Clinical Epidemiology
Dovepress

REVIEW

The Western Denmark Heart Registry and Population-Based National Health Registries

Christine Gyldenkerne[1,2], Kevin Kris Warnakula Olesen[1], Pernille Gro Thrane[1], Malene Kærslund Hansen[1], Nina Stødkilde-Jørgensen[1], Malene Højgaard Andersen[1], Martin Bødtker Mortensen[1,3], Jesper Møller Jensen[1], Bjarne Linde Nørgaard[1,4], Henrik Toft Sørensen[2], Michael Maeng[1,4]

[1]Department of Cardiology, Aarhus University Hospital, Aarhus, Denmark; [2]Department of Clinical Epidemiology, Aarhus University and Aarhus University Hospital, Aarhus, Denmark; [3]Ciccarone Center for the Prevention of Cardiovascular Disease, Johns Hopkins University School of Medicine, Baltimore, Maryland, USA; [4]Department of Clinical Medicine, Aarhus University Hospital, Aarhus, Denmark

Correspondence: Christine Gyldenkerne, Department of Cardiology, Aarhus University Hospital, Palle Juul-Jensens Boulevard 99, Aarhus N, 8200, Denmark, Tel +4560949704, Email chgyld@clin.au.dk

Abstract: The Western Denmark Heart Registry (WDHR) is a semi-national, multicenter-based clinical registry with unique potential for cardiovascular research. The registry has provided detailed prospectively registered information on patient and procedure characteristics since 1999. WDHR data can be linked to additional data in other healthcare registries in Denmark. Therefore, the WDHR is a valuable data resource for cardiovascular research, providing a foundation for numerous research projects and publications. This review describes three currently available cohorts from the WDHR containing individual-level information on: i) 200,647 first-time coronary angiographies from 2003 to 2021, ii) 88,630 first-time percutaneous coronary interventions from 1999 to 2022, and iii) 85,512 first-time coronary computed tomography angiographies from 2008 to 2021. Furthermore, we describe other frequently cross-linked Danish healthcare registries containing information on various patient characteristics and outcomes, such as vital status, cause of death, hospitalizations, medications, and laboratory test results. The comprehensive overview of these cohorts aims to assist researchers, collaborators, and other interested parties in understanding the scope and potential applications of the available data. All cohorts are regularly updated, thereby supporting continuing research on cardiovascular clinical practice and prognosis in Denmark.

Keywords: epidemiology, cardiovascular disease, cohort, coronary angiography, percutaneous coronary intervention, computed tomography angiography

Introduction

Cardiovascular diseases are a leading cause of morbidity and mortality worldwide.[1,2] In recent decades, clinical registries have emerged as a powerful tool in cardiovascular research. These registries, which contain comprehensive patient data, offer unprecedented opportunities to study disease patterns, identify risk and prognostic factors, and evaluate treatment outcomes in routine clinical care settings.

The Western Denmark Heart Registry (WDHR) is such a clinical registry, containing detailed prospectively registered patient and procedural information on cardiac procedures in Western Denmark. WDHR can be linked to all other population-based registries in Denmark with long-term individual-level follow-up and virtually no loss to follow-up.[3] Thus, WDHR is a valuable data resource for cardiovascular research with the potential to influence cardiovascular patient care. Since its initiation more than two decades ago, the WDHR has been the basis for numerous research projects and publications, with research in continuous development.

The purpose of this review is to provide a comprehensive overview of three unique cohorts derived from the WDHR and associated Danish healthcare registries. By detailing these cohorts, this review aims to support researchers, collaborators, and interested parties in understanding the breadth and potential applications of the available data. The three cohorts provide detailed individual-level information on the following procedures obtained from the WDHR: i) coronary angiographies (CAGs), ii)

Received: 24 July 2024
Accepted: 18 November 2024
Published: 26 November 2024

percutaneous coronary interventions (PCIs), and iii) coronary computed tomography angiographies (CCTAs). Additionally, the cohorts contain information on various patient characteristics from other Danish healthcare registries described in this review. Importantly, these cohorts are regularly updated to be able to provide current information.

