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

Final Report

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Prepared by: Patrick Saunders-Hastings,[1] Sze Wing Heong,[1] Pradeep Rajan,[1] Timothy Burrell,[2] Jeff Beers,[3] Judith Cope,[4] Deborah Thompson,[4] Cindy Ke Zhou[4]

Author Affiliations:

[1] Gevity Consulting Inc., Ottawa, Ontario, Canada

[2] IBM Watson Health, Cambridge, Massachusetts, United States of America

[3] IBM Global Business Services, Issaquah, Washington, United States of America

[4] Center for Biologics Evaluation and Research, Food and Drug Administration, Silver Spring, Maryland, United States of America

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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
BEST	Biologics Effectiveness and Safety
CAP	Community-acquired Pneumonia
CBER	Center for Biologics Evaluation and Research
CCC	Complex Chronic Conditions
CDC	Centers for Disease Control and Prevention
CI	Confidence Interval
CMS	Centers for Medicare and Medicaid Services
COPD	Chronic Obstructive Pulmonary Disease
CPT	Current Procedural Terminology
CT	Computerized Tomography
DRG	Diagnosis-related Group
DX	Diagnosis
ED	Emergency Department
EHR	Electronic Health Record
EMR	Electronic Medical Record
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
HAP	Hospital-acquired Pneumonia
HCAP	Healthcare-associated Pneumonia
HMO	Health Maintenance Organization
HSV	Herpes Simplex Virus
ICD-9-CM	International Classification of Diseases, Ninth Revision, Clinical Modification
ICD-10-AM	International Classification of Disease, Tenth Revision, Australian Modification
ICD-10-CM	International Classification of Diseases, Tenth Revision, Clinical Modification
ILI	Influenza-like Illness
LHR	Likelihood Ratio
LOINC	Logical Observation Identifiers Names and Codes
NDC	National Drug Code
NPV	Negative Predictive Value
PICO	Population, Intervention, Comparator, Outcome
PPV	Positive Predictive Value

RODS	Real-time Outbreak and Disease Surveillance
RSV	Respiratory Syncytial Virus
SME	Subject Matter Expert
SP	*Streptococcus pneumoniae*
VAE	Ventilator-associated Event
VAP	Ventilator-associated Pneumonia

A Summary

The United States (U.S.) Food and Drug Administration (FDA) Biologics Effectiveness and Safety (BEST) Initiative conducted a structured literature review (through May 12, 2020) to identify validated coding algorithms for ascertaining cases of pneumonia in large administrative healthcare databases. The studies selected for this targeted review used billing codes in claims or electronic health record (EHR) databases to derive pneumonia coding algorithms.

Several relevant studies were identified, with five U.S. studies providing performance measures (positive predictive value [PPV], negative predictive value [NPV], sensitivity and/or specificity) for EHR- or claims-derived algorithms that sought to identify pneumonia cases. These studies employed medical record review to assess the validity of the International Classification of Diseases, Ninth Revision (ICD-9-CM) codes 480-486 (inclusive or a subset) that were used to identify potential pneumonia cases in EHR or claims databases. Overall, the findings indicate that these ICD-9-CM codes are associated with moderate to high PPV and low sensitivity for identifying pneumonia cases, with the range of performance measures influenced by study-specific code selection.

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 pneumonia. 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 (GEM) for reference.[i] The draft algorithm was reviewed by clinical subject matter experts (SMEs) from IBM (TB, JB), FDA Center for Biologics Evaluation and Research (CBER) (JC, DT), and Acumen. The final pneumonia algorithm includes 53 ICD-9-CM codes and 54 ICD-10-CM codes. While there are ICD codes that incorporate information on the etiology of pneumonia, there is a single, all-encompassing code in both ICD-9-CM (486 – pneumonia, organism unspecified) and ICD-10-CM (J18.9 – pneumonia, unspecified organism) that refers to the clinical event of pneumonia. These codes do not include information on etiology, although they can be paired with other diagnosis codes that suggest the etiology of the pneumonia event. Other studies using administrative databases to identify potential cases of pneumonia employed this approach.

As an initial step in assessing the feasibility of using the algorithm to identify pneumonia, the algorithm was applied in the IBM MarketScan® Research Databases (Commercial and Medicare Supplemental), a collection of commercially insured individuals in the U.S. Statistics describing the frequency and proportions of codes included in the algorithm were generated, with the results reported below.

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, FDA 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/

Pneumonia is an infection of the parenchyma (pulmonary alveoli and respiratory bronchioles) in one or both lungs (or certain lobes) that causes inflammation of the lower respiratory tract.[1] Inflammation can result in air sacs filling with fluid, which contributes to pneumonia symptoms such as cough with or without mucus, fever, chills, and difficulty breathing.[2] Pneumonia is often caused by a bacterial infection, most commonly by *Streptococcus pneumoniae* (SP), and in atypical cases by *Mycoplasma pneumoniae* or *Legionella pneumophila (*Legionnaire's Disease). In addition, viruses (typically influenza and rhinoviruses) and fungi (*Pneumocystis jirovecii*) can also cause pneumonia. Risk factors for developing pneumonia include age, specifically young children (less than 5 years of age)[3] and older adults (individuals over 65 years of age account for >50% of pneumonia cases and 90% of all deaths due to lower respiratory tract infections)[4]; comorbid conditions (e.g., brain disorders, immunocompromised status, other lung diseases, and diabetes mellitus); medical treatments (e.g., ventilator support); and lifestyle choices (e.g., smoking).[1,5]

Pneumonia is typically characterized by the setting of infection acquisition: through community-acquired pneumonia (CAP), in institutional settings (i.e., hospital-acquired pneumonia [HAP], ventilator-associated pneumonia [VAP]), or that is healthcare-associated (HCAP) (i.e., outpatients who had contact with the healthcare system and present with pneumonias having an etiology more similar to HAP than CAP).[5,6] In addition, rarer types of pneumonia of unknown etiology include chronic eosinophilic pneumonia[7], cryptogenic organizing pneumonia[8], and idiopathic non-specific interstitial pneumonia.[9]

The diagnosis of pneumonia typically involves an assessment of medical history along with a physical examination, laboratory tests (e.g., sputum analysis and culture), and imaging (e.g., chest radiography) to determine the presence and type of pneumonia. Treatment for pneumonia includes antibiotics for bacterial pneumonia and, in severe cases, antibiotics and fluids given through an intravenous line alongside supplemental oxygen therapy, with potential placement on a ventilator.[2] Viral and fungal pneumonia is typically treated with antivirals and antifungal medications, respectively.

Pneumonia is among the most common illnesses in the U.S., with more than 10 million cases of infectious pneumonia occurring annually.[10] Further, pneumonia contributes to increased mortality and is the sixth leading cause of death in the U.S., the highest of any infectious disease. The associated healthcare costs are significant, with the cost of managing a single case of pneumonia in the hospital estimated at $7,000; this represents a 20-fold increase over the costs of care in an outpatient setting.

The objective of this review was to assess and understand the validity of electronic coding algorithms using billing codes for identifying pneumonia 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 pneumonia was conducted, leveraging findings from U.S. and international studies to inform the development of an algorithm. The focus of the review was on algorithms derived from administrative claims data (i.e., claims-based), while algorithms derived from EHRs that used standard billing codes (i.e., EHR-based) were also considered. The draft algorithm was reviewed by clinical SMEs (TB, JB, JC, DT) 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 pneumonia, which could be of value in future validation studies assessing the performance of the proposed algorithm via medical chart review; **Sections E** and **F** present the algorithm and its associated assumptions and decisions, respectively; **Section G** presents the results of an initial application of the algorithms to characterize the population with pneumonia 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:** *pneumonia*

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

Briefly, the review process began with conducting comprehensive searches of existing publications available in the CBER[iii] 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 for the PubMed search. The end date of the PubMed search was May 12, 2020. The Google Scholar search was limited to January 1, 2010–April 17, 2020. The PubMed search strategy is summarized below. Search terms are not case sensitive.

- ***Search 1***: (ICD AND Pneumonia AND Validation): **retrieved 45 articles**
- ***Search 2*****:** (ICD AND Pneumonia AND Validity): **retrieved 45 articles**
- ***Search 3*****:** (Accuracy AND ICD AND Identifying AND Pneumonia AND Administrative Data): **retrieved 9 articles**
- ***Search 4*****:** (Identify AND Accuracy AND Pneumonia): **retrieved 650 articles**

Targeted and *ad hoc* searches of the gray literature were conducted, including clinical guidelines and reports from organizations such as the U.S. 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 publications. Abstract review was subsequently conducted for these publications.

All abstracts were reviewed[v], and 31 articles were reviewed in full text. Of these, 11 were retained for extraction and informed algorithm development efforts. 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. claims- or EHR-based validation study (i.e., reporting measures of validity and diagnostic accuracy)
- ***Ranking 2:*** U.S. study that reported a claims- or EHR-based coding algorithm but no independent validation OR a non-U.S. validation study

[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
[v] Since this was not a systematic review, we did not track the total number of abstracts screened after de-duplication.

- ***Ranking 3:*** Non-U.S. study that reported a claims- or EHR-based coding algorithm but no independent validation

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, 11 publications were identified as being particularly relevant (**Appendix A**).[11-21] Each publication reported either measures of diagnostic accuracy associated with EHR-based algorithms (i.e., pneumonia codes derived from billing codes of admission or discharge medical records) or claims-based coding algorithms (i.e., pneumonia codes derived from administrative insurance claims databases). Additional publications identified in the literature review applied a coding algorithm without validation to identify pneumonia cases in administrative claims or EHR data. Of the 11 publications, six studies were from the U.S.[11,15-18,21], two studies were from Canada[12,13], one study each from Italy[14] and Australia[20], and the remaining study was a systematic review that included pneumonia studies from the U.S., France, Belgium, and Germany.[19] Publication dates for these studies ranged from 1999 to 2018. Across the selected studies, ICD-9-CM codes were the primary code sets used to identify pneumonia cases (none reported using ICD-10-CM codes). Overall, ICD-9-CM codes 480-487 (inclusive or a subset) were consistently used to identify pneumonia cases among U.S. (as well as some international) populations. We summarized the 11 studies 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 total of two U.S. studies[18,21], two international studies[12,13], and one international meta-analysis[19] were identified that reported on diagnostic accuracy associated with the coding algorithms derived from claims data for pneumonia.

Williams and colleagues[21] sought to determine the accuracy of diagnoses in administrative claims data for pediatric CAP hospitalizations. Among 3,646 children (<1 year to 18 years of age) identified as having possible CAP, the authors tested the following six algorithms, each of which had a sub-definition excluding complex chronic conditions (CCC):

1) Primary or any secondary diagnosis of pneumonia or effusion/empyema;
2) Primary diagnosis of pneumonia or effusion/empyema;
3) Primary diagnosis of pneumonia or effusion/empyema OR primary diagnosis of pneumonia-related complication PLUS any secondary diagnosis of pneumonia or effusion/empyema;
4) Primary or any secondary diagnosis of pneumonia;
5) Primary diagnosis of pneumonia;
6) Primary diagnosis of pneumonia OR primary diagnosis of pneumonia-related complication or effusion/empyema PLUS any secondary diagnosis of pneumonia;

The authors randomly sampled 998 (25%) children for medical record review and compared to two reference standards: 1) provider-confirmed CAP diagnosis (described in detail in **Section E**), and 2) definite CAP diagnosis (provider diagnosis with consistent clinical and radiographic evidence).

Across these algorithms, the following ICD-9-CM codes were used to identify pneumonia: 480.0 (viral pneumonia due to adenovirus), 480.1 (viral pneumonia due to respiratory syncytial virus [RSV]), 480.2 (viral pneumonia due to parainfluenza virus), 480.8 (viral pneumonia due to other virus not elsewhere classified), 480.9 (viral pneumonia, unspecified), 481 (pneumococcal pneumonia [Streptococcus pneumoniae pneumonia]), 482.0 (pneumonia due to Klebsiella pneumoniae), 482.30 (pneumonia due to Streptococcus, unspecified), 482.31 (pneumonia due to Streptococcus, group A), 482.32 (pneumonia due to Streptococcus, group B), 482.41 (methicillin susceptible pneumonia due to Staphylococcus aureus), 482.42 (methicillin resistant pneumonia due to Staphylococcus aureus), 482.83 (pneumonia due to other gram-negative bacteria), 482.89 (pneumonia due to other specified bacteria), 482.9 (bacterial pneumonia, unspecified), 483.8 (pneumonia due to other specified organisms), 484.3 (pneumonia in whooping cough), 485 (bronchopneumonia, organism unspecified), 486 (pneumonia, organism unspecified), 487.0 (influenza with pneumonia).

In comparison to a reference standard that required a provider-confirmed diagnoses, the authors reported a PPV of 67.9–89.6% across the algorithms, along with an NPV of 82.6–99.8%, specificity of 75.7–96.4%, and a sensitivity of 60.7–99.7%. Key algorithm-specific findings reported that a pneumonia or effusion/empyema diagnosis code in any position (Algorithm 1) identified nearly all children with provider-confirmed CAP, with a sensitivity of 99.7% (95% confidence interval [CI] 99.3-100%); specificity of 75.7% (95% CI 73.3–78%); PPV of 67.9% (95% CI 65–70.8%); and NPV of 99.8% (95% CI 99.5–100%). Including only children with a primary diagnosis of pneumonia (Algorithm 2) improved specificity to 90.9% (95% CI 89.4–92.5%) but reduced sensitivity to 71.0% (95% CI 67.6–74.4%). The greatest improvement in specificity was observed in Algorithm 4 (84.2% [95% CI 82.2–86.1%]) when including children with a primary or any secondary diagnosis of pneumonia, compared to Algorithm 1 (75.7% [95% CI 73.3-78%]), which included both pneumonia and effusion/empyema diagnoses. In general, algorithms that included pneumonia codes alone (Algorithms 4-5) or with a pneumonia-related complication or effusion or empyema (Algorithm 6) showed an improvement in specificity (84.2-92.2% vs. 75.7-90.9%) at the cost of reduced sensitivity (67.6-98.4% vs. 71-99.7%), compared to algorithms that did not (Algorithms 1–3).

Algorithms that excluded children with a CCC discharge code (denoted as Algorithms 1b, 2b, 3b, 4b, 5b, 6b thereafter) increased specificity (89.7–96.4% vs. 75.7-92.2%), but decreased sensitivity (60.7–90.6% vs. 67.6-99.7%) relative to algorithms that included CCCs. Overall, for provider-confirmed CAP, the authors noted that the algorithms with the best performance (i.e., highly sensitive and specific) were Algorithms 1b (PPV 81.9% [95% CI 79.2–84.7%]; NPV 94.9% [95% CI 93.6–96.1%]; sensitivity 90.6% [95% CI 88.4–92.8%]; specificity 89.7% [95% CI 88–91.3%]) and Algorithm 4b (PPV 84.4% [95% CI 81.8–87.1%]; NPV 94.4% [95% CI 93.1–95.6%]; sensitivity 89.4% [95% CI 87.1-91.7%]; specificity 91.5% [95% CI 90-93%]), respectively.

Compared to a reference standard that required a definite CAP diagnosis, Williams and colleagues[21] reported a PPV of 54.6–77.9% across the algorithms, along with an NPV of 87.8–99.8%, specificity of 68.7–93.0%, and a sensitivity of 65.6–99.6%. Overall, the authors noted that performance measures for algorithms compared to a definite CAP diagnosis reference standard were similar across algorithms (results provided in **Appendix A**). Compared to the performance measures for algorithms tested with provider-confirmed CAP, the requirement of a definite diagnosis with objective clinical evidence (i.e., radiographic confirmation) resulted in a reduction in specificity for all algorithms.

