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REVIEW

Cardiovascular Data Quality in the Danish National Patient Registry (1977–2024): A Systematic Review

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Background: The increasing use of routinely collected health data for research puts great demands on data quality. The Danish National Patient Registry (DNPR) is renowned for its longitudinal data registration since 1977 and is a commonly used data source for cardiovascular epidemiology.

Objective: To provide an overview and examine determinants of the cardiovascular data quality in the DNPR.

Methods: We performed a systematic literature search of MEDLINE (PubMed) and the Danish Medical Journal, and identified papers validating cardiovascular variables in the DNPR during 1977–2024. We also included papers from reference lists, citations, journal e-mail notifications, and colleagues. Measures of data quality included the positive predictive value (PPV), negative predictive value, sensitivity, and specificity.

Results: We screened 2,049 papers to identify 63 relevant papers, including a total of 229 cardiovascular variables. Of these, 200 variables assessed diagnoses, 24 assessed treatments (10 surgeries and 14 other treatments), and 5 assessed examinations. The data quality varied substantially between variables. Overall, the PPV was ≥90% for 36% of variables, 80–89% for 26%, 70–79% for 16%, 60–69% for 7%, 50–59% for 4%, and <50% for 11% of variables. The predictive value was generally higher for treatments (PPV≥95% for 92%) and examinations (PPV≥95% for 100%) than for diagnoses (PPV≥80% for 71%). Moreover, the PPV varied for individual diagnoses depending on the algorithm used to identify them. Key determinants for validity were patient contact type (inpatient vs outpatient), diagnosis type (primary vs secondary), setting (university vs regional hospitals), and calendar year.

Conclusion: The validity of cardiovascular variables in the DNPR is high for treatments and examinations but varies considerably between individual diagnoses depending on the algorithm used to define them.

Keywords: cardiovascular diseases, epidemiological methods, medical record linkage, registries, validation studies

Introduction

Patient registries with complete nationwide coverage and individual-level linkage potential are rare.[1] The Danish National Patient Registry (DNPR), established in 1977, is renowned for its longitudinal data registration and is, therefore, a commonly used data source for population-based research.[2] It encompasses personal and admission data, and information on diagnoses, treatments, and examinations.[2] However, the increasing use of routinely collected health data for research puts great demands on data quality. Variables recorded in the DNPR are not automatically validated; consequently, the assessment of data quality relies on ad hoc validation studies. Although an increasing number of such validation studies have been published, the information is scattered and has not been systematically reviewed since 2015.[2]

The reporting of the cardiovascular data quality in registry-based research is often insufficient. Not uncommonly, papers only cite a single validation study, typically the most recent one (in terms of publication year) or the one reporting the highest positive predictive value (PPV). Optimally, referencing should reflect a summary of the evidence available from all existing validation studies for a specific variable in the study period. In addition to prioritizing larger over

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smaller validation studies, such summaries should consider the components of the algorithm used to identify a study variable and to what extent these components align with previous validation studies. Thus, the diagnosis code is only one component of an algorithm used to identify a disease in the DNPR. Other components include admission data (eg admission type, patient contact, and department specialty), other diagnostic specifications (such as primary vs secondary diagnoses), procedures, in-hospital medical treatment, previous medical history (to identify incident events), time since first diagnosis (to identify recurrent events), and calendar year.[2] The importance of individual algorithm components for the validity of a variable has not been examined.

To provide an overview of the cardiovascular data quality in the DNPR and to examine key determinants of validity, we reviewed all validated cardiovascular variables in the DNPR from 1977 through 2024.

Methods

Setting

The Danish healthcare system is universal and tax-supported, providing all Danish residents equal access to health care.[2,3] Thus, access to general practitioners, private practicing specialists, hospitals, outpatient specialty clinics, and partial reimbursement of prescribed medication is covered by taxes.[2,3] Self-payment covers the remaining costs related to medication and dental care.[2] Referral to hospitals or specialists is initiated by the general practitioner, excluding emergency-related hospital contacts and contacts to ophthalmologists and ear, nose, and throat specialists.[2,3]

The ten-digit Civil Personal Register (CPR) number, assigned to all persons residing in Denmark at birth or immigration,[4] allows individual-level linkage of the DNPR to other Danish registries.[4]

The Danish National Patient Registry

Coverage

The primary aim of the DNPR is to monitor hospital and health services utilization.[2] Since 1978, the DNPR has had complete nationwide coverage of inpatient contacts. From 1995 onwards, all outpatient, psychiatric, and emergency department contacts have been included.

Data types

The DNPR records administrative data, diagnoses, treatments, and examinations.[2] *Administrative* data include personal and admission data, eg hospital and department codes, admission type, patient contact type (inpatient [IN], outpatient [OUT], or emergency department [ED]), and dates of admission and discharge.[2] For each hospital contact, one primary (A) and optional secondary (B) diagnoses are registered in the DNPR.[2,3] The *diagnoses* are assigned at discharge, at transfer to another department, or at the end of an outpatient visit (before 2019 the diagnosis was assigned at the end of an outpatient course).[2] According to the classification systems used (see below), *treatments* are categorized as surgery, other treatments, anesthesia, and intensive care. To provide cardiological context, we focused on cardiac surgery and subcategorized "other treatments" into invasive procedures (eg radiofrequency ablation and percutaneous coronary intervention), in-hospital medical treatments, pacemakers, and mechanical circulatory support. Examinations include both non-invasive (eg cardiac CT angiography) and invasive examinations (eg coronary angiogram) (Figure 1).

Classification systems

The classifications used in the DNPR are provided in the Health Care Classification System (Danish, Sundhedsvæsenets Klassifikations System [SKS]).[2] The SKS is a collection of international, Nordic, and Danish classifications.[2] SKS codes contain up to ten alphanumeric characters, the first being a letter representing a primary group, following a monohierarchical classification system.[2] Thus, diagnoses are registered under "D", surgery under "K", other treatments under "B", anesthesia and intensive care under "N", and examinations under "U" or "ZZ".[2] Until the end of 1993, diagnoses were reported according to the World Health Organization's *International Classification of Diseases* (ICD), *eight revision* (ICD-8), and since 1994 according to the *tenth revision* (ICD-10).[2] From 1977–1995 surgeries were reported according to the Danish Classification of Surgical Procedures and Therapies, and since 1996 according to the Danish version of the Nordic Medico-Statistical Committee Classification of Surgical Procedures (NOMESCO).[2]

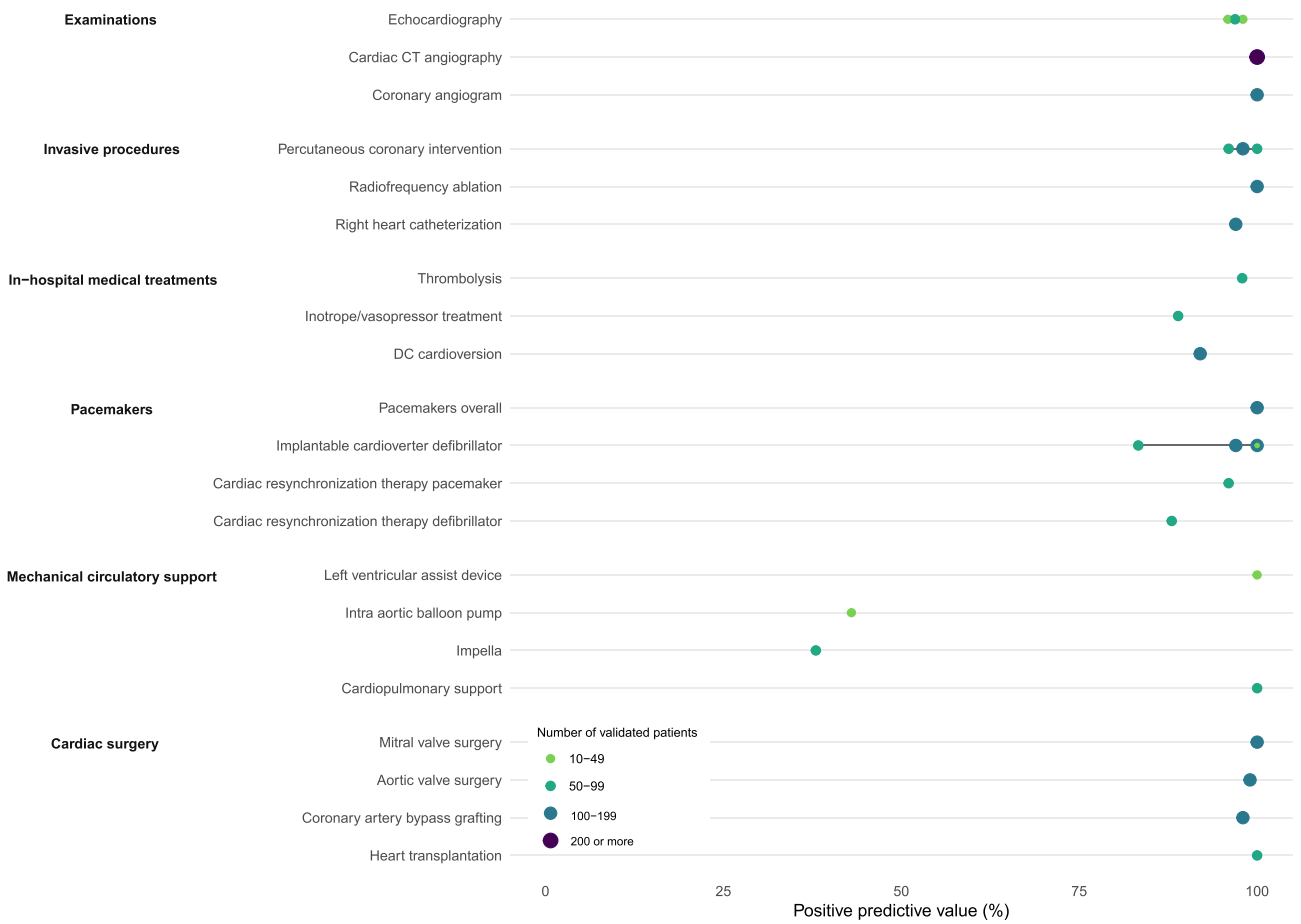

Figure 1 Overview of the range of positive predictive values reported for individual cardiovascular treatments and examinations in the Danish National Patient Registry (1977–2024).
Notes: The figure includes one PPV per validated variable. Thus, in cases where several PPVs were reported for a variable, we used the highest PPV. All PPVs for each validated variable are listed in Table 1.

All hospitals are legally required to upload their data to the DNPR at least monthly. In practice this is, however, often done on a weekly or daily basis.[2] Since 2003, private hospitals have been obliged to report to the DNPR.[2]

Measures of data quality

Data quality covers accuracy and completeness. Measures for accuracy include the PPV and the negative predictive value (NPV).[2,3] The *PPV* is the most often used measure and is defined as the proportion of patients registered with a given disease who truly have the disease. The *NPV* refers to the proportion of people without a given registration of a disease who truly do not have the disease. Measures of completeness, include sensitivity and specificity. *Sensitivity* is the proportion of true cases with a given disease who are correctly registered with that disease in the DNPR (true positive). *Specificity* is the proportion of people without a given disease who are correctly classified as unaffected in the registry (true negative). Of note, the NPV and specificity of cardiovascular variables in the DNPR are rarely assessed as they require a sample of people without diagnosis/procedure codes.

