484.1	Pneumonia in cytomegalic inclusion disease	DX	09
484.3	Pneumonia in whooping cough	DX	09
484.5	Pneumonia in anthrax	DX	09
484.6	Pneumonia in aspergillosis	DX	09
484.7	Pneumonia in other systemic mycoses	DX	09
484.8	Pneumonia in other infectious diseases classified elsewhere	DX	09
485	Bronchopneumonia, organism unspecified	DX	09
486	Pneumonia, organism unspecified	DX	09
487.0	Influenza with pneumonia convert	DX	09
487.1	Influenza with other respiratory manifestations	DX	09
487.8	Influenza with other manifestations	DX	09
488.01	Influenza due to identified avian influenza virus with pneumonia	DX	09
488.02	Influenza due to identified avian influenza virus with other respiratory manifestations	DX	09
488.09	Influenza due to identified avian influenza virus with other manifestations	DX	09
488.11	Influenza due to identified 2009 H1N1 influenza virus with pneumonia	DX	09
488.12	Influenza due to identified 2009 H1N1 influenza virus with other respiratory manifestations	DX	09
488.19	Influenza due to identified 2009 H1N1 influenza virus with other manifestations	DX	09
488.81	Influenza due to identified novel influenza A virus with pneumonia	DX	09
488.82	Influenza due to identified novel influenza A virus with other respiratory manifestations	DX	09
488.89	Influenza due to identified novel influenza A virus with other manifestations	DX	09
491.0	Simple chronic bronchitis convert	DX	09
491.1	Mucopurulent chronic bronchitis	DX	09
491.20	Obstructive chronic bronchitis without exacerbation	DX	09
491.21	Obstructive chronic bronchitis with (acute) exacerbation	DX	09
491.22	Obstructive chronic bronchitis with acute bronchitis	DX	09
491.8	Other chronic bronchitis	DX	09
491.9	Unspecified chronic bronchitis	DX	09
492.0	Emphysematous bleb	DX	09
492.8	Other emphysema	DX	09

Code	Description	Code Category	Code Type
493.00	Extrinsic asthma, unspecified	DX	09
493.01	Extrinsic asthma with status asthmaticus	DX	09
493.02	Extrinsic asthma with (acute) exacerbation	DX	09
493.10	Intrinsic asthma, unspecified	DX	09
493.11	Intrinsic asthma with status asthmaticus	DX	09
493.12	Intrinsic asthma with (acute) exacerbation	DX	09
493.20	Chronic obstructive asthma, unspecified	DX	09
493.21	Chronic obstructive asthma with status asthmaticus	DX	09
493.22	Chronic obstructive asthma with (acute) exacerbation	DX	09
493.81	Exercise induced bronchospasm	DX	09
493.82	Cough variant asthma	DX	09
493.90	Asthma, unspecified type, unspecified	DX	09
493.91	Asthma, unspecified type, with status asthmaticus	DX	09
493.92	Asthma, unspecified type, with (acute) exacerbation	DX	09
494.0	Bronchiectasis without acute exacerbation	DX	09
494.1	Bronchiectasis with acute exacerbation	DX	09
495.0	Farmers' lung	DX	09
495.1	Bagassosis	DX	09
495.2	Bird-fanciers' lung	DX	09
495.3	Suberosis	DX	09
495.4	Malt workers' lung	DX	09
495.5	Mushroom workers' lung	DX	09
495.6	Maple bark-strippers' lung	DX	09
495.7	"Ventilation" pneumonitis	DX	09
495.8	Other specified allergic alveolitis and pneumonitis	DX	09
495.9	Unspecified allergic alveolitis and pneumonitis	DX	09
496	Chronic airway obstruction, not elsewhere classified	DX	09
519.00	Tracheostomy complication, unspecified	DX	09
519.01	Infection of tracheostomy	DX	09
519.02	Mechanical complication of tracheostomy	DX	09
519.09	Other tracheostomy complications	DX	09
519.11	Acute bronchospasm	DX	09
519.19	Other diseases of trachea and bronchus	DX	09
519.2	Mediastinitis	DX	09
519.3	Other diseases of mediastinum, not elsewhere classified	DX	09
519.4	Disorders of diaphragm	DX	09
519.8	Other diseases of respiratory system, not elsewhere classified	DX	09
519.9	Unspecified disease of respiratory system	DX	09
786.00	Respiratory abnormality, unspecified	DX	09
786.01	Hyperventilation	DX	09
786.02	Orthopnea	DX	09
786.03	Apnea	DX	09
786.04	Cheyne-Stokes respiration	DX	09
786.05	Shortness of breath	DX	09
786.06	Tachypnea	DX	09
786.07	Wheezing	DX	09
786.09	Other respiratory abnormalities	DX	09
786.1	Stridor	DX	09
786.2	Cough	DX	09
786.30	Hemoptysis, unspecified	DX	09
786.31	Acute idiopathic pulmonary hemorrhage in infants [AIPHI]	DX	09
786.39	Other hemoptysis	DX	09
786.4	Abnormal sputum	DX	09
786.50	Chest pain, unspecified	DX	09
786.51	Precordial pain	DX	09
786.52	Painful respiration	DX	09