Kern and colleagues[18] conducted a validation study in a commercially insured U.S. population with chronic obstructive pulmonary disease (COPD). Among 311 abstracted records (paper-based and electronic) with a documented pneumonia diagnosis identified from a larger cohort of COPD patients, pneumonia cases (mean age of 67.5 years) were identified using ICD-9-CM codes 480–486 (inclusive) in claims data. The authors reported an overall PPV of 80.2% (95% CI 75.8–84.0%) for all pneumonia cases, noting that PPV was higher for diagnoses from inpatient/hospitalization/emergency department (ED) visits (87.6%, 95% CI 81.9–92.0%) compared to outpatient/office visits (73.4%, 95% CI 66.8–79.3%). In addition, the authors reported the highest PPV by medical record type was 87.6% (95% CI 80.9%–92.6) for a hybrid of paper and electronic medical records (EMR).

Two studies reported diagnostic accuracy for pneumonia identified in claims data among non-U.S. populations.[12,13] These two Canadian studies by Cadieux and colleagues assessed medical records and billing claims. In a pilot study of nine primary care practices in Montreal, Cadieux and colleagues[12] evaluated the accuracy of diagnostic codes in claims for identifying acute respiratory illness (ARI). Among 729 patients, the diagnosis of ARI was abstracted from medical records for 3,526 visits. Researchers compared the chart diagnosis with the ICD-9 code on the corresponding claim. For ICD-9 code-specific performance measures, the study reported for influenza (480, 487) PPV of 66% (95% CI 58–74%); NPV of 100%; sensitivity of 45% (95% CI 30–60%); and specificity of 100%. For bacterial pneumonia (481-486), the following measures were reported: PPV of 91% (95% CI 85–97%); NPV of 99% (95% CI 99–100%); sensitivity of 38% (95% CI 28–47%); and specificity of 100%.

In the subsequent study Cadieux and colleagues[13] assessed the accuracy of pneumonia diagnosis codes from a random sampling of claims from 3,600 primary care physicians in Quebec. The authors reported the accuracy of five syndrome definitions (fever, gastrointestinal, neurological, rash, and respiratory including influenza-like illness [ILI]) based on diagnostic codes from a sample of claims compared to clinical information in the corresponding medical record (n=1,098 physicians completed the record review for 10,669 corresponding visits). The authors reported performance measures (PPV, [95% CI]) for individual ICD-9 codes selected for four respiratory disease-related syndromes. We have summarized below performance results for pneumonia-related ICD-9 codes for each of these four syndromes:

- ILI large-group (sensitive): 486.0 (100%), 487.0 (100%),
- ILI small-group (specific): 487.0 (0%),
- Real-time Outbreak and Disease Surveillance (RODS)-Respiratory: 480.0 (0%), 480.1 (33% [0–87%]), 480.8 (100%), 482.1 (33% [0–71%]), 482.2 (100%), 482.9 (50% [0–100%]), 484.0 (33% [0–87%]), 484.1 (50% [1–99%]), 484.5 (0%), 484.8 (0%), 486.0 (100%), 487.0 (100%),
- Centers for Disease Control and Prevention (CDC)-Department of Defenses Electronic Surveillance System for Early Notification of Community-based Epidemics (ESSENCE)-Respiratory: 480.0 (100%), 480.1 (67% [13–100%]), 480.8 (100%), 481.9 (100%), 482.1 (50% [10-90%]), 482.2 (100%), 482.9 (50% [0-100%]), 484.1 (50% [1–99%]), 484.5 (100%), 484.8 (100%), 486.0 (100%), 487.0 (100%).

In a systematic literature review with meta-analysis, Redondo-González and colleagues[19] assessed the accuracy of diagnoses in administrative claims data for hospital-acquired nosocomial pneumonia that was VAP/ventilator-associated events (VAEs) and non-VAEs (non-VAP/VAE), respectively. The studies included in the analyses that reported on VAPs and non-VAPs were from the U.S., France, Belgium, and Germany. For non-VAP/VAEs, one U.S. study used ICD-9-CM codes 480–487.0, as well as 507.0 (pneumonitis due to solids and liquids), 510.x (emphysema with fistula), and 513.x (abscess of lung and

mediastinum). For other non-VAP/VAE studies, specific codes were not reported. For VAP/VAEs, studies from the U.S. and Belgium used ICD-9-CM codes 480-488 and 997.31 (respiratory complications not elsewhere classified). All the studies on VAP/VAEs utilized ICD-9-CM codes, whereas 75% of studies assessing patients with non-VAP/VAEs used ICD-10 codes (from Germany and France, specific codes not reported). For non-VAP/VAEs, the authors reported from a pooled analysis a sensitivity of 42%, specificity of 99%, positive likelihood ratio (LHR) of 47.28, and negative LHR of 0.60. For VAP/VAEs, the authors reported from a pooled analysis a sensitivity of 64%, specificity of 93%, positive LHR of 6.89, and negative LHR of 0.41. From a pooled analysis of all nosocomial pneumonia cases, the authors reported a sensitivity of 45%, specificity of 98%, positive LHR of 19.19, and negative LHR of 0.56. Further, the authors noted that studies using ICD-10 codes exhibited a significantly lower discriminative ability in identifying nosocomial pneumonia cases in claims data, compared with those that used ICD-9-CM.

2.b Medical Records-based Algorithms with Validation

Three U.S. studies[11,16,17] and one Australian study[20] assessed the validity of pneumonia algorithms derived from billing codes in EHRs.

Drahos and colleagues[16] sought to determine the accuracy of diagnoses in an integrated health system for identifying infections of pneumonia and herpes simplex virus (HSV). Among 25,064 patients from a health maintenance organization (HMO), 175 patients with an ICD-9-CM diagnostic code for pneumonia were selected for validation via medical record review. For pneumonia, the authors selected ICD-9-CM codes 480-486 (inclusive) and reported an overall PPV of 88% (specific ICD-9-CM code not reported). Requiring multiple ICD-9-CM codes for pneumonia slightly improved PPV (90.7%), but greatly increased the number of true cases verified (63.6%) compared to a single ICD-9-CM code (36.3%). In addition, requiring an ICD-9-CM code and medication prescription increased the PPV for pneumonia to 96.8%. Finally, excluding diagnoses from the inpatient setting increased the PPV to 92.4%.

Aronsky and colleagues[11] sought to determine the accuracy of pneumonia diagnoses in a U.S. clinical information system for a tertiary care hospital. Among the 10,828 consecutive ED encounters during the study period, 272 patients were identified as meeting a multi-step independent clinical pneumonia reference standard[vi]. The authors sought to assess performance measures for the following three ICD-9 CM-based coding algorithms[vii] for these 272 patients:

1) 480–483, 485-487.0;
2) 112.4 (Candidiasis of lung), 114.0 (primary coccidioidomycosis [pulmonary]), 115.05 (infection by Histoplasma capsulatum, pneumonia), 115.15 (infection by *Histoplasma duboisii*, pneumonia), 115.95 (Histoplasmosis, unspecified, pneumonia), 480.0, 480.1, 480.2, 480.8, 480.9, 481–487 (inclusive);
3) 480-483 and 485-487.0 as primary diagnosis, or 518.8 (other diseases of lung) and 038.x (septicemia) as primary diagnosis and 480–483 or 485-487.0 as secondary diagnosis.

For ICD algorithms (1-3), the study reported a PPV ranging from 79.4% (95% CI 73.0–84.5%) to 80.8% (95% CI 75.1–85.5%) (highest PPV from Algorithm 2), NPV ranging from 98.8% (95% CI 98.6–99.0%) to 99.1% (95% CI 98.9-99.3%), with highest NPV for Algorithms 2 and 3; sensitivity of 55.1% (95% CI 49.2–60.9%) to 66.2% (95% CI 60.4–71.5%) (highest sensitivity from Algorithm 3), and the same specificity (99.6%) for Algorithm 1 (95% CI 99.5–99.7%), Algorithm 2 (95% CI 99.5–99.7%), and Algorithm 3 (95% CI 99.4–99.7%) associated with a pneumonia diagnosis. Overall, the authors noted that for either a combined in- and out-patient or an inpatient-only population, algorithms 2 and 3 exhibited the best performance.

[vi] Patients were required to meet the following criteria: 1) pneumonia-compatible complaint, 2) a radiology chest examination, 3) an ICD-9-CM admission or discharge diagnosis of pneumonia, 4) at least a 1% probability of pneumonia as calculated by a computerized decision support system, and (5) a search for the term pneumonia in the ED, admission, and discharge report.

[vii] Two additional algorithms in Aronsky (2005) utilized diagnosis-related group (DRG) codes: 1) 89 and 90; and 2) 79, 80, 89, and 90.

Guevara and colleagues[17] conducted a U.S. community-based pneumonia incidence study using discharge diagnostic data from 15 acute care hospitals. Among 4,385 adult patients hospitalized for pneumonia, cases were identified based on the following ICD-9-CM codes listed in the first five positions for three classes[viii] of pneumococcal disease (SP: *Streptococcus pneumoniae*):

1) **Class 1** (definite SP cases): 038.0 [streptococcal septicemia], 038.2 [pneumococcal septicemia], 481.0 [pneumococcal pneumonia], 482.3, 486, 518.81 [acute respiratory failure],
2) **Class 2** (definite and probable SP cases): 038.0, 038.2, 481.0, 482.3, 486, 518.81,
3) **Class 3** (definite, probable, and possible SP cases): 038.0, 038.2, 481.0, 482.3, 486, 518.81.

The authors applied clinical definitions for definite, probable, and possible SP cases which are reported in **Table 2. Clinical case definitions for pneumococcal pneumonia.**. Except for codes 038.0 and 038.2, sensitivity was consistent across case definitions (i.e., did not increase or decrease >10%). PPV increased by 10% or more for codes 481.0, 482.3, and 518.81, when probable and possible SP cases were included (Class 1 to 3). In contrast, NPV decreased for each code with the inclusion of probable and possible SP cases. Overall, the authors reported that using codes in any of the first five positions was preferential to using first position codes only as this approach was able to detect more SP pneumonia cases without large differences in performance measures. Moreover, regardless of position or case definition ICD-9-CM code 481.0 was the most sensitive code for detecting patients with pneumococcal pneumonia. Performance measures (i.e., PPV, NPV, sensitivity and specificity) for each diagnosis code are listed in **Appendix A**.

Finally, Skull and colleagues[20] reported on the utilization of ICD-10-Australian Modification (ICD-10-AM) codes for identifying pneumonia in discharge diagnoses for hospitalized patients 65 years and older in Australia. The authors used ICD-10-AM codes J10-J18 (inclusive). ICD-10-AM code J18.9 (pneumonia, unspecified) was the most commonly used, and was responsible for 91.5% of cases. The highest PPV (96.2%, 95% CI 95.4–97.0%), NPV (98.2%, 95% CI 97.6–98.6%), sensitivity (97.8%, 95% 97.1–98.3%), and specificity (96.9%, 95% CI 96.2–97.5%) reported was from a case identification approach that used ICD-10-AM codes compared to a medical record notation of pneumonia.

2.c Algorithm Application without Validation

Two studies (one from the U.S. and one from Italy) identified pneumonia using a code-based algorithm without reporting measures of diagnostic accuracy. The U.S. study[15] assessed the effect of inhaled corticosteroids on outcomes for COPD patients from the Department of Veterans Affairs. A total of 15,758 eligible patients aged 65 years and older were identified using billing codes in EHRs for pneumonia (ICD-9-CM codes 480–483 and 485–487.0).

The hospital-based study from Italy by Cascini and colleagues[14] utilized the following ICD-9-CM discharge diagnoses codes to identify 24,338 pneumonia events as the primary or secondary diagnosis among patients 65 years and older: 480-487, 039.1 (pulmonary actinomycotic infection), 052.1 (Varicella [hemorrhagic] pneumonitis), 055.1 (postmeasles pneumonia), 073.0 (ornithosis with pneumonia), 112.4 (Candidiasis of lung), 114.0 (primary coccidioidomycosis [pulmonary]), 136.3 (pneumocystosis), 003.22 (Salmonella pneumonia), 115.05 (infection by Histoplasma capsulatum, pneumonia), 115.15 (infection by *Histoplasma duboisii*, pneumonia), and 115.95 (Histoplasmosis, unspecified, pneumonia).

D Pneumonia Clinical Case Definition

Pneumonia is defined as a form of acute respiratory infection that affects the lungs. When an individual has pneumonia, lung inflammation caused by bacterial, viral, or fungal infection occurs, in which the air sacs fill with pus and fluid and may become solid. Inflammation may affect both lungs (double

[viii] Criteria for definite (240 patients, 5.5%), probable (53 patients, 1.5%), and possible (268 patients, 6.1%) SP cases reported in Guevara (1999) is provided in **Table 2. Clinical case definitions for pneumococcal pneumonia.**

pneumonia), one lung (single pneumonia), or only certain lobes (lobar pneumonia). Common causes of viral pneumonia are influenza and RSV; common causes of bacterial pneumonia include SP (pneumococcus). The presenting features of viral and bacterial pneumonia are similar (more symptoms may occur in cases of viral pneumonia), and can include chest pain with breathing or coughing, cough, difficulty breathing, with or without fever. The diagnosis of pneumonia typically involves an assessment of medical history along with a physical examination, laboratory tests, and imaging (e.g., chest radiography) to determine the type of pneumonia. Additional tests for patients at greater risk (e.g., over the age of 65 years, already in the hospital, comorbid conditions) include a computerized tomography (CT) scan and pleural fluid culture.

Although publications that reported universally accepted criteria for defining definite/probable/possible pneumonia were not identified, the following case definition criteria was employed by Williams and colleagues[21] in a study to verify pneumonia cases identified from their administrative claims-based algorithms:

1. A provider diagnosis of pneumonia within the first 48 hours of hospitalization (mention of suspected CAP in the medical record along with consistent management strategy),
2. Abnormal temperature (≥38.0°C) or a white blood cell count outside the range of 5,000-15,000 µL,
3. Evidence of a lower respiratory tract illness (e.g., cough or increased work of breathing), and
4. Chest radiograph indicating pneumonia (e.g., infiltrate or consolidation).

In addition, Guevara and colleagues[17] reported the following selection criteria for identifying patients with CAP, which is broadly consistent with Williams et al (2013):

Chest radiograph taken within 48 hours of admission indicating a new density consistent with pneumonia and any of the following:

1. Fever (reported fever or chills, or documented temperature >100.8°F [>38.2°C] within 24 hours of admission)
2. Abnormal white blood cell count (>11,000/mm^3, <3,000/mm^3, or with abnormal differential),
3. Hypothermia (documented temperature of <96°F [<35.6°C] within 24 hours of admission), or
4. Productive cough (reported by patient or patient proxy)

Guevara and colleagues also provided specific criteria for defining the likelihood of pneumococcal pneumonia from the patient medical record and is reproduced in **Table 2. Clinical case definitions for pneumococcal pneumonia.** below.

Table 2. Clinical case definitions for pneumococcal pneumonia.

Definite
SP isolated from blood or pleural fluid
Probable
Isolation of SP from purulent sputum (defined as sputum with moderate or large numbers of neutrophils seen on Gram stain) in which gram-positive diplococci were noted in moderate or large amounts of sputum Gram Stain
Possible
Isolation of SP from purulent sputum in the absence of a compatible Gram stain, or a Gram's stain of purulent sputum demonstrating a predominance of gram-positive diplococci without isolation of SP from the sputum.
Non-pneumococcal disease
No evidence of SP in blood, pleural fluid, sputum, or sputum Gram stain

Source: Guevara et al[17]
Abbreviations: SP, *Streptococcus pneumoniae*

Should a validation study of the pneumonia algorithm be executed, these definitions could potentially be used to inform chart review and adjudication.

E Pneumonia Coding Algorithm

The aim of this review was to develop an algorithm to identify cases of pneumonia that could be of potential interest following exposure to a biologic product. To form a comprehensive list of pneumonia codes for clinical consideration, all ICD-9-CM codes for pneumonia 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. [ix] 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. This approach supports alignment and comparability with past studies and reflects current coding practices.