Systematic review

Search strategy

Figure 2 presents an overview of the review process, including the search string. To provide an overview of the data quality of cardiovascular variables in the DNPR, we performed a systematic literature search of MEDLINE (PubMed) and the Danish Medical Journal (http://ugeskriftet.dk/udgivelser). Both databases were searched until 2023. In practice, we performed two

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Table 1 Bibliography of All Validated Cardiovascular Variables in the Danish National Patient Registry (1977–2024)

Algorithm Components						n[c]	PPV; NPV; Sensitivity; Specificity[d]	Reference Standard	Reference
Codes (Chronological)[a]	Condition	Study Period	Specified Patient Subgroup	Contact Type; Diagnosis Type; Occurrence Type	Codes (Specified)[b]				
Diagnoses									
C00–D48: Neoplasms									
C38	Cardiac tumors	2010–2012	–	IN/OUT; A/B; 1st	C38, C380, C388, D151, D487A, C380X, ZM88400	26	PPV=84.6 (66.5–93.9)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
E00–E90: Endocrine, nutritional, and metabolic diseases									
E780	Hypercholesterolemia	2010–2012	–	IN/OUT; A/B; 1st	E780	94	PPV=95.7 (89.6–98.3)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
G00–G99: Diseases of the nervous system									
G45	Transient ischemic attack	1998–1999	–	IN[e]; A/B[e]; n/a	G45	38	PPV=57.9 (42.2–72.2) to 68.4 (52.5–80.9)	MR; DS	Krarup LH et al, Neuroepidemiology. 2007[7]
		1994–1999[e]	–	IN/OUT/ED; A/B[e]; n/a	G45	134	PPV=60.5 (52.0–68.3)	MR; DS	Johnsen SP et al, Clin Epidemiol. 2002[8]
		2017–2020	Age 28d–17y	IN/OUT/ED; A/B; 1st	G45	34	PPV=8.8 (3.1–23.0)	MR	Bindslev JB et al, Clin Epidemiol. 2023[9]
I00–I99: Diseases of the circulatory system									
I10	Arterial hypertension	1983–1990	–	IN; A; n/a	40199	310	PPV=40 (26–55) to 60 (49–70)[f]	MR	Nielsen HW et al, Ugeskr Læger. 1996[10]
		2010–2012	–	IN/OUT; A/B; 1st	I10–I15	97	PPV=91.8 (84.6–95.8)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
		1977–2010	Males	IN/OUT; A/B; n/a	400–404; I10–I15	524	PPV=88.2 (85.4–90.9)	PR	Schmidt M et al, BMJ Open 2013[11]
		2014–2015	Primary and secondary hypertension, age <16y	n/a; A/B; n/a	I10–I12, I15	200	PPV=93.5 (89.2–96.2); Se= 84.2 (78.9–88.4)	MR for PPV. Pediatric cases validated with MR for se	Langhoff AF et al, Acta Pediatr. 2019[12]

		2005–2017	–	IN/OUT; A/B; n/a	110–115	30,463	PPV=90.0 (89.7–90.4); NPV= 76.2 (76.1–76.3); Se=21.9 (21.6–22.1); Sp=99.0 (99.0–99.1)	Self-reported (survey)	Bonnesen K et al, Clin. Epidemiol. 2024[13]
1200	Acute coronary syndrome	1993–2003	–	IN/OUT/ED; A/B[e]; n/a	410, 42727; 1200, 121, 146	1,558	$PPV_{IN/OUT/ED}$=65.5 (63.1–67.9); PPV_{IN}=80.1 (77.7–82.3)	MR; DS; blood tests; ECG	Joensen AM et al, J Clin Epidemiol. 2009[14]
		2007	–	IN/OUT/ED; A/B; n/a	1200, 121, 122	494	$PPV_{verified}$=86.6 (83.4–89.4); $PPV_{verified+possible}$=87.9 (84.7–90.5)	MR; ECG; biomarkers; Possible cases fulfill criteria, but biochemical markers are missing	Bork CS et al, Dan Med J. 2017[15]
		2007	–	IN/OUT/ED: A; n/a	1200, 121, 122	398	$PPV_{verified}$=90.2 (86.9–92.8); $PPV_{verified+possible}$=91.5 (88.3–93.8)	MR; ECG; biomarkers; Possible cases fulfill criteria, but biochemical markers are missing	Bork CS et al, Dan Med J. 2017[15]
		2007	–	IN/OUT/ED: B; n/a	1200, 121, 122	96	$PPV_{verified}$=71.9 (62.2–79.9); $PPV_{verified+possible}$=72.9 (63.3–80.8)	MR; ECG; biomarkers; Possible cases fulfill criteria, but biochemical markers are missing	Bork CS et al, Dan Med J. 2017[15]
	Unstable angina pectoris	1993–2003	–	IN/OUT/ED; A/B[e]; n/a	1200	444	$PPV_{IN/OUT/ED}$=27.5 (23.5–31.8); PPV_{IN}=42.0 (36.0–48.0)	MR; DS; blood tests; ECG	Joensen AM et al, J Clin Epidemiol. 2009[14]
		2010–2012	–	IN; A/B; 1st	1200	96	PPV=87.5 (79.4–92.7)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
1209	Stable angina pectoris	1977–2013	Breast cancer	IN/OUT/ED[e]; A/B[e]; n/a	413; 120	15	PPV=46.7 (24.8–69.9)	Self-reported outcome	Langballe R et al, J Cancer Surviv. 2018[16]

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Table 1 (Continued).

Algorithm Components						n[c]	PPV; NPV; Sensitivity; Specificity[d]	Reference Standard	Reference
Codes (Chronological)[a]	Condition	Study Period	Specified Patient Subgroup	Contact Type; Diagnosis Type; Occurrence Type	Codes (Specified)[b]				
		2007	–	IN/OUT/ED; A/B; n/a	I209, I251	455	$PPV_{definite}$=5.9 (4.1–8.5); $PPV_{definite+probable}$ =45.9 (41.4–50.5)	MR	Bork CS et al, Dan Med J. 2017[15]
		2007	–	IN/OUT/ED; A; n/a	I209, I251	360	$PPV_{definite}$=4.2 (2.5–6.8); $PPV_{definite+probable}$=44.7 (39.7–49.9)	MR	Bork CS et al, Dan Med J. 2017[15]
		2007	–	IN/OUT/ED; B; n/a	I209, I251	95	$PPV_{definite}$=12.6 (7.4–20.8); $PPV_{definite+probable}$=50.5 (40.7–60.4)	MR	Bork CS et al, Dan Med J. 2017[15]
		2010–2012	–	IN; A/B; 1st	I20 (without I200), I25, I259	96	PPV=92.7 (85.7–96.4)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
I21	MI	1979–1980	–	IN; A/B; n/a	410–414	527	PPV=92.4 (89.8–94.4)	DS	Madsen M et al, Ugeskr laeger. 1990[17]
		1982–1991	–	IN; A/B; n/a	410, 42724, 42727, 42791, 42797	5,022	PPV_A=94.3 (93.6–94.9); PPV_{A+B}= 93.4 (92.6–94.0); Se_A=62.8 (61.7–64.0); Se_{A+B}=69.5 (68.4–70.6)	DANMONICA definite or possible cases incl. cardiac arrest	Madsen M et al, J Clin Epidemiol. 2003[18]
		1993–2003	–	IN/OUT/ED; A/B[e]; n/a	410; I21	1,072	$PPV_{IN/OUT/ED}$=81.9 (79.5–84.1); $PPV_{IN;\ A/B}$=92.4 (90.4–93.9); $PPV_{IN;\ A}$=94.4 (92.6–95.7)	MR; DS; blood tests; ECG	Joensen AM et al, J Clin Epidemiol. 2009[14]
		1996–2009	–	IN[e]; A; n/a	I21	148	PPV=100 (97.5–100)	MR	Coloma PM et al, BMJ Open 2013[19]
		1998–2007	–	IN/OUT; A; n/a	I21–I23	50	PPV=98.0 (89.5–99.7)	DS	Thygesen SK et al, BMC Med Res Methodol. 2011[20]
		2010–2012	–	IN; A/B; 1st	I21	99	PPV=97.0 (91.5–99.0)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]

		1977–2013	Breast cancer	IN/OUT/ED[e]; A/B[e]; n/a	410; I21–I23	2	PPV=100.0 (34.2–100.0)	Self-reported outcome	Langballe R et al, J Cancer Surviv. 2018[16]
		2001–2014	Diabetes mellitus	n/a; n/a; n/a	I21–I24	69	PPV=75.4 (64.0–84.0)	MR; DS; laboratory results; MRI; CT scans	Dalsgaard EM et al, BMC Public Health 2019[21]
	MI after PCI	2006–2012	DES, all hospitals	IN; A/B; n/a	I21	618	PPV=41.8 (37.9–45.7); NPV= 99.8 (99.6–99.9); Se=95.2 (92.0–97.2); Sp=93.4 (92.7–94.0)	MR	Egholm G et al, Clin Epidemiol. 2016[22]
		2006–2012	DES, all hospitals	IN; A; n/a	I21	338	PPV=70.4 (65.3–75.0); NPV= 99.2 (99.0–99.4); Se=85.0 (80.4–88.7); Sp=98.2 (97.8–98.5)	MR	Egholm G et al, Clin Epidemiol. 2016[22]
		2006–2012	DES, all hospitals, acute admissions only	IN; A/B; n/a	I21	357	PPV =73.4 (68.6–77.7); NPV= 99.6 (99.3–99.7); Se=93.9 (90.5–96.2); Sp=98.3 (97.9–98.6)	MR	Egholm G et al, Clin Epidemiol. 2016[22]
		2006–2012	DES, all hospitals, acute admissions only	IN; A; n/a	I21	284	PPV =81.0 (76.0–85.1); NPV= 99.1 (98.8–99.3); Se=82.1 (77.2–86.2); Sp=99.0 (98.7–99.2)	MR	Egholm G et al, Clin Epidemiol. 2016[22]
		2006–2012	DES, hospitals with CAG capability, acute admissions only	IN; A/B; n/a	I21	282	PPV=67.7 (62.1–72.9); NPV= 99.0 (98.7–99.2); Se=78.0 (72.4–82.7); Sp=98.3 (98.0–98.6)	MR	Egholm G et al, Clin Epidemiol. 2016[22]
		2006–2012	DES, hospitals with CAG capability, acute admissions only	IN; A; n/a	I21	189	PPV=86.8 (81.2–90.9); NPV= 97.9 (97.4–98.2); Se=58.0 (52.1–63.6); Sp=99.5 (99.3–99.7)	MR	Egholm G et al, Clin Epidemiol. 2016[22]
	STEMI	2010–2012	–	IN; A/B; 1st	I211B, I210B, I213	23	PPV=95.7 (79.0–99.2)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
	Non-STEMI	2010–2012	–	IN; A/B; 1st	I211A, I210A, I214	39	PPV=92.3 (79.7–97.4)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
	Recurrent MI	2010–2012	–	IN; A/B; 1st	I21	100	PPV=88.0 (80.2–93.0)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]

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Table 1 (Continued).

Algorithm Components						n[c]	PPV; NPV; Sensitivity; Specificity[d]	Reference Standard	Reference
Codes (Chronological)[a]	Condition	Study Period	Specified Patient Subgroup	Contact Type; Diagnosis Type; Occurrence Type	Codes (Specified)[b]				
	Perioperative MI	2016–2021	Age ≥18y with a non-cardiac surgery code at admission for MI or < 30d prior to MI	IN; A/B[e]; 1st	I21 + KA–E, KG, KH, KQ, KJ, KK, KL, KM, KN, or KP	167	PPV=92.2 (87.1–95.4)	MR	Korsgaard S et al, Circ Cardiovasc Qual outcomes 2022[23]
I24–I25	Coronary heart disease, overall	1977–2013	Breast cancer	IN/OUT/ED[e]; A/B[e]; n/a	411, 412, 414; I24–I25	8	PPV=50.0 (21.5–78.5)	Self-reported outcome	Langballe R et al, J Cancer Surviv. 2018[16]
I26	PE	1994–2006	–	IN/OUT/ED; A/B; n/a	45099; I26	353	PPV_{All}=67.4 (62.4–72.1); $PPV_{IN/OUT}$=82.1 (77.2–86.1); PPV_{ED}= 29.6 (22.0–38.5); PPV_{A}=87.0 (81.9–90.9)	MR; DS; blood tests; ultrasound; venography; echo; V-P lung scan; CT scan	Severinsen MT et al, J Clin Epidemiol. 2010[24]
		2010–2012	–	IN/OUT; A/B; 1st	I26	49	PPV=89.8 (78.2–95.6)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
		1980–2001	During pregnancy or postpartum	IN[e]; A[e]; n/a	45000–45099; I260–I269 + (650–666; O80–84)	22	$PPV_{preg+postpartum}$=81.8 (59.7–94.8)[f]; PPV_{preg}= 63.6 (40.7–82.8)[f]	MR	Larsen TB et al, J Clin Epidemiol. 2005[25]
		2003–2006	After admission to stroke unit and age ≥18y	IN; A/B; n/a	I26	11	PPV=90.9 (62.3–98.4); NPV= 97.4 (95.8–98.4); Se=0.0 (0.0–32.4); Sp=100 (99.3–100)	MR	Ingeman A et al, Clin Epidemiol. 2010[26]
		2008–2014	<6 mo after surgical treatment for spinal degenerative diseases	IN/OUT[e]; A[e]; n/a	I260, I269, T817D	2	PPV=50.0 (9.5–90.6)	MR; patient confirmation	Winther C et al, Dan Med J. 2019[27]
	Recurrent PE	2010–2012	–	IN; A/B; 1st	I26	54	PPV=70.4 (57.2–80.9)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
I26	Blood clots in head, lung, arms, legs, or pelvis	1977–2013	Breast cancer	IN/OUT/ED[e]; A/B[e]; n/a	432–435, 44441–44490, 450; I26, I63–I66, I693, I694, I742–I745	17	PPV=70.6 (46.9–86.7)	Self-reported outcome	Langballe R et al, J Cancer Surviv. 2018[16]
I27	Pulmonary hypertension	2010–2012	–	IN/OUT; A/B; 1st	I27	100	PPV=87.0 (79.0–92.2)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]

