

## Supplementary material

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### **Best practices for identifying hospitalized lower respiratory tract infections using administrative data: a systematic literature review of validation studies**

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**Supplementary table 1. PICOTS inclusion and exclusion criteria**

Parameter	Criteria
<b>Population</b>	Included: <ul style="list-style-type: none"> <li>- adults ≥18 years of age</li> </ul>
<b>Intervention</b>	None
<b>Comparison</b>	Not applicable. However, best practices for estimation of hospitalized LRTI incidence (including CAP and HAP as subgroups) using ICD codes and code-based algorithms will be assessed, including sensitivity, specificity, PPV, and/or NPV, in contrast to a gold-standard comparator such as case-by-case medical chart review.
<b>Time</b>	Publications from 1996 to present
<b>Study design</b>	<p>Included:</p> <p>Observational epidemiological</p> <ul style="list-style-type: none"> <li>- cross-sectional</li> <li>- cohort</li> <li>- case-control</li> <li>- surveillance-based</li> <li>- and interventional studies of hospitalized LRTIs.</li> </ul> <p>Peer-reviewed studies assessing the validity of using ICD-9 and/or ICD-10 codes for the estimation of incidence rates of hospitalized LRTIs (including CAP and HAP) in the adult population, and</p> <p>Online reports/white papers (if available and/or relevant)</p> <p>Excluded:</p> <ul style="list-style-type: none"> <li>- Publications of the following type will be excluded: <ul style="list-style-type: none"> <li>o case reports</li> <li>o editorials</li> <li>o conference abstracts</li> <li>o commentaries</li> <li>o narrative reviews</li> </ul> </li> <li>- Systematic literature reviews and meta-analyses will be checked for relevant references not found during the literature search, and relevant references will be saved separately.</li> <li>- Non-human data (e.g., in-vitro, in-silico, animal models) will be excluded.</li> </ul>
<b>Outcome</b>	Hospitalized, non-COVID-19 LRTI incidence rates based on ICD-9 or ICD-10 codes, including the following outcomes: <ul style="list-style-type: none"> <li>- acute and pathogen-specific bronchitis,</li> <li>- pneumonia (both CAP and HAP as subgroups).</li> </ul>
<b>Country</b>	Studies from all countries in the world are eligible
<b>Language</b>	Included: <p>English, French, Spanish, Portuguese, Dutch, German, Italian</p>

CAP, community-acquired pneumonia; HAP, hospital-acquired pneumonia; ICD, international classification of diseases; LRTI, lower respiratory tract infection; NPV, negative predictive value; PPV, positive predictive value

Supplementary table 2

**Supplementary table 2. Search strategy**

Search string	Number of hits
<p>((((((((((Bronchitis OR (Bronchitis[MeSH Terms])) OR (lower respiratory tract infection)) OR (lower respiratory tract infection[MeSH Terms])) OR ("LRTI")) OR (pneumonia)) OR (pneumonia[MeSH Terms])) OR (community acquired pneumonia[MeSH Terms])) OR (pneumonia hospitalizations[MeSH Terms])) AND (((((((((((International Classification of Diseases) OR (International Classification of Diseases[MeSH Terms])) OR (ICD)) OR (ICD code*)) OR (ICD code*[MeSH Terms])) OR (ICD-9-CM)) OR (ICD-10-CM)) OR (ICD-9)) OR (ICD-10)) OR (coding)) OR (coding[MeSH Terms])) OR (clinical coding)) OR (clinical coding[MeSH Terms])) OR (claim*)) OR (administrative data))) AND (((((((((((accuracy) OR (data accuracy)) OR (sensitivity)) OR (sensitivity[MeSH Terms])) OR (specificity)) OR (specificity[MeSH Terms])) OR (validation)) OR (validated)) OR (predictive value of tests)) OR (positive predictive value)) OR (positive predictive value[MeSH Terms])) OR (negative predictive value)) OR (negative predictive value[MeSH Terms])) OR (algorithm*)) OR (algorithm*[MeSH Terms]))) AND (((((((hospitalization) OR (hospitalization[MeSH Terms])) OR (inpatient)) OR (inpatient[MeSH Terms])) OR (admission*)) OR (admission*[MeSH Terms]))) NOT ((SARS-CoV-2) OR (COVID-19))</p>	<p>1807</p>

**Supplementary table 3. Quality Assessment of Diagnostic Accuracy Studies 2 (QUADAS-2) adapted tool with domain criteria**

Domain		Criteria	Classification
1	<b>Could the selection of patients have introduced bias?</b>	Was a systematic sampling of patients enrolled used?	Yes, No, Unclear (NR)
		Did the study avoid inappropriate exclusions?	Yes, No, Unclear (NR)
2	<b>Could the conduct or interpretation of the index test have introduced bias?</b>	Were the index test results interpreted without knowledge of the results of the reference standard?	Yes, No, Unclear (NR)
		Does the study avoid restricting to primary coding position only?	Yes, No, Unclear (NR)
		Does the study avoid changes in coding practices or guidelines during the study period?	Yes, No, Unclear (NR)
3a	<b>Could the reference standard, its conduct, or its interpretation have introduced bias?</b>	Is the reference standard likely to correctly identify the target condition?	Yes, No, Unclear (NR)
		Were the reference standard results interpreted without knowledge of the results of the index test?	Yes, No, Unclear (NR)
3b	<b>Applicability</b>	Are there concerns that the target condition as defined by the reference standard does not match the question? Does the study differentiate between CAP and HAP or was about only one of them?	Low, High, or Unclear
4	<b>Could the patient flow have introduced bias?</b>	Did all patients receive the same reference standard?	Yes, No, Unclear (NR)
		Were all patients included in the analysis?	Yes, No, Unclear (NR)

CAP, community-acquired pneumonia; HAP, hospital-acquired pneumonia; NR, not reported

## Supplementary table 4

## Supplementary table 4. Description of included studies

Reference (first author, year)	Country	Population description	Age group (years)	Data source	Study period	ICD coding system	Reference standard	Number of cases	Total sample size
<b>Lower respiratory tract infection (LRTI)</b>									
Henriksen, 2014 [1]	Denmark	All patients admitted to the medical ED of a university hospital <sup>a</sup>	≥15	EMR in administrative database <sup>b</sup> , national health register <sup>c</sup> , other databases <sup>d</sup>	2010-2011	ICD-10	Review of medical files	1368	5977
Rattanaumpawan, 2016 [2]	Thailand	Adult patients hospitalized in general medicine wards	≥15	Siriraj Hospital database	2013	ICD-10	Review of medical files	441	546
<b>Pneumonia (overall)</b>									
Aronsky, 2005 [3]	USA	Adult patients seen in the ED of a hospital <sup>e</sup>	≥18	CDSS	1999-2000	ICD-9	Review of medical files, coding, radiology, and physician diagnosis	129 (algorithm 1) 159 (algorithm 2) 164 (algorithm 3)	NR
Skull, 2008 [4]	Australia	Patients in two major teaching hospitals <sup>f</sup>	≥65	Monthly separation lists of completed admissions for patients	2000-2002	ICD-10	Review of medical files and radiological data	2319	5101
Ahmed, 2014 [5]	USA	Patients, not prisoners or pregnant women	≥18	Study for ALI/ARDS prevention subset. EMR, other databases <sup>g</sup>	2010	ICD-9	Review of medical files, coding	122	1443
Holland-Bill, 2014 [6]	Denmark	Inpatients at a university hospital <sup>g</sup> , with a primary discharge diagnosis of a preselected infectious condition and history of solid malignancy <sup>h</sup>	≥18	Medical records <sup>i</sup> and national health register <sup>c</sup>	2006-2010	ICD-10	Review of medical files, PGA, and confirmation by evidence-based criteria	95	95
Kern, 2015 [7]	USA	Claims data for commercially insured individuals	≥40	HealthCore Integrated Research Environment	2009-2012	ICD-9	Review of medical files	185	185
Higgins, 2020 [8]	USA	Patients with pneumonia diagnosis and atypical bacterial or viral pathogens test results	≥18	178 U.S. hospitals Premier Healthcare Database	2010-2015	ICD-9	Laboratory data	21041	161529
<b>Empyema</b>									
Søgaard, 2011 [9]	Denmark	Patients diagnosed with pleural empyema in the North Denmark Region	≥15	Danish Civil Registry System and national health register <sup>c</sup>	2000-2009	ICD-10	Review of medical files (clinical, radiology and laboratory data)	149	149