Code	Description	Code Category	Code Type
786.59	Other chest pain	DX	09
786.6	Swelling, mass, or lump in chest	DX	09
786.7	Abnormal chest sounds	DX	09
786.8	Hiccough	DX	09
786.9	Other symptoms involving respiratory system and chest	DX	09
A22.1	Pulmonary anthrax	DX	10
A37.91	Whooping cough, unspecified species with pneumonia	DX	10
A38.9	Scarlet fever, uncomplicated	DX	10
A48.1	Legionnaires' disease	DX	10
B25.0	Cytomegaloviral pneumonitis	DX	10
H65.xxx	Nonsuppurative otitis media	DX	10
H66.xxx	Suppurative and unspecified otitis media	DX	10
H67.1	Otitis media in diseases classified elsewhere, right ear	DX	10
H67.2	Otitis media in diseases classified elsewhere, left ear	DX	10
H67.3	Otitis media in diseases classified elsewhere, bilateral	DX	10
H67.9	Otitis media in diseases classified elsewhere, unspecified ear	DX	10
H68.xxx	Eustachian salpingitis and obstruction	DX	10
H69.xxx	Other and unspecified disorders of Eustachian tube	DX	10
H80.xx	Otosclerosis	DX	10
J00	Acute nasopharyngitis [common cold]	DX	10
J01.00	Acute maxillary sinusitis unspecified	DX	10
J01.01	Acute recurrent maxillary sinusitis	DX	10
J01.10	Acute frontal sinusitis unspecified	DX	10
J01.11	Acute recurrent frontal sinusitis	DX	10
J01.20	Acute ethmoidal sinusitis unspecified	DX	10
J01.21	Acute recurrent ethmoidal sinusitis	DX	10
J01.30	Acute sphenoidal sinusitis unspecified	DX	10
J01.31	Acute recurrent sphenoidal sinusitis	DX	10
J01.40	Acute pansinusitis unspecified	DX	10
J01.41	Acute recurrent pansinusitis	DX	10
J01.80	Other acute sinusitis	DX	10
J01.81	Other acute recurrent sinusitis	DX	10
J01.90	Acute sinusitis, unspecified	DX	10
J01.91	Acute recurrent sinusitis, unspecified	DX	10
J02.0	Streptococcal pharyngitis	DX	10
J02.9	Acute pharyngitis, unspecified	DX	10
J03.00	Acute streptococcal tonsillitis, unspecified	DX	10
J03.01	Acute recurrent streptococcal tonsillitis	DX	10
J03.80	Acute tonsillitis due to other specified organisms	DX	10
J03.81	Acute recurrent tonsillitis due to other specified organisms	DX	10
J03.90	Acute tonsillitis, unspecified	DX	10
J03.91	Acute recurrent tonsillitis, unspecified	DX	10
J04.0	Acute laryngitis	DX	10
J04.10	Acute tracheitis without obstruction	DX	10
J04.11	Acute tracheitis with obstruction	DX	10
J04.2	Acute laryngotracheitis	DX	10
J04.30	Supraglottitis, unspecified without obstruction	DX	10
J04.31	Supraglottitis, unspecified with obstruction	DX	10
J05.0	Acute obstructive laryngitis [croup]	DX	10
J05.10	Acute epiglottitis without obstruction	DX	10
J05.11	Acute epiglottitis with obstruction	DX	10
J06.0	Acute laryngopharyngitis	DX	10
J06.9	Acute upper respiratory infection, unspecified	DX	10
J09.X1	Influenza due to identified novel influenza A virus with pneumonia	DX	10