The final algorithm is presented in **Table 3**. The workgroup has developed an algorithm that includes diagnosis codes for pneumonia consistent with approaches identified in the peer-reviewed literature. This algorithm may be subject to refinements for future specific research questions. Annual counts of patients with specific 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 complete list of all excluded codes is provided in **Appendix C**. These codes were ultimately determined by the clinical SMEs to be too general or unrelated to pneumonia 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 pneumonia.

Briefly, the proposed algorithm can be summarized as follows:

> **INCLUDE: ANY** (“either–or” logic) of the codes listed in **Table 3**, regardless of health care setting or coding position (only one code required).

Table 3. Pneumonia algorithm.

Code	Description	Code Cat	Code Type
003.22	Salmonella pneumonia	DX	9
021.2	Pulmonary tularemia	DX	9
039.1	Pulmonary actinomycotic infection	DX	9
052.1	Varicella (hemorrhagic) pneumonitis	DX	9
055.1	Postmeasles pneumonia	DX	9
073.0	Ornithosis with pneumonia	DX	9
112.4	Candidiasis of lung	DX	9
114.0	Primary coccidioidomycosis (pulmonary)	DX	9
115.05	Infection by Histoplasma capsulatum, pneumonia	DX	9
115.15	Infection by Histoplasma duboisii, pneumonia	DX	9
115.95	Histoplasmosis, unspecified, pneumonia	DX	9
130.4	Pneumonitis due to toxoplasmosis	DX	9
136.3	Pneumocystosis	DX	9
480.0	Viral pneumonia due to adenovirus	DX	9
480.1	Viral pneumonia due to respiratory syncytial virus	DX	9
480.2	Viral pneumonia due to parainfluenza virus	DX	9
480.3	Viral pneumonia due to SARS-associated coronavirus	DX	9

[ix] 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.

Code	Description	Code Cat	Code Type
480.8	Viral pneumonia due to other virus not elsewhere classified	DX	9
480.9	Viral pneumonia, unspecified	DX	9
481	Pneumococcal pneumonia [Streptococcus pneumoniae pneumonia]	DX	9
482.0	Pneumonia due to Klebsiella pneumoniae	DX	9
482.1	Pneumonia due to Pseudomonas	DX	9
482.2	Pneumonia due to Hemophilus influenzae [H. influenzae]	DX	9
482.30	Pneumonia due to Streptococcus, unspecified	DX	9
482.31	Pneumonia due to Streptococcus, group A	DX	9
482.32	Pneumonia due to Streptococcus, group B	DX	9
482.39	Pneumonia due to other Streptococcus	DX	9
482.40	Pneumonia due to Staphylococcus, unspecified	DX	9
482.41	Methicillin susceptible pneumonia due to Staphylococcus aureus	DX	9
482.42	Methicillin resistant pneumonia due to Staphylococcus aureus	DX	9
482.49	Other Staphylococcus pneumonia	DX	9
482.81	Pneumonia due to anaerobes	DX	9
482.82	Pneumonia due to Escherichia coli [E. coli]	DX	9
482.83	Pneumonia due to other gram-negative bacteria	DX	9
482.84	Pneumonia due to Legionnaires' disease	DX	9
482.89	Pneumonia due to other specified bacteria	DX	9
482.9	Bacterial pneumonia, unspecified	DX	9
483.0	Pneumonia due to mycoplasma pneumoniae	DX	9
483.1	Pneumonia due to chlamydia	DX	9
483.8	Pneumonia due to other specified organisms	DX	9
484.1	Pneumonia in cytomegalic inclusion disease	DX	9
484.3	Pneumonia in whooping cough	DX	9
484.5	Pneumonia in anthrax	DX	9
484.6	Pneumonia in aspergillosis	DX	9
484.7	Pneumonia in other systemic mycoses	DX	9
484.8	Pneumonia in other infectious diseases classified elsewhere	DX	9
485	Bronchopneumonia, organism unspecified	DX	9
486	Pneumonia, organism unspecified	DX	9
487.0	Influenza with pneumonia	DX	9
488.01	Influenza due to identified avian influenza virus with pneumonia	DX	9
488.11	Influenza due to identified 2009 H1N1 influenza virus with pneumonia	DX	9
488.81	Influenza due to identified novel influenza A virus with pneumonia	DX	9
517.1	Rheumatic pneumonia	DX	9
A02.22	Salmonella pneumonia	DX	10
A21.2	Pulmonary tularemia	DX	10
A22.1	Pulmonary Anthrax	DX	10
A37.01	Whooping cough due to Bordetella pertussis with pneumonia	DX	10
A37.11	Whooping cough due to Bordetella parapertussis with pneumonia	DX	10
A37.81	Whooping cough due to other Bordetella species with pneumonia	DX	10
A37.91	Whooping cough, unspecified species with pneumonia	DX	10
A42.0	Pulmonary actinomycosis	DX	10
A48.1	Legionnaires' disease	DX	10
B01.2	Varicella pneumonia	DX	10
B05.2	Measles complicated by pneumonia	DX	10
B25.0	Cytomegaloviral pneumonitis	DX	10
B37.1	Pulmonary candidiasis	DX	10
B38.0	Acute pulmonary coccidioidomycosis	DX	10
B39.0	Acute pulmonary histoplasmosis capsulati	DX	10
B44.0	Invasive pulmonary aspergillosis	DX	10
B58.3	Pulmonary toxoplasmosis	DX	10

Code	Description	Code Cat	Code Type
B59	Pneumocystosis	DX	10
J09.X1	Influenza due to identified novel influenza A virus with pneumonia	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 virus pneumonia	DX	10
J10.08	Influenza due to other identified influenza virus with other specified pneumonia	DX	10
J11.00	Influenza due to unidentified influenza virus with unspecified type of pneumonia	DX	10
J11.08	Influenza due to unidentified influenza virus with specified pneumonia	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	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
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

Abbreviation: DX, ICD-CM diagnosis.

F Assumptions and Decisions

The algorithm presented in **Section F** 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 based on clinical consultation, it was decided that methods for diagnosing and treating pneumonia — 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. This is consistent with approaches observed in the literature.

- 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 potential pneumonia cases. Users may adjust this approach to include primary, secondary or unspecified-position codes. Such specification is likely better done at the statistical planning stage when a specific research question has been formulated.
- Risk windows used to determine the association of pneumonia with a specific exposure should be determined according to the research question and exposure of interest.
- Codes for septicemia were excluded as — though this can result from pneumonia — there are many other known causes.
- Codes for primary/acute pulmonary coccidioidomycosis were included in the algorithm. Codes for chronic, non-pulmonary, and unspecified coccidioidomycosis were excluded out of concern that these codes could potentially increase the risk of misclassification.
- Codes for pyothorax were excluded. This can be a complication of pneumonia. However, those cases would be expected to also have a pneumonia diagnosis and therefore the exclusion of these codes should not unduly exclude potential cases of pneumonia.

G Algorithm Characterization

G1 Methods

To characterize pneumonia 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[x] online analytic platform, to query and analyze the diagnostic codes included in the pneumonia algorithm (**Table 3**). The analyses presented herein did not require exposure to a biologic product. It is recommended that the proposed algorithm undergo a validation study prior to use, and 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 pneumonia within a given calendar year, rather than counts of codes, were presented. As such, counts relate to the first diagnosed pneumonia 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 pneumonia 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 given 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 old), this population group has been left out of two charts that depict the proportions of individuals with pneumonia by age. Infants under one year of age were not excluded from queries of the absolute number of patients receiving a pneumonia diagnosis.

[x] IBM MarketScan Research. Insight for Better Healthcare. https://marketscan.truvenhealth.com/marketscanportal/Portal.aspx

G2 Results

Of the codes included in the pneumonia algorithm, codes for unspecified pneumonia (ICD-9-CM 486 and ICD-10-CM J18.9) were the most frequently used (**Appendix B**). Of those receiving at least one pneumonia diagnosis between 2014 and 2018 (n=1,682,997), 36.3% (n=611,051) and 51.1% (n=859,546) had at least one ICD-9-CM 486 and ICD-10-CM J18.9 code, respectively.

In addition to the code-specific queries, 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 pneumonia. **Table 4** provides a summary of aggregate counts for ICD-9-CM and ICD-10-CM codes, suggesting that approximately 14.1–16.7 individuals per 1,000 individuals included in the MarketScan Research Databases received at least one code associated with pneumonia 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, 1,682,997 individuals (3.6%) had at least one ICD-9-CM or ICD-10-CM diagnosis code for pneumonia.

Table 4. Counts of patients with pneumonia by code set and year.

Code/ Description	Year				
	2014	**2015[a]**	**2016**	**2017**	**2018**
ICD-9-CM	423,123	258,969			
ICD-10-CM		124,444	360,625	296,109	273,688
ICD-9-CM OR ICD-10-CM	423,123	361,090	360,625	296,109	273,688
MarketScan Research Databases Enrollment[b]	28,407,959	22,117,235	21,616,291	19,563,847	19,371,891
Proportion of Patients with Pneumonia per 1,000 Enrolled Population[c]	**14.9**	**16.3**	**16.7**	**15.1**	**14.1**

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] Individuals included in this row are those who were enrolled for the full calendar year (January 1–December 31) for 2014, 2015, 2016, 2017, and 2018, respectively.

[c] 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 pneumonia. **Figure 1** illustrates the proportion of the enrolled population with a pneumonia diagnosis and suggests that the transition did not result in a substantial change to the proportion of individuals receiving a pneumonia diagnosis. However, the proportion of patients receiving a pneumonia diagnosis decreased year-over-year between 2016 and 2018. 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. Independent analyses also indicated a decrease in the proportion of patients receiving a diagnosis for Bell's palsy, COPD, acute respiratory distress syndrome and acute bronchitis 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). It was also noted that the average age of the enrolled population decreased from 62–63 years between 2014 and 2017 to 60 years in 2018, suggesting that the study population was younger and potentially healthier in 2018. This difference may have decreased the proportion of patients receiving a pneumonia diagnosis, as the risk of pneumonia increases with advancing age after 65 years [4].

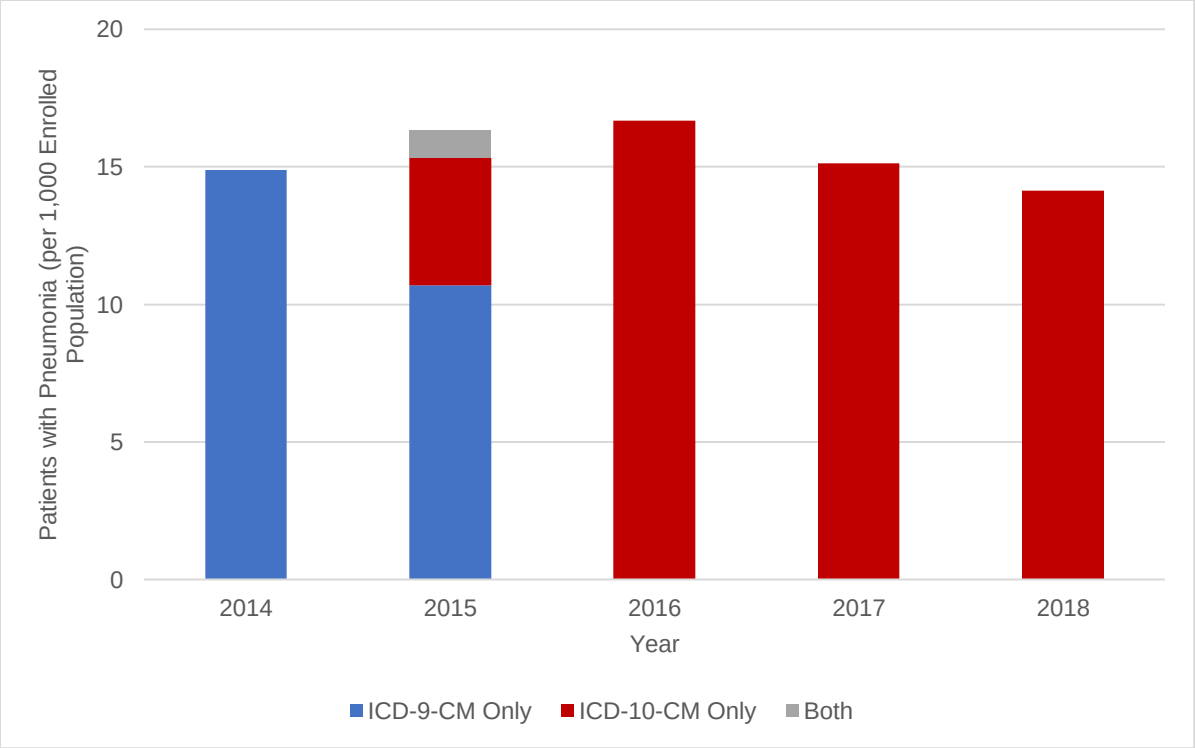

Figure 1. Proportion of patients with pneumonia per 1,000 enrolled, by year (2014–2018).

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 ICD-9-CM pneumonia diagnosis 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 693,906 (2.1%) with at least one diagnosis for pneumonia during this period, with an average age at first diagnosis of 44 years. The relationship between age and pneumonia diagnosis followed a "U" shape. The number of patients with at least one ICD-9-CM diagnosis code for pneumonia was highest for the 0-17 years age group, followed by a decline in patients with an ICD-9-CM pneumonia diagnosis until the 35-44 years age group. The number of patients with a pneumonia diagnosis increased with higher age groups, beginning with the 35–44-year age group.

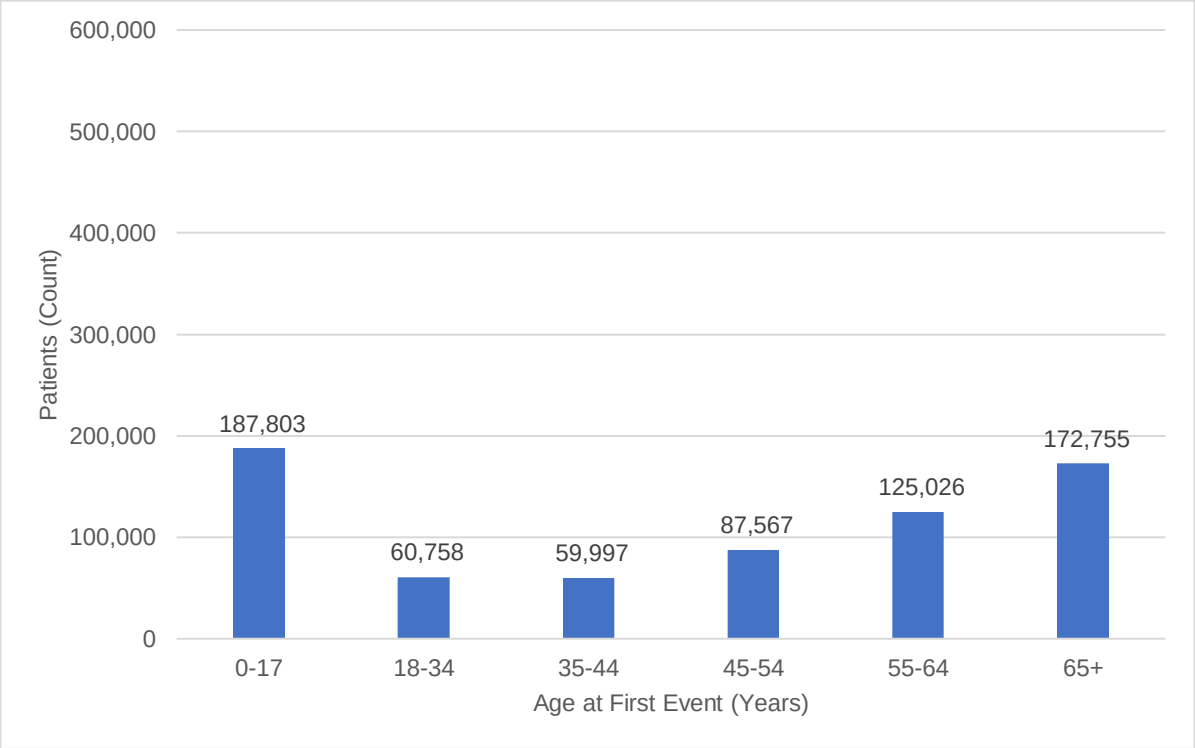

Figure 2. Patients with at least one ICD-9-CM diagnosis code for pneumonia, January 1, 2014–September 30, 2015, stratified by age group.