Supplementary table 4

Reference (first author, year)	Country	Population description	Age group (years)	Data source	Study period	ICD coding system	Reference standard	Number of cases	Total sample size
<b>Community-acquired pneumonia (CAP)</b>									
Whittle, 1997 [10]	USA	All discharges from a university hospital <sup>j</sup>	≥18	Discharge summaries, dictated admission notes, and radiology reports	1989-1990	ICD-9	Review of medical files (clinical and radiology data)	144	144
Guevara, 1999 [11]	USA	Adults hospitalized for pneumonia in 15 acute-care hospitals in two counties <sup>k</sup>	≥18	Community-based pneumonia incidence study	1991-1992	ICD-9	Clinical data, radiological and microbiologic data	4385	NR
Schneeweiss, 2007 [12]	USA	Patients at Department of Veteran's Affairs hospitals in New England	≥18	Department of Veterans Affairs administrative database, EMR	2001-2004	ICD-9	Diagnostic criteria and the final ID specialist criteria of the gold-standard diagnosis	23	23
van de Garde, 2007 [13]	The Netherlands	Adult inpatients for CAP in two university medical centers and five teaching hospitals	≥18	Data from an efficacy RCT, hospital discharge records	2000-2004	ICD-9	Clinical, radiological and laboratory data	293	293
Grijalva, 2008 [14]	USA	Patients diagnosed with rheumatoid arthritis	≥18	Tennessee Medicaid (TennCare) databases	1995-2004	ICD-9	Review of medical files	161	161
Yu, 2011 [15]	USA	Persons with outpatient medical encounters and hospitalizations with a pneumonia ICD-9-CM code <sup>l</sup>	≥18	Administrative data systems	1997-2005	ICD-9	Review of medical files	2525	3839
Mukhopadhyay, 2017 [16]	Singapore	Adults hospitalized with CAP at a university hospital <sup>m</sup>	≥21	EMR-linked administrative data	2010-2012	ICD-9	Clinical and radiological data	100	200
Jones, 2018 [17]	USA	Visits to USA Veteran's Affairs EDs with a chest imaging and at least one clinical document generated within 24 of the visit time	≥18	The Veterans Informatics and Computing Infrastructure	2006-2012	ICD-9	Review of medical files	2881470	NR
Wiese, 2018 [18]	USA	Adults enrolled in the Tennessee Medicaid healthcare program	50-110	Tennessee Hospital Discharge Data System, pharmacy information from Medicare part D	2008-2012	ICD-9	Review of medical files and radiological data	340	340
Rodriguez-Barradas, 2020 [19]	USA	Patient of VACS cohort (with or without HIV) whose first CAP hospitalization was based on ICD-9 codes after enrollment	≥18	VACS database	2002-2008	ICD-9	Review of medical files	549	549

Supplementary table 4

Reference (first author, year)	Country	Population description	Age group (years)	Data source	Study period	ICD coding system	Reference standard	Number of cases	Total sample size
<b>Any hospital-acquired pneumonia (HAP)</b>									
Romano, 2002 [20]	USA	Patients, discharged from a nonfederal acute-care hospital after an inpatient lumbar surgery	≥18	Medical records, hospital discharge abstracts <sup>n</sup>	1990-1991	ICD-9	Recoding based on medical files review and ICD manual	4	991
Quan, 2004 [21]	Canada	Inpatients discharged from general medical and general surgical services of three adult acute-care hospitals in Calgary, Alberta	≥18	Regional hospital administrative discharge data	1996-1997	ICD-10	Review of medical files	88	1200
Azaouagh, 2008 [22]	Germany	Inpatients at a university hospital <sup>o</sup>	≥18	University hospital database	2005	ICD-10	Review of medical files (clinical, radiological and laboratory data)	NR	3000
Maass, 2015 [23]	Germany	Patients with a minimum hospitalization of 5 days	≥65	Hospital administrative database	2010	ICD-10	Review of medical files	2876	NR
Wolfensberger, 2018 [24]	Switzerland	Patients assigned to the proxy code U69.00 as having a HAP according to ICD-10 definition criteria (ICD-HAP) at a university hospital <sup>p</sup>	≥18	University hospital database, medical records	2016	ICD-10	Reviewing medical files (Clinical, radiological and laboratory data)	165	159
<b>Ventilator-associated pneumonia (VAP)</b>									
Verelst, 2010[25]	Belgium	Adult non-obstetric patients	≥16	Belgian Hospital Discharge Dataset	2004-2006	ICD-9	Review of medical files	58	763
Cass, 2013 [26]	USA	Patients on the medical/surgical, neuro/trauma, cardiovascular, or coronary care ICUs during their hospital stay	≥18	Administrative and hospital surveillance data <sup>q</sup>	2009	ICD-9	Hospital surveillance data	427	1500

ALI/ARDS, acute lung injury/acute respiratory distress syndrome; CAP, community-acquired pneumonia; CDSS, computerized decision support system; CT, computed tomography; ED, emergency department; EMR, electronic medical records; HAP, hospital-acquired pneumonia; HIV, human immunodeficiency virus; ICD, international classification of diseases; ICU, intensive care unit; ID, infection diseases; IV, intravenous; LRTI, lower respiratory tract infection; NR, not specified in the article; PGA, physician global assessment; RCT, randomized clinical trial; USA, United States of America; VACS, Veterans Aging Cohort Study; VAP, ventilator-associated pneumonia; <sup>a</sup> Odense University Hospital, Denmark; <sup>b</sup> Funen Patient Administrative System; <sup>c</sup> Danish National Patient Register; <sup>d</sup> Odense Pharmacoepidemiological Database, the Danish National Cancer Register, and the Danish National Alcohol- and Drug Treatment Register; <sup>e</sup> LDS Hospital in Salt Lake City, Utah; <sup>f</sup> Royal Melbourne Hospital and Western Hospital Footscray; <sup>g</sup> Aalborg University Hospital; <sup>h</sup> The population was restricted to patients with a history of a solid malignancy ( ICD-10 codes C00eC79, excluding nonmelanoma skin cancer code C44) within 5 years before the admission with an infection; <sup>i</sup> Aalborg University Hospital medical records; <sup>j</sup> Presbyterian University Hospital; <sup>k</sup> Franklin and Summit, Ohio; <sup>l</sup> ICD-9 codes 480–487.0 and 507.0; <sup>m</sup> National University Hospital; <sup>n</sup> California Office of Statewide Health Planning and Development Patient Discharge Data Set; <sup>o</sup> University Hospital Essen; <sup>p</sup> University Hospital Zurich; <sup>q</sup> Greenville Memorial Hospital, the 3M Health Information Systems ClinTrac Abstracting Module; <sup>r</sup> Mayo Clinic Life Sciences System, The Multidisciplinary Epidemiology and Translational Research in Intensive Care (METRIC) datamart

**Supplementary table 5. Results of the risk of bias assessment, QUADAS-2 adapted tool**

	Patient selection	Index test	Reference standard	Flow and timing
Skull, 2008-1 [4]	Low	Low	Low	High
Skull, 2008-2 [4]	Low	Low	High	Low
Skull, 2008-3 [4]	Low	Low	Low	High
Wiese, 2018-1 [18]	Low	High	Low	Low
Wiese, 2018-2 [18]	Low	High	Low	High
Jones, 2018 [17]	Low	Low	Low	Low
Rodriguez-Barradas, 2020 [19]	Unclear	Low	Low	Low
Wolfensberger, 2018 [24]	Low	Unclear	Low	Low
Yu, 2011 [15]	High	Low	Low	Low
Verelst, 2010 [25]	Low	Low	Unclear	Low
Søgaard, 2011 [9]	Low	Low	Unclear	Low
Quan, 2004 [21]	Low	Unclear	Unclear	Low
Mukhopadhyay, 2017 [16]	Low	Unclear	Low	High
Maass, 2015 [23]	Low	Low	Low	Low
Rattanaumpawan, 2016 [2]	Low	Unclear	Unclear	Low
Kern, 2015 [7]	Low	Unclear	Unclear	Low
Henriksen, 2014 [1]	Low	Low	Low	Low
Aronsky, 2005 [3]	Low	Unclear	Unclear	Low
Ahmed, 2014 [5]	Unclear	Unclear	High	Low
Schneeweiss, 2007 [12]	Low	High	Low	Low
Holland-Bill, 2014-1 [6]	Low	High	Low	Low
Holland-Bill, 2014-2 [6]	Low	High	Low	Low
van de Garde, 2007 [13]	Low	Unclear	Unclear	Low
Grijalva, 2008 [14]	High	Low	Low	Low
Cass, 2013 [26]	Low	High	Unclear	Low
Higgins, 2020 [8]	Low	Unclear	Unclear	Low
Azaouagh, 2008 [22]	High	Unclear	Low	Low
Guevara, 1999 [11]	Low	Low	Unclear	High
Whittle, 1997 [10]	Low	Low	Low	Low
Romano, 2002 [20]	Low	Unclear	Unclear	Low