Setting

The Danish healthcare system provides tax-supported health care for all Danish residents, including free access to general practitioners, hospitals, and outpatient specialty clinics, as well as partial reimbursement of redeemed medication prescriptions. Denmark has numerous nationwide healthcare registries containing routinely collected administrative, health, and clinical quality data. Civil Personal Register (CPR) numbers can link individual-level data across registries. These unique ten-digit personal identifiers are assigned to all Danish residents at birth or immigration and are registered in the Danish Civil Registration System. The Danish Civil Registration System, initiated in 1968, also contains data including vital status, migration, sex, and home address. Data from this registry allow for accurate accounting for censoring due to emigration or death in epidemiological research, virtually eliminating loss to follow-up. The Danish healthcare system and Danish Civil Registration System have been described in detail previously.[3–5]

The Western Denmark Heart Registry

The WDHR is a semi-national, multicenter-based clinical registry established on January 1, 1999. The registry contains information on all patients referred for diagnostic and invasive cardiac procedures in Western Denmark, containing a population of approximately 3.2 million inhabitants (54% of the Danish population) from both rural and urban areas. All hospitals in Western Denmark that perform cardiac procedures participate in the WDHR. These hospitals include three university hospitals and ten regional hospitals. PCIs are performed at the university hospitals, and CAGs and CCTAs are performed at university and selected regional hospitals (Figure 1). Physicians register patients' data in a 100% web-based data management system using patients' unique CPR numbers. This information comprises administrative data (eg, referral, admission, and discharge data), data on risk factors (eg, family history of ischemic heart disease, smoking, diabetes, hypertension, hypercholesterolemia, body mass index, kidney function, and left ventricular ejection fraction), procedural data (specific to each procedure, as described below), and procedure-related complications. Data completeness and validity of registration are high in the WDHR, as detailed for each cohort below. A detailed description of the data available from WDHR has been reported.[6]

Currently Available Cohorts from the Western Denmark Heart Registry

Coronary Angiographies

CAGs have been registered in the WDHR since 1999. The specific procedure data for CAGs include procedure indication and priority, arterial access, start and stop times of catheterization, contrast volume and brand, fluoroscopy time, radiation dose, location and severity of coronary stenosis, and periprocedural complications. For CAGs, the quality of registrations is high, with an overall positive predictive value (PPV) of approximately 95% for risk factor variables, 97% for procedure variables, and 95% for discharge variables.[6]

The currently available CAG cohort includes 200,647 first-time CAGs performed between January 2003 and December 2021 (Figure 2). Selected characteristics of the current CAG cohort are provided in Table 1. However, additional patient and procedure characteristics are available with data from the WDHR, the Danish Civil Registration System, the Danish National Patient Registry, the Danish Causes of Death Registry, the Danish National Prescription Registry, and the Register of Laboratory Results for Research; these registers are described in detail below. Examples of its use are provided in Table 2.[7–9]

Percutaneous Coronary Interventions

PCIs have been registered in the WDHR since 1999. Specific procedure data for PCIs include the indication for PCIs, the number of treated vessels and lesions, the number of balloons, the number and type of stents, the use of periprocedural antiplatelet and antithrombotic therapy, and periprocedural complications. For patients with ST-segment elevation myocardial infarction, procedure data also include the time of symptom onset, time of first medical contact, time of

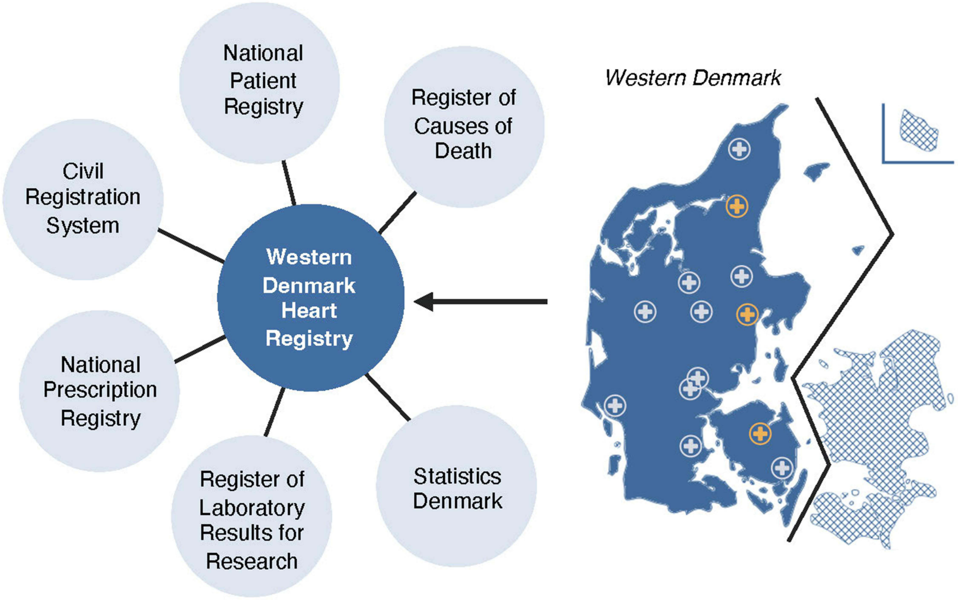

Figure 1 Coverage of the WDHR and linked data sources.