I30–I32	Pericarditis	2010–2012	–	IN/OUT; A/B; 1st	I30–I32	98	PPV=91.8 (84.7–95.8)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
	Pericarditis or pericardial constriction	1977–2013	Breast cancer	IN/OUT/ED[e]; A/B[e]; n/a	39109, 39300, 39301, 420, 42301–42309, 42300; I010, I092, I30, I310, I32, I311	2	PPV=100.0 (34.2–100.0)	Self-reported outcome	Langballe R et al, J Cancer Surviv. 2018[16]
I312	Non-traumatic bleeding (thorax and respiratory passages)	2019 March–December	Age ≥65y	IN/OUT/ED; A/B; 1st	I312, J942, R04	102	PPV=94.1 (87.8–97.3)	MR	Thaarup M et. al. Clin Epidemiol. 2023[28]
I33	Infective endocarditis	2007–2017	–	IN/OUT[e] (Only IN, as no OUT contacts were identified); A/B[e]; n/a	I33, I38–I39	1,484	PPV=77.1 (74.9–79.2)	MR	Lassen H et al, Int J. Infect Dis. 2020[29]
		2010–2012	–	IN/OUT; A/B; 1st	I33, I38, I398	96	PPV=82.3 (73.5–88.6)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
		2010–2012	–	IN; A/B; 1st	I33, I38, I398	92	PPV=83.7 (74.8–89.9); $PPV_{admission\ <2\ weeks}$=65.2 (44.9–81.2); $PPV_{admission\ \geq 2}$ =89.9 (80.5–95.0)	MR; DS	Østergaard L et al, Epidemiol Infect. 2018[30]
		2010–2012	Prosthetic heart valve	IN; A/B; 1st	I33, I38, I398, KFKD, KFMD, KFGE, KFJF	15	PPV=86.7 (62.1–96.3)	MR; DS	Østergaard L et al, Epidemiol Infect. 2018[30]
		2010–2012	No prosthetic heart valve	IN; A/B; 1st	I33, I38, I398	77	PPV=83.1 (73.2–89.9)	MR; DS	Østergaard L et al, Epidemiol Infect. 2018[30]
		2010–2012	Cardiac implantable electronic device	IN; A/B; 1st	I33, I38, I398, BFCA0, BFCB0	21	PPV=81.0 (60.0–92.3)	MR; DS	Østergaard L et al, Epidemiol Infect. 2018[30]
		2010–2012	No implantable electronic device	IN; A/B; 1st	I33, I38, I398	71	PPV=84.5 (74.4–91.1)	MR; DS	Østergaard L et al, Epidemiol Infect. 2018[30]
		2010–2012	Transesophageal echo during admission	IN; A/B; 1st	I33, I38, I398, UXUC81	63	PPV=82.5 (71.4–90.0)	MR; DS	Østergaard L et al, Epidemiol Infect. 2018[30]
		2010–2012	No transesophageal echo during admission	IN; A/B; 1st	I33, I38, I398	29	PPV=86.2 (69.4–94.5)	MR; DS	Østergaard L et al, Epidemiol Infect. 2018[30]

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Table 1 (Continued).

Algorithm Components						n[c]	PPV; NPV; Sensitivity; Specificity[d]	Reference Standard	Reference
Codes (Chronological)[a]	**Condition**	**Study Period**	**Specified Patient Subgroup**	**Contact Type; Diagnosis Type; Occurrence Type**	**Codes (Specified)[b]**				
		2010–2012	PET/CT during admission	IN; A/B; 1st	I33, I38, I398 WDIPSFAXX, WDLPSFAXX, WDTCPXYXX	4	PPV=75.0 (30.1–95.4)	MR; DS	Østergaard L et al, Epidemiol Infect. 2018[30]
		2010–2012	No PET/CT during admission	IN; A/B; 1st	I33, I38, I398	88	PPV=84.1 (75.1–90.3)	MR; DS	Østergaard L et al, Epidemiol Infect. 2018[30]
I34–I39	Valvular heart disease	1977–2013	Breast cancer	IN/OUT/ED[e]; A/B[e]; n/a	394–397, 424; I05–I08, I34–I39	11	PPV=72.7 (43.4–90.3)	Self-reported outcome	Langballe R et al, J Cancer Surviv. 2018[16]
I34	Mitral regurgitation or stenosis	2010–2012	–	IN/OUT; A/B; 1st	I05, I34, I390, I511A	49	PPV=95.9 (86.3–98.9)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
I35	Aortic regurgitation or stenosis	2010–2012	–	IN/OUT; A/B; 1st	I06, I35, I391	50	PPV=98.0 (89.5–99.7)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
I40	Myocarditis	2010–2012	–	IN/OUT; A/B; 1st	I40, I41, I090, I514	66	PPV=63.6 (51.6–74.2)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
I42	Cardiomyopathy	2010–2012	–	IN/OUT; A/B (except takotsubo cardiomyopathy IN only); 1st	I420, I421, I422, I425, I428A, I428B	89	PPV=89.9 (81.9–94.6)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
	Peripartum cardiomyopathy	2005–2014	Registered <9 mo before or 12 mo after delivery or stillbirth recorded in DNPR, MBR or CDR	n/a; n/a; n/a	I42	143	PPV=30.1 (23.2–38.0)	MR	Ersbøll AS et al, Euro J Heart Fail. 2017[31]
I420	Dilated cardiomyopathy	2010–2012	–	IN/OUT; A/B; 1st	I420	20	PPV=75.0 (53.1–88.8)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
I421–I422	Hypertrophic cardiomyopathy	2010–2012	–	IN/OUT; A/B; 1st	I421, I422	20	PPV=90.0 (69.9–97.2)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
I425	Restrictive cardiomyopathy	2010–2012	–	IN/OUT; A/B; 1st	I425	9	PPV=77.8 (45.3–93.7)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]

I428A	Arrhythmogenic right ventricular cardiomyopathy	2010–2012	–	IN/OUT; A/B; 1st	I428A	20	PPV=100.0 (83.9–100.0)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
I428B	Takotsubo cardiomyopathy	2010–2012	–	IN; A/B; 1st	I428B	20	PPV=100.0 (83.9–100.0)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
I42–I43+I50	Cardiomyopathy or congestive heart failure	1977–2013	Breast cancer	IN/OUT/ED[e]; A/B[e]; n/a	425, 42709–42719, 428; I42–I43, I50, I110, I130, I132	6	PPV=16.7 (3.0–56.4)	Self-reported outcome	Langballe R et al, J Cancer Surv. 2018[16]
I43	Peripartum cardiomyopathy	2005–2014	Registered <9 mo before or 12 mo after delivery or stillbirth recorded in DNPR, MBR or CDR	n/a; n/a; n/a	I43	3	PPV=33.3 (6.2–79.2)	MR	Ersbøll AS et al, Euro J Heart Fail. 2017[31]
I44	Bradycardia	2010–2012	–	IN/OUT; A/B; 1st	I440, I441, I442, I443, I455A, I455B, I455C, I455G	100	PPV=87.0 (79.0–92.2)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
I44–I45	Atrioventricular block, left bundle branch block, and atrial fibrillation	1977–2013	Breast cancer	IN/OUT/ED[e]; A/B[e]; n/a	42720–42797; I44–I45, I47–I49	29	PPV=69.0 (50.8–82.7)	Self-reported outcome	Langballe R et al, J Cancer Surviv. 2018[16]
I46	Cardiac arrest	1993–2003	–	IN/OUT/ED; A/B[e]; n/a	42727; I46	42	$PPV_{IN/OUT/ED}$=50.0 (35.5–64.5); PPV_{IN}=53.1 (36.5–69.1)	MR; DS; blood tests; ECG	Joensen AM et al, J Clin Epidemiol. 2009[14]
		2010–2012	–	IN; A/B; 1st	I46	100	PPV=94.0 (87.5–97.2)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
I47	Ventricular tachycardia or fibrillation	2010–2012	–	IN/OUT; A/B; 1st	I470, I472, I490	96	PPV=80.2 (71.1–87.0)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
I48	Atrial fibrillation or flutter	1980–2002	–	n/a; n/a; n/a	42793, 42794; I48	174	PPV=98.9 (95.9–99.7)	MR; heart rhythm documentation	Frost L et al, AM J Med. 2007[32]
		1980–2002	–	n/a; n/a; n/a	42793, 42794; I48	116	PPV=96.6 (91.5–98.7)	MR; heart rhythm documentation	Frost L et al, Arch Intern Med. 2004[33]

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Table 1 (Continued).

Algorithm Components						n[c]	PPV; NPV; Sensitivity; Specificity[d]	Reference Standard	Reference
Codes (Chronological)[a]	Condition	Study Period	Specified Patient Subgroup	Contact Type; Diagnosis Type; Occurrence Type	Codes (Specified)[b]				
		1993–2009	–	IN/OUT/ED; A/B; n/a	42793, 42794; I48	284	PPV_{All}=92.3 (88.6–94.8); $PPV_{IN/OUT}$=94.0 (90.5–96.3) (independent of diagnosis type and department specialty); PPV_{ED}= 64.7 (41.3–82.7)	MR; heart rhythm documentation	Rix TA et al, Scand Cardiovasc J. 2012[34]
		2010–2012	–	IN/OUT; A/B; 1st	I48	97	PPV=94.9 (88.5–97.8)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
I489A	Atrial flutter	1977–1999	–	IN/OUT/ED; A/B; n/a	42794; I489A	108	PPV=50.0 (40.7–59.3)	MR; heart rhythm documentation	Rix TA et al, Scand Cardiovasc J. 2012[34]
I50	Heart failure	1998–1999	–	IN; A/B; n/a	I50	156	PPV=80.8 (73.9–86.2); NPV= 90.1 (88.9–91.2); Sp=98.9 (98.5–99.2); Se=29.4 (25.3–33.9)	Clinical examination	Kümler T et al, Eur J Heart Fail. 2008[35]
		1998–2007	–	IN/OUT; A; n/a	I50, I110, I130, I132	50	PPV=100 (92.9–100)	DS	Thygesen SK et al, BMC Med Res Methodol. 2011[20]
		2007	–	IN/OUT/ED; A/B; n/a	I500–I509	500	$PPV_{Overall\ (definite+probable)}$ =83.6 (80.1–86.6); PPV_{A}=88.0 (84.5–90.8); PPV_{B}=66.0 (56.3–74.5)	MR; DS	Delekta J et al, Dan Med J. 2018[36]
		2010–2012	–	IN; A/B; 1st	I500, I501, I502, I503, I508, I509, I110, I130, I132, I420, I426, I427, I428, I429	96[h]	$PPV_{IN;\ A/B;\ 1st}$ =75.8 (66.3–83.3); $PPV_{IN;\ A/B;\ 2nd}$ =76.0 (66.6–83.5)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
		2005–2007	Heart failure at university hospital cardiac care unit	IN/OUT; A/B; n/a	I110, I130, I132, I420, I426–9, I500–I501, I509	758	$PPV_{Overall}$: 84.0 (81.3–86.5); $PPV_{First\text{-}time\ events}$: 77.9 (74.1–81.6)[f]	MR	Mard S et al, Clin Epidemiol. 2010[37]

		2016–2018	Reduced ejection fraction (EF ≤40%), surviving at least 120 d and receiving renin-angiotensin system inhibitors and/or beta-blockers	IN/OUT; A; 1st	I50	485	PPV=94.9 (92.5–96.5); NPV= 63.0 (56.5–69.1); Se=85.0 (81.8–87.8); Sp=84.7 (78.3–89.4)	MR; echo	Madelaire C et al, Clin Epidemiol. 2020[38]
		2017–2022	–	IN/OUT; A/B; 1st	I130, I132, I420, I426–I429, I500–I502, I508, I509, I510	200[h]	$PPV_{IN/OUT;\ A/B;\ 1st}$=80.5 (74.5–85.4); $PPV_{IN;\ A;\ 1st}$=80.0 (67.0–88.8); $PPV_{IN;\ B;\ 1st}$=76.0 (62.6–85.7); $PPV_{OUT;\ A;\ 1st}$=80.0 (67.0–88.8); $PPV_{OUT;\ B;\ 1st}$=86.0 (73.8–93.1)	MR	Bonnesen K et al, Int J Popul Data Sci. 2024[39]
		2017–2022	–	IN/OUT; A; 1st	I50	91	PPV=82.4 (73.3–88.9)	MR	Bonnesen K et al, Int J Popul Data Sci. 2024[39]
	Readmission for heart failure	2017–2022	Readmission after implantable cardioverter-defibrillator	IN/OUT; A; 2nd	I130, I132, I420, I426–I429, I500–I502, I508, I509, I510 after procedures BFCB00, BFCB01, BFCB20	71[h]	$PPV_{IN/OUT;\ A;\ 2nd}$=25.4 (16.7–36.6); $PPV_{IN;\ A;\ 2nd}$=38.1 (20.8–59.1); $PPV_{OUT;\ A;\ 2nd}$=20.0 (11.2–33.0)	MR	Bonnesen K et al, Int J Popul Data Sci. 2024[39]
			Readmission after cardiac resynchronization therapy	IN/OUT; A; 2nd	I130, I132, I420, I426–I429, I500–I502, I508, I509, I510 after procedures BFCB05, BFCB06, BFCA21, BFCA63, BFCB03, BFCB21	62[h]	$PPV_{IN/OUT;\ A;\ 2nd}$=17.7 (10.2–29.0); $PPV_{IN;\ A;\ 2nd}$=38.5 (17.7–64.5); $PPV_{OUT;\ A;\ 2nd}$=12.2 (5.7–24.2)	MR	Bonnesen K et al, Int J Popul Data Sci. 2024[39]
	Peripartum heart failure	2005–2014	Registered <9 mo before or 12 mo after delivery or stillbirth recorded in DNPR, MBR or CDR	n/a; n/a; n/a	I50	114	PPV=39.5 (31.0–48.7)	MR	Ersbøll AS et al, Euro J Heart Fail. 2017[31]

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Table 1 (Continued).