Supplementary table 6

**Supplementary table 6. Characteristics and validation measures of ICD algorithms to diagnose LRTI in adults**

1°/2°, primary/secondary; (#) "secondary position" (i.e., 2°) means in *any* secondary position, not only in the second *place*; \* Coding position in most cases refers to "Classical pneumonia codes position", but sometimes to other pneumonia-related codes; ALI/ARDS, acute lung injury/acute respiratory distress syndrome; ARF, acute respiratory failure; B-HDDS, Belgian Hospital Discharge Dataset; CAP, community-acquired pneumonia; CART, classification and regression tree analysis to identify true CAP cases; CDC, Centers for Disease Control and Prevention; COPD, chronic obstructive pulmonary disease; ED: emergency department; EHR, electronic health record; EMR, electronic medical record; HAP: hospital-acquired pneumonia; HELICS, the Hospitals in Europe Link for Infection Control through Surveillance; HIV, human immunodeficiency virus; HOSP, hospital; ICD, international classification of diseases; ICU, intensive care unit; LOS, length of hospital stay; LR+: Likelihood ratio positive; LR-: Likelihood ratio negative; LRTI, lower respiratory tract infection; MCLSS, Mayo Clinic Life Sciences System; NL, the Netherlands; NLP, natural language processing; NPV, negative predictive value; OSHPD, Office of Statewide Health Planning and Development; POA, present on admission; PPV, positive predictive value; Se, sensitivity; Sp, specificity; USA, United States of America; VA, veterans affairs; VACS, Veterans Aging Cohort Study; VAP, ventilator-associated pneumonia; VINCI, The Veterans Informatics and Computing Infrastructure

Country, reference	Study period	Data source (coding timing)	Algorithm	Coding position *	Codes <sup>1</sup> Classical pneumonia codes Aspiration pneumonia codes Other specific infection codes Related to respiratory system codes Latrogen/Complication codes	Reference standard	Treatment		Population	Se (%)	Sp (%)	PPV (%)	NPV (%)	LR+	LR-
							set-ting	Time frame							
<b>LRTI</b>															
<b>ICD-10</b>															
Denmark, Henriksen 2014 [1]	09/2010 - 08/2011	Electronic patient journal, large population-based registers <sup>2</sup> (discharge)	ICD-10 codes for LRTI	Any	<b>Codes<sup>1</sup>:</b> A31.0A, A48.1, B37.1, J12.0, J13.9, J14.9, J15, J15.0, J15.1, J15.2, J15.4, J15.5, J15.7, J15.8, J15.9, J17.0, J17.8, J18, J18.0, J18.1, J18.8, J18.9, J20.9, J20.9A, J21.9, J22.9, J69.0, J69.8, J69.8A <b>Other:</b> A15.0, A15.1, A15.2, A15.9, B90.9, J40.9, J44.0, J85.1, J85.2, J86.0, J86.9 <b>Classical pneumonia codes:</b> J12.0, J13, J14, J15.0-J15.9, J16.0, J17.0, J17.8, J18, J18.0, J18.1, J18.8, J18.9s <b>Aspiration pneumonia codes:</b> J69.0, J69.8, J69.8A <b>Other specific infection codes:</b> A15.0, A15.1, A15.2, A15.9, A31.0, A48.1, B37.1, B90.9, J22 <b>Related to respiratory system codes:</b> J85.2 <sup>3</sup> , J85.1 <sup>4</sup> , (J20.9, J21.9, J40) <sup>5</sup> , J44.0 <sup>6</sup> , (J86.0, J86.9) <sup>7</sup>	Review of clinical, radiological and laboratory data	ED	Identified in the first 48h of the admission to ED	≥15 yrs	71	92	71	91	8.3 (7.5-9.2)	0.3 (0.3-0.4)

<sup>1</sup> All the codes included in the paper without classification (codes list)

<sup>2</sup> Funen Patient Administrative System, Danish National Patient Register, Odense Pharmacoepidemiological Database, the laboratory information system at Department of Clinical Microbiology at Odense University Hospital, the Danish National Cancer Register, as well as the Danish National Alcohol- and Drug Treatment Register

<sup>3</sup> Lung abscess without pneumonia

<sup>4</sup> Lung abscess with pneumonia

<sup>5</sup> Bronchitis codes

<sup>6</sup> COPD with LRTI (except influenza)

<sup>7</sup> Pyothorax codes

Supplementary table 6

Country, reference	Study period	Data source (coding timing)	Algorithm	Coding position *	Codes <sup>1</sup> Classical pneumonia codes Aspiration pneumonia codes Other specific infection codes Related to respiratory system codes latrogen/Complication codes	Reference standard	Treatment setting	Time frame	Population	Se (%)	Sp (%)	PPV (%)	NPV (%)	LR+	LR-
Thailand, Rattanaum-pawan 2016 [2]	02/2013 - 05/2013	Siriraj Hospital database (not stated)	ICD-10 codes for infectious conditions- LRTI	Any	<b>Codes<sup>1</sup>:</b> A15-A16, A19, A150-153, A157-162, A167-169, A202, A221, A310, A420, A430, A481 B012, B052, B206, B250, B334, B371, B380-382, B390-392, B400-402, B410, B420, B440-441, B450, B460, B583, B59, B671 J100, J110, J160, J12-18, J120-123, J128-129, J150-159, J168, J180-182, J188-189. P23, P230-239 <b>Classical pneumonia codes:</b> J10, J11.0, J12.0, J12.1, J12.2, J12.3, J12.8, J12.9, J13, J14, J15.0- J15.7, J15.8, J15.9, J16.0, J16.8, J17.0, J17.1, J17.2, J17.3, J17.8, J18* <b>Other specific infection codes:</b> A15*-A16*, A19*, A20.2, A22.1, A31.0, A42.0, A43.0, A48.1, B01.2, B05.2, B20.6, B25.0, B33.4, B37.1, B38.0, B38.1, B38.2, B39.0-B392, B400-B402, B410, B420, B440-441, B450, B460, B58.3, B59, B67.1, P23, P230-239	Review of clinical and laboratory data	HOSP	Admission and during hospitalization	≥15 yrs	57	94	84		8.80	0.46

**Pneumonia (overall)**

**ICD-9**

USA, Aronsky 2005 [3]	11/1999 - 04/2000	Computerized decision support system (not stated)	Algorithm 1 <sup>8</sup>	1°	<b>Codes<sup>1</sup>:</b> 480-483; 485-487.0 <b>Classical pneumonia codes:</b> 480-483; 485-487.0	Review of clinical and radiological data and recoding	HOSP <sup>9</sup>	≥18 yrs	55	99	85	96	60.89	0.46
	Algorithm 2 <sup>10</sup>		1°	<b>Codes<sup>1</sup>:</b> 3.22, 21.2, 39.1, 52.1, 55.1, 73.0, 112.4, 114.0, 115.05, 115.15, 115.95, 130.4, 136.3, 480, 480.0, 480.1, 480.2, 480.8, 480.9, 481, 482, 482.0, 482.1, 482.2, 482.3, 482.4, 482.8, 482.9, 483, 484.1, 484.3, 484.5, 484.6, 484.7, 484.8, 485, 486, 487, 507.0, 510.0, 510.9, 511.1, 513.0 <b>Classical pneumonia codes:</b> 480, 480.0, 480.1, 480.2, 480.8, 480.9, 481, 482, 482.0, 482.1, 482.2, 482.3, 482.4, 482.8, 482.9, 483, 484.1, 484.3, 484.5, 484.6, 484.7, 484.8, 485, 486, 487 <b>Aspiration pneumonia codes:</b> 507.0	68				99	86	97	68.30	0.32	