Figure 3 presents counts of patients with an ICD-10-CM diagnosis for pneumonia 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 1,074,639 individuals (3.0%) with at least one diagnosis for pneumonia during this time period, the average age at first diagnosis was 41 years. Similar to the results for ICD-9-CM diagnosis, the relationship between age and absolute counts of pneumonia diagnoses based on ICD-10-CM codes also followed a "U" shape. The number of patients with at least one ICD-10-CM diagnosis code for pneumonia was highest for the 0-17 years age group, followed by a decline in patients with an ICD-10-CM pneumonia diagnosis until the 35-44 years age group. At the 45-54 years age group and older a steady increase in patients with a pneumonia diagnosis was observed. It should be noted that the absolute counts presented in **Figure 2** (January 1, 2014, to September 30, 2015) are lower than those in **Figure 3**, where pneumonia encounters were queried for a longer time period (October 1, 2015 to December 31, 2018).

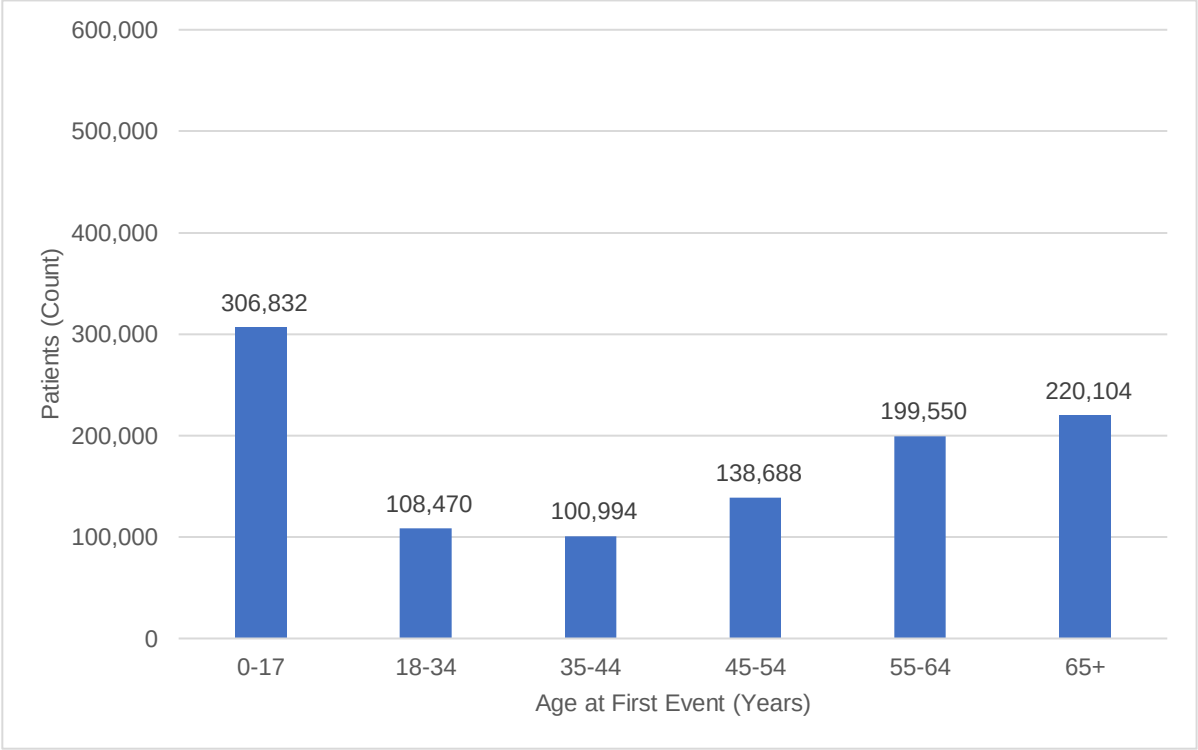

Figure 3. Patients with at least one ICD-10-CM diagnosis code for pneumonia, October 1, 2015–December 31, 2018, stratified by age group.

Figure 4 presents counts of patients with either an ICD-9-CM or ICD-10-CM code for pneumonia among a cohort of 46,153,898 individuals who were continuously enrolled for at least one calendar year between 2014 and 2018. Among 1,682,997 individuals (3.6%) who received a diagnosis code for pneumonia between January 1, 2014, and December 31, 2018, the average age at first diagnosis was 42 years. Absolute patient counts were highest in the age group of 0–17-years, with the lowest absolute counts in the age group of 18–34 and 35–44-years.

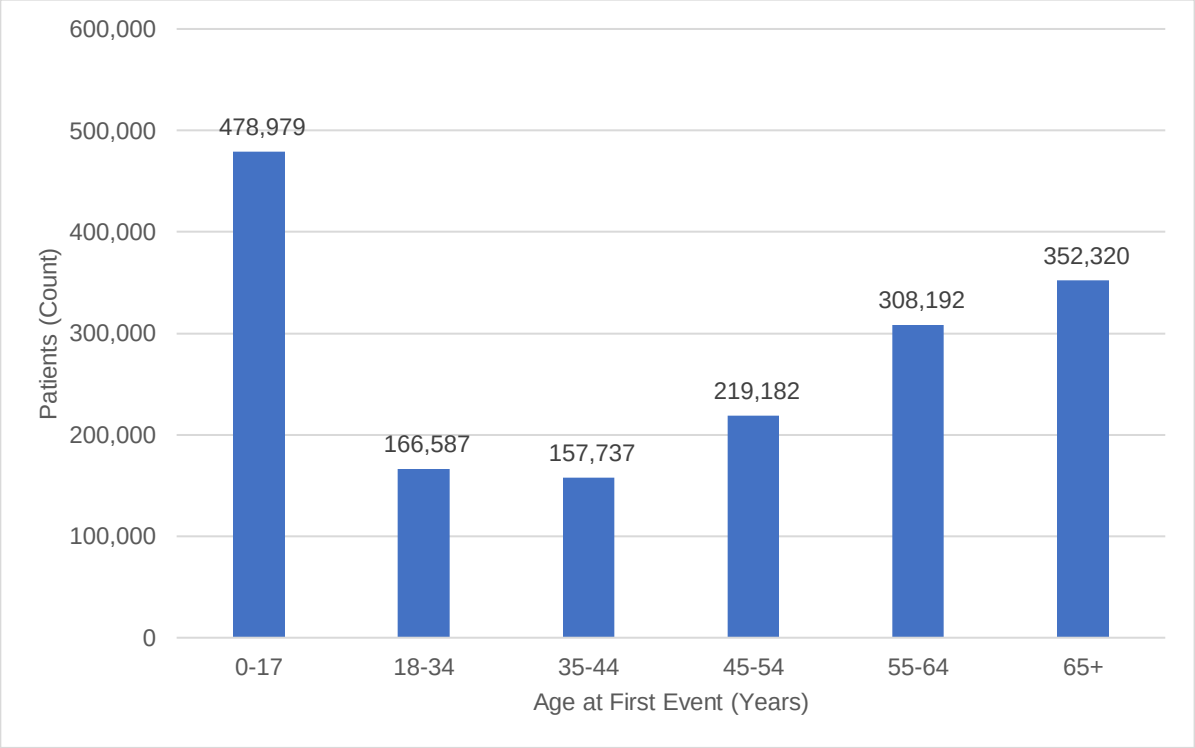

Figure 4. Patients with at least one diagnosis code for pneumonia (ICD-9-CM or ICD-10-CM), January 1, 2014–December 31, 2018, stratified by age group.

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 pneumonia (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 group 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 pneumonia increases with age, with an initial peak in early childhood (3–5 years) which is followed by a lower proportion through later childhood and adulthood; the proportion then increases sharply among seniors. In addition, the results indicate that the proportion of patients with pneumonia is distributed evenly between males and females until later life, with pneumonia reported more frequently among elderly men than women.

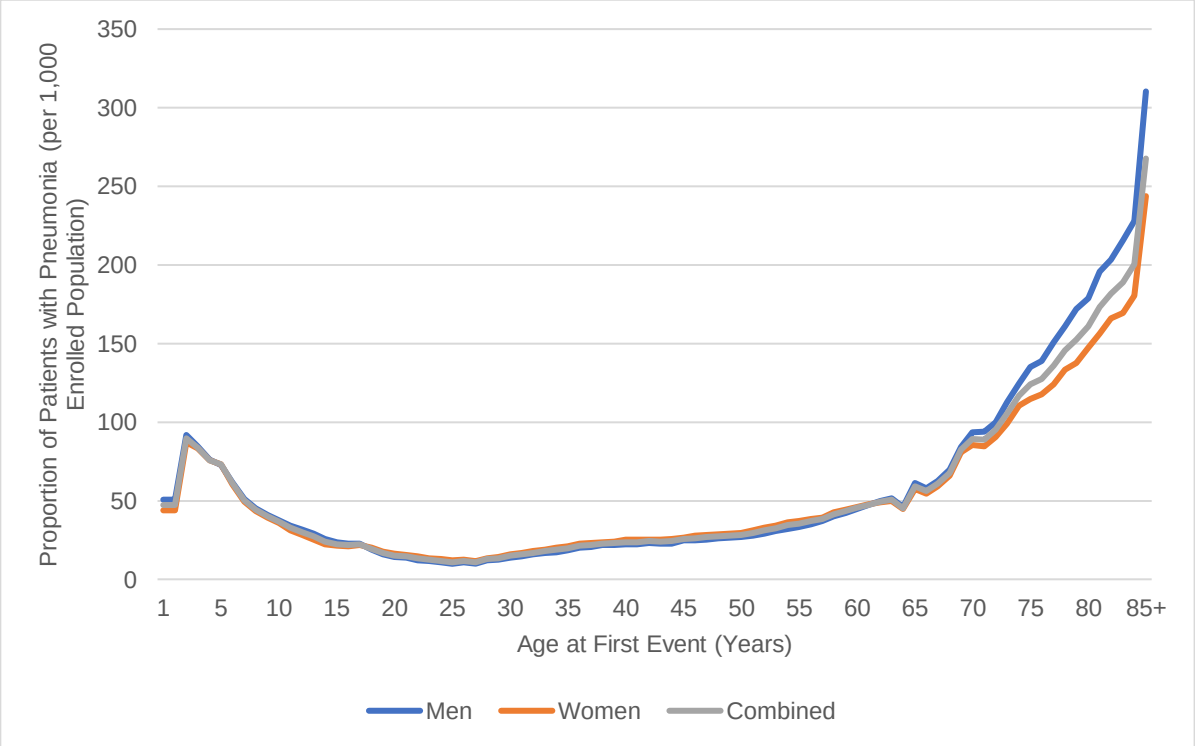

Figure 5. Proportion of patients (1-85+ years)* with at least one diagnosis code for pneumonia (ICD-9-CM or ICD-10-CM) per 1,000 population, by age and gender (January 1, 2014–December 31, 2018).

*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 pneumonia is excluded from the chart.

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

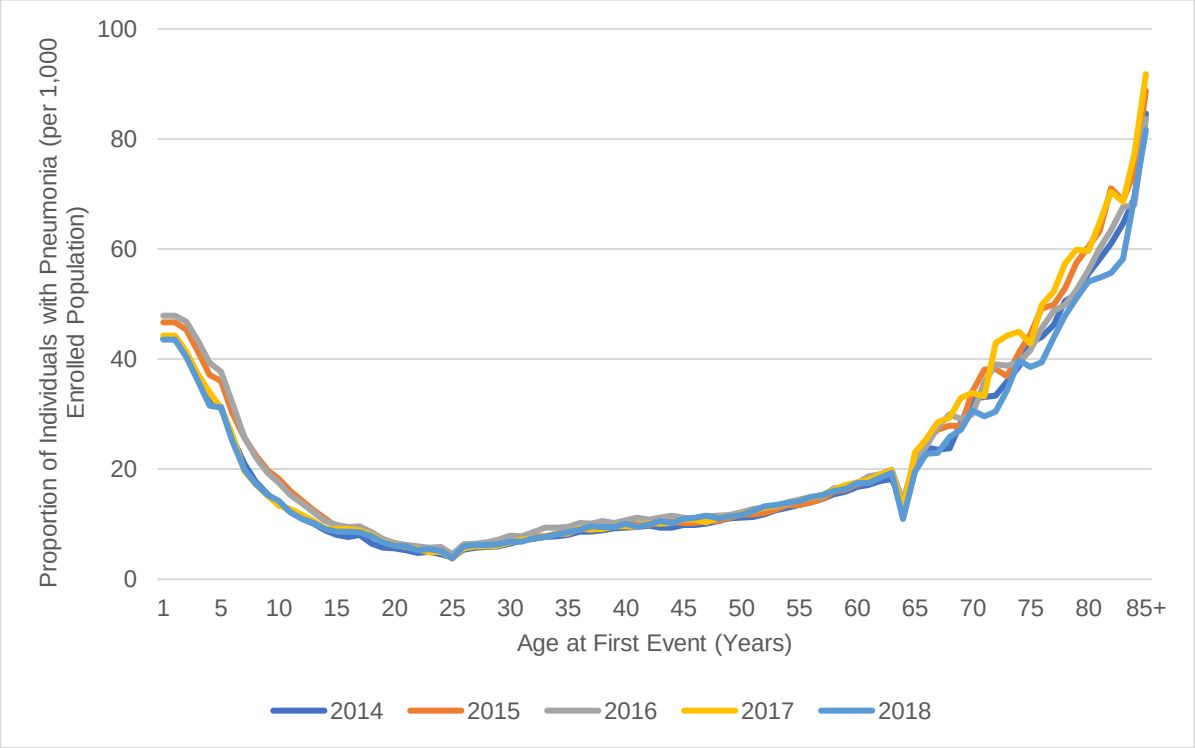

Figure 6. Proportion of patients (1-85+ years)* with at least one diagnosis code for pneumonia (ICD-9-CM or ICD-10-CM) per 1,000 population, by age and calendar year (January 1, 2014–December 31, 2018).

*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 pneumonia is excluded from the chart.

Analyses were also conducted to test whether there was a temporal association in the occurrence or reporting of pneumonia according to the time of the year, possibly as a result of an association with infection circulations or vaccination schedules. To test this, enrollment and pneumonia encounter data for January 1–June 30 and July 1–December 31 were queried for each year. As presented in **Table 5** and **Figure 7**, the proportion of patients experiencing pneumonia was lower in the second half of the year across the entire study period.

Table 5. Counts and proportions of patients experiencing pneumonia*, 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	259,320	222,283	232,178	189,096	173,682
July–December patient count	239,361	199,591	169,533	155,322	143,144
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)	**8.3**	**9.2**	**9.9**	**8.8**	**8.2**
July–December proportion (per 1,000 enrolled)	**7.8**	**8.4**	**7.1**	**7.4**	**6.9**

*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.