Algorithm Components						n[c]	PPV; NPV; Sensitivity; Specificity[d]	Reference Standard	Reference
Codes (Chronological)[a]	**Condition**	**Study Period**	**Specified Patient Subgroup**	**Contact Type; Diagnosis Type; Occurrence Type**	**Codes (Specified)[b]**				
I60	Non-traumatic bleeding	2019 March–December	Age ≥65y	IN/OUT/ED; A/B; 1st	I60, I61, I62, I312, J942, R04, K228(F), K250, K252, K254, K256, K260, K262, K264, K266, K270, K272, K274, K276, K280, K282, K284, K286, K290, K298 (A), K625, K638B, K638C, K661, K838(F), K868(G), K920, K921, K922, M250, N938, N939, N95, R31, R58	907[h]	$PPV_{IN/OUT/ED;\ A/B;\ 1st}$=94.1 (92.3–95.4); $PPV_{IN/OUT/ED;\ A;\ 1st}$= 98.7 (97.6–99.3); $PPV_{IN/OUT/ED;\ B;\ 1st}$=68.8 (60.7–75.9)	MR	Thaarup M et al, Clin Epidemiol. 2023[28]
I60–I69	Cerebrovascular disease	1994–1999	–	IN/OUT/ED; A/B[e]; n/a	I60–I698, G45	565	PPV=68.5 (64.6–72.2)	MR; DS	Johnsen SP et al, J Clin Epidemiol. 2002[8]
		1998–1999	–	IN[e]; A/B[e]; n/a	I60–I69, G45	236	PPV=78.4 (72.7–83.2) to 80.1 (74.5–84.7)	MR; DS	Krarup LH et al, Neuroepidemiology. 2007[7]
		1998–2007	–	IN/OUT; A; n/a	I60–I69, G45–G46	50	PPV=94.0 (83.8–97.9)	DS	Thygesen SK et al, BMC Med Res Methodol. 2011[20]
I60–I64	Stroke	1994–1999[e]	–	IN/OUT/ED; A/B[e]; n/a	I60–I64	377	PPV=79.3 (74.9–83.1)	MR; DS	Johnsen SP et al, J Clin Epidemiol. 2002[8]
		1998–1999	–	IN[e]; A/B[e]; n/a	I60–I64	164	PPV=80.5 (73.8–85.8) to 86.0 (79.8–90.5)	MR; DS	Krarup LH et al, Neuroepidemiology. 2007[7]
		1980–2002	Atrial fibrillation/flutter	n/a; A/B; n/a	430–434, 436; I60–I64	164	PPV=97.0 (93.1–98.7)	MR	Frost L et al, AM J Med. 2007[32]

		1993–2009	Age 50–64y, no previous cancer	IN/OUT/ED; A/B; 1st	430, 431, 433, 434, 43601, 43690; I60, I61, I63, I64	3,326[h]	$PPV_{IN/OUT/ED;\ A/B;\ 1st}$=69.3 (67.7–70.9); $PPV_{IN;\ A/B;\ 1st}$=79.6 (77.9–81.3)[f]; $PPV_{OUT;\ A/B;\ 1st}$=43.0 (37.6–48.5)[f]; $PPV_{ED;\ A/B;\ 1st}$=54.1 (50.9–57.5)[f]	MR; DS	Lühdorf P et al, Scand J Pub Health 2017[40]
		1993–2009	Age 50–64y, no previous cancer	IN/OUT/ED; A/B; 1st	I60	3,326	PPV=60.6 (53.4–67.7)[f]	MR; DS	Lühdorf P et al, Scand J Pub Health 2017[40]
		1993–2009	Age 50–64y, no previous cancer	IN/OUT/ED; A/B; 1st	I61	3,326	PPV=73.1 (68.1–78.0)[f]	MR; DS	Lühdorf P et al, Scand J Pub Health 2017[40]
		1993–2009	Age 50–64y, no previous cancer	IN/OUT/ED; A/B; 1st	I63	3,326	PPV=80.1 (77.9–82.3)[f]	MR; DS	Lühdorf P et al, Scand J Pub Health 2017[40]
		1993–2009	Age 50–64y, no previous cancer	IN/OUT/ED; A/B; 1st	I64	3,326	PPV=57.8 (55.4–60.3)[f]	MR; DS	Lühdorf P et al, Scand J Pub Health 2017[40]
		2001–2014	Diabetes mellitus	n/a; n/a; n/a	I61–I65	46	PPV=69.6 (55.2–80.9)	MR; DS; laboratory results; MRI; CT scans	Dalsgaard EM et al, BMC Public Health 2019[21]
		2010	Admission to neurologic wards	IN; A; n/a	I61, I63–I64	46	PPV=93.5 (82.5–97.8); NPV= 71.8 (62.8–79.4); Se=58.1 (46.7–68.7); Sp=96.3 (89.8–98.8)	MR including MRI and CT scan for PPV. Other neurologic disorders were included to assess Se, Sp, and NPV	Wildenschild K et al, Clin Epidemiol. 2013[41]
		2017–2020	Age 28d–17y	IN/OUT/ED; A/B; 1st	I60–I64, I67–I68, G08, G45	309	PPV=38.8 (33.6–44.4)	MR	Bindslev JB et al, Clin Epidemiol. 2023[9]
I60–I62	Hemorrhage stroke	2001–2014	Diabetes mellitus	n/a; n/a; n/a	I60–I62	5	PPV=60.0 (23.1–88.2)	MR; DS; laboratory results; MRI; CT scans	Dalsgaard EM et al, BMC Public Health 2019[21]

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Table 1 (Continued).

Algorithm Components						n[c]	PPV; NPV; Sensitivity; Specificity[d]	Reference Standard	Reference
Codes (Chronological)[a]	**Condition**	**Study Period**	**Specified Patient Subgroup**	**Contact Type; Diagnosis Type; Occurrence Type**	**Codes (Specified)[b]**				
		2019 March–December	Age ≥65y	IN/OUT/ED; A/B; 1st	I60–I62	168	PPV=92.9 (87.9–95.9)	MR	Thaarup M et. al. Clin Epidemiol. 2023[28]
I60	Subarachnoid hemorrhage	1998–1999	–	IN[e]; A/B[e]; 1st	I60	3	PPV=66.7 (20.8–93.9)	MR; DS	Krarup LH et al, Neuroepidemiology. 2007[7]
		1994–1999[e]	–	IN/OUT/ED; A/B[e]; n/a	I60	29	PPV=48.3 (31.4–65.6)	MR; DS	Johnsen SP et al, J Clin Epidemiol. 2002[8]
		1977–1995	–	IN[e]; A/B[e]; n/a	430; I60	191	$PPV_{neurosurgery\ wards}$=93 (85–98)[f]; $PPV_{neurology\ wards}$=75 (60–87)[f]; $PPV_{non\text{-}specialty\ wards}$=47 (36–59)[f]	MR; DS; autopsy reports	Gaist D et al, BMJ. 2000[42]
		2008–2014	Age ≥18y	IN; A; n/a	I600–I609	842	PPV=63.8 (60.5–67.0)	MR; DS; imaging; spinal fluid analysis	Sonne A et al, Clin Epidemiol. 2019[43]
		2015–2018	Emergency telephone call to the Copenhagen emergency medical dispatch center identified in DNPR or at a department of neurosurgery and neurointensive care	IN; A[e]; n/a	I600–I609	668	PPV=33.5 (30.1–37.2)	MR	Sonne A et al, Scand J Trauma Resusc Emerg Med. 2021[44]
		2017–2020	Age 28d–17y	IN/OUT/ED; A/B; 1st	I60	30	$PPV_{for\ any\ type\ of\ stroke}$=6.7 (1.9–21.3); PPV_{SAH}=0 (0.0–11.4)	MR	Bindslev JB et al, Clin Epidemiol. 2023[9]
I61	ICH	1998–1999	–	IN[e]; A/B[e]; 1st	I61	23	PPV=73.9 (53.5–87.5)	MR; DS	Krarup LH et al, Neuroepidemiology. 2007[7]

		1994–1999[e]	–	IN/OUT/ED; A/B[e]; n/a	I61	35	PPV=65.7 (49.2–79.2)	MR; DS	Johnsen SP et al, J Clin Epidemiol. 2002[8]
		2009–2017	Age >20y	IN; A; n/a	I61	3,169[h]	$PPV_{IN;\ A;\ n/a}$=76.2 (74.7–77.6); $PPV_{IN;\ B;\ n/a}$=49.4 (45.5–53.3); $PPV_{IN;\ A/B;\ n/a}$=71.7 (70.3–73.1); $PPV_{OUT/ED;\ A/B;\ n/a}$=7.4 (3.2–16.1); $PPV_{IN/OUT/ED;\ A/B;\ n/a}$=70.6 (69.1–72.0)	DS; brain imaging reports	Hald SM et al, Clin Epidemiol. 2020[45]
		2010–2015	Age>18y	IN; A; n/a	I61	400	PPV=89.5 (86.1–92.1)	DS; brain imaging reports	Hald SM et al, Clin Epidemiol. 2018[46]
		2017–2020	Age 28d–17y	IN/OUT/ED; A/B; 1st	I61–I62	107	PPV_{ICH}= 37.4 (28.8–46.8); $PPV_{any\ type\ of\ stroke}$=42.1 (33.1–51.5)	MR	Bindslev JB et al, Clin Epidemiol. 2023[9]
	Spontaneous ICH	2009–2017	Age >20y	IN; A; n/a	I61	3,169[h]	$PPV_{IN;\ A;\ n/a}$=70.2 (68.6–71.8); $PPV_{IN;\ B;\ n/a}$=43.7 (39.9–47.6); $PPV_{IN;\ A/B;\ n/a}$=65.8 (64.3–67.3); $PPV_{OUT/ED;\ A/B;\ n/a}$=7.4 (3.2–16.1); $PPV_{IN/OUT/ED;\ A/B;\ n/a}$=64.8 (63.3–66.3)	DS; brain imaging reports	Hald SM et al, Clin Epidemiol. 2020[45]
		2010–2015	Age >18y	IN; A; n/a	I61	400	PPV=76.8 (72.4–80.6)	DS; brain imaging reports	Hald SM et al, Clin Epidemiol. 2018[46]
	Recurrence of spontaneous ICH	2009–2018	First-time spontaneous ICH with a 120d blank period. See paper for different follow up	IN[e]; A[e]; 1st	I61	98	PPV=80.6 (71.7–87.2); NPV=98.2 (97.5–98.6); Se=63.7 (55.0–71.6); Sp=99.2 (98.8–99.5)	MR; brain imaging reports	Jensen MM et al, Clin Epidemiol. 2021[47]
I620	Acute non-traumatic subdural hematoma	2000–2012	–	IN; A; n/a	I620	45	PPV=62.2 (47.6–74.9)	MR	Poulsen FR et al, Pharmacoepidemiol Drug Saf. 2016[48]
I62+I65–I69	Other cerebrovascular disease	1998–1999	–	IN[e]; A/B[e]; 1st	I62+I65–I69	34	PPV=5.9 (1.6–19.1) to 17.7 (8.4–33.5)	MR; DS	Krarup LH et al, Neuroepidemiology. 2007[7]
		2017–2020	Age 28d–17y	IN/OUT/ED; A/B; 1st	I67–I68, except I676 + I676A	43	PPV=39.5 (26.4–54.4); $PPV_{stroke\ as\ reference}$=11.6 (5.1–24.5)	MR	Bindslev JB et al, Clin Epidemiol. 2023[9]

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Table 1 (Continued).