<sup>8</sup> A limited set of frequently used ICD-9 codes

<sup>9</sup> It does not make distinction between CAP and HAP

<sup>10</sup> ICD-9 codes for a wide spectrum of possible pneumonia cases

Supplementary table 6

Country, reference	Study period	Data source (coding timing)	Algorithm	Coding position *	Codes <sup>1</sup> Classical pneumonia codes Aspiration pneumonia codes Other specific infection codes Related to respiratory system codes latrogen/Complication codes	Reference standard	Treatment setting	Time frame	Population	Se (%)	Sp (%)	PPV (%)	NPV (%)	LR+	LR-
					<b>Other specific infection codes:</b> 3.22, 21.2, 39.1, 52.1, 55.1, 73.0, 112.4, 114.0, 115.05, 115.15, 115.95, 130.4, 136.3 <b>Related to respiratory system codes:</b> (510.0, 510.9) <sup>11</sup> , (511.1, 513.0) <sup>12</sup>										
			Algorithm 3 <sup>13</sup>	1° or 2° (#) <sup>14</sup>	<b>Codes<sup>1</sup>:</b> 480-483; 485-487.0, 507 as 1° diagnosis; or 518.8*, 038*, as 1° diagnosis and 480-483; 485-487.0 as 2° (#) diagnosis <b>Classical pneumonia codes:</b> 480-483; 485-487.0 <b>Aspiration pneumonia codes:</b> 507.0 <b>Other specific infection codes:</b> 038* <sup>15</sup> <b>Related to respiratory system codes:</b> 518.8 <sup>12</sup>					70	99	85	97	63.45	0.31
USA, Ahmed 2014 [5]	01/2010 - 12/2010	EMRs <sup>16</sup> , data from the MCLSS (admission)	ICD-9 codes for pneumonia	Not stated, likely any	<b>Codes<sup>1</sup>:</b> 480.0, 480.1, 480.2, 480.3, 480.8, 480.9, 481, 482.0, 482.1, 482.2, 482.30, 482.31, 482.32, 482.39, 482.40, 482.41, 482.49, 482.81, 482.82, 482.83, 482.89, 482.9, 483.0, 483.1, 483.8, 484.1, 484.3, 484.5, 484.6, 484.7, 484.8, 485, 486 <b>Classical pneumonia codes:</b> 480.0, 480.1, 480.2, 480.3, 480.8, 480.9, 481, 482.0, 482.1, 482.2, 482.30, 482.31, 482.32, 482.39, 482.40, 482.41, 482.49, 482.81, 482.82, 482.83, 482.89, 482.9, 483.0, 483.1, 483.8, 484.1, 484.3, 484.5, 484.6, 484.7, 484.8, 485, 486	Agreement between the 3 tested algorithms and review of medical files when discordant	HOSP <sup>9</sup>	≥18 yrs <sup>17</sup>	77	98	78	98	38.50	0.23	
USA, Kern 2015 [7]	03/2009 - 03/2012	HealthCore Integrated Research Environment (not stated)	ICD-9-CM codes for pneumonia	Any	<b>Codes<sup>1</sup>:</b> 480.xx-486.xx <b>Classical pneumonia codes:</b> 480.xx-486.xx	Review of medical files	HOSP <sup>9</sup>	≥40 yrs <sup>18</sup>			88				

<sup>11</sup> Empyema codes

<sup>12</sup> Other unspecified pneumonia-related codes

<sup>13</sup> Adds codes to algorithm 1 that are representative of severe pneumonia (e.g., sepsis or respiratory failure in a pneumonia patient) and are similar to the case identification algorithm for the pneumonia ORYX core measure by the Joint Commission on Accreditation of Healthcare Organizations

<sup>14</sup> if 1° is sepsis or respiratory failure

<sup>15</sup> Sepsis (if pneumonia 2° (#))

<sup>16</sup> The Multidisciplinary Epidemiology and Translational Research in Intensive Care (METRIC) datamart

<sup>17</sup> A subset of an ongoing prospective study for ALI/ARDS prevention

<sup>18</sup> With COPD

Supplementary table 6

Country, reference	Study period	Data source (coding timing)	Algorithm	Coding position *	Codes <sup>1</sup> Classical pneumonia codes Aspiration pneumonia codes Other specific infection codes Related to respiratory system codes Iatrogen/Complication codes	Reference standard	Treatment setting	Time frame	Population	Se (%)	Sp (%)	PPV (%)	NPV (%)	LR+	LR-
<b>ICD-10</b>															
Australia, Skull 2008 [4]	04/2000 - 03/2002	Monthly separation lists of completed admissions for patients <sup>19</sup> (admission)	ICD-10-AM codes for pneumonia <sup>20</sup>	Any <sup>21</sup>	Codes <sup>1</sup> : J10-J18 Classical pneumonia codes: J10-J18	Radio-logical data	HOSP <sup>9</sup>	≥65 yrs	89	62	71	84	2.35	0.17	
									98	97	96	98	31.55	0.02	
									98	64	68	97	2.73	0.03	
Denmark, Holland-Bill 2014 [6]	01/2006 - 12/2010	DNRP, Aalborg University Hospital medical records (discharge)	Diagnostic codes according to the Danish version of the ICD-10	1 <sup>o</sup>	Codes <sup>1</sup> : J12-J18 Classical pneumonia codes: J12-J18	Diagnosis of reviewing physician based on chart review	HOSP	Physician global assessment (PGA)	≥18 yrs <sup>22</sup>			93			
												89			

<sup>19</sup> From Royal Melbourne Hospital and Western Hospital Footscray<sup>20</sup> Identified if one or more of these codes appeared in any of the 14 diagnostic code positions for each hospital separation<sup>21</sup> (Between the 14 positions)<sup>22</sup> With immunocompromising conditions

Supplementary table 6

**Empyema**

**ICD-10**

Denmark, Sogaard 2011 [9]	2000 - 2004	Danish Civil Registry System, DNRP (discharge)	1° or 2° (#) diagnosis of empyema	1° or 2° (#)	<b>Codes<sup>1</sup>:</b> (J86.0, J86.9) <sup>23</sup> <b>Related to respiratory system codes:</b> (J86.0, J86.9) <sup>24</sup>	Review of clinical, radiology and laboratory data	HOSP	9	≥15 yrs			95		
	2005 - 2009											87		

**Community-acquired pneumonia**

**ICD-9**

USA, Whittle 1997 [10]	07/1989 - 06/1990	Discharge summaries, dictated admission notes, and radiology reports for each of these admissions (discharge)	CAP <sup>25</sup> <sub>28</sub>	1° 1°, or 2° (#) <sup>29</sup>	<b>Codes<sup>1</sup>:</b> 03.221, 21.21, 39.11, 52.11, 55.11, 73.01, 112.4, 114.01, 115.05, 115.15, 115.95, 130.41, 136.31, 480, 480.1, 480.2, 480.8, 480.9, 481, 482.0-482.4, 482.81, 482.9, 483, 484.1, 484.5x, 484.31, 484.61, 484.7, 484.81, 485, 486, 487.0, 507.0, 510.0, 510.91, 511.11, 513.0 <b>Classical pneumonia codes:</b> 480, 480.1, 480.2, 480.8, 480.9, 481, 482.0-482.4, 482.81, 482.9, 483, 484.1, 484.5x, 484.31, 484.61, 484.7, 484.81, 485, 486, 487.0 <b>Aspiration pneumonia codes:</b> 507.0 <b>Other specific infection codes:</b> 3.221, 21.21, 39.11, 52.11, 55.11, 73.01, 112.4, 114.01, 115.05, 115.15, 115.95, 130.41, 136.31 <b>Related to respiratory system codes:</b> (510.0, 510.9) <sup>26</sup> , (511.1, 513.0) <sup>27</sup>	Review of clinical and radiology data	HOSP	Symptoms present within 24 hr of admission and that the official reading of a chest radiograph performed within 48h of admission was consistent with pneumonia	≥18 yrs	84	86	92		6.00	0.19
	89									80	89		4.45	0.14	