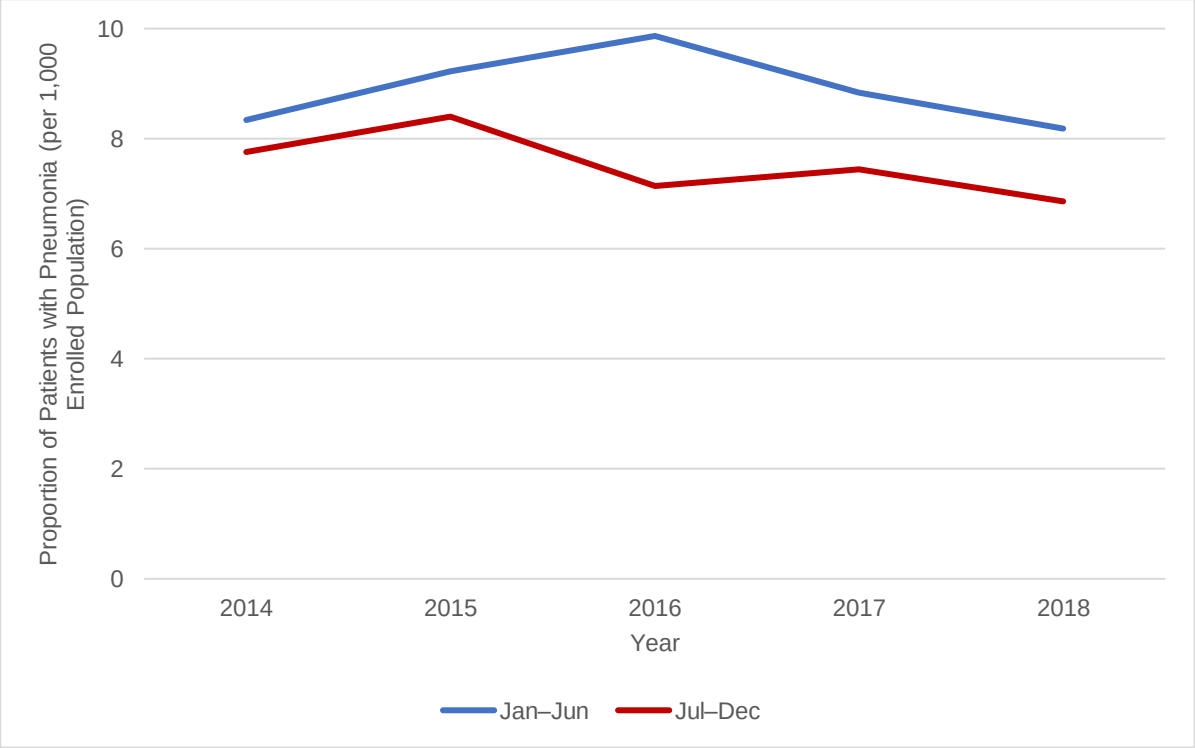

Figure 7. Proportion of patients with at least one diagnosis code for pneumonia (ICD-9-CM or ICD-10-CM) per 1,000 population, stratified by time of year (2014–2018).

H Discussion and Conclusion

The objective of this structured review was to assess and understand the validity of electronic coding algorithm for identifying pneumonia from administrative claims and EHRs using billing codes. 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. The EHRs were assessed as supplemental data to support the completeness of the code lists in this report.

A structured review of the literature found 11 publications of interest, two of which[18,21] reported validated algorithms developed from claims data (i.e., claims-based). No publications were found that used an algorithm based on ICD-10-CM codes. All validation studies reviewed the medical records to assess the validity of ICD-9-CM codes 480-486 (inclusive or for a subset) in their respective databases. Overall, studies reported a moderate-to-high PPV and a low sensitivity (i.e., increased chance of missing true cases) associated with the diagnosis codes with the range of performance measures influenced by study-specific code selection. The utilization of additional ICD-9-CM diagnosis codes may improve the algorithm sensitivity at the cost of specificity. These findings — in combination with international validation studies and a wide range of U.S. and international epidemiologic studies — were used to develop an updated algorithm that was revised via consultation with clinical SMEs. The final pneumonia algorithm included 53 ICD-9-CM codes and 54 ICD-10-CM codes.

The final algorithm was then applied in the MarketScan Research Databases to test the feasibility of algorithm use and conduct initial analyses describing the epidemiology of pneumonia in a U.S. commercially insured population. Counts of patients with specific diagnosis codes associated with pneumonia were queried (**Table B1**). These results suggest that codes for unspecified pneumonia were by far the most frequently used, with ICD-9-CM 486 and ICD-10-CM J18.9 being reported among 36.3% and 51.1% of those receiving at least one pneumonia diagnosis code, respectively. This result suggests that the majority of pneumonia cases do not have a specific etiology recorded in claims data. The most frequently used type- or cause-specific pneumonia codes were ICD-9-CM 482.9, (bacterial pneumonia, unspecified), ICD-10-CM J18.1 (lobar pneumonia, unspecified organism), and ICD-10-CM J15.9 (unspecified bacterial pneumonia) reported among 3.7%, 9.8%, and 5.7% of those receiving at least one pneumonia diagnosis code, respectively.

Overall, approximately 14.1–16.7 individuals per 1,000 population had at least one pneumonia diagnosis code per year between 2014 and 2018. This finding is within the large range of 1–33 hospitalized cases of pneumonia per 1,000 population reported in prior studies [4,22]. However, the rate of hospitalizations is likely to be impacted by several factors, including the age of the population, type of pneumonia, and comorbid conditions. Further, 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 pneumonia during the study period.

Absolute patient counts were highest in the age group of 0–17 years. An initial peak in early life (i.e., before age 5) is consistent with childhood susceptibility to pneumonia and the significant health impact associated with pediatric pneumonia, which is the leading cause of mortality and morbidity in children [3]. Although the highest proportion of pneumonia cases was observed in childhood, the average age at first diagnosis with pneumonia was approximately 42 years. A higher average age of diagnosis may be attributable in part to a gradual increase in the proportion of patients with pneumonia between 25 and 65 years of age. A marked increase in the proportion of patients with pneumonia was observed after 66 years of age, which is consistent with prior research findings that pneumonia is more frequent in the elderly, increasing with age from as low as 1 per 1,000 in the general population to 12 per 1,000 over age 75 years [4].

The proportion of patients experiencing pneumonia was similar among males and females until older age (62 years and older) when pneumonia was reported more frequently among elderly men than women. This finding is consistent with prior research indicating older males are more susceptible to infection in general [23], and in particular are at greater risk of pneumonia-related mortality in comparison to females [24].

It should be noted that the higher proportion of pneumonia among males may also be due to differences in unmeasured risk factors (e.g., smoking).

The proportion of patients experiencing pneumonia appeared to vary between the first and second halves of the calendar year, with a higher proportion of patients experiencing pneumonia in the first half of the year across all years of the study period. These findings are consistent with a systematic review of the seasonal distribution of CAP, which found a peak in hospitalizations from January through to April with significantly higher hospital admissions for CAP in the northern hemisphere winter and spring [25]. Future analysis of the MarketScan Research Databases could consider whether seasons and specific months are associated with peaks in pneumonia.

Strengths of this study are the development of a pneumonia algorithm using ICD-9-CM and ICD-10-CM coding standards, based on a structured review of coding 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 pneumonia 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, the workgroup sought to optimize algorithm sensitivity by including ICD-9-CM (486) and ICD-10-CM (J18.9) codes for unspecified pneumonia, though this approach could increase the risk of misclassification whereby cases were erroneously coded as pneumonia-related. Nonetheless, this approach is consistent with previous validation studies [11-13,16-18,20,21]. Finally, unmeasured risk factors (e.g., lifestyle, chronic conditions) or medication use may have influenced the findings and could result in an under- or over-ascertainment of pneumonia cases overall, or for specific sub-groups. 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.

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Appendix A. Literature Review Extracted Results

Table A1, below, includes a summary of the data extraction table used to extract papers of relevance to pneumonia algorithms. The 11 papers summarized in this table informed the development of the proposed pneumonia algorithm.

Table A1. Pneumonia Data Extraction Table

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR-based Algorithm[xi]
Aronsky, 2005	Accuracy of Administrative Data for Identifying Patients with Pneumonia	U.S.	Used ICD-9-CM codes 038.x, 112.4, 114.0, 115.05, 115.15, 115.95, 480-483, 485-487.0, 507, and 518.8 to identify potential pneumonia in the U.S.	Medical record review was used as the reference standard.	5 Algorithms: 1) ICD-9-CM codes: 480-483; 485-487.0; 2) ICD-9-CM codes: 112.4, 114.0, 115.05, 115.15, 115.95, 480.0, 480.1, 480.2, 480.8, 480.9, 481-487 3) 480-483; 485-487.0, 507 as primary diagnosis; or 518.8, 038.x as primary diagnosis and 480-483; 485-487.0 as secondary diagnosis; 4)DRG 89, 90; 5)DRG 79, 80, 89, 90	Algorithm 1 PPV: 79.4% (95% CI 73.0-84.5%) NPV: 98.8% (95% CI 98.6-99.0%) Sensitivity: 55.1% (95% CI 49.2-60.9%) Specificity: 99.6% (99.5-99.7%) Algorithm 2 PPV: 80.8% (95% CI 75.1-85.5%) NPV: 99.1% (95% CI 98.9-99.3%) Sensitivity: 65.1% (95% CI 59.2-70.5%) Specificity: 99.6% (95% CI 99.5-99.7%) Algorithm 3 PPV: 80.4% (95% CI 74.7-85.0%) NPV: 99.1% (95% CI 98.3-99.3%) Sensitivity: 66.2% (95% CI 60.4-71.5%) Specificity: 99.6% (95% CI 99.4-99.7%)	EHR

[xi] Each publication reported on a either a claims-based (i.e., pneumonia codes derived from insurance claims) or EHR-based (i.e., pneumonia codes derived from medical records) algorithm.

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR-based Algorithm[xi]
						Algorithm 4 PPV: 72.6% (95% CI 65.7-78.6%) NPV: 98.7% (95% CI 98.4-98.9%) Sensitivity: 47.8% (95% CI 41.9-53.7%) Specificity: 99.5% (95% CI 99.4-99.6%) Algorithm 5 PPV: 74.0% (67.9-79.3%) NPV: 99.0% (98.8-99.2%) Sensitivity: 60.7% (54.7-66.3%) Specificity: 99.4% (99.3-99.6%)	
Cadieux, 2008	Accuracy of physician billing claims for identifying acute respiratory infections in primary care	Canada	Used ICD-9 codes 480 and 487 to identify potential influenza and ICD-9 codes 481-486 to identify potential pneumonia in Canada	Medical record review was used as the reference standard.	ICD-9 codes 480 and 487 for influenza and 481-486 for bacterial pneumonia	Influenza: PPV: 66% (95% CI 58–74%) NPV: 100% Sensitivity: 45% (95% CI 30–60%) Specificity: 100% Bacterial pneumonia PPV: 91% (95% CI 85–97%) NPV: 99% (95% CI 99–100%) Sensitivity: 38% (95% CI 28–47%) Specificity: 100%	Claims
Cadieux, 2011	Accuracy of syndrome definitions based on diagnoses in physician claims	Canada	Used ICD-9 codes 480-487 to identify potential pneumonia cases in Canada	Medical record review was used as the reference standard.	ICD-9 codes 480-487 (included in 4 respiratory disease syndrome groups)	ILI large-group (sensitive) (PPV, 95% CI) 486.0 (100%), 487.0 (100%) ILI small group (specific) (PPV, 95% CI) 487.0 (0%) RODS (PPV, 95% CI) 480.0 (0%), 480.1 (33% [0-87%]), 480.8 (100%), 482.1 (33% [0-71%]), 482.2 (100%), 482.9 (50% [0-100%]), 484.0	Claims

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR-based Algorithm[xi]
						(33% [0-87%]), 484.1 (50% [1-99%]), 484.5 (0%), 484.8 (0%), 486.0 (100%), 487.0 (100%) ESSENCE (PPV, 95% CI) 480.0 (100%), 480.1 (67% [13-100%]), 480.8 (100%), 481.9 (100%), 482.1 (50% [10-90%]), 482.2 (100%), 482.9 (50% [0-100%]), 484.1 (50% (1-99%), 484.5 (100%), 484.8 (100%), 486.0 (100%), 487.0 (100%)	
Cascini, 2013	Pneumonia Burden in Elderly Patients: A Classification Algorithm Using Administrative Data	Italy	Used ICD-9-CM codes 480-487, 039.1, 052.1, 055.1, 073.0, 112.4, 114.0, 136.3, 003.22, 115.05, 115.15, 115.95 to identify potential pneumonia cases in the Italy	NA (no validation)	ICD-9-CM codes 480-487, 039.1, 052.1, 055.1, 073.0, 112.4, 114.0, 136.3, 003.22, 115.05, 115.15, 115.95	NA (no validation)	EHR
Chen, 2011	Observational study of inhaled corticosteroids on outcomes for COPD patients with pneumonia	U.S.	Used ICD-9-CM codes 480-483 and 485-487.0 to identify potential pneumonia cases in the U.S.	NA (no validation)	ICD-9-CM codes 480–483 and 485–487.0	NA (no validation)	EHR

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR-based Algorithm[xi]
Drahos, 2013	Accuracy of ICD-9-CM codes in identifying infections of pneumonia and herpes simplex virus in administrative data	U.S.	Used ICD-9-CM codes 480-486 (inclusive) to identify potential pneumonia cases in the U.S.	Medical record review was used as the reference standard.	ICD-9-CM 480-486 (inclusive)	Single ICD-9-CM code Pneumonia PPV: 88% (specific ICD-9-CM code not reported). Requiring an ICD-9-CM code and medication prescription Pneumonia PPV: 96.8%	EHR
Guevara, 1999	Accuracy of ICD-9-CM Codes in Detecting Community-Acquired Pneumococcal Pneumonia for Incidence and Vaccine Efficacy Studies	U.S.	Used ICD-9-CM codes 038.0, 038.00, 038.2, 038.20, 481.0, 482.3, 486.00, 518.81 to identify potential pneumonia cases in the U.S.	Medical record review was used as the reference standard.	<u>3 Case Definitions</u> 1) Class 1 (definite SP cases: ICD-9-CM codes 038.0, 038.2, 481.0, 482.3, 486.00, 518.81, 2) Class 2 (define and probable SP cases: ICD-9-CM codes 038.00, 038.20, 481.0, 482.3, 486.00, 518.81, 3) Class 3 (definite, probable, and possible SP cases: ICD-9-CM codes 038.00, 038.20, 481.0, 482.3, 486.00, 518.81	<u>Class 1 (definite SP cases): Sensitivity, Specificity, PPV, NPV</u> ICD-9-CM 038.0 Code position 1: 10.4%, 99.8%, 80.7%, 94.7% Code position 1-5: 20.4%, 99.6%, 74.2%, 95.2% ICD-9-CM 038.2 Code position 1: 5.0%, >99.9%, 92.3%, 94.4% Code position 1-5: 19.2%, >99.9%, 95.8%, 95.2% ICD-9-CM 481.0 Code position 1: 45.4%, 97.8%, 56.8%, 96.6% Code position 1-5: 58.3%, 97.5%, 59.1%, 97.4% ICD-9-CM 482.3 Code position 1: 6.7%, 99.2%, 34.8%, 94.4% Code position 1-5: 11.3%, 99.0%, 40.3%, 94.7% ICD-9-CM 486 Code position 1: 10.8%, 54.8%, 1.5%, 90.7%	EHR

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR-based Algorithm[xi]
						Code position 1-5: 14.2%, 48.4%, 1.7%, 90.0% ICD-9-CM 518.81 Code position 1: 2.5%, 97.5%, 5.9%, 94.1% Code position 1-5: 15.0%, 91.5%, 10.0%, 94.5% <u>Class 2 (definite and probable SP cases): Sensitivity, Specificity, PPV, NPV</u> ICD-9-CM 038.0 Code position 1: 8.5%, 99.8%, 80.7%, 93.4% Code position 1-5: 17.1%, 99.6%, 74.6%, 94.0% ICD-9-CM 038.2 Code position 1: 4.1%, >99.9%, 92.3%, 93.2% Code position 1-5: 15.7%, >99.9%, 95.8%, 93.9% ICD-9-CM 481.0 Code position 1: 50.2%, 97.8%, 63.9%, 96.2% Code position 1-5: 61.4%, 97.5%, 65.0%, 97.1% ICD-9-CM 482.3 Code position 1: 6.8%, 99.2%, 40.0%, 93.3% Code position 1-5: 10.6%, 99.0%, 43.7%, 93.5% ICD-9-CM 486 Code position 1: 10.9%, 54.8%, 1.8%, 88.9% Code position 1-5: 13.7%, 48.4%, 2.0%, 88.0%	