Algorithm Components						n[c]	PPV; NPV; Sensitivity; Specificity[d]	Reference Standard	Reference
Codes (Chronological)[a]	Condition	Study Period	Specified Patient Subgroup	Contact Type; Diagnosis Type; Occurrence Type	Codes (Specified)[b]				
		1994–1999[e]	–	IN/OUT/ED; A/B[e]; n/a	I62+I65–I698	54	PPV=33.3 (22.2–46.6)	MR; DS	Johnsen SP et al, J Clin Epidemiol. 2002[8]
I63–I68	Pediatric stroke	2010–2015	Age 28d–16y	IN; n/a; n/a	I63–I639, I64–I649, I67–I679, I68–I689	152	$PPV_{any\ time}$=74.3 (66.9–80.6); $PPV_{ischemic\ stroke}$=53.3 (45.4–61.0)	MR	Helmuth IG et al, Pediatric Neurol. 2018[49]
I63–I64	Pediatric arterial thrombosis	1994–2006	Age 0–18y	IN/OUT/ED[e]; A/B; n/a	I63–I64, H341–H342, I74, N280A, N280D, I21	472	PPV_{all}=53.6 (49.1–58.1); PPV_{ED}= 7.3 (2.5–19.4); PPV_{ward}=58.0 (53.3–62.6); $PPV_{neonates}$=75.3 (64.9–83.4)	MR; lab tests; ECG; radiology reports	Tuckuviene R et al, Clin Epidemiol. 2010[50]
I63	Ischemic stroke	1994–1999	–	IN/OUT/ED; A/B[e]; n/a	I63	113	PPV=87.6 (80.3–92.5)	MR; DS	Johnsen SP et al, J Clin Epidemiol. 2002[8]
		1998–1999	–	IN[e]; A/B[e]; 1[st]	I63	33	PPV=97.0 (84.7–99.5) to 100 (89.6–100)	MR; DS	Krarup LH et al, Neuroepidemiology. 2007[7]
		2001–2014	Diabetes mellitus	n/a; n/a; n/a	I63	23	PPV=78.3 (58.1–90.3)	MR; DS; laboratory results; MRI; CT scans	Dalsgaard EM et al, BMC Public Health 2019[21]
		2017–2020	Age 28d–17y	IN/OUT/ED; A/B; 1[st]	I63 except I636	54	PPV=83.3 (71.3–91.0)	MR	Bindslev JB et al, Clin Epidemiol. 2023[9]
I636	Central venous thrombosis	2017–2020	Age 28d–17y	IN/OUT/ED; A/B; 1[st]	I636, I676, I676A, G08	13	PPV=30.8 (12.7–57.6)	MR	Bindslev JB et al, Clin Epidemiol. 2023[9]
I64	Unspecified stroke	1998–1999	–	IN[e]; A/B[e]; 1[st]	I64	105	PPV=72.4 (63.2–80.0) to 80.0 (71.4–86.5) for unspecified stroke confirmed as being any stroke	MR; DS	Krarup LH et al, Neuroepidemiology. 2007[7]

		1994–1999[e]	–	IN/OUT/ED; A/B[e]; n/a	I64	200	PPV=76.0 (69.6–81.4) for unspecified stroke confirmed as being any stroke	MR; DS	Johnsen SP et al, J Clin Epidemiol. 2002[8]
		2001–2014	Diabetes mellitus	n/a; n/a; n/a	I64	18	PPV=50.0 (29.0–71.0)	MR; DS; laboratory results; MRI; CT scans	Dalsgaard EM et al, BMC Public Health 2019[21]
		2017–2020	Age 28d–17y	IN/OUT/ED; A/B; 1st	I64	28	PPV=57.1 (39.1–73.5)	MR	Bindslev JB et al, Clin Epidemiol. 2023[9]
I675	Moyamoya disease	1994–2017	–	IN/OUT; A/B; n/a	I675	74[e]	PPV=86.5 (76.9–92.5)[e]	MR; radiology notes; radiographic film	Birkeland P et al, Euro J. of Neurol. 2020[51]
I70	Peripheral arterial disease	1993–2009	Identified in DNPR + Danish National Vascular Registry	IN/OUT; A/B; 1st	44390, 44500, 44509, 44590, 44599, 44020, 44030; I739A, I739C, I739B, I702A, I702	1,097[h]	$PPV_{IN/OUT;\ A/B;\ 1st}$=61.5 (58.6–64.4); $PPV_{IN/OUT:\ A;\ n/a}$=76.1 (73.4–78.7); $PPV_{IN/OUT:\ B;\ n/a}$=59.0 (50.5–66.9); $PPV_{IN:\ A/B;\ n/a}$=81.2 (76.3–85.3); $PPV_{OUT:\ A/B;\ n/a}$=66.8 (64.0–69.4)	MR	Lasota AN et al, Eur J Vasc Endovasc Surg. 2017[52]
		1998–2007	–	IN/OUT; A; n/a	I70–I74, I77	50	PPV=100 (92.9–100)	DS	Thygesen SK et al, BMC Med Res Methodol. 2011[20]
I702	Atherosclerosis of lower extremities	1993–2009	Identified in DNPR + Danish National Vascular Registry	IN/OUT; A/B; n/a	I702, I702A No ICD-8 codes identified	771	PPV=68.6 (65.3–71.8)	MR	Lasota AN et al, Eur J Vasc Endovasc Surg. 2017[52]
I710	Aortic dissection	1996–2016	–	IN; A; n/a	I710, I710A, I710B	3,767	PPV=71.1 (69.6–72.5) for specific time period, see paper	MR; surgical descriptions; CT scans; MRI	Obel LM et al, Clin Epidemiol. 2022[53]
		2010–2012	–	IN; A/B; 1st	44109; I710	50	PPV=92.0 (81.2–96.9)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
		2006–2016	–	IN; A; n/a	I710	1,586	PPV=63.5 (61.1–65.8)	MR; surgical descriptions; CT scans; MRI	Obel LM et al, Clin Epidemiol. 2022[53]

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Table 1 (Continued).

Algorithm Components						n[c]	PPV; NPV; Sensitivity; Specificity[d]	Reference Standard	Reference
Codes (Chronological)[a]	**Condition**	**Study Period**	**Specified Patient Subgroup**	**Contact Type; Diagnosis Type; Occurrence Type**	**Codes (Specified)[b]**				
I710A	Aortic dissection, type A	2006–2016	–	IN; A; n/a	I710A	598	PPV=90.3 (87.7–92.4)	MR; surgical descriptions; CT scans; MRI	Obel LM et al, Clin Epidemiol. 2022[53]
I710B	Aortic dissection, type B	2006–2016	–	IN; A; n/a	I710B	438	PPV=88.1 (84.8–90.8)	MR; surgical descriptions; CT scans; MRI	Obel LM et al, Clin Epidemiol. 2022[53]
I711	Aortic aneurysm/ dilatation	2010–2012	–	IN/OUT; A/B; 1st	I711–I716, I718–I719	50	PPV=100.0 (92.9–100)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
I739	Peripheral vascular disease, other	1993–2009	Identified in DNPR + Danish National Vascular Registry	IN/OUT; A/B; n/a	44390, 44500; I739 No cases identified with ICD-8 codes.	664	PPV=70.3 (66.8–73.7)	MR	Lasota AN et al, Eur J Vasc Endovasc Surg. 2017[52]
I739A	Arterial claudication	2010–2012	–	IN/OUT; A/B; 1st	I739A	97	PPV=90.7 (83.3–95.0)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
I800	Superficial thrombophlebitis	1980–2001	During pregnancy/post-partum	IN[e]; A[e]; n/a	45101, 45191; I800 + (650–666; O80–84)	125	$PPV_{preg+postpartum}$=89.6 (84.3–95.0)[f]; PPV_{preg}=88.0 (81.0–82.8)[f]	MR	Larsen TB et al, J Clin Epidemiol. 2005[25]
I801–3	DVT	1994–2006	–	IN/OUT/ED; A/B; n/a	45100, 45108, 45109, 45199; I801–I809	742	PPV_{All}=54.6 (51.0–58.1); $PPV_{IN/OUT}$=71.3 (67.4–74.9); PPV_{ED}= 31.9 (27.1–37.0); PPV_{A}=72.4 (68.2–76.2)	MR; DS; blood tests; ultrasound; venography; echo; V-P lung scan; CT scan	Severinsen MT et al, J Clin Epidemiol. 2010[24]
		2010–2012	–	IN/OUT; A/B; 1st	I801–I803	50	PPV=86.0 (73.8–93.1)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
		1980–2001	During pregnancy and post-partum	IN[e]; A[e]; n/a	45100, 45108–45109, 45190, 45192, 45199; I801–I809 + (650–666; O80–84)	153	$PPV_{preg+postpartum}$=86.3 (79.8–91.3)[f]; PPV_{preg}=74.5 (66.8–81.2)[f]	MR	Larsen TB et al, J Clin Epidemiol. 2005[25]
		2008–2014	<6 mo after surgical treatment for spinal degenerative diseases	IN/OUT[e]; A[e]; n/a	I802, I803, T817C	10	PPV=70.0 (39.7–89.2)	MR; patient confirmation	Winther C et al, Dan Med J. 2019[27]

	Recurrent DVT	2010–2012	–	IN; A/B; 1st	I801–I803	39	PPV=74.4 (58.9–85.4)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
I801–I82	Pediatric VTE	1994–2006	Age 0–18y	IN/OUT/ED[e]; A/B; n/a	I676, I636, G08, H348, I26, I801–I809, I81–I82, O225A, O873, O223, O228–O229, O87A–O87F, O871	640	PPV_{all}=53.9 (50.0–57.7); PPV_{ED}= 7.4 (4.1–13.1); PPV_{ward}=66.3 (62.1–70.3); $PPV_{neonates}$=82.4 (66.5–91.7)	MR	Tuckuviene R et al, Clin Epidemiol. 2010[50]
I801–3+I26	VTE	1994–2006	–	IN/OUT/ED; A/B; n/a	45099, 45100, 45108, 45109, 45199; I26, I801–I809	1,100	PPV_{All}=58.5 (55.5–61.3); $PPV_{IN/OUT}$=75.0 (71.9–77.8); PPV_{ED}= 31.3 (27.2–35.7); PPV_{A}=77.0 (73.7–80.0)	MR; DS; blood tests; ultrasound; venography; echo; V-P lung scan; CT scan	Severinsen MT et al, J Clin Epidemiol. 2010[24]
		2010–2012	–	IN/OUT; A/B; 1st	I801–I803, I26	99	PPV=87.9 (80.0–92.9)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
		2010–2012	Without code for ultrasound or CT during admission	IN/OUT; A/B; 1st	I801–I803, I26	22	PPV=77.3 (56.6–89.9)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
		2010–2012	VTE with code for ultrasound (UXUG) or CT (UXCA) during admission	IN/OUT; A/B; 1st	I801–I803, I26	77	PPV=90.9 (82.4–95.5)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
		2010–2012	VTE with code for ultrasound (UXUG) and CT (UXCA) during admission	IN/OUT; A/B; 1st	I801–I803, I26	13	PPV=100.0 (77.2–100.0)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
		2004–2012	VTE + AC prescription ≤30 d after	IN/OUT; A/B; n/a	I801–3, I26	20	PPV=90.0 (69.9–97.2)	MR	Schmidt M et al, J Thromb Haemost. 2014[54]
		2001–2009	Non-pregnant women, age 15–49y	IN/OUT[e]; A/B[e]; n/a	438, 450, 45100, 45108, 45199, 45302; I26, I676, I801–I803, I822–I823, I828–I829	200	PPV=76.0 (69.6–81.4); PPV_{+AC}=99[f]	MR; ultrasound; plebography; CT; scientigraphy	Lidegaard O et al, BMJ. 2011[55]
		1980–2001	During pregnancy and postpartum	IN[e]; A[e]; n/a	45000–45099, 45100–45199; I260–I269, I800–I809 + (650–666, O80–84)	304	$PPV_{preg+postpartum}$=87.3 (83.0–90.9)[f]; PPV_{preg}=79.3 (74.3–83.8)[f]	MR	Larsen TB et al, J Clin Epidemiol. 2005[25]

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Table 1 (Continued).