<sup>23</sup> Danish version of ICD-10 codes J86.0 Pyothorax with fistula and J86.9 Pyothorax without fistula

<sup>24</sup> Pyothorax with and without fistula

<sup>25</sup> CAP is considered when pneumonia diagnosis codes are in the main position, in other cases considered not CAP

<sup>26</sup> Empyema codes

<sup>27</sup> Other unspecified pneumonia-related codes

<sup>28</sup> If pneumonia is the main diagnosis or if pneumonia diagnosis is in other position and the principal diagnosis is related to pneumonia or several codes that are related to pneumonia (bacteremia, shock, respiratory failure, pneumothorax, congestive heart failure, volume depletion/electrolyte imbalance, disseminated intravascular coagulation, and chronic obstructive lung disease)

<sup>29</sup> If principal code is pneumonia-related

Supplementary table 6

Singapore Mukhopadhyay 2017 [16]	01/2010 - 06/2012	EMR-linked administrative data (admission and discharge)	Admission diagnosis of pneumonia <sup>30</sup>	Not stated, likely any	<b>Codes<sup>1</sup>:</b> 480-487 <b>Classical pneumonia codes:</b> 480-487	Diagnosis of reviewing physician based on chart review	HOSP	<sup>31</sup>	≥21 yrs	85	78	75	87	3.89	0.20
USA, Schneeweiss 2007 [12]	03/2001 - 03/2004	The Department of VA administrative database, EMRs (discharge)	ICD-9-CM for serious bacterial pneumonia	1°	<b>Codes<sup>1</sup>:</b> 3.22, 480.x-487.x, 513 <b>Classical pneumonia codes:</b> 480.x-487.x <b>Other specific infection codes:</b> 3.22 <b>Related to respiratory system codes:</b> 513 <sup>32</sup>	Diagnosis of reviewing physician based on chart review	HOSP	<sup>33</sup>	≥18 yrs			70			
						Based on diagnostic criteria from chart review (clinical, radiological and laboratory)						70			
NL, van de Garde 2007 [13]	07/2000 - 03/2004	Patient data from a randomized open label clinical trial <sup>34</sup> , hospital discharge records <sup>35</sup> (admission)	ICD-9-CM code was listed in the 1° or 2° (#) positions for each different patient category <sup>36</sup>	1°	<b>Codes<sup>1</sup>:</b> 481-486 <b>Classical pneumonia codes:</b> 481-486	Review of medical files (clinical, radiological and laboratory data)	HOSP	Patients hospitalized for CAP, not given time frame. New or progressive infiltrate on a chest X-ray	≥18 yrs	72					
				Any						80					

<sup>30</sup> Identified by text mining AND a proxy search term for pneumonia in the chest radiograph report AND discharge ICD-9-CM codes for pneumonia

<sup>31</sup> Chest radiograph on the date of admission, and no hospital discharge in the 14 days prior to the date of admission

<sup>32</sup> Other unspecified pneumonia-related codes

<sup>33</sup> Focus on infections that resulted in a hospital admission with a 1° discharge diagnosis of a bacterial or opportunistic infection, excluding nosocomial infections

<sup>34</sup> (July 2000 - March 2004) on efficacy of an early switch of intravenous antibacterial treatment to oral treatment of CAP

<sup>35</sup> From the medical registration department of the participating hospitals

<sup>36</sup> Pneumonia by pneumococcus, with other organism specified and no organism specified

Supplementary table 6

USA, Grijalva 2008 [14]	1995 - 2004	Tennessee Medicaid (TennCare) databases (discharge)	Computerized definitions for events leading to hospitalization in TennCare patients (ICD-9-CM codes)	Any	<b>Codes<sup>1</sup>:</b> 480*, 481*, 482*, 483*, 484*, 485*, 486*, 487.0 <b>Classical pneumonia codes:</b> 480*, 481*, 482*, 483*, 484*, 485*, 486*, 487.0	Diagnosis by treating physician	HOSP	<sup>37</sup>	≥18 yrs <sup>38</sup>			84				
				1°								95				
				2° (#)								60				
USA, Yu 2011 [15]	01/1997 - 01/2005	Administrative data systems (discharge)	1° discharge diagnosis code of pneumonia	1°	<b>Codes<sup>1</sup>:</b> 480-487 or 507.0 <b>Classical pneumonia codes:</b> 480-487.0 <b>Aspiration pneumonia codes:</b> 507.0	Diagnosis by treating physician	HOSP	Illness present at admission <sup>39</sup>	18-64 yrs	63	93	91	68	9.00	0.40	
			As above OR in any position <sup>40</sup>	Any					≥65 yrs	65	85	89	57	4.33	0.41	
			As above OR in any position <sup>41</sup>						18-64 yrs	81	82	84	78	4.50	0.23	
									≥65 yrs	89	63	82	75	2.41	0.17	
USA, Jones 2018 [17]	2006 - 2012	VINCI (admission)	For pneumonia coding using the 1°/principal ICD-9 code for pneumonia <sup>42</sup> , or a 2° (#) ICD-9 code for pneumonia and a 1°/principal ICD-9 code for sepsis <sup>43</sup> or respiratory failure <sup>44</sup>	1° or 2° (#) if 1° is sepsis or respiratory failure	<b>Codes<sup>1</sup>:</b> 481-486 <b>Classical pneumonia codes:</b> 481-486 <b>Other specific infections codes:</b> Sepsis 038* (if pneumonia 2° (#))	Diagnosis or pneumonia treatment by treating physician	HOSP	All visits to the USA Veterans Affairs (VA) EDs throughout the USA 2006-2012 <sup>45</sup>	≥18 yrs	44	100	100	95	∞	0.56	
		VINCI (discharge)								67	99	86	97	67.00	0.33	
		VINCI (admission)		As above, plus NLP												
								≥18 yrs	89	98	80	99	44.50	0.11		

<sup>37</sup> Episodes of CAP were deemed as confirmed if pneumonia was considered the main reason for hospitalization on admission; and, at the end of the hospitalization, pneumonia was considered the main disease present at admission by the treating physician.

<sup>38</sup> with rheumatoid arthritis

<sup>39</sup> Hospitalizations due to causes other than pneumonia, including nosocomial pneumonia with pneumonia symptoms onset after hospital admission, were classified as 'not CAP'.

<sup>40</sup> Plus LOS ≤3 days (without code 507) OR LOS >3 days with ARF code as 1° (CART)

<sup>41</sup> (Without code 507), with LOS ≤9 days without an operation procedure code assigned to hospitalization

<sup>42</sup> (481–486)

<sup>43</sup> (038.0, 038.11, 038.12, 038.x, 995.91, 995.92, 785.52)

<sup>44</sup> (518.81–84, 799.1)

<sup>45</sup> That had chest imaging (computed tomography [CT] scan or chest X-ray) obtained within 24 hours of the visit time and at least one clinical document generated within 24 hours from the visit time with a standard note title consistent with an ED note or an addendum