Code	Description	Code Category	Code Type
J09.X2	Influenza due to identified novel influenza A virus with other respiratory manifestations	DX	10
J09.X3	Influenza due to identified novel influenza A virus with gastrointestinal manifestations	DX	10
J09.X9	Influenza due to identified novel influenza A virus with other manifestations	DX	10
J10.00	Influenza due to other identified influenza virus with unspecified type of pneumonia	DX	10
J10.01	Influenza due to other identified influenza virus with the same other identified influenza	DX	10
J10.08	Influenza due to other identified influenza virus with other specified pneumonia	DX	10
J10.1	Influenza due to other identified influenza virus with other respiratory manifestations	DX	10
J10.2	Influenza due to other identified influenza virus with gastrointestinal manifestations	DX	10
J10.81	Influenza due to other identified influenza virus with encephalopathy	DX	10
J10.82	Influenza due to other identified influenza virus with myocarditis	DX	10
J10.83	Influenza due to other identified influenza virus with otitis media	DX	10
J10.89	Influenza due to other identified influenza virus with other manifestations	DX	10
J11.0	Influenza due to unidentified influenza virus with unspecified type of pneumonia	DX	10
J11.1	Influenza due to unidentified influenza virus with other respiratory manifestations	DX	10
J11.2	Influenza due to unidentified influenza virus with gastrointestinal manifestations	DX	10
J11.81	Influenza due to unidentified influenza virus with encephalopathy	DX	10
J11.89	Influenza due to unidentified influenza virus with other manifestations	DX	10
J12.0	Adenoviral pneumonia	DX	10
J12.1	Respiratory syncytial virus pneumonia	DX	10
J12.2	Parainfluenza virus pneumonia	DX	10
J12.3	Human metapneumovirus pneumonia	DX	10
J12.81	Pneumonia due to SARS-associated coronavirus	DX	10
J12.89	Other viral pneumonia	DX	10
J12.9	Viral pneumonia, unspecified	DX	10
J13	Pneumonia due to Streptococcus pneumoniae	DX	10
J14	Pneumonia due to Hemophilus influenzae [H. influenzae]	DX	10
J15.0	Pneumonia due to Klebsiella pneumoniae	DX	10
J15.1	Pneumonia due to Pseudomonas	DX	10
J15.20	Pneumonia due to staphylococcus unspecified	DX	10
J15.211	Pneumonia due to Methicillin susceptible Staphylococcus aureus	DX	10
J15.212	Pneumonia due to Methicillin resistant Staphylococcus aureus	DX	10
J15.29	Pneumonia due to other staphylococcus	DX	10
J15.3	Pneumonia due to streptococcus, group B	DX	10
J15.4	Pneumonia due to other streptococci	DX	10
J15.5	Pneumonia due to Escherichia coli	DX	10
J15.6	Pneumonia due to other Gram-negative bacteria	DX	10
J15.7	Pneumonia due to Mycoplasma pneumoniae	DX	10
J15.8	Pneumonia due to other specified bacteria	DX	10
J15.9	Unspecified bacterial pneumonia	DX	10