Algorithm Components						n[c]	PPV; NPV; Sensitivity; Specificity[d]	Reference Standard	Reference
Codes (Chronological)[a]	Condition	Study Period	Specified Patient Subgroup	Contact Type; Diagnosis Type; Occurrence Type	Codes (Specified)[b]				
		1995–2012	Prostate cancer	IN/OUT; A/B; n/a	I26, I801–3 (+C61)	115	PPV=86.1 (78.6–91.3); NPV=98.3 (94.0–99.5); Se=98.0 (93.1–99.5); Sp=87.8 (81.1–92.3)	MR; VTE diagnosis	Drljevic A et al, Clin Epidemiol. 2014[56]
		2008–2014	<6 mo after surgical treatment for spinal degenerative diseases	IN/OUT[e]; A[e]; n/a	I260, I269, I802, I803, T817C, T817D	12	PPV=66.7 (39.1–86.2)	MR; patient confirmation	Winther C et al, Dan Med J. 2019[27]
		2007–2014	Diffuse large B-cell lymphoma	IN/OUT/ED[e]; A/B[e]; n/a	45099, 45100, 45108, 45109, 45199; I26, I801–I809[e]	20	PPV=85.0 (64.0–94.8); Se=53.1 (36.5–69.1)	MR; radiological imaging	Borg IH et al, Leuk Lymphoma 2016[57]
	Recurrent VTE	2010–2012	–	IN; A/B; 1st	I801–I803, I26	93	PPV=72.0 (62.2–80.2)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
		2010–2012	Without code for ultrasound or CT	IN; A/B; 1st	I801–I803, I26	25	PPV=44.0 (26.7–62.9)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
		2010–2012	Recurrent VTE with code for ultrasound (UXUG) or CT (UXCA) during admission	IN; A/B; 1st	I801–I803, I26, UXUG or UXCA	68	PPV=82.4 (71.6–89.6)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
		2010–2012	Recurrent VTE with code for ultrasound (UXUG) and CT (UXCA) during admission	IN; A/B; 1st	I801–I803, I26, UXUG or UXCA	7	PPV=71.4 (35.9–91.8)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
		2004–2012	>3 mo after first–time diagnosis + ultrasound/ CT scan during admission or AC prescription ≤30 d after	IN/OUT; A/B; n/a	I801–3, I26	90	$PPV_{IN/OUT,\ A/B,\ scan}$=27.5 (16.1–42.8); $PPV_{IN/OUT,\ A/B,\ AC\ use}$=30.2 (18.6–45.1); $PPV_{IN,\ A/B,\ scan}$=79.0 (56.7–91.5); $PPV_{IN,\ A/B,\ AC\ use}$=56.5 (36.8–74.4)	MR	Schmidt M et al, J Thromb Haemost. 2014[54]

I829	DVT after stroke	2003–2006	After admission to stroke units and age ≥18y	IN; A/B; n/a	I829	8	PPV=87.5 (52.9–97.8); NPV= 97.1 (95.4–98.2); Se=16.7 (3.0–56.4); Sp=100 (99.3–100)	MR	Ingeman A et al, Clin Epidemiol. 2010[26]
I829A–E	Stroke complications	2003–2006	After admission to stroke unit and age ≥18y	IN; A/B; n/a	J12–J18, N300, N308, N309, N10, L899, R297, EUHE, I829A–E, I26, K590	88	PPV=76.1 (66.3–83.8); NPV= 85.1 (83.9–86.1); Se=7.7 (5.8–10.3); Sp=99.5 (99.2–99.7)	MR	Ingeman A et al, Clin Epidemiol. 2010[26]
K00–K93: Diseases of the digestive system									
K228	Gastrointestinal and intraabdominal bleeding	2019 March–December	Age ≥65y	IN/OUT/ED; A/B; 1st	K228(F), K250, K252, K254, K256, K260, K262, K264, K266, K270, K272, K274, K276, K280, K282, K284, K286, K290, K298 (A), K625, K638B, K638C, K661, K838(F), K868(G), K920, K921, K922	468	PPV=92.7 (90.0–94.8)	MR	Thaarup M et al, Clin Epidemiol. 2023[28]
N00–N99: Diseases of the genitourinary system									
N938	Reproductive tract bleeding	2019 March–December	Age ≥65y	IN/OUT/ED; A/B; 1st	N938, N939, N95	10	PPV=100.0 (72.3–100.0)	MR	Thaarup M et al, Clin Epidemiol. 2023[28]
O00–O99: Pregnancy, childbirth, and puerperium									
O13	Gestational hypertension	1982–1987	–	IN; A/B[e]; n/a	n/a	112	PPV=70[f]; NPV=98[f]; Se=75[f]	MR	Kristensen J et al, J Clin Epidemiol. 1996[58]
		1998–2000	–	IN/OUT; A/B[e]; n/a	O139	3,039	PPV=56.3 (33.2–76.9); NPV= 97.3 (96.7–97.8); Se=10.0 (5.4–17.9); Sp=99.8 (99.5–99.9)	MR	Klemmensen ÅK et al, Am J Epidemiol. 2007[60]
		1998–2000	–	IN/OUT; A/B[e]; n/a	O139–O141–O142, O149–O150	3,039	PPV=88.8 (81.0–93.6); NPV= 96.9 (96.2–97.5); Se=48.9 (41.6–56.2); Sp=99.6 (99.3–99.8)	MR	Klemmensen ÅK et al, Am J Epidemiol. 2007[60]
		2010–2012	–	n/a; n/a; n/a	O13	62	PPV=29.0 (19.2–41.3); NPV= 98.7 (98.1–99.1); Se =39.1 (26.4–53.5); Sp =97.9 (97.2–98.5)	MR; biochemical results	Luef BM et al, Acta Obstet Gynecol Scand. 2016[59]

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Table 1 (Continued).

Algorithm Components						n[c]	PPV; NPV; Sensitivity; Specificity[d]	Reference Standard	Reference
Codes (Chronological)[a]	**Condition**	**Study Period**	**Specified Patient Subgroup**	**Contact Type; Diagnosis Type; Occurrence Type**	**Codes (Specified)[b]**				
O903	Peripartum cardiomyopathy or heart failure	2005–2014	Women identified in DNPR, MBR, and CDR 9 mo prior to giving birth to 12 mo postpartum	n/a; n/a; n/a	O903, I50 or O754, I42 or I43	207	PPV_{O903}=95.7 (79.0–99.2); $PPV_{All\ codes}$=29.5 (23.7–36.0)	MR	Ersbøll AS et al, Euro J Heart Fail. 2017[31]
Q00–Q99: Congenital malformations, deformations, and chromosomal abnormalities									
Q20	Congenital cardiac malformations	1991–1994	–	IN; A/B[e]; n/a	740–759; Q00–99 (except 75569, 75210–75219, Q53, Q65)	744	PPV=88.2 (85.7–90.3); Se=89.9 (87.5–91.9)	MR; Medical Birth Registry; National Registry of Congenital Abnormalities	Larsen H et al, Scand J Public Health. 2003[61]
		1994–2002	–	IN/OUT[e]; A/B[e]; n/a	Q20–Q26	418	PPV=89.0 (85.6–91.7)	MR; Echo; autopsy	Jepsen B et al, Int J Risk Saf Med. 2006[62]
		2000–2008	–	IN/OUT/ED[e]; A/B[e]; n/a	Q20–25, except Q209, Q219, Q229, Q239, Q249, Q259	3,356	PPV=98.4 (98.0–99.8)	MR	Agergaard P et al, Clin Epidemiol. 2011[63]
R00–R99: Symptoms, signs, and abnormal clinical and laboratory findings, not elsewhere classified									
R31	Urinary tract bleeding	2019	Age ≥65y	IN/OUT/ED; A/B; 1st	R31	135	PPV=99.3 (95.9–99.9)	MR	Thaarup M et al, Clin Epidemiol. 2023[28]
R559	Syncope	2007–2010	–	IN/ED; A; n/a	R559	750	$PPV_{IN/ED}$=94.7 (92.8–96.1); PPV_{IN}= 95.0 (93.0–96.5); PPV_{ED}=93.3 (88.2–96.3)	MR	Ruwald MH et al, Europace 2013[64]
		2008	Admission to or visiting the ED for medical reasons	IN/ED; A; n/a	R559	49	PPV=95.9 (86.3–98.9); NPV= 99.5 (99.2–99.6); Se= 62.7 (51.4–72.7); Sp=100.0 (99.9–100.0)	MR	Ruwald MH et al, Europace 2013[64]
R570	Shock overall	2005–2012	–	IN; A/B; n/a	R570–R572, A419A (+BFHC92, BFHC93 excl. BFHC93E–H, BFHC95)	158	PPV=86.1 (79.8–90.6); $PPV_{+\ Inotrope/vasopressor}$=93.1 (84.8–97.0)	MR	Lauridsen MD et al, BMC Med Res Methodol. 2015[65]

	Cardiogenic shock	2005–2012	–	IN; A/B; n/a	R570 (+BFHC92, BFHC93 excl. BFHC93E–H, BFHC95)	46	PPV=93.5 (82.5–97.8); $PPV_{+\ Inotrope/\ vasopressor}$=96.0 (80.5–99.3)	MR	Lauridsen MD et al, BMC Med Res Methodol. 2015[65]
R571	Hypovolemic shock	2005–2012	–	IN; A/B; n/a	R571 (+BFHC92, BFHC93 excl. BFHC93E–H, BFHC95)	34	PPV=70.6 (53.8–83.2); $PPV_{+\ Inotrope/\ vasopressor}$=69.2 (42.4–87.3)	MR	Lauridsen MD et al, BMC Med Res Methodol. 2015[65]
R572	Septic shock	2005–2012	–	IN; A/B; n/a	R572, A419A (+BFHC92, BFHC93 excl. BFHC93E–H, BFHC95)	78	PPV=69.2 (58.3–78.4); $PPV_{+\ Inotrope/\ vasopressor}$=82.4 (66.5–91.7)	MR	Lauridsen MD et al, BMC Med Res Methodol. 2015[65]
S00–T98: Injury, poisoning and certain other consequences of external causes									
T817	Postsurgical VTE	2009–2019	Age ≥18y and <180d after first-time lower limb orthopedic surgery	IN/OUT[e]; A/B[e]; n/a	I26, I801–I809, T817C, T817D, KNEx, KNFx, KNGx, KNHx	420	PPV=85.2 (81.5–88.3); NPV=99.5 (98.6–99.8)	MR	Galsklint J et al, Clin Epidemiol. 2022[66]
	Postsurgical DVT	2009–2019	Age ≥18y and <180d after first-time lower limb orthopedic surgery	IN/OUT[e]; A/B[e]; n/a	I801–I809, T817C, KNEx, KNFx, KNGx, KNHx	275	PPV=82.6 (77.6–86.6); NPV=99.5 (98.6–99.8)	MR	Galsklint J et al, Clin Epidemiol. 2022[66]
	Postsurgical PE	2009–2019	Age ≥18y and <180d after first-time lower limb orthopedic surgery	IN/OUT[e]; A/B[e]; n/a	I26, T817D, KNEx, KNFx, KNGx, KNHx	145	PPV=90.3 (84.5–94.2); NPV=100 (99.5–100)	MR	Galsklint J et al, Clin Epidemiol. 2022[66]
T823D, T823E	Stent thrombosis	2010–2012	–	IN; A/B; 1[st]	T823D, T823E	24	PPV=91.7 (74.2–97.7)	MR; DS	Sundbøll J et al, BMJ Open 2016[6]
Treatments									
Surgery									
KFG00	Intra-aortic balloon pump	2017–2022	–	IN	KFXG00	14	PPV=42.9 (21.4–67.4)	MR	Bonnesen K et al, Int J Popul Data Sci. 2024[39]
KFK	Mitral valve surgery	2010–2012	–	IN	KFK	100	PPV=100 (96.3–100.0)	MR	Adelborg K et al, BMJ Open 2016[67]

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Table 1 (Continued).

Algorithm Components						n[c]	PPV; NPV; Sensitivity; Specificity[d]	Reference Standard	Reference
Codes (Chronological)[a]	**Condition**	**Study Period**	**Specified Patient Subgroup**	**Contact Type; Diagnosis Type; Occurrence Type**	**Codes (Specified)[b]**				
KFM	Aortic valve surgery	2010–2012	–	IN	KFM	100	PPV=99.0 (94.6–99.8)	MR	Adelborg K et al, BMJ Open 2016[67]
KFNA–KFNE	Coronary artery bypass grafting	2010–2012	–	IN	KFNA–KFNE, KFNH20	100	PPV=98.0 (93.0–99.5)	MR	Adelborg K et al, BMJ Open 2016[67]
KFQA	Heart transplantation	2010–2012	–	IN	KFQA	39	PPV=100 (91.0–100.0)	MR	Adelborg K et al, BMJ Open 2016[67]
		2017–2022	–	IN	KFQA00, KFQA10	56	PPV=100.0 (93.6–100.0)	MR	Bonnesen K et al, Int J Popul Data Sci. 2024[39]
KFXD00	Cardiopulmonary support	2017–2022	–	IN	KFXD00, KFXE00	50	PPV=100.0 (92.9–100.0)	MR	Bonnesen K et al, Int J Popul Data Sci. 2024[39]
KFXL00	Impella	2017–2022	–	IN	KFXL00	50	PPV=38.0 (25.9–51.9)	MR	Bonnesen K et al, Int J Popul Data Sci. 2024[39]
KFXL10	Left ventricular assist device	2017–2022	–	IN	KFXL10, KZFX70	20	PPV=100.0 (83.9–100)	MR	Bonnesen K et al, Int J Popul Data Sci. 2024[39]
KTFC00	Right heart catheterization	2010–2012	–	IN	KTFC00	100	PPV=97.0 (91.6–99.0)	MR	Adelborg K et al, BMJ Open 2016[67]
Procedure									
KFNG, KFNF	PCI overall	2010–2012	–	IN	KFNG, KFNF	100	PPV=98.0 (93.0–99.5)	MR	Adelborg K et al, BMJ Open 2016[67]
	PCI, unspecified	2010–2012	–	IN	KFNG, KFNF	50	PPV=100.0 (92.3–100)	MR	Adelborg K et al, BMJ Open 2016[67]
KFNG05	PCI with stent implantation	2010–2012	–	IN	KFNG05	50	PPV=96.0 (86.5–98.9)	MR	Adelborg K et al, BMJ Open 2016[67]