Supplementary table 6

USA, Wiese 2018 [18]	2008 - 2012	TennCare Tennessee Hospital Discharge Data System, pharmacy information from Medicare part D (discharge)	Pneumonia - 1° position <sup>46</sup> Pneumonia - 2° (#) position (1° diagnosis code with pneumonia diagnosis (above) in any other diagnosis field) <sup>47</sup>	1°	<b>Codes<sup>1</sup>:</b> 003.22, 480.x*, 481, 482.x, 483.x, 484.x, 485.x, 486.x, 487.0, 510.x, 038.x, 790.7, 995.91, 995.92 <b>Classical pneumonia:</b> 480.x*, 481, 482.x, 483.x, 484.x, 485.x, 486.x, 487.0 <b>Other specific infections codes:</b> 3.22 <sup>48</sup> , (038, 790.7, 995.91, 995.92) <sup>49</sup> <b>Related to respiratory system codes:</b> 510	Review of clinical, radiological, microbiological, and pharmacological data	HOSP <sup>50</sup>	50-110 yrs			97				
						Radiological data									50-110 yrs
USA, Rodriguez-Barradas 2020 [19]	06/2002 - 09/2008	VACS survey cohort database (not stated)	CAP such as bacterial <sup>51</sup> or viral pneumonia <sup>52</sup> (restricted CAP codes), and additional ICD-9 codes, consistent with miscellaneous lung infections <sup>53</sup>  As above plus those that received antimicrobials within 72h of admission <sup>60</sup>	1° or 2° (#) <sup>54</sup>	<b>Codes<sup>1</sup>:</b> 481-486, 480, 487, 506, 507, 510, 511.1 <b>Classical pneumonia codes:</b> 481-486, 480, 487 <b>Aspiration pneumonia codes:</b> 507.0 <b>Related to respiratory system codes:</b> (510.0, 510.9) <sup>55</sup> , (506, 511.1) <sup>56</sup>	Review of clinical, laboratory, and radiological data, antibiotic prescription	HOSP	CAP within 48h of admission	≥18 yrs <sup>57</sup>			72			
									≥18 yrs <sup>58</sup>			74			
									≥18 yrs <sup>59</sup>			66			
									≥18 yrs <sup>57</sup>			74			
									≥18 yrs <sup>58</sup>			76			
									≥18 yrs <sup>59</sup>			69			
			Any		<b>Codes<sup>1</sup>:</b> 480-487						74				

<sup>46</sup> (003.22, 480.x\*, 481, 482.x, 483.x, 484.x, 485.x, 486.x, 487.0)

<sup>47</sup> (510.x, 038.x, 790.7, 995.91, 995.92)

<sup>48</sup> Bacterial pathogen-specific pneumonia

<sup>49</sup> sSepsis, septicemia (if pneumonia 2° (#))

<sup>50</sup> The reviews were focused on clinical, microbiological, and radiological information from the 2 days prior to the admission date through 2 days after admission to limit the possibility of identifying infections that developed during the hospitalisation.

<sup>51</sup> (481-486)

<sup>52</sup> (480, 487)

<sup>53</sup> Including aspiration pneumonitis (507), inhalation (506), empyema (510), pleurisy (511.1), and lung abscess (513) and other infections associated with pneumonia and/or due to infection elsewhere, (3.22, 21.2, 39.1, 52.1, 55.1, 73, 517.1)

<sup>54</sup> If 1° is sepsis, respiratory failure, HIV or bacteremia if 1°

<sup>55</sup> Empyema codes

<sup>56</sup> Other unspecified pneumonia-related codes

<sup>57</sup> Overall

<sup>58</sup> With HIV

<sup>59</sup> And HIV-uninfected

<sup>60</sup> Identified by pharmacy package in EHR



Supplementary table 6

		Algorithm 1 <sup>61</sup>		<b>Classical pneumonia codes: 480-487</b>				≥18 yrs <sup>58</sup>			76			
		Algorithm 1 plus those that received antimicrobials within 72h of admission <sup>60</sup>						≥18 yrs <sup>59</sup>			69			
		Algorithm 1 plus 507 in any position		<b>Codes<sup>1</sup>: 480-487, 507</b> <b>Classical pneumonia codes: 480-487</b> <b>Aspiration pneumonia codes: 507.0</b>				≥18 yrs <sup>57</sup>			76			
		Algorithm 1 plus 507 in any position plus those that received antimicrobials within 72h of admission <sup>60</sup> <small>! Bookmark not defined.</small>						≥18 yrs <sup>58</sup>			77			
		Algorithm 2 <sup>62</sup>	1° or 2°(#) <sup>54</sup>	<b>Codes<sup>1</sup>: 480-487</b> <b>Classical pneumonia codes: 480-487</b> <b>Other specific infections codes: 038<sup>63</sup>, 042<sup>64</sup></b>				≥18 yrs <sup>59</sup>			73			
		Algorithm 2 <sup>62</sup> plus those that received antimicrobials within 72h of admission <sup>60</sup>						≥18 yrs <sup>57</sup>			73			
		Algorithm 2 <sup>62</sup> , plus 507		<b>Codes<sup>1</sup>: 480-487</b> <b>Classical pneumonia codes: 480-487</b> <b>Aspiration pneumonia codes: 507.0</b> <b>Other specific infections codes: 038<sup>63</sup>, 042<sup>64</sup></b>				≥18 yrs <sup>58</sup>			75			
		Algorithm 2 <sup>62</sup> plus 428		<b>Codes<sup>1</sup>: 480-487, 428</b> <b>Classical pneumonia codes: 480-487</b> <b>Other specific infection codes: 038<sup>63</sup>, 042<sup>64</sup></b> <b>Related to respiratory system codes: 428<sup>56</sup></b>				≥18 yrs <sup>59</sup>			66			
								≥18 yrs <sup>57</sup>			75			
								≥18 yrs <sup>58</sup>			76			
								≥18 yrs <sup>59</sup>			70			
								≥18 yrs <sup>57</sup>			81			
								≥18 yrs <sup>58</sup>			82			
								≥18 yrs <sup>59</sup>			75			
								≥18 yrs <sup>57</sup>			82			
								≥18 yrs <sup>58</sup>			83			
								≥18 yrs <sup>59</sup>			73			
								≥18 yrs <sup>57</sup>			79			
								≥18 yrs <sup>58</sup>			81			
								≥18 yrs <sup>59</sup>			70			
								≥18 yrs <sup>57</sup>			80			
								≥18 yrs <sup>58</sup>			82			
								≥18 yrs <sup>59</sup>			71			

<sup>61</sup> 480-487 in any position

<sup>62</sup> 480-487 in 1° or 2°(#)<sup>54</sup> position only to selected diagnosis (a CAP-related code in 1° position with the exception that they could be in 2° (#) position if the following HIV, sepsis,

respiratory insufficiency, and bacteremia codes were in 1° position: 042, 038, 518.81, 518.82, 518.85, 995.91, 995.92, 790.7, 790.70)

<sup>63</sup> Sepsis (if pneumonia 2°(#))

<sup>64</sup> VIH (if pneumonia 2°(#))

Supplementary table 6

		Algorithm 2 <sup>62</sup> plus 491	<b>Codes<sup>1</sup>:</b> 480–487, 491 <b>Classical pneumonia codes:</b> 480-487 <b>Other specific infection codes:</b> 038 <sup>63</sup> , 042 <sup>64</sup> <b>Related to respiratory system codes:</b> 491 <sup>56</sup>						≥18 yrs <sup>57</sup>			81			
		Algorithm 2 <sup>62</sup> plus 491, 428 and 507	<b>Codes<sup>1</sup>:</b> 480–487, 491, 428 and 507 <b>Classical pneumonia codes:</b> 480–487 <b>Aspiration pneumonia codes:</b> 507.0 <b>Other specific infection codes:</b> 038 <sup>63</sup> , 042 <sup>64</sup> <b>Related to respiratory system codes:</b> (428, 491) <sup>65</sup>						≥18 yrs <sup>57</sup>			79			
									≥18 yrs <sup>58</sup>			82			
									≥18 yrs <sup>59</sup>			76			
									≥18 yrs <sup>58</sup>			81			
									≥18 yrs <sup>59</sup>			68			