Code	Description	Code Category	Code Type
J16.0	Chlamydial pneumonia	DX	10
J16.8	Pneumonia due to other specified infectious organisms	DX	10
J17	Pneumonia in diseases classified elsewhere	DX	10
J18.0	Bronchopneumonia, unspecified organism	DX	10
J18.1	Lobar pneumonia, unspecified organism	DX	10
J18.2	Hypostatic pneumonia, unspecified organism	DX	10
J18.8	Other pneumonia, unspecified organism	DX	10
J18.9	Pneumonia, unspecified organism	DX	10
J21.0	Acute bronchiolitis due to respiratory syncytial virus	DX	10
J21.8	Acute bronchiolitis due to respiratory syncytial virus (RSV)	DX	10
J22	Unspecified acute lower respiratory infection	DX	10
J32.0	Chronic maxillary sinusitis	DX	10
J32.1	Chronic frontal sinusitis	DX	10
J32.2	Chronic ethmoidal sinusitis	DX	10
J32.3	Chronic sphenoidal sinusitis	DX	10
J32.4	Chronic pansinusitis	DX	10
J32.8	Other chronic sinusitis	DX	10
J32.9	Chronic sinusitis, unspecified	DX	10
J41.0	Simple chronic bronchitis	DX	10
J41.1	Mucopurulent chronic bronchitis	DX	10
J41.8	Mixed simple and mucopurulent chronic bronchitis	DX	10
J42	Unspecified chronic bronchitis	DX	10
J43.0	Unilateral pulmonary emphysema [MacLeod's syndrome]	DX	10
J43.1	Panlobular emphysema	DX	10
J43.2	Centrilobular emphysema	DX	10
J43.8	Other emphysema	DX	10
J43.9	Emphysema, unspecified	DX	10
J44.0	Chronic obstructive pulmonary disease with (acute) lower respiratory infection	DX	10
J44.1	Chronic obstructive pulmonary disease with (acute) exacerbation	DX	10
J44.9	Chronic obstructive pulmonary disease, unspecified	DX	10
J45.20	Mild intermittent asthma uncomplicated	DX	10
J45.21	Mild intermittent asthma with (acute) exacerbation	DX	10
J45.22	Mild intermittent asthma with status asthmaticus	DX	10
J45.30	Mild persistent asthma uncomplicated	DX	10
J45.31	Mild persistent asthma with (acute) exacerbation	DX	10
J45.32	Mild persistent asthma with status asthmaticus	DX	10
J45.40	Moderate persistent asthma uncomplicated	DX	10
J45.41	Moderate persistent asthma with (acute) exacerbation	DX	10
J45.42	Moderate persistent asthma with status asthmaticus	DX	10
J45.50	Severe persistent asthma uncomplicated	DX	10
J45.51	Severe persistent asthma with (acute) exacerbation	DX	10
J45.52	Severe persistent asthma with status asthmaticus	DX	10
J45.901	Unspecified asthma with (acute) exacerbation	DX	10
J45.902	Unspecified asthma with status asthmaticus	DX	10
J45.909	Unspecified asthma uncomplicated	DX	10
J45.990	Exercise induced bronchospasm	DX	10
J45.991	Cough variant asthma	DX	10
J45.998	Other asthma	DX	10
J47.0	Bronchiectasis with acute lower respiratory infection	DX	10
J47.1	Bronchiectasis with (acute) exacerbation	DX	10
J47.9	Bronchiectasis, uncomplicated	DX	10
J67.0	Farmers' lung	DX	10
J67.1	Bagassosis	DX	10
J67.2	Bird-fanciers' lung	DX	10
J67.3	Suberosis	DX	10