BFCA0, KFPE, KFPF	Cardiac pacemaker	2010–2012	–	IN	BFCA0, BFCA6, KFPE00, KFPE10, KFPE20, KFPE96, KFPF00, KFPF10, KFPF20, KFPF96	100	PPV=100 (96.3–100.0)	MR	Adelborg K et al, BMJ Open 2016[67]
BFCB	Implantable cardiac defibrillator, overall	2010–2012	–	IN	BFCB0, BFCB6, KFPG	100	PPV=100 (96.3–100.0)	MR	Adelborg K et al, BMJ Open 2016[67]
		2017–2022	–	IN	BFCB00, BFCB01, BFCB20	100	PPV=97.0 (91.6–99.0)	MR	Bonnesen K et al, Int J Popul Data Sci 2024[39]
	Implantable cardiac defibrillator, primary	2010–2012	–	IN	BFCB0, BFCB6, KFPG	54	PPV=83.3 (71.3–91.0)	MR	Adelborg K et al, BMJ Open 2016[67]
	Implantable cardiac defibrillator, secondary	2010–2012	–	IN	BFCB0, BFCB6, KFPG	46	PPV=100.0 (92.3–100.0)	MR	Adelborg K et al, BMJ Open 2016[67]
	Cardiac resynchronization therapy defibrillator	2017–2022	–	IN	BFCB03, BFCB21	50	PPV=88.0 (76.2–94.4)	MR	Bonnesen K et al, Int J Popul Data Sci. 2024[39]
	Cardiac resynchronization therapy pacemaker	2017–2022	–	IN	BFCB05, BFCB06, BFCA21, BFCA63	50	PPV=96.0 (86.5–98.9)	MR	Bonnesen K et al, Int J Popul Data Sci. 2024[39]
BFFA0	Cardioversion	2010–2012	–	IN/OUT	BFFA0	100	PPV=92.0 (85.0–95.9)	MR	Adelborg K et al, BMJ Open 2016[67]
BFFB	Radiofrequency ablation	2010–2012	–	IN	BFFB	100	PPV=100.0 (96.3–100.0)	MR	Adelborg K et al, BMJ Open 2016[67]
BFHC92	Inotropes/ vasopressors in shock patients	2005–2012	–	IN	BFHC92–BFHC93, BFHC95 (excl. BFHC93E–H) (+R570–R572, A419A)	72	PPV=88.9 (79.6–94.3)	MR	Lauridsen MD et al, BMC Med Res Methodol. 2015[65]
BOHA1	Thrombolysis	2010–2012	–	IN	BOHA1	96	PPV=97.9 (92.7–99.4)	MR	Adelborg K et al, BMJ Open 2016[67]

(*Continued*)

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Table 1 (Continued).

Algorithm Components						n[c]	PPV; NPV; Sensitivity; Specificity[d]	Reference Standard	Reference
Codes (Chronological)[a]	**Condition**	**Study Period**	**Specified Patient Subgroup**	**Contact Type; Diagnosis Type; Occurrence Type**	**Codes (Specified)[b]**				
Examinations									
UXAC85	Coronary angiogram	2010–2012	–	IN	UXAC85	100	PPV=100.0 (96.3–100)	MR	Adelborg K et al, BMJ Open 2016[67]
UXCC00A	Cardiac CT angiography	2008–2012	–	n/a	UXCC00A	289	PPV=100 (98.7–100)	MR	Nielsen LH et al, Clin Epidemiol. 2014[68]
UXUC80–UXUC81	Echocardiography, overall	2010–2012	–	IN/OUT	UXUC80, UXUC81	98	PPV=96.9 (91.4–99.0)	MR	Adelborg K et al, BMJ Open 2016[67]
UXUC80	TTE	2010–2012	–	IN/OUT	UXUC80	49	PPV=98.0 (89.3–99.6)	MR	Adelborg K et al, BMJ Open 2016[67]
UXUC81	TEE	2010–2012	–	IN/OUT	UXUC81	49	PPV=95.9 (86.3–98.9)	MR	Adelborg K et al, BMJ Open 2016[67]

Notes: [a] The ordering corresponds to the SKS browser, ie, ICD-10 for diagnoses and NOMESCO for surgery. [b] ICD codes without and with capital letters refer to ICD-8 and ICD-10 codes, respectively. [c] Reflects the reviewed number of records in the DNPR (ie, the denominator in calculations of PPV). [d] Confidence intervals were calculated using Wilson's score method. [e] Information not specified in validation papers but confirmed through correspondence with authors. Unspecified and unconfirmed data are listed as not available (n/a). [f] Recalculation of confidence intervals using Wilson's score method not possible due to insufficient data. [g] Confidence limit equals 100 due to rounding. [h] The highest number is reported. See paper for the denominator for each PPV.

Abbreviations: A=primary diagnosis; AC=anticoagulant therapy; B=secondary diagnosis; CDR=Causes of Death Registry; CT=Computed Tomography; d=day; DANMONICA=Danish Monitoring Trends and Determinants in Cardiovascular Disease Project; DES=drug eluting stent; DNPR=Danish National Patient Registry; DS=discharge summaries; DVT=deep venous thrombosis; echo=echocardiography; ED=emergency department; ICD=international classification of diseases; ICH=intracerebral hemorrhage; IN=inpatient contact; MBR=Medical Birth Registry; MI=acute myocardial infarction; mo=month; MR=medical records; n/a=not available; NPV=negative predictive value; NSTEMI=Non-ST elevation myocardial infarction; OUT=outpatient contact; PCI=percutaneous coronary intervention; PE=Pulmonary embolism; PPV=positive predictive value; PR=Prescription Registry; Se=study sample sensitivity; Sp=study sample specificity; STEMI=ST segment myocardial infarction; TEE=transesophageal echocardiography; TTE=transthoracic echocardiography; Ultrasound=ultrasonography; V-P=ventilation-perfusion; VTE=venous thromboembolism; y=year(s); 1st =first-time; 2nd=readmission; – = no subgroup.

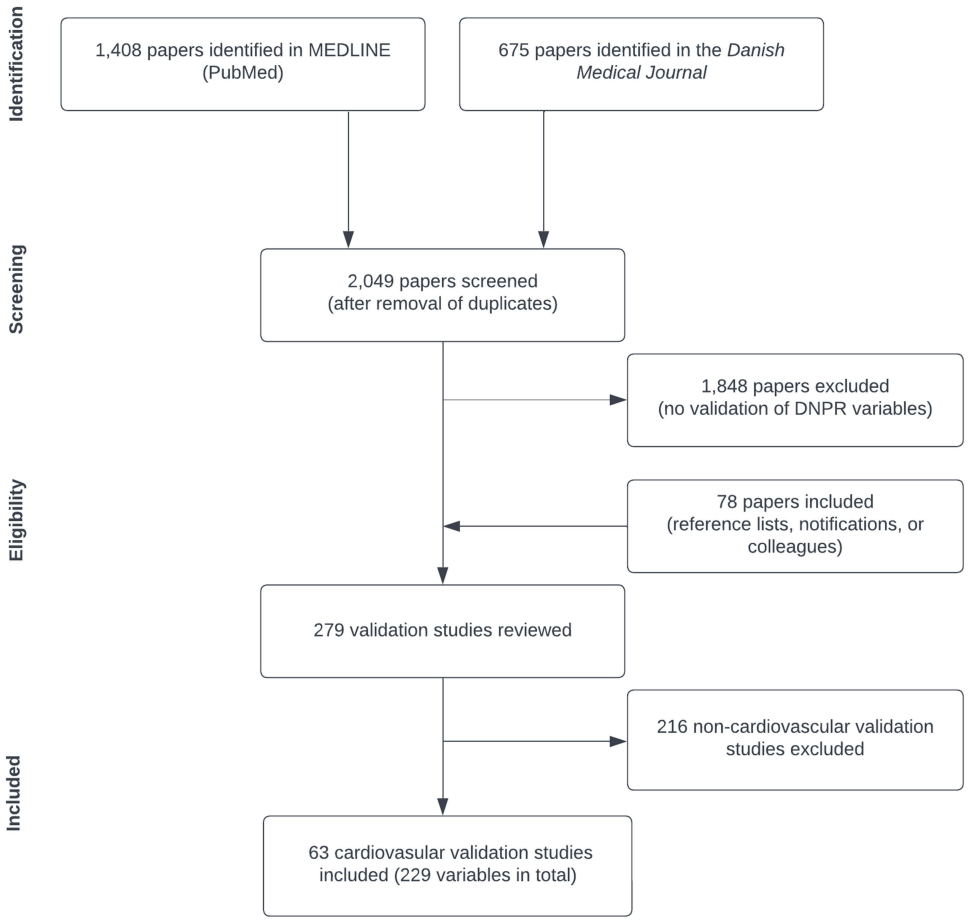

Figure 2 Flow-chart of the systematic review of studies validating cardiovascular variables in the Danish National Patient Registry (1977–2024).
Notes: The literature search was performed using the following search string in 1) PubMed: "Danish National Patient Registry" OR "Danish National Registry of Patients" OR "Danish National Hospital Register" OR "Danish National Health Registry" OR "Danish National Patient Register" OR "Danish Hospital Discharge Registry" OR "Danish National Hospital Registry" OR "Danish Hospital Registers"; and 2) the Danish Medical Journal: "Landspatientregisteret".

searches, the first in 2015 (covering 1977–2015), and the second in 2023 (covering 2013–2023). We used identical search strings (in 2015 and 2023) as developed and published in 2015.[2] It included the Danish name ("Landspatientregisteret") as well as commonly used English terms for the DNPR. Validation may be a secondary aim not highlighted in the title or abstract of an article, potentially leading to incompleteness of the search string. Further, we used a two-year overlap with the previous search to increase the completeness. We therefore also retrieved relevant papers from reference lists, citations in screened papers, e-mail notifications from the journal Clinical Epidemiology (known to publish many validation studies), and colleagues. To provide the most updated overview, we included such additional papers through October 2024. The literature review was conducted by MS and SAJS for the 1977–2015 period and by KHL and CHF for the 2013–2024 period.

Eligibility

Titles, abstracts, and, if necessary, the full text of all retrieved papers were screened for eligibility. A study was eligible for inclusion if it was published during 1977–2024 and reported any information on data quality for cardiovascular diseases within the ICD chapter I00–I99: *Diseases of the circulatory system*, and cardiovascular conditions outside the ICD I00–I99 chapter eg cardiac tumors (C00–D48: *Neoplasms*) or congenital cardiac malformations (Q00–Q99: *Congenital malformations, deformations, and chromosomal abnormalities*). We also included validation studies of cardiovascular treatments, ie, surgery (K codes) or other treatments (B codes), and examinations (U codes).

Extracted information

All authors independently extracted relevant information from eligible papers (MS/SAJS in 2015, and KHL/CHF in 2024). For each study, we extracted patient contact type (IN/OUT/ED), diagnosis type (A/B), occurrence type (first-time/

readmission), codes/algorithms used, measures of accuracy (PPV/NPV), measure of completeness (sensitivity/specificity), the reference standard used, and results (absolute numbers, proportions, and confidence intervals [CIs]). In case of missing information, we requested additional details from the corresponding author. As CIs can be calculated in several ways, we recalculated proportions using Wilson's score method based on the absolute numbers provided in the articles, as it ensured comparability across studies.[5] If no absolute numbers were available in the article, we reported the proportions as stated by the authors. Any disagreements during the review were resolved by discussions.

Results

Literature search

We identified 1,408 papers in PubMed and 675 papers in the Danish Medical Journal. After removal of duplicates a total of 2,049 papers were screened, and among these 1,848 papers were excluded because they did not validate variables in the DNPR. Additionally, 78 papers were identified from reference lists, citations, journal e-mail notifications, or colleagues. We reviewed 279 validation studies of which 63 papers assessed cardiovascular variables (34 additional papers since the first 2015 search). These 63 papers included a total of 229 cardiovascular variables covering a broad range of cardiovascular diseases, treatments, and examinations (Figure 2).

Bibliography of cardiovascular variables

A complete bibliography of all validated cardiovascular variables is presented in Table 1. The bibliography includes detailed information on time period, patient contact type, type of diagnosis, occurrence type, specified patient subgroup, measurement(s) of validity, and the reference standard used. When we describe the validity of a disease/treatment in the following sections, we refer to the validity of the algorithm used to identify the disease/treatment in the DNPR.