**Any hospital-acquired pneumonia**

**ICD-9**

USA, Romano 2002 [20]	01/1990 - 12/1991	Medical records and OSHPD Patient Discharge Data Set (discharge)	Pneumonia or empyema ICD- 9-CM	Not stated, likely any	<b>Codes<sup>1</sup>:</b> 480.x-487.0, 507.0, 510.x, 513.x <b>Classical pneumonia codes:</b> 480.x–487.0 <b>Aspiration pneumonia codes:</b> 507.0 <b>Related to respiratory system codes:</b> 510.x, 513.x	Recoding based on chart review and ICD manual	HOSP	Complica- tions secondary to an elective lumbar discec- tomy	≥18 yrs <sup>66</sup>	100	100	25	100	333.33	0.00
Canada, Quan 2004 [21]	04/1996 - 03/1997	Adminis- trative hospital discharge data (discharge)	ICD-9-CM coding for pneumonia and 997.3 for respiratory complication	Any <sup>67</sup>	<b>Codes<sup>1</sup>:</b> 481, 482.0–482.4, 480, 480.0, 480.1, 480.2, 480.8, 480.9, 487.0, 112.4, 114.0, 115.05, 115.15, 115.95, 484.6, 484.7, 136.3, 507.0, 482, 482.8, 482.9, 483, 484.1, 484.3, 484.5, 484.8, 73.0, 39.1, 55.1, 003.22, 130.4, 21.2, 52.1, 510.0, 510.9, 511.1, 513.0, 485, 486. 997.3 <b>Classical pneumonia codes:</b> 480, 480.0, 480.1, 480.2, 480.8, 480.9, 481, 482 482.0-482.4, 482.8, 482.9, 483, 484.1, 484.3, 484.5, 484.8, 484.6, 484.7, 487.0 <b>Aspiration pneumonia codes:</b> 507 <b>Other specific infections codes:</b> 73.0, 3.22, 21.2, 39.1, 55.1, 52.1, 112.4, 114.0, 115.05, 115.15, 115.95, 130.4, 136.3 <b>Related to respiratory system codes:</b> (510.0, 510.9) <sup>68</sup> , (511.1, 513.0) <sup>69</sup> <b>Iatrogen/Complication codes:</b> 997.3	Review of medical files and recoding	HOSP	Complica- tion diagnoses arising some time after hospital admission	≥18 yrs	35	99	50	99	58.33	0.65

<sup>65</sup> Other unspecified pneumonia-related codes

<sup>66</sup> Patients with elective lumbar discectomies

<sup>67</sup> (Up to 16 diagnoses)

<sup>68</sup> Empyema codes

<sup>69</sup> Other unspecified pneumonia-related codes

Supplementary table 6

ICD-10														
Germany, Azaouag 2008 [22]	04/2005 - 09/2005	A database of the University Hospital Essen <sup>70</sup> (discharge)	A 'case' if coded with at least one of these ICD-10-GM-2005 <sup>71</sup> codes <sup>72</sup>	Secondary diagnosis field	<b>Codes</b> <sup>1</sup> : A48.1, B01.2, B05.2, B25.0, B59, J10.0, J11.0, J12, J13, J14, J15, J16, J17, J18, J68.0, J69, J82, J85.1 <b>Classical pneumonia codes</b> : J10.0, J11.0, J12, J13, J14, J15, J16, J17, J18 <b>Aspiration pneumonia codes</b> : J69 <b>Other specific infections codes</b> : A48.1, B01.2, B05.2, B25.0, B59 <b>Related to respiratory system codes</b> : (J68, J82, J85.1) <sup>73</sup>	Review of medical files (clinical, radiological and laboratory data)	HOSP	Nosocomial pneumonia, not specified time	≥18 years <sup>74</sup>	43	99	64	43.78	0.58
											8			
											33			
											76			
											89			
Germany, Maass 2015 [23]	05/2010 - 12/2010	Hospital administrative database	Pneumonia ICD 10-GM codes (not specified in the paper) including HAP code	2 <sup>o</sup> (#) diagnosis codes	<b>Codes</b> <sup>1</sup> : U69.00 <sup>75</sup> ; used pneumonia codes were not specified in the paper <b>latrogen/Complication codes</b> : U69.00 <sup>75</sup>	Review of medical files according to CDC criteria	HOSP	With a minimum hospitalization of 5 days	≥65 yrs	23	100	91	233.00	0.77
Switzerland,	2016	University Hospital	All patients assigned to the	Not stated,	<b>Codes</b> <sup>1</sup> : U69.00 <sup>75</sup> <b>latrogen/Complication codes</b> : U69.00 <sup>75</sup>	Review of clinical,	HOSP	Proxy code U69.00 as	≥18 yrs	59	98		32.78	0.42

<sup>70</sup> The database is mandatory (by law) and will be handed out to third parties e.g., health insurance companies

<sup>71</sup> German modification

<sup>72</sup> Which may not be present at admission or be the main diagnosis at discharge

<sup>73</sup> Other affections related to respiratory system

<sup>74</sup> With mixed comorbidities

<sup>75</sup> Hospital-acquired pneumonia

Supplementary table 6

Wolfensberger 2018 [24]		Zurich database, medical charts (discharge)	proxy code U69.00 as having a HAP <sup>76</sup>	likely any		radiological and laboratory data, based on HELICS definition		having a HAP according to ICD-10, pneumonia more than 48h after admission									
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**Ventilator-associated pneumonia**

ICD-9															
Belgium, Verelst 2010 [25]	2004 - 2006	B-HDDS <sup>77</sup> (admission)	ICD-9-CM pneumonia* in any 2° (#) diagnosis field <sup>78</sup>	2°	Codes <sup>1</sup> : 997.3 Iatrogen/Complications codes: 997.31 <sup>79</sup>	Review of medical files	HOSP	Associated with mechanical ventilation	≥16 yrs <sup>80</sup>			30	99		
	2004 - 2006	B-HDDS <sup>77</sup> (not present at admission)							≥16 yrs <sup>81</sup>			30	99		
USA, Cass 2013 [26]	01/2009 - 12/2009	Administrative and hospital surveillance data <sup>82,83</sup> (not stated)	Restricted definition for VAP <sup>84</sup>	Not stated, likely any	Codes <sup>1</sup> : 997.31 Iatrogen/Complications codes: 997.31 <sup>79</sup>	As defined by the hospital surveillance	ICU	<sup>85</sup>	≥18 yrs	25	100	28	100	83.33	0.75
	01/2009 - 12/2009	Expanded definition for VAP <sup>86</sup>	≥18 yrs						61	93	4	100	9.06	0.42	

<sup>76</sup> According to ICD-10 definition criteria (ICD-HAP)

<sup>77</sup> Has been compulsory for all in-patients in acute hospitals in Belgium

<sup>78</sup> AND a Belgian nomenclature code for artificial ventilation (211046)

<sup>79</sup> Ventilator-associated pneumonia

<sup>80</sup> Data present on admission files

<sup>81</sup> Data not present on admission files

<sup>82</sup> 3M Health Information Systems ClinTrac Abstracting Module

<sup>83</sup> From Greenville Memorial Hospital

<sup>84</sup> Diagnosis code 997.31: VAP; negative POA field

<sup>85</sup> Administrative data indicated an infection not present on admission, infection acquired during their hospitalization

<sup>86</sup> With 30 diagnosis codes (plus negative POA field)

Supplementary table 6

01/2009 - 12/2009	Restricted definition for VAP <sup>87</sup>	<b>Codes<sup>1</sup>: 997.31</b> <b>latrogen/Complications codes: 997.31<sup>79</sup></b>	≥18 yrs <sup>88</sup>	25	99	28	99	20.83	0.76
	Expanded definition for VAP <sup>89</sup>	<b>Codes<sup>1</sup>: 480.0, 480.1, 480.2, 480.3, 480.8,</b> 480.9, 481, 482.0, 482.1, 482.2, 482.30, 482.31, 482.32, 482.39, 482.40, 482.41, 482.49, 482.81, 482.82, 482.83, 482.84, 482.89, 482.9, 483.0, 483.1, 483.8, 485, 486, 487.0, 997.31 <b>Classical pneumonia codes: 480.0, 480.1, 480.2,</b> 480.3, 480.8, 480.9, 481, 482.0, 482.1, 482.2, 482.30, 482.31, 482.32, 482.39, 482.40, 482.41, 482.49, 482.81, 482.82, 482.83, 482.84, 482.89, 482.9, 483.0, 483.1, 483.8, 485, 486, 487.0 <b>latrogen/Complications codes: 997.31</b>		61	83	6	99	3.55	0.47

<sup>87</sup> Diagnosis code 997.31: VAP; negative POA field for population which required continuous invasive mechanical ventilation

<sup>88</sup> Mechanically ventilated patient

<sup>89</sup> With 30 diagnosis codes (plus negative POA field) for population which required continuous invasive mechanical ventilation