Code	Description	Code Category	Code Type
J67.4	Malt workers' lung	DX	10
J67.5	Mushroom workers' lung	DX	10
J67.6	Maple bark-strippers' lung	DX	10
J67.7	Air conditioner and humidifier lung	DX	10
J67.8	Hypersensitivity pneumonitis due to other organic dusts	DX	10
J67.9	Hypersensitivity pneumonitis due to unspecified organic dust	DX	10
J98.01	Acute bronchospasm	DX	10
J98.09	Other diseases of bronchus, not elsewhere classified	DX	10
J98.11	Atelectasis	DX	10
J98.19	Other pulmonary collapse	DX	10
J98.2	Interstitial emphysema	DX	10
J98.3	Compensatory emphysema	DX	10
J98.4	Other disorders of lung	DX	10
J98.51	Mediastinitis	DX	10
J98.59	Other diseases of mediastinum, not elsewhere classified	DX	10
J98.6	Disorders of diaphragm	DX	10
J98.8	Other specified respiratory disorders	DX	10
J98.9	Respiratory disorder, unspecified	DX	10
R04.0	Epistaxis	DX	10
R04.1	Hemorrhage from throat	DX	10
R04.2	Hemoptysis	DX	10
R04.81	Acute idiopathic pulmonary hemorrhage in infants	DX	10
R04.89	Hemorrhage from other sites in respiratory passages	DX	10
R04.9	Hemorrhage from respiratory passages, unspecified	DX	10
R05	Cough	DX	10
R06.00	Dyspnea unspecified	DX	10
R06.01	Orthopnea	DX	10
R06.02	Shortness of breath	DX	10
R06.03	Acute respiratory distress	DX	10
R06.09	Other forms of dyspnea	DX	10
R06.1	Stridor	DX	10
R06.2	Wheezing	DX	10
R06.3	Periodic breathing	DX	10
R06.4	Hyperventilation	DX	10
R06.5	Mouth breathing	DX	10
R06.6	Hiccough	DX	10
R06.7	Sneezing	DX	10
R06.81	Apnea, not elsewhere classified	DX	10
R06.82	Tachypnea, not elsewhere classified	DX	10
R06.83	Snoring	DX	10
R06.89	Other abnormalities of breathing	DX	10
R06.9	Unspecified abnormalities of breathing	DX	10
R07.0	Pain in throat	DX	10
R07.1	Chest pain on breathing	DX	10
R07.2	Precordial pain	DX	10
R07.81	Pleurodynia	DX	10
R07.82	Intercostal pain	DX	10
R07.89	Other chest pain	DX	10
R07.9	Chest pain, unspecified	DX	10
R09.01	Asphyxia	DX	10
R09.02	Hypoxemia	DX	10
R09.1	Pleurisy	DX	10
R09.2	Respiratory arrest	DX	10
R09.3	Abnormal sputum	DX	10
R09.81	Nasal congestion	DX	10
R09.82	Postnasal drip	DX	10

Code	Description	Code Category	Code Type
R09.89	Other specified symptoms and signs involving the circulatory and respiratory systems	DX	10
R22.0	Localized swelling, mass and lump, head	DX	10
R22.1	Localized swelling, mass and lump, neck	DX	10
R22.2	Localized swelling, mass and lump, trunk	DX	10
R22.30	Localized swelling, mass and lump, unspecified upper limb	DX	10
R22.31	Localized swelling, mass and lump, right upper limb	DX	10
R22.32	Localized swelling, mass and lump, left upper limb	DX	10
R22.33	Localized swelling, mass and lump, upper limb bilateral	DX	10
R22.40	Localized swelling, mass and lump, unspecified lower limb	DX	10
R22.41	Localized swelling, mass and lump, right lower limb	DX	10
R22.42	Localized swelling, mass and lump, left lower limb	DX	10
R22.43	Localized swelling, mass and lump, lower limb bilateral	DX	10
R22.9	Localized swelling, mass and lump, unspecified	DX	10
86313	Immunoassay, infectious agent	CPT	
86317	Under Qualitative or Semiquantitative Immunoassays	CPT	
86318	Under Qualitative or Semiquantitative Immunoassays	CPT	
86403	Under Qualitative or Semiquantitative Immunoassays	CPT	
86588	Streptococcus, direct screen	CPT	
86609	Under Qualitative or Semiquantitative Immunoassays	CPT	
87060	Nose/throat culture, bacteria	CPT	
87072	Culture Specimen by Kit	CPT	
87081	Under Microbiology Procedures	CPT	
87082	Culture Specimen by Kit	CPT	
87086	Under Microbiology Procedures	CPT	
87205	Under Microbiology Procedures	CPT	
87210	Under Microbiology Procedures	CPT	
87430	Under Microbiology Procedures	CPT	
87449	Under Microbiology Procedures	CPT	
87880	Under Microbiology Procedures	CPT	

Abbreviation: CPT, Current Procedural Terminology; DX, ICD-CM diagnosis.