To supplement Table 1 and to provide an overview of key findings, we have summarized the PPVs according to the coding classification systems (Table 1S and 2S) and clinical categorization (Figures 1 and 3). Table 1S presents a summary of the results for the validated cardiovascular diseases including ICD code, number of validation studies/variables, study period range, and PPV range. Table 2S presents a similar summary of treatments, categorized as surgeries, procedures, and examinations. Variables presented in Tables 1, 1S, and 2S are listed chronologically according to the coding classification systems. Figures 1 and 3 provide a visual overview of the PPVs for cardiovascular diseases and treatments according to clinical areas. If a study reported more than one PPV for the same variable (ie using different algorithms), we only included one of the reported PPVs in the figure. All reported PPVs for each validated variable are listed in Table 1.

Cardiovascular variables overall

Among the 229 validated cardiovascular variables, 200 variables assessed diagnoses and 29 assessed procedures, including 10 surgeries, 14 other treatments, and 5 examinations (Tables 1S and 2S). The information stated in the medical record was most commonly used as the reference standard for validation. Most often one cardiovascular diagnosis, treatment, examination, or procedure was validated in each paper, but two recent studies validated 29 cardiovascular diagnoses and 14 procedures, respectively.[6,67] Overall, the PPV was ≥90% for 83 (36%) variables, 80–89% for 59 (26%) variables, 70–79% for 36 (16%) variables, 60–69% for 17 (7%) variables, 50–59% for 9 (4%) variables, and <50% for 25 (11%) variables (Table 1). The data quality was generally higher for treatments (92% had PPVs ≥95%) and examinations (100% had PPVs ≥95%) than diagnoses (71% had PPVs ≥80%) (Table 1).

Cardiovascular diagnoses

Although many different diagnoses have been validated (Table 1), some remain to be assessed. For many diagnoses, eg, ischemic heart disease, the PPV improved over time. Thirty variables assessed the validity of a diagnosis of ischemic heart disease. There was an increase in the rate of validated variables over time. Eighteen variables describing acute myocardial infarction (MI) were validated. For MI, the PPVs increased over time from 92% (1979–1980) to >97% (1996–2012).[6,14,16–23] However, lower PPVs were also reported in MI subgroups.[16,21] Acute coronary syndrome was validated four times during 1993–2007. The PPV increased from 66% (1993–2003) to 92% (2007).[14,15] Likewise, the

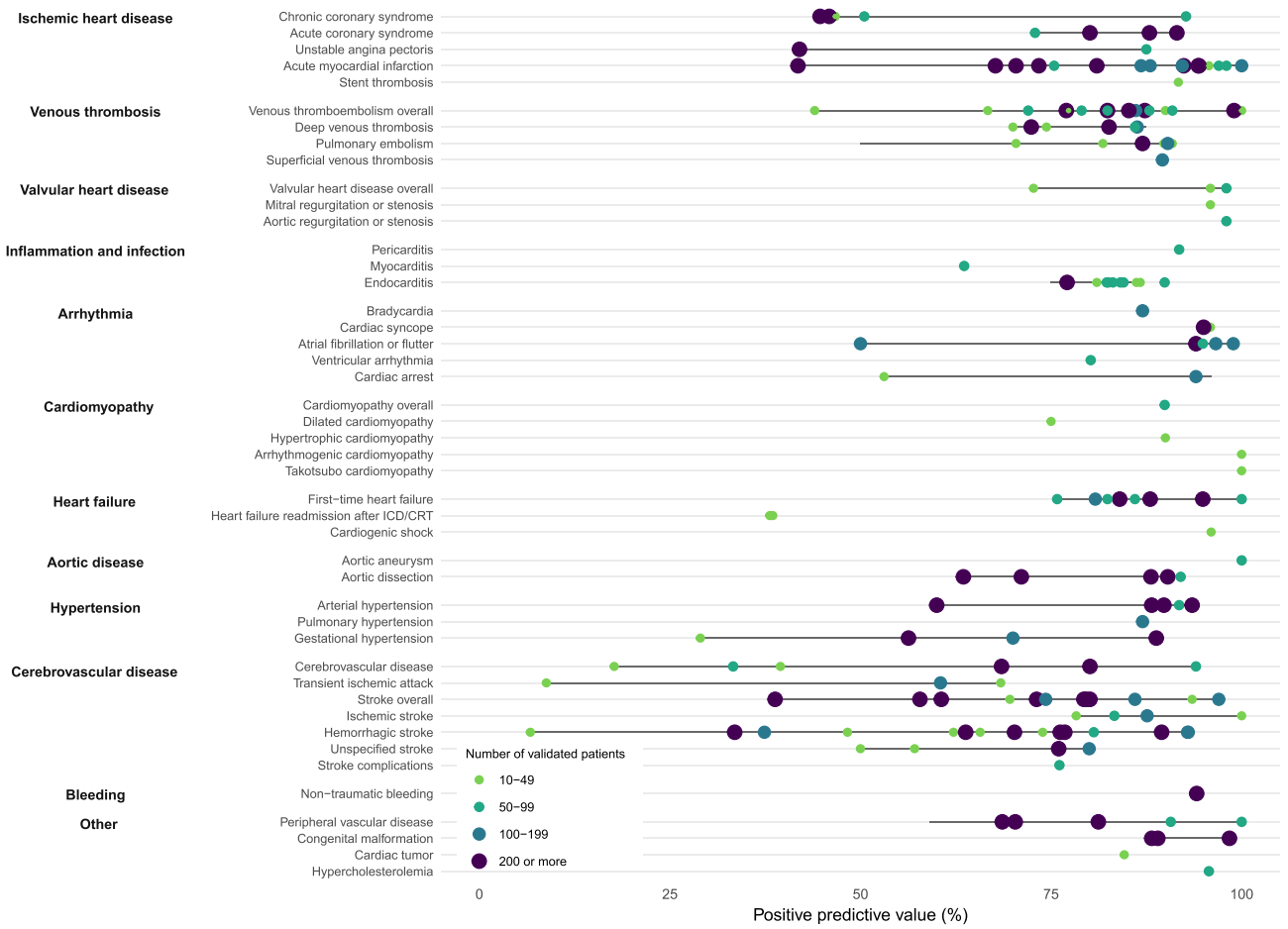

Figure 3 Overview of the range of positive predictive values reported for individual cardiovascular diagnoses in the Danish National Patient Registry (1997–2024).
Notes: The figure includes one PPV per validated variable. Thus, in cases where several PPVs were reported for a variable, we used the highest PPV. All PPVs for each validated variable are listed in Table 1.
Abbreviation: ICD=implantable cardiac defibrillator; CRT=cardiac resynchronization therapy.

PPV for unstable angina pectoris increased from 28% (1993–2003) to 88% (2010–2012).[6,14] The PPV for angina pectoris ranged from 4 to 93% with the lowest estimates observed in subgroups, eg in breast cancer patients (PPV 47%).[6,15,16]

Treatment and examinations

Four studies have validated cardiac treatments and examinations (Table 1),[39,65,67,68] the majority validated during 2010–2012.[67] Most variables had PPVs >95% (24/29 variables). The PPV range for examinations (including echocardiography, cardiac CT angiography, and coronary angiogram) was 96–100%. For invasive procedures (including percutaneous coronary intervention, radiofrequency ablation, and right heart catheterization), the PPV range was 96–100%, while the PPV range was 89–98% for in-hospital medical treatment (including DC cardioversion, thrombolysis, and inotrope/vasopressor treatment). The PPV range was 98–100% for cardiac surgery (including mitral valve surgery, aortic valve surgery, coronary artery bypass grafting, and heart transplantation). Except for impella (PPV 38%) and intra-aortic balloon pump (PPV 43%), the PPV was also high for mechanical circulatory support (PPV 100%), including left ventricular assist device and cardiopulmonary support. Finally, the PPV was between 83 and 100% for cardiac devices, including cardiac pacemaker, cardiac resynchronization therapy pacemaker, implantable cardiac defibrillator, implantable cardioverter defibrillator, and cardiac resynchronization therapy defibrillator.

Determinants of validity

We found that the validity of a diagnosis was not solely based on the ICD code, but a combination of the ICD code and administrative data (patient contact type, type of diagnosis, and occurrence type),[39,45] setting, and time period.[53] For most diagnoses or treatment codes, only one overall PPV was reported. In some cases, PPVs were also reported for subgroups, eg breast cancer patients or patients with diabetes mellitus.[16,21] Overall, NPVs, sensitivity, and specificity were only reported for a few validated variables.[22,26,35,38]

Discussion

We identified 63 papers, which validated a total of 229 variables in the DNPR during 1977–2024. The variables covered the most common cardiovascular diagnoses, treatments, and examinations. Of these, 200 variables assessed diagnoses, 24 assessed treatments (10 surgeries and 14 other treatments), and 5 assessed examinations. We observed a considerable increase in the number of validation studies[45,46] and PPVs[6,13,] for many diagnoses over time.[6,17,18,20,22,35,39,45,46] The data quality varied substantially between variables. The predictive value was generally higher for treatments (PPV≥95% for 92%) and examinations (PPV≥95% for 100%) than for diagnoses (PPV≥80% for 71%). Key determinants for the validity of diagnoses were patient contact type (inpatient vs outpatient), diagnosis type (primary vs secondary), setting (university vs regional hospitals), and calendar year.

Variations in predictive values

Predictive values depend on disease prevalence, which in turn may vary according to the setting. Thus, some studies only included diagnoses/treatments recorded at university hospitals,[37] where higher PPVs are expected owing to the higher prevalence in these specialized settings. The diagnostic process for a disease may also affect the PPV. For example, low PPVs may be seen in diseases that can be challenging to diagnose, such as myocarditis (PPV=64% during 2010–2012).[6] A condition, which is difficult to diagnose may likewise be challenging to validate. Some studies excluded patients with insufficient information in their medical records, which may result in lower PPVs. Similarly, PPV improvements over time may be explained by the implementation of diagnostic guidelines (eg new diagnostic criteria) or modalities to confirm or reject a disease. For instance, the use of troponin measurements for diagnosing acute myocardial infarction or updated definitions of myocardial infarction and myocardial injury.[69,70] Increased awareness of correct coding among clinicians may also play a role. Finally, until 2019, the distribution of finances to the Danish hospitals was based on the use of ICD-codes according to the Diagnosis Related Groups system (DRG), which may have motivated more detailed or comprehensive coding, eg coding B diagnoses or treatments.[70]

Researchers should be aware that because of these possible time trends in data quality, the results may not be extrapolated outside the validated calendar periods. For instance, aortic dissection was validated during 1996–2016 while types of aortic dissection (type A and B) were only validated during the latter part of 2006–2016; thus, the validity stratified by type of dissection may not generalize to times before 2006.[53] This is particularly a limitation for diagnoses and treatments with sparse validated data.

Strengths and limitation

Although the most common cardiovascular diseases, treatments, and examinations registered in DNPR have been validated, several variables remain to be examined. Nevertheless, variables related to cardiovascular disease have been more thoroughly validated than other medical specialties, eg diseases of the eye and ear (ICD-10 codes: H00–H95) or skin and subcutaneous tissue diseases (ICD-10 codes: L00–L99).[2] Furthermore, there has been an increase in the rate of validated cardiovascular variables over time.[2] Despite using a systematic search to identify all relevant papers, our search string may have missed some validation studies within cardiovascular diseases.

Some papers did not provide information on eg patient contact type, type of diagnosis, occurrence type, and numbers for recalculation. Although we contacted authors in case of uncertainty, we were not always able to obtain the relevant missing information. Any missing information is listed as not available (Table 1). In a few cases, the paper was excluded due to sparse information.

Perspectives and implications

This paper elucidates that the validity of diagnoses registered in the DNPR depends on components in the algorithm used for validation. Therefore, we recommend that researchers specify variable definitions according to such characteristics and strongly advise against using superficial and imprecise wordings for data quality such as "The validity of cardiovascular diagnoses in the DNPR is high" to imply that it is therefore also high for the given study variable. In contrast, we have shown that the PPV varies considerably between individual diagnoses and depends on the algorithm used to define them.

This overview of validated cardiovascular variables provides researchers with an opportunity to assess and report the validity of a diagnosis, treatment, or examination according to their study population based on several validated variables instead of a single validation study. Based on these key factors, researchers can avoid reporting a single PPV, which may give overconfidence to one or few selected validation studies, and instead provide an interval of most likely PPVs to summarize the available evidence.

Conclusions

The predictive values for cardiovascular variables in the DNPR were overall high for treatments and examinations, supporting their use for cardiovascular registry-based research. For diagnoses, the validity varied considerably between individual variables and depended on the components of the algorithm used to define them. Such components must, therefore, be considered when designing and interpreting a study using cardiovascular data from the DNPR. Importantly, not all cardiovascular variables have been validated and the data quality may change over time. The ongoing need for conducting validation studies to assess the data quality of cardiovascular variables in the DNPR, therefore, remains.

Data sharing statement

The study is based on published papers. The search string and all papers included in the study are cited in the paper.

Data permission and ethics approval

The study is based on published papers; thus this study does not need ethical approval.

Author contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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