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR-based Algorithm[xi]
						ICD-9-CM 518.81 Code position 1: 3.1%, 97.5%, 8.7%, 92.9% Code position 1-5: 14.0%, 91.5%, 11.2%, 93.3% <u>Class 3 (definite, probable, and possible SP cases): Sensitivity, Specificity, PPV, NPV</u> ICD-9-CM 038.0 Code position 1: 4.5%, 99.8%, 80.7%, 87.7% Code position 1-5: 8.9%, 99.6%, 74.5%, 88.2% ICD-9-CM 038.2 Code position 1: 2.1%, >99.9%, 92.3%, 87.4% Code position 1-5: 8.4%, >99.9%, 95.9%, 88.2% ICD-9-CM 481.0 Code position 1: 44.0%, 97.8%, 74.9%, 92.3% Code position 1-5: 52.9%, 97.5%, 75.4%, 93.4% ICD-9-CM 482.3 Code position 1: 11.2%, 99.2%, 67.7%, 88.4% Code position 1-5: 14.1%, 99.0%, 66.4%, 88.7% ICD-9-CM 486 Code position 1: 13.6%, 54.8%, 4.2%, 81.2% Code position 1-5: 15.5%, 48.4%, 4.2%, 79.6% ICD-9-CM 518.81	

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR-based Algorithm[xi]
						Code position 1: 3.6%, 97.5%, 17.4%, 87.3% Code position 1-5: 14.4%, 91.5%, 20.0%, 87.9%	
Kern, 2015	Validation of an administrative claims-based diagnostic code for pneumonia in a US-based commercially insured COPD population	U.S.	Used ICD-9-CM code 480-486 (inclusive) to identify potential pneumonia cases in the U.S.	Medical record review was used as the reference standard.	ICD-9-CM 480-486 (inclusive)	Overall (all cases) PPV: 80.2% (95% CI 75.8-84.0%) Diagnoses from inpatient/hospitalization/ED PPV: 87.6% (95% CI 81.9-92.0%) Diagnoses from outpatient/office visits PPV: 73.4% (95% CI 66.8-79.3%) Record type Paper: PPV: 80.2 (95% CI 71.1-87.5%) EMR: PPV: 73.3% (95% CI 65.5-80.2%) Paper/EMR hybrid: PPV: 87.6% (95% CI 80.9%–92.6)	Claims
Redondo-González 2018	Validity and Reliability of Administrative Coded Data for the Identification of Hospital-Acquired Infections: An Updated Systematic Review with Meta-Analysis and Meta-Regression Analysis	U.S., France, Belgium, Germany (reported on VAP/VAEs)	Used ICD-9-CM codes 480-487.0 to identify potential non-VA/VAE in the U.S., Germany, and France; and ICD-9-CM codes 480-488 to identify potential VAP/VAE in the U.S. and Belgium	Medical record review was used as the reference standard.	ICD-9-CM codes 480-487.0 for a non-VA/VAE and ICD-9-CM codes 480-488 for a VAP/VAE.	VAP/VAE (pooled analyses) Sensitivity: 64% Specificity: 93% Positive LHR: 6.89 Negative LHR: 0.41 Non-VAP/VAE (pooled analysis) Sensitivity: 42% Specificity: 99% Positive LHR: 47.28 Negative LHR: 0.60 All nosocomial pneumonia (pooled analysis)	Claims

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR-based Algorithm[xi]
						Sensitivity of 45% Specificity of 98% Positive LHR: 19.19 Negative LHR: 0.56	
Skull, 2008	ICD-10 codes are a valid tool for identification of pneumonia in hospitalized patients aged ≥ 65 years	Australia	Used ICD-10-AM codes J10-J18 (inclusive) to identify potential pneumonia cases in Australia	Medical record review was used as the reference standard.	ICD-10-AM codes J10-J18 (inclusive)	<u>ICD-10 coding vs. medical notation of pneumonia</u> PPV: 96.2% (95% CI 95.4-97.0%) NPV: 98.2% (95% CI 97.6-98.6%) Sensitivity: 97.8% (95% 97.1-98.3%) Specificity: 96.9% (95% CI 96.2-97.5%) <u>ICD-10 coding vs. CXR report</u> PPV: 71.4% (95% CI 69.4-73.3%) NPV: 84.4% (95% CI 82.2-86.4%) Sensitivity: 89.2% (95% 87.7-90.6%) Specificity: 62.0% (95% CI 59.6-64.4%) <u>ICD-10 coding vs. medical notation of pneumonia and CXR</u> PPV: 68.1% (95% CI 68.1-72.0%) NPV: 97.1% (95% CI 96.1-98.1%) Sensitivity: 97.8% (95% 96.9-98.5%)	EHR

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR-based Algorithm[xi]
						Specificity: 64.2% (95% CI 62.0-66.4%)	
Williams, 2013	Identifying Pediatric Community-Acquired Pneumonia Hospitalizations: Accuracy of Administrative Billing Codes	U.S.	Used ICD-9-CM codes 480.0 to 480.2, 480.8 to 480.9, 481, 482.0, 482.30 to 482.32, 482.41 to 482.42, 482.83, 482.89 to 482.90, 483.8, 484.3, 485, 486, and 487.0 to identify potential pneumonia cases in the U.S.	Medical record review (prescriber confirmed and definite diagnosis) used as the reference standard.	1) primary or any secondary diagnosis of pneumonia or effusion/empyema; 1b) primary or any secondary diagnosis of pneumonia or effusion/empyema excluding complex chronic conditions [CCCs]; 2) primary diagnosis of pneumonia or effusion/empyema; 2b) primary diagnosis of pneumonia or effusion/empyema excluding CCCs; 3) primary diagnosis of pneumonia or effusion/empyema or primary diagnosis of pneumonia-related complication plus any secondary diagnosis of pneumonia or effusion/empyema; 3b) primary diagnosis of pneumonia or effusion/empyema or primary diagnosis of	**Provider Confirmed CAP** <u>Algorithm 1</u> PPV: 67.9% (95% CI 65-70.8%) NPV: 99.8% (95% CI 99.5-100%) Sensitivity: 99.7% (95% CI 99.3-100%) Specificity: 75.7% (95% CI 73.3-78%) <u>Algorithm 1b</u> PPV: 81.9% (95% CI 79.2-84.7%) NPV: 94.9% (95% CI 93.6-96.1%) Sensitivity: 90.6% (95% CI 88.4-92.8%) Specificity: 89.7% (95% CI 88-91.3%) <u>Algorithm 2</u> PPV: 80.1% (95% CI 76.9-83.3%) NPV: 85.9% (95% CI 84.1-87.7%) Sensitivity: 71% (95% CI 67.6-74.4%) Specificity: 90.9% (95% CI 89.4-92.5%)	Claims

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR-based Algorithm[xi]
					pneumonia-related complication plus any secondary diagnosis of pneumonia or effusion/empyema excluding CCCs; 4) primary or any secondary diagnosis of pneumonia; 4b) primary or any secondary diagnosis of pneumonia excluding CCCs; 5) primary diagnosis of pneumonia; 5b) primary diagnosis of pneumonia excluding CCCs; 6) primary diagnosis of pneumonia or primary diagnosis of pneumonia-related complication or effusion/empyema plus any secondary diagnosis of pneumonia; 6b) primary diagnosis of pneumonia or primary diagnosis of pneumonia-related complication or effusion/empyema plus any secondary diagnosis of pneumonia excluding CCCs	<u>Algorithm 2b</u> PPV: 89.1% (95% CI 86.4-91.9%) NPV: 83.7% (95% CI 81.9-85.6%) Sensitivity: 63.8% (95% CI 60.2-67.4%) Specificity: 96% (95% CI 94.9-97%) <u>Algorithm 3</u> PPV: 79.1% (95% CI 75.9-82.3%) NPV: 86.5% (95% CI 84.7-88.3%) Sensitivity: 72.8% (95% CI 69.4-76.1%) Specificity: 90.1% (95% CI 88.5-91.7%) <u>Algorithm 3b</u> PPV: 88.6% (95% CI 85.8-91.4%) NPV: 84.2% (95% CI 82.3-86%) Sensitivity: 65.1% (95% CI 61.6-68.7%) Specificity: 95.7% (95% CI 94.6-96.8%) <u>Algorithm 4</u> PPV: 76.2% (95% CI 73.4-79%) NPV: 99% (95% CI 98.4-99.6%) Sensitivity: 98.4% (95% CI 97.4-99.3%) Specificity: 84.2% (95% CI 82.2-86.1%) <u>Algorithm 4b</u>	

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR-based Algorithm[xi]
						PPV: 84.4% (95% CI 81.8-87.1%) NPV: 94.4% (95% CI 93.1-95.6%) Sensitivity: 89.4% (95% CI 87.1-91.7%) Specificity: 91.5% (95% CI 90-93%) <u>Algorithm 5</u> PPV: 81.7% (95% CI 78.5-84.9%) NPV: 84.7% (95% CI 82.8-86.5%) Sensitivity: 67.6% (95% CI 64.1-71.2%) Specificity: 92.2% (95% CI 90.7-93.6%) <u>Algorithm 5b</u> PPV: 89.6% (95% CI 86.8-92.4%) NPV: 82.6% (95% CI 80.7-84.5%) Sensitivity: 60.7% (95% CI 57.1-64.4%) Specificity: 96.4% (95% CI 95.4-97.4%) <u>Algorithm 6</u> PPV: 81.1% (95% CI 77.9-84.2%) NPV: 86.3% (95% CI 84.5-88.1%) Sensitivity: 71.8% (95% CI 68.4-75.1%) Specificity: 91.4% (95% CI 89.8-92.9%) <u>Algorithm 6b</u> PPV: 89.4% (95% CI 86.6-92.1%)	

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR-based Algorithm[xi]
						NPV: 83.9% (95% CI 82.1-85.8%) Sensitivity: 64.3% (95% CI 60.7-67.9%) Specificity: 96.1% (95% CI 95-97.1%) **Definite CAP** Algorithm 1 PPV: 54.6% (95% CI 51.5-57.6%) NPV: 99.8% (95% CI 99.5-100%) Sensitivity: 99.6% (95% 99.1-100%) Specificity: 68.7% (95% 66.3-71.1%) Algorithm 1b PPV: 67% (95% CI 63.7-70.4%) NPV: 96.6% (95% CI 95.5-97.6%) Sensitivity: 92.1% (95% CI 89.9-94.4%) Specificity: 82.9% (95% CI 81-84.9%) Algorithm 2 PPV: 68.3% (95% CI 64.6-72%) NPV: 90.3% (95% CI 88.8-91.9%) Sensitivity: 75.3% (95% CI 71.7-78.9%) Specificity: 86.8% (95% CI 85.1-88.6%) Algorithm 2b PPV: 77.8% (95% CI 74.1-81.5%)	

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR-based Algorithm[xi]
						NPV: 88.9% (95% CI 87.3-90.5%) Sensitivity: 69.3% (95% CI 65.4-73.2%) Specificity: 92.6% (95% CI 91.2-93.9%) <u>Algorithm 3</u> PPV: 67.4% (95% CI 63.7-71.1%) NPV: 90.9% (95% CI 89.4-92.4%) Sensitivity: 77.1% (95% CI 73.6-80.7%) Specificity: 86% (95% CI 84.2-87.7%) <u>Algorithm 3b</u> PPV: 77.2% (95% CI 73.5-80.9%) NPV: 89.3% (95% CI 87.7-90.8%) Sensitivity: 70.6% (95% CI 66.7-74.4%) Specificity: 92.1% (95% CI 90.8-93.5%) <u>Algorithm 4</u> PPV: 61.2% (95% CI 57.9-64.4%) NPV: 99.1% (95% CI 98.6-99.7%) Sensitivity: 98.2% (95% CI 97-99.3%) Specificity: 76.5% (95% CI 74.3-78.7%) <u>Algorithm 4b</u> PPV: 69% (95% CI 65.7-72.4%) NPV: 96.1% (95% CI 95-97.2%)	

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR-based Algorithm[xi]
						Sensitivity: 90.9% (95% CI 88.4-93.3%) Specificity: 84.6% (95% CI 82.8-86.5%) <u>Algorithm 5</u> PPV: 69.3% (95% CI 65.5-73.1%) NPV: 89.1% (95% CI 87.5-90.7%) Sensitivity: 71.3% (95% CI 67.5-75.1%) Specificity: 88.1% (95% CI 86.4-89.8%) <u>Algorithm 5b</u> PPV: 77.9% (95% CI 74.1-81.7%) NPV: 87.8% (95% CI 86.1-89.4%) Sensitivity: 65.6% (95% CI 61.7-69.6%) Specificity: 93% (95% CI 91.7-94.3%) <u>Algorithm 6</u> PPV: 69.1% (95% CI 65.4-72.8%) NPV: 90.6% (95% CI 89.1-92.2%) Sensitivity: 76.1% (95% CI 72.5-79.6%) Specificity: 87.2% (95% CI 85.5-88.9%) <u>Algorithm 6b</u> PPV: 77.9% (95% CI 74.2-81.6%) NPV: 89% (95% CI 87.4-90.6%) Sensitivity: 69.7% (95% CI 65.8-73.5%)	

Citation	Title	Country	Summary	Disease Definition	Algorithm/Criteria	Validity	Claims/EHR-based Algorithm[xi]
						Specificity: 92.6% (95% CI 91.2-93.9%)	

Abbreviations: CAP, community acquired pneumonia; CCC, complex chronic conditions; CXR, chest radiograph; DRG, Diagnosis-related group; ED, Emergency Department; 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-AM, International Classification of Diseases, Tenth Revision, Australian Modification; ICD-10-CM, International Classification of Diseases, Tenth Revision, Clinical Modification; ILI, Influenza-like illness; LHR, Likelihood ratio; non-VA/VAE, non-ventilated-associated event; RODS, Real-time Outbreak and Disease Surveillance; SP, *Streptococcus pneumoniae*; VAP/VAE, ventilator-associated pneumonia/event

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 a pneumonia 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 a pneumonia 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.