Supplementary table 7

**Supplementary table 7. Characteristics and validation measures of ICD-9 algorithms to diagnose pathogen-specific LRTI in adults**

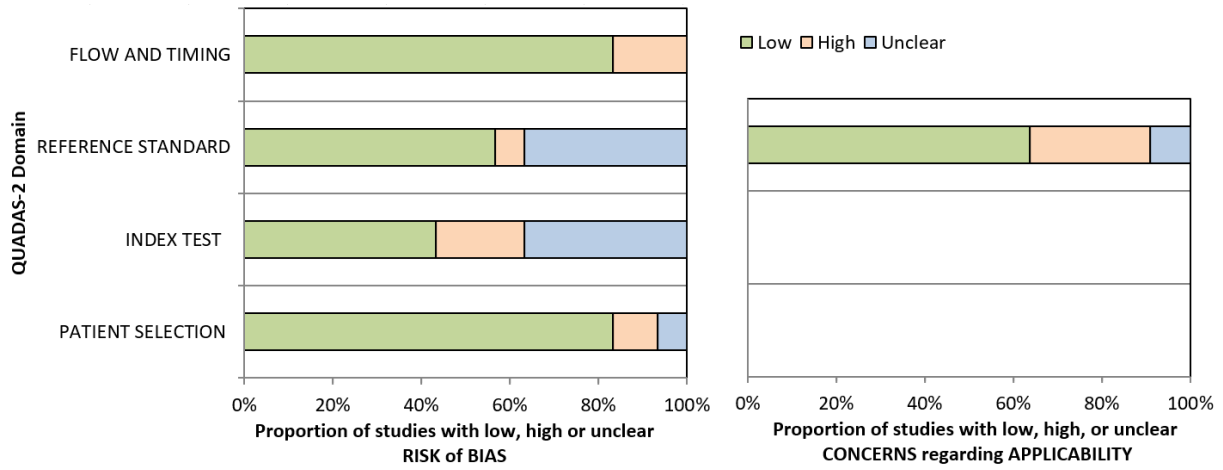
Country, reference, data source	Algorithm and coding position	Codes	Pathogen	Reference standard	Se (%)	Sp (%)	PPV (%)	NPV (%)	True pos.	False neg.	False pos.	True neg.	Sample size (reference)	Pr.	LR+	LR-
<b>Pneumonia</b>																
USA, (Higgins, 2020 [8]), data from 178 US hospitals in the Premier Healthcare Database	Primary diagnosis of pneumonia or a primary diagnosis of respiratory failure (ICD-9-CM codes: 518.81, 518.82, 518.84, and 799.1) or sepsis (ICD-9-CM codes: 785.52, 790.7, 995.91, 995.92, and 038.0-038.9) combined with a secondary diagnosis of pneumonia	482.41	MSSA	Blood or respiratory culture, urinary antigen, or PCR	14.2	99.9	91.1	95.4	1233	7454	120	152722	161529	0.8	142.0	0.9
		482.42			49.3	99.4	76	98.1	2849	2936	898	154379	161062	1.8	82.2	0.5
		481, 482.30	<i>Streptococcus pneumoniae</i>		60.1	99.2	73.4	98.5	3525	2345	1280	154668	161818	2.2	75.1	0.4
		482.1	<i>Pseudomonas</i> spp		46.9	99.7	80.3	98.5	2052	2321	505	156651	161529	1.3	156.3	0.5
		482.82	<i>Escherichia coli</i>		17.3	100.0	88.7	98.4	557	2661	71	158240	161529	0.3		0.8
		482	<i>Klebsiella pneumoniae</i>		35.7	99.9	79.1	99.1	774	1396	205	159154	161529	0.5	357.0	0.6
		482.2	<i>Haemophilus influenzae</i>		42.8	99.9	84.7	99.4	708	946	128	159747	161529	0.4	428.0	0.6
		483	<i>Mycoplasma pneumoniae</i>		53.5	99.8	61.8	99.7	564	491	348	160126	161529	0.3	267.5	0.5
		482.84	<i>Legionella</i> spp		78.4	99.9	82.5	99.9	486	134	103	160806	161529	0.3	784.0	0.2
		487.x, 488.x	Influenza virus		95.9	98.9	70.8	99.9	4168	178	1723	155460	161529	2.6	87.2	0.0
		480.1	RSV		24.1	100	67.2	99.9	41	129	20	161339	161529	0.0		0.8
480.2	Parainfluenza virus	14	100	57.1	99.9	20	123	15	161371	161529	0.0		0.9			
<b>Community-acquired pneumonia</b>																
USA, (Guevara, 1999 [11]), data from a community-based pneumonia incidence study in Ohio	ICD-9-CM code in first position	481	<i>S. pneumoniae</i>	<b>Class 1: Definite</b> (Isolated from blood or pleural fluid)	0	97.8	56.8	96.6	109		83		330	33.0	20.6	0.6
	ICD-9-CM code in 1-5 position				58.3	97.5	59.1	97.4	140		97		394	35.5	23.3	0.4
	ICD-9-CM code in first position	482.3			6.7	99.2	34.8	94.4	16		30		93	17.2	8.4	0.9
	ICD-9-CM code in 1-5 position				11.3	99.0	40.3	94.7	27		40		119	22.7	11.3	0.9
	ICD-9-CM code in first position	486			10.8	54.8	1.5	90.7	26		1727		1803	1.4	0.2	1.6
	ICD-9-CM code in 1-5 position				14.2	48.4	1.7	90.0	34		1975		2062	1.6	0.3	1.8
	ICD-9-CM code in 1-5 position, Group 2: group 1 + 481.00	38.2, 481.00			64.2	97.4	60.9	97.7	186		99		443	42.0	24.8	0.4

Supplementary table 7

Country, reference, data source	Algorithm and coding position	Codes	Pathogen	Reference standard	Se (%)	Sp (%)	PPV (%)	NPV (%)	True pos.	False neg.	False pos.	True neg.	Sample size (reference)	Pr.	LR+	LR-	
	ICD-9-CM code in 1-5 position, Group 3: Group 2 + 38.00	38.2, 481.00, 38.00			76.7	97.0	61.3	98.5	235		116		510	46.1	25.3	0.2	
	ICD-9-CM code in 1-5 position, Group 4: Group 3 + 482.30	38.2, 481.00, 38.00, 482.30			81.3	96.1	56.4	98.8	262		156		629	41.7	20.6	0.2	
	ICD-9-CM code in 1-5 position, Group 5: Group 4 + 518.81	38.2, 481.00, 38.00, 482.30, 518.81			81.3	96.0	56.2	98.8	298				1035	28.8	20.5	0.2	
	ICD-9-CM code in 1-5 position, Group 6: Group 5 + 486.00	38.2, 481.00, 38.00, 482.30, 518.81, 486.00			89.2	44.5	9.2	98.5	332				3097	10.7	1.6	0.2	
NL, (van de Garde, 2007 [13], patient data from a randomized open label clinical trial <sup>a</sup> Hospital discharge record <sup>b</sup> )	ICD-9 codes, position not stated, likely any	481	<i>S. pneumoniae</i>	Sputum samples and blood samples were collected, cultured, and evaluated following standard procedures. In addition, Binax NOW-tests were used to detect urinary antigen for <i>Legionella pneumophila</i> and <i>S. pneumoniae</i>	35								293				
		482.x, 483.x	Pneumonia with other organism specified		18.3									293			
		485-486	Pneumonia, organism unspecified		62.6										293		

<sup>a</sup> on efficacy of an early switch of intravenous antibacterial treatment to oral treatment of CAP; <sup>b</sup> from the medical registration department of the participating hospitals; CAP, community-acquired pneumonia; neg, negative; CM: clinical modifications; ICD, international classification of diseases; LR+: Likelihood ratio positive; LR-: Likelihood ratio negative; LRTI, lower respiratory tract infection; MSSA, Methicillin-sensitive *Staphylococcus aureus*; NL, The Netherlands; NPV, negative predictive value; pos, positive; PPV, positive predictive value; Pr, prevalence; RSV, respiratory syncytial virus; Se, sensitivity; Sp, specificity; USA, United States of America

**Supplementary figure 1. Results of the risk of bias assessment, QUADAS-2 adapted tool**





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