Authors also ran code-specific queries for a subset of codes noted in **Table C1** (ICD-9-CM codes 491.21 and 491.22, ICD-10-CM codes J44.0 and J44.1) in the MarketScan Research Databases (Commercial and Medicare Supplemental) during January 1, 2014–December 31, 2018 to assess the number of patients with these diagnosis codes that were ultimately excluded. This was done to gain an understanding of how many patients received diagnoses related to these codes, which were judged by clinicians to be the most closely related diagnoses of those excluded since they specify acute exacerbation or infection related to a chronic condition. Patients receiving these diagnoses will be excluded as a result of each code being omitted from the algorithm, though it should be noted that patients with excluded codes may be included in the analysis if they *also* have a code that was in the algorithm. Results are presented in **Table C2**.

The transition from ICD-9-CM to ICD-10-CM occurred October 1, 2015; no ICD-9-CM codes were queried after this date and no ICD-10-CM codes were queried prior to this date. The coding standard-specific subtotal rows were calculated by querying all codes for a particular code standard together; the “Total (Count)” column was calculated by querying the individual code in a cohort of patients who were enrolled for at least one calendar year between 2014 and 2018.

Subtotal rows and Total columns may be smaller than the sum of individual cells, because patients with multiple codes in a single year and with more than one of the same diagnosis codes in different years will only be counted once in these rows and columns. As a result, the sum of all “% of Total” cells in a single column may exceed 100%. However, the “Total” column could also be larger than the sum of individual years, as a result of situations where an individual is only enrolled for part of the year that they experience an acute bronchitis event but is then continuously enrolled for a separate year. For example, an individual could be continuously enrolled for a few days, weeks, or months in 2016 and receive a diagnosis related to chronic obstructive bronchitis, then be continuously enrolled for all of 2017. This event would not be captured in the column for the 2016 (as the individual would be excluded from that cohort) but would be captured in the “Total” column.

Of those receiving an obstructive chronic bronchitis (ICD-9-CM) or chronic obstructive pulmonary disease (ICD-10-CM) diagnosis between 2014 and 2018 (n=346,269), codes for obstructive chronic bronchitis with (acute) exacerbation (ICD-9-CM 491.21) and chronic obstructive pulmonary disease with (acute) exacerbation (ICD-10-CM J44.1) were the most frequently used during the study period. Specifically, 19.4% (n=67,297) and 60.8% (n=210,605) had at least one ICD-9-CM 491.21 and ICD-10-CM J44.1 code, respectively. In addition, 9.8% (n=33,997) and 19.9% (n=68,956) received a code for obstructive chronic bronchitis with acute bronchitis (ICD-9-CM 491.22) and chronic obstructive pulmonary disease with (acute) lower respiratory infection (ICD-10-CM J44.0), respectively.

Table C2. Annual patient counts and proportions for ICD-9-CM and ICD-10-CM diagnosis codes of interest excluded from the acute bronchitis algorithm (2014–2018).

Code	Code Description	Year										Total (Count)	Total (% of Total)
		2014 (Count)	2014 (% of Total)	2015 (Count)	2015 (% of Total)	2016 (Count)	2016 (% of Total)	2017 (Count)	2017 (% of Total)	2018	2018 (% of Total)		
ICD-9-CM													
491.21	Obstructive chronic bronchitis with (acute) exacerbation	95,614	89.6%	28,461	30.2%							67,297	19.4%
491.22	Obstructive chronic bronchitis with acute bronchitis	21,022	19.7%	12,552	13.3%							33,997	9.8%
ICD-9-CM Subtotal		106,761	100.0%	67,786	72.0%							163,759	47.3%
ICD-10-CM													
J44.0	Chronic obstructive pulmonary disease with (acute) lower respiratory infection			8,682	9.2%	23,290	24.1%	22,490	27.7%	14,707	24.5%	68,956	19.9%
J44.1	Chronic obstructive pulmonary disease with (acute) exacerbation			35,885	38.1%	86,303	89.42%	71,854	88.6%	53,541	89.2%	210,605	60.8%
ICD-10-CM Subtotal				40,984	43.5%	96,511	100.0%	81,132	100.0%	60,047	100.0%	235,725	68.1%
Total		106,761	100.0%	94,122	100.0%	96,511	100.0%	81,132	100.0%	60,047	100.0%	346,269	100.0%

Abbreviations: ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification; ICD-10-CM, International Classification of Diseases, Tenth Revision, Clinical Modification.