Results suggest that codes for unspecified pneumonia were by far the most frequently used, with ICD-9-CM 486 and ICD-10-CM J18.9 being reported among 36.3% and 51.1% of those receiving at least one pneumonia diagnosis code, respectively

Table B1. Annual patient counts and proportions for ICD-9-CM and ICD-10-CM diagnosis codes proposed for inclusion in pneumonia 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													
003.22	Salmonella pneumonia	28	0.0	15	0.0							42	0.0
021.2	Pulmonary tularemia	5	0.0	7	0.0							13	0.0
039.1	Pulmonary actinomycotic infection	246	0.1	147	0.0							387	0.0
052.1	Varicella (hemorrhagic) pneumonitis	40	0.0	22	0.0							66	0.0
055.1	Postmeasles pneumonia	16	0.0	4	0.0							19	0.0
073.0	Ornithosis with pneumonia	24	0.0	21	0.0							49	0.0
112.4	Candidiasis of lung	562	0.1	278	0.1							981	0.1
114.0	Primary coccidioidomycosis (pulmonary)	1,098	0.3	682	0.2							1,715	0.1
115.05	Infection by Histoplasma capsulatum, pneumonia	266	0.1	218	0.1							458	0.0
115.15	Infection by Histoplasma duboisii, pneumonia	8	0.0	6	0.0							14	0.0
115.95	Histoplasmosis, unspecified, pneumonia	103	0.0	76	0.0							177	0.0
130.4	Pneumonitis due to toxoplasmosis	8	0.0	5	0.0							14	0.0
136.3	Pneumocystosis	907	0.2	519	0.1							1,480	0.1
480.0	Viral pneumonia due to adenovirus	834	0.2	529	0.1							1,449	0.1
480.1	Viral pneumonia due to respiratory syncytial virus	1,454	0.3	929	0.3							2,683	0.2
480.2	Viral pneumonia due to parainfluenza virus	378	0.1	258	0.1							695	0.0
480.3	Viral pneumonia due to SARS-associated coronavirus	50	0.0	31	0.0							84	0.0
480.8	Viral pneumonia due to other virus not elsewhere classified	1,588	0.4	1,017	0.3							2,805	0.2
480.9	Viral pneumonia, unspecified	7,306	1.7	3,917	1.1							11,963	0.7
481	Pneumococcal pneumonia [Streptococcus pneumoniae pneumonia]	11,501	2.7	6,735	1.9							19,790	1.2
482.0	Pneumonia due to Klebsiella pneumoniae	1,387	0.3	877	0.2							2,575	0.2

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)		
482.1	Pneumonia due to Pseudomonas	2,168	0.5	1,201	0.3							3,689	0.2
482.2	Pneumonia due to Hemophilus influenzae [H. influenzae]	744	0.2	486	0.1							1,376	0.1
482.30	Pneumonia due to Streptococcus, unspecified	1,155	0.3	623	0.2							1,945	0.1
482.31	Pneumonia due to Streptococcus, group A	307	0.1	175	0.0							501	0.0
482.32	Pneumonia due to Streptococcus, group B	123	0.0	87	0.0							243	0.0
482.39	Pneumonia due to other Streptococcus	394	0.1	221	0.1							681	0.0
482.40	Pneumonia due to Staphylococcus, unspecified	574	0.1	287	0.1							986	0.1
482.41	Methicillin susceptible pneumonia due to Staphylococcus aureus	1,396	0.3	744	0.2							2,487	0.1
482.42	Methicillin resistant pneumonia due to Staphylococcus aureus	1,818	0.4	1,022	0.3							3,247	0.2
482.49	Other Staphylococcus pneumonia	148	0.0	136	0.0							323	0.0
482.81	Pneumonia due to anaerobes	329	0.1	186	0.1							557	0.0
482.82	Pneumonia due to Escherichia coli [E. coli]	398	0.1	183	0.1							679	0.0
482.83	Pneumonia due to other gram-negative bacteria	2,545	0.6	1,558	0.4							4,822	0.3
482.84	Pneumonia due to Legionnaires' disease	446	0.1	325	0.1							823	0.0
482.89	Pneumonia due to other specified bacteria	6,178	1.5	3,347	0.9							10,256	0.6
482.9	Bacterial pneumonia, unspecified	36,747	8.7	21,242	5.9							61,927	3.7
483.0	Pneumonia due to mycoplasma pneumoniae	9,133	2.2	5,561	1.5							15,365	0.9
483.1	Pneumonia due to chlamydia	661	0.2	384	0.1							1,099	0.1
483.8	Pneumonia due to other specified organisms	5,187	1.2	4,772	1.3							10,813	0.6
484.1	Pneumonia in cytomegalic inclusion disease	103	0.0	66	0.0							188	0.0
484.3	Pneumonia in whooping cough	75	0.0	42	0.0							129	0.0
484.5	Pneumonia in anthrax	9	0.0	10	0.0							21	0.0
484.6	Pneumonia in aspergillosis	316	0.1	190	0.1							541	0.0

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)		
484.7	Pneumonia in other systemic mycoses	319	0.1	169	0.0							539	0.0
484.8	Pneumonia in other infectious diseases classified elsewhere	557	0.1	424	0.1							1,047	0.1
485	Bronchopneumonia, organism unspecified	18,113	4.3	10,815	3.0							30,490	1.8
486	Pneumonia, organism unspecified	365,802	86.5	224,174	62.1							611,051	36.3
487.0	Influenza with pneumonia	10,237	2.4	5,314	1.5							16,755	1.0
488.01	Influenza due to identified avian influenza virus with pneumonia	439	0.1	199	0.1							696	0.0
488.11	Influenza due to identified 2009 H1N1 influenza virus with pneumonia	533	0.1	118	0.0							672	0.0
488.81	Influenza due to identified novel influenza A virus with pneumonia	633	0.1	214	0.1							*935*	0.1
517.1	Rheumatic pneumonia	30	0.0	20	0.0							48	0.0
ICD-9-CM Subtotal		**423,123**	**100.0**	**258,969**	**71.7**							**702,911**	**41.8**
ICD-10-CM													
A02.22	Salmonella pneumonia			5	0.0	8	0.0	7	0.0	5	0.0	27	0.0
A21.2	Pulmonary tularemia			1	0.0	4	0.0	4	0.0	2	0.0	14	0.0
A22.1	Pulmonary Anthrax			2	0.0	12	0.0	3	0.0	2	0.0	21	0.0
A37.01	Whooping cough due to Bordetella pertussis with pneumonia			11	0.0	67	0.0	45	0.0	47	0.0	190	0.0
A37.11	Whooping cough due to Bordetella parapertussis with pneumonia			3	0.0	10	0.0	2	0.0	7	0.0	28	0.0
A37.81	Whooping cough due to other Bordetella species with pneumonia			2	0.0	5	0.0	5	0.0	1	0.0	19	0.0
A37.91	Whooping cough, unspecified species with pneumonia			26	0.0	61	0.0	42	0.0	40	0.0	186	0.0
A42.0	Pulmonary actinomycosis			30	0.0	59	0.0	48	0.0	41	0.0	166	0.0

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)		
A48.1	Legionnaires' disease			153	0.0	399	0.1	404	0.1	501	0.2	1,511	0.1
B01.2	Varicella pneumonia			5	0.0	39	0.0	30	0.0	27	0.0	117	0.0
B05.2	Measles complicated by pneumonia			1	0.0	7	0.0	8	0.0	11	0.0	28	0.0
B25.0	Cytomegaloviral pneumonitis			51	0.0	134	0.0	151	0.1	142	0.1	490	0.0
B37.1	Pulmonary candidiasis			134	0.0	423	0.1	336	0.1	288	0.1	1,518	0.1
B38.0	Acute pulmonary coccidioidomycosis			210	0.1	566	0.2	413	0.1	383	0.1	1,467	0.1
B39.0	Acute pulmonary histoplasmosis capsulati			68	0.0	212	0.1	165	0.1	124	0.0	607	0.0
B44.0	Invasive pulmonary aspergillosis			81	0.0	172	0.0	143	0.0	140	0.1	565	0.0
B58.3	Pulmonary toxoplasmosis			0	0.0	7	0.0	2	0.0	5	0.0	16	0.0
B59	Pneumocystosis			255	0.1	727	0.2	607	0.2	577	0.2	2,353	0.1
J09.X1	Influenza due to identified novel influenza A virus with pneumonia			160	0.0	1,511	0.4	1,777	0.6	1,656	0.6	5,763	0.3
J10.00	Influenza due to other identified influenza virus with unspecified type of pneumonia			251	0.1	1,625	0.5	2,157	0.7	2,763	1.0	7,580	0.5
J10.01	Influenza due to other identified influenza virus with the same other identified influenza virus pneumonia			215	0.1	1,154	0.3	1,604	0.5	1,444	0.5	4,809	0.3
J10.08	Influenza due to other identified influenza virus with other specified pneumonia			80	0.0	651	0.2	835	0.3	1,110	0.4	3,071	0.2
J11.00	Influenza due to unidentified influenza virus with unspecified type of pneumonia			596	0.2	3,613	1.0	5,401	1.8	4,664	1.7	15,689	0.9
J11.08	Influenza due to unidentified influenza virus with specified pneumonia			61	0.0	432	0.1	403	0.1	482	0.2	1,564	0.1
J12.0	Adenoviral pneumonia			192	0.1	380	0.1	326	0.1	265	0.1	1,237	0.1
J12.1	Respiratory syncytial virus pneumonia			302	0.1	1,275	0.4	1,061	0.4	1,161	0.4	4,510	0.3
J12.2	Parainfluenza virus pneumonia			98	0.0	379	0.1	385	0.1	455	0.2	1,495	0.1
J12.3	Human metapneumovirus pneumonia			48	0.0	463	0.1	503	0.2	621	0.2	1,842	0.1

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)		
J12.81	Pneumonia due to SARS-associated coronavirus			16	0.0	54	0.0	35	0.0	33	0.0	157	0.0
J12.89	Other viral pneumonia			507	0.1	1,491	0.4	1,274	0.4	1,143	0.4	4,918	0.3
J12.9	Viral pneumonia, unspecified			1,857	0.5	5,462	1.5	3,959	1.3	3,586	1.3	16,350	1.0
J13	Pneumonia due to Streptococcus pneumoniae			1,287	0.4	3,503	1.0	2,692	0.9	2,127	0.8	10,719	0.6
J14	Pneumonia due to Hemophilus influenzae			203	0.1	654	0.2	574	0.2	501	0.2	2,185	0.1
J15.0	Pneumonia due to Klebsiella pneumoniae			339	0.1	868	0.2	741	0.3	552	0.2	3,194	0.2
J15.1	Pneumonia due to Pseudomonas			712	0.2	1,718	0.5	1,370	0.5	1,182	0.4	5,669	0.3
J15.20	Pneumonia due to staphylococcus unspecified			148	0.0	445	0.1	286	0.1	249	0.1	1,352	0.1
J15.211	Pneumonia due to Methicillin susceptible Staphylococcus aureus			351	0.1	1,069	0.3	893	0.3	790	0.3	3,847	0.2
J15.212	Pneumonia due to Methicillin resistant Staphylococcus aureus			506	0.1	1,425	0.4	1,081	0.4	819	0.3	4,886	0.3
J15.29	Pneumonia due to other staphylococcus			37	0.0	139	0.0	85	0.0	63	0.0	395	0.0
J15.3	Pneumonia due to streptococcus, group B			147	0.0	385	0.1	313	0.1	224	0.1	1,206	0.1
J15.4	Pneumonia due to other streptococci			386	0.1	1,213	0.3	921	0.3	817	0.3	3,785	0.2
J15.5	Pneumonia due to Escherichia coli			123	0.0	302	0.1	273	0.1	228	0.1	1,175	0.1
J15.6	Pneumonia due to other Gram-negative bacteria			813	0.2	2,530	0.7	2,158	0.7	1,899	0.7	9,413	0.6
J15.7	Pneumonia due to Mycoplasma pneumoniae			4,481	1.2	10,347	2.9	7,923	2.7	7,085	2.6	31,187	1.9
J15.8	Pneumonia due to other specified bacteria			2,107	0.6	5,614	1.6	4,764	1.6	4,013	1.5	18,295	1.1
J15.9	Unspecified bacterial pneumonia			11,731	3.2	31,915	8.8	23,482	7.9	19,675	7.2	95,362	5.7
J16.0	Chlamydial pneumonia			72	0.0	248	0.1	267	0.1	286	0.1	909	0.1
J16.8	Pneumonia due to other specified infectious organisms			2,665	0.7	6,804	1.9	5,492	1.9	5,152	1.9	22,757	1.4
J17	Pneumonia in diseases classified elsewhere			311	0.1	3,167	0.9	770	0.3	557	0.2	5,566	0.3
J18.0	Bronchopneumonia, unspecified organism			5,085	1.4	16,066	4.5	12,819	4.3	11,559	4.2	48,436	2.9

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)		
J18.1	Lobar pneumonia, unspecified organism			6,264	1.7	24,575	6.8	50,030	16.9	69,804	25.5	165,479	9.8
J18.2	Hypostatic pneumonia, unspecified organism			353	0.1	674	0.2	365	0.1	204	0.1	1,938	0.1
J18.8	Other pneumonia, unspecified organism			4,663	1.3	13,112	3.6	9,521	3.2	7,610	2.8	39,422	2.3
J18.9	Pneumonia, unspecified organism			101,548	28.1	299,089	82.9	228,540	77.2	197,932	72.3	859,546	51.1
ICD-10-CM Subtotal				**124,444**	**34.5**	**360,625**	**100.0**	**296,109**	**100.0**	**273,688**	**100.0**	**1,079,714**	**64.2**
Total		**423,123**	**100.0**	**361,090**	**100.0**	**360,625**	**100.0**	**296,109**	**100.0**	**273,688**	**100.0**	**1,682,997**	**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.
Note: Codes highlighted in yellow represent those that accounted for at least 10% of the overall count among the 2014-2018 cohort.

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 due to their potential relation to pneumonia, either as an etiologically relevant pathogen (e.g., varicella, influenza) or as a condition that can sometimes accompany pneumonia (e.g., ornithosis, coccidioidomycosis, chickenpox). In consultation with clinical SMEs (TB, JB, JC, DT), these codes — which were not specific to pneumonia — 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 pneumonia diagnosis.

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

Code	Description	Code Category	Code Type
003.21	Salmonella meningitis	DX	9
003.23	Salmonella arthritis	DX	9
003.24	Salmonella osteomyelitis	DX	9
021.3	Oculoglandular tularemi	DX	9
021.8	Other specified tularemia	DX	9
021.9	Unspecified tularemia	DX	9
038.0	Streptococcal septicemia	DX	9
038.2	Pneumococcal septicemia [Streptococcus pneumoniae septicemia]	DX	9
038.8	Other specified septicemias	DX	9
038.9	Unspecified septicemia	DX	9
039.0	Cutaneous actinomycotic infection	DX	9
039.2	Abdominal actinomycotic infection	DX	9
039.3	Cervicofacial actinomycotic infection	DX	9
039.4	Madura foot	DX	9
039.8	Actinomycotic infection of other specified sites	DX	9
039.9	Actinomycotic infection of unspecified site	DX	9
052.0	Postvaricella encephalitis	DX	9
052.2	Postvaricella myelitis	DX	9
052.7	Chickenpox with other specified complications	DX	9
052.8	Chickenpox with unspecified complication	DX	9
052.9	Varicella without mention of complication	DX	9
055.0	Postmeasles encephalitis	DX	9
055.2	Postmeasles otitis media	DX	9
055.8	Measles with unspecified complication	DX	9
055.9	Measles without mention of complication	DX	9
073.7	Ornithosis with other specified complications	DX	9
073.8	Ornithosis with unspecified complication	DX	9
073.9	Ornithosis, unspecified	DX	9
073.9	Ornithosis, unspecified	DX	9
112.0	Candidiasis of mouth	DX	9
112.1	Candidiasis of vulva and vagina	DX	9
112.2	Candidiasis of other urogenital sites	DX	9
112.3	Candidiasis of skin and nails	DX	9
112.5	Disseminated candidiasis	DX	9
112.9	Candidiasis of unspecified site	DX	9
114.1	Primary extrapulmonary coccidioidomycosis	DX	9
114.2	Coccidioidal meningitis	DX	9
114.3	Other forms of progressive coccidioidomycosis	DX	9
114.4	Chronic pulmonary coccidioidomycosis	DX	9
114.5	Pulmonary coccidioidomycosis, unspecified	DX	9
114.9	Coccidioidomycosis, unspecified	DX	9
115.00	Infection by Histoplasma capsulatum, without mention of manifestation	DX	9
115.01	Infection by Histoplasma capsulatum, meningitis	DX	9

Code	Description	Code Category	Code Type
115.02	Infection by Histoplasma capsulatum, retinitis	DX	9
115.03	Infection by Histoplasma capsulatum, pericarditis	DX	9
115.04	Infection by Histoplasma capsulatum, endocarditis	DX	9
115.09	Infection by Histoplasma capsulatum, other	DX	9
115.10	Infection by Histoplasma duboisii, without mention of manifestation	DX	9
115.10	Infection by Histoplasma duboisii, without mention of manifestation	DX	9
115.11	Infection by Histoplasma duboisii, meningitis	DX	9
115.12	Infection by Histoplasma duboisii, retinitis	DX	9
115.13	Infection by Histoplasma duboisii, pericarditis	DX	9
115.14	Infection by Histoplasma duboisii, endocarditis	DX	9
115.19	Infection by Histoplasma duboisii, other	DX	9
115.90	Histoplasmosis, unspecified, without mention of manifestation	DX	9
115.90	Histoplasmosis, unspecified, without mention of manifestation	DX	9
115.91	Histoplasmosis, unspecified, meningitis	DX	9
115.92	Histoplasmosis, unspecified, retinitis	DX	9
115.93	Histoplasmosis, unspecified, pericarditis	DX	9
115.94	Histoplasmosis, unspecified, endocarditis	DX	9
115.99	Histoplasmosis, unspecified, other	DX	9
117.3	Aspergillosis	DX	9
130.0	Meningoencephalitis due to toxoplasmosis	DX	9
130.1	Conjunctivitis due to toxoplasmosis	DX	9
130.2	Chorioretinitis due to toxoplasmosis	DX	9
130.3	Myocarditis due to toxoplasmosis	DX	9
130.5	Hepatitis due to toxoplasmosis	DX	9
130.7	Toxoplasmosis of other specified sites	DX	9
130.8	Multisystemic disseminated toxoplasmosis	DX	9
130.9	Toxoplasmosis, unspecified	DX	9
136.0	Ainhum	DX	9
136.1	Behcet's syndrome	DX	9
136.4	Psorospermiasis	DX	9
136.5	Sarcosporidiosis	DX	9
136.8	Other specified infectious and parasitic diseases	DX	9
136.9	Unspecified infectious and parasitic diseases	DX	9
487.1	Influenza with other respiratory manifestations	DX	9
488.02	Influenza due to identified avian influenza virus with other respiratory manifestations	DX	9
488.09	Influenza due to identified avian influenza virus with other manifestations	DX	9
488.12	Influenza due to identified 2009 H1N1 influenza virus with other respiratory manifestations	DX	9
488.19	Influenza due to identified 2009 H1N1 influenza virus with other manifestations	DX	9
488.82	Influenza due to identified novel influenza A virus with other respiratory manifestations	DX	9
488.89	Influenza due to identified novel influenza A virus with other manifestations	DX	9
490	Bronchitis, not specified as acute or chronic	DX	9
496	Chronic airway obstruction, not elsewhere classified	DX	9
510.0	Empyema with fistula	DX	9
510.9	Empyema without mention of fistula	DX	9
511.0	Pleurisy without mention of effusion or current tuberculosis	DX	9
511.1	Pleurisy with effusion, with mention of a bacterial cause other than tuberculosis	DX	9
511.9	Unspecified pleural effusion	DX	9
790.1	Elevated sedimentation rate	DX	9
790.3	Excessive blood level of alcohol	DX	9
790.4	Nonspecific elevation of levels of transaminase or lactic acid dehydrogenase [LDH]	DX	9
790.5	Other nonspecific abnormal serum enzyme levels	DX	9
790.6	Other abnormal blood chemistry	DX	9
790.7	Bacteremia	DX	9

Code	Description	Code Category	Code Type
790.8	Viremia, unspecified	DX	9
799.1	Respiratory arrest	DX	9
995.0	Other anaphylactic reaction	DX	9
995.1	Angioneurotic edema, not elsewhere classified	DX	9
995.3	Allergy, unspecified, not elsewhere classified	DX	9
995.4	Shock due to anesthesia, not elsewhere classified	DX	9
995.7	Other adverse food reactions, not elsewhere classified	DX	9
995.90	Systemic inflammatory response syndrome, unspecified	DX	9
995.91	Sepsis	DX	9
995.92	Severe sepsis	DX	9
995.93	Systemic inflammatory response syndrome due to non-infectious process without acute organ dysfunction	DX	9
995.94	Systemic inflammatory response syndrome due to non-infectious process with acute organ dysfunction	DX	9
997.1	Cardiac complications, not elsewhere classified	DX	9
997.2	Peripheral vascular complications, not elsewhere classified	DX	9
997.5	Urinary complications, not elsewhere classified	DX	9
003.20	Localized salmonella infection, unspecified	DX	9
003.29	Other localized salmonella infections	DX	9
021.0	Ulceroglandular tularemia	DX	9
021.1	Enteric tularemia	DX	9
038.1*	Staphylococcal septicemia	DX	9
038.3	Septicemia due to anaerobes	DX	9
038.4*	Septicemia due to other gram-negative organisms	DX	9
055.7*	Measles with other specified complications	DX	9
112.8*	Candidiasis of other specified sites	DX	9
136.2*	Specific infections by free-living amebae	DX	9
487.8	Influenza with other manifestations	DX	9
491*	Chronic bronchitis	DX	9
492*	Emphysema	DX	9
507*	Pneumonitis due to solids and liquids	DX	9
511.8*	Other specified forms of pleural effusion except tuberculous	DX	9
513*	Abscess of lung and mediastinum	DX	9
518.8*	Other diseases of lung	DX	9
790.0*	Abnormality of red blood cells	DX	9
790.2*	Abnormal glucose	DX	9
790.9*	Other nonspecific findings on examination of blood	DX	9
995.2*	Unspecified adverse effect of drug medicinal and biological substance not elsewhere classified	DX	9
995.5*	Child maltreatment syndrome	DX	9
995.6*	Anaphylactic reaction due to unspecified food	DX	9
995.8*	Other specified adverse effects not elsewhere classified	DX	9
997.0*	Nervous system complications	DX	9
997.3*	Respiratory complications not elsewhere classified	DX	9
997.4*	Digestive system complications not elsewhere classified	DX	9
997.6*	Amputation stump complication	DX	9
997.7*	Vascular complications of other vessels	DX	9
997.9*	Complications affecting other specified body systems not elsewhere classified	DX	9
A02.20	Localized salmonella infection, unspecified	DX	10
A02.21	Salmonella meningitis	DX	10
A02.23	Salmonella arthritis	DX	10
A02.24	Salmonella osteomyelitis	DX	10
A02.25	Salmonella pyelonephritis	DX	10
A02.29	Salmonella with other localized infection	DX	10
A21.0	Ulceroglandular tularemia	DX	10
A21.1	Oculoglandular tularemia	DX	10
A21.3	Gastrointestinal tularemia	DX	10

Code	Description	Code Category	Code Type
A21.7	Generalized tularemia	DX	10
A21.8	Other forms of tularemia	DX	10
A21.9	Tularemia, unspecified	DX	10
A22.0	Cutaneous anthrax	DX	10
A22.2	Gastrointestinal anthrax	DX	10
A22.7	Anthrax sepsis	DX	10
A22.8	Other forms of anthrax	DX	10
A22.9	Anthrax, unspecified	DX	10
A37.00	Whooping cough due to Bordetella pertussis without pneumonia	DX	10
A37.10	Whooping cough due to Bordetella parapertussis without pneumonia	DX	10
A37.80	Whooping cough due to other Bordetella species without pneumonia	DX	10
A37.90	Whooping cough, unspecified species without pneumonia	DX	10
A40.0	Sepsis due to streptococcus, group A	DX	10
A40.1	Sepsis due to streptococcus, group B	DX	10
A40.3	Sepsis due to Streptococcus pneumoniae	DX	10
A40.8	Other streptococcal sepsis	DX	10
A40.9	Streptococcal sepsis, unspecified	DX	10
A41*	Other sepsis	DX	10
A42.1	Abdominal actinomycosis	DX	10
A42.2	Cervicofacial actinomycosis	DX	10
A42.7	Actinomycotic sepsis	DX	10
A42.8*	Other forms of actinomycosis	DX	10
A42.9	Actinomycosis, unspecified	DX	10
A48.0	Gas gangrene	DX	10
A48.2	Non-pneumonic Legionnaires' disease [Pontiac fever]	DX	10
A48.3	Toxic shock syndrome	DX	10
A48.4	Brazilian purpuric fever	DX	10
A48.5*	Other specified botulism	DX	10
A48.8	Other specified bacterial diseases	DX	10
A70	Chlamydia psittaci infections	DX	10
B01.0	Varicella meningitis	DX	10
B01.1*	Varicella encephalitis, myelitis and encephalomyelitis	DX	10
B01.8*	Varicella with other complications	DX	10
B01.9	Varicella without complication	DX	10
B05.0	Measles complicated by encephalitis	DX	10
B05.1	Measles complicated by meningitis	DX	10
B05.3	Measles complicated by otitis media	DX	10
B05.4	Measles with intestinal complications	DX	10
B05.81	Measles keratitis and keratoconjunctivitis	DX	10
B05.89	Other measles complications	DX	10
B05.9	Measles without complication	DX	10
B25.1	Cytomegaloviral hepatitis	DX	10
B25.2	Cytomegaloviral pancreatitis	DX	10
B25.8	Other cytomegaloviral diseases	DX	10
B25.9	Cytomegaloviral disease, unspecified	DX	10
B34*	Viral infection of unspecified site	DX	10
B37.0	Candidal stomatitis	DX	10
B37.2	Candidiasis of skin and nail	DX	10
B37.3	Candidiasis of vulva and vagina	DX	10
B38.1	Chronic pulmonary coccidioidomycosis	DX	10
B38.2	Pulmonary coccidioidomycosis, unspecified	DX	10
B38.3	Cutaneous coccidioidomycosis	DX	10
B38.4	Coccidioidomycosis meningitis	DX	10
B38.7	Disseminated coccidioidomycosis	DX	10
B38.8*	Other forms of coccidioidomycosis	DX	10
B38.9	Coccidioidomycosis, unspecified	DX	10
B39.1	Chronic pulmonary histoplasmosis capsulati	DX	10

Code	Description	Code Category	Code Type
B39.2	Pulmonary histoplasmosis capsulati, unspecified	DX	10
B39.3	Disseminated histoplasmosis capsulati	DX	10
B39.4	Histoplasmosis capsulati, unspecified	DX	10
B39.5	Histoplasmosis duboisii	DX	10
B39.9	Histoplasmosis, unspecified	DX	10
B44.1	Other pulmonary aspergillosis	DX	10
B44.2	Tonsillar aspergillosis	DX	10
B44.7	Disseminated aspergillosis	DX	10
B44.8*	Other forms of aspergillosis	DX	10
B44.9	Aspergillosis, unspecified	DX	10
E07*	Other disorders of thyroid	DX	10
E89*	Postprocedural endocrine and metabolic complications and disorders, not elsewhere classified	DX	10
G03*	Meningitis due to other and unspecified causes	DX	10
G97*	Intraoperative and postprocedural complications and disorders of nervous system, not elsewhere classified	DX	10
H59*	Intraoperative and postprocedural complications and disorders of eye and adnexa, not elsewhere classified	DX	10
I97*	Intraoperative and postprocedural complications and disorders of circulatory system, not elsewhere classified	DX	10
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
J10.1	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
J11.1	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
J11.82	Influenza due to unidentified influenza virus with myocarditis	DX	10
J11.83	Influenza due to unidentified influenza virus with otitis media	DX	10
J11.89	Influenza due to unidentified influenza virus with other manifestations	DX	10
J40	Bronchitis, not specified as acute or chronic	DX	10
J41*	Simple and mucopurulent chronic bronchitis	DX	10
J43*	Emphysema	DX	10
J44*	Other chronic obstructive pulmonary disease	DX	10
J69*	Pneumonitis due to solids and liquids	DX	10
J80	Acute respiratory distress syndrome	DX	10
J85*	Abscess of lung and mediastinum	DX	10
J86.0	Pyothorax with fistula	DX	10
J86.9	Pyothorax without fistula	DX	10
J90	Pleural effusion, not elsewhere classified	DX	10
J91*	Pleural effusion in conditions classified elsewhere	DX	10
J94.1	Fibrothorax	DX	10
J94.2	Hemothorax	DX	10
J94.8	Other specified pleural conditions	DX	10
J94.9	Pleural condition, unspecified	DX	10
J95*	Intraoperative and postprocedural complications and disorders of respiratory system, not elsewhere classified	DX	10
J96*	Respiratory failure, not elsewhere classified	DX	10

Code	Description	Code Category	Code Type
J98*	Other respiratory disorders	DX	10
K91*	Intraoperative and postprocedural complications and disorders of digestive system, not elsewhere classified	DX	10
M96*	Intraoperative and postprocedural complications and disorders of musculoskeletal system, not elsewhere classified	DX	10
N99*	Intraoperative and postprocedural complications and disorders of genitourinary system, not elsewhere classified	DX	10
R06.3	Periodic breathing	DX	10
R09.1	Pleurisy	DX	10
R65.10	Systemic inflammatory response syndrome (SIRS) of non-infectious origin without acute organ dysfunction	DX	10
R65.11	Systemic inflammatory response syndrome (SIRS) of non-infectious origin with acute organ dysfunction	DX	10
R65.20	Severe sepsis without septic shock	DX	10
R65.21	Severe sepsis with septic shock	DX	10
R70*	Elevated erythrocyte sedimentation rate and abnormality of plasma viscosity	DX	10
R71*	Abnormality of red blood cells	DX	10
R73*	Elevated blood glucose level	DX	10
R74*	Abnormal serum enzyme levels	DX	10
R78*	Findings of drugs and other substances, not normally found in blood	DX	10
R79*	Other abnormal findings of blood chemistry	DX	10
R97*	Abnormal tumor markers	DX	10
T36*	Poisoning by, adverse effect of and underdosing of systemic antibiotics	DX	10
T37*	Poisoning by, adverse effect of and underdosing of other systemic anti-infectives and antiparasitics	DX	10
T38*	Poisoning by, adverse effect of and underdosing of hormones and their synthetic substitutes and antagonists, not elsewhere classified	DX	10
T39*	Poisoning by, adverse effect of and underdosing of nonopioid analgesics, antipyretics and antirheumatics	DX	10
T40*	Poisoning by, adverse effect of and underdosing of narcotics and psychodysleptics [hallucinogens]	DX	10
T41*	Poisoning by, adverse effect of and underdosing of anesthetics and therapeutic gases	DX	10
T42*	Poisoning by, adverse effect of and underdosing of antiepileptic, sedative-hypnotic and antiparkinsonism drugs	DX	10
T43*	Poisoning by, adverse effect of and underdosing of psychotropic drugs, not elsewhere classified	DX	10
T44*	Poisoning by, adverse effect of and underdosing of drugs primarily affecting the autonomic nervous system	DX	10
T45*	Poisoning by, adverse effect of and underdosing of primarily systemic and hematological agents, not elsewhere classified	DX	10
T46*	Poisoning by, adverse effect of and underdosing of agents primarily affecting the cardiovascular system	DX	10
T47*	Poisoning by, adverse effect of and underdosing of agents primarily affecting the gastrointestinal system	DX	10
T48*	Poisoning by, adverse effect of and underdosing of agents primarily acting on smooth and skeletal muscles and the respiratory system	DX	10
T49*	Poisoning by, adverse effect of and underdosing of topical agents primarily affecting skin and mucous membrane and by ophthalmological, otorhinorlaryngological and dental drugs	DX	10
T50*	Poisoning by, adverse effect of and underdosing of diuretics and other and unspecified drugs, medicaments and biological substances	DX	10
T74*	Adult and child abuse, neglect and other maltreatment, confirmed	DX	10
T76*	Adult and child abuse, neglect and other maltreatment, suspected	DX	10
T78*	Adverse effects, not elsewhere classified	DX	10
T81*	Complications of procedures, not elsewhere classified	DX	10
T87*	Complications peculiar to reattachment and amputation	DX	10
T88*	Other complications of surgical and medical care, not elsewhere classified	DX	10

Abbreviation: DX, ICD-CM diagnosis.
*Denotes non-billable code. All subsidiary codes have been excluded.