Notes: The WDHR covers the population of Western Denmark (55% of the Danish population). The WDHR data can be cross-linked with multiple data sources according to individuals' unique Civil Personal Register numbers. Data sources cross-linked to the currently available WDHR cohorts are shown. Gray crosses indicate regional hospitals, and orange crosses indicate university hospitals.

Abbreviation: WDHR, Western Denmark Heart Registry.

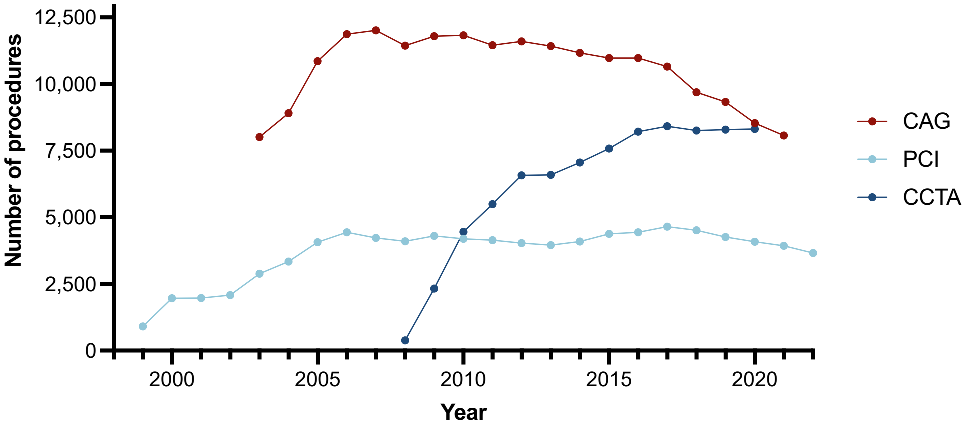

Figure 2 Trends in the annual number of first-time coronary angiographies (CAGs), percutaneous coronary interventions (PCIs), and cardiac computed tomography angiographies (CCTAs) in the three currently available cohorts from the Western Denmark Heart Registry.

Abbreviations: CAG, coronary angiography; CCTA, coronary computed tomography angiography; PCI, percutaneous coronary intervention.

arrival at the PCI center, start and stop times of catheterization, and time of first intervention. For PCI, the PPV of registrations has been reported to be 96% for risk factor variables and 98% for procedure and discharge variables.[6]

The currently available PCI cohort includes 88,630 first-time PCIs performed between January 1999 and December 2022 (Figure 2), and a total of 119,444 stented lesions. Selected characteristics of the current PCI cohort are provided in Table 1. However, various additional patient and procedure characteristics are available with data from the WDHR, the Danish Civil Registration System, the Danish National Patient Registry, the Danish Causes of Death Registry, the Danish National Prescription Registry, and the Register of Laboratory Results for Research. Table 2 provides examples of its use.[10,11]

Table 1 Selected Characteristics of the CAG, PCI, and CCTA Cohorts on the Procedure Date

	CAG cohort (n=200,647)	PCI cohort (n=88,630)	CCTA cohort (n=85,512)
Age, median (first quartile, third quartile)	66 (57, 74)	66 (57, 75)	58 (50, 66)
Male sex	129,123 (64.4%)	64,455 (72.7%)	41,294 (48.3%)
Active smoking	50,602 (25.2%)	25,898 (29.2%)	16,729 (19.6%)
Missing	23,476 (11.7%)	11,691 (13.2%)	8,640 (10.1%)
Body mass index, median (first quartile, third quartile)	27 (24, 30)	27 (24, 30)	27 (24, 30)
Missing	26,294 (13.1%)	72,966 (17.7%)	10,466 (12.2%)
Familiar ischemic heart disease	71,113 (35.4%)	31,144 (35.1%)	32,874 (38.4%)
Missing	23,238 (11.6%)	13,982 (15.8%)	7,682 (9.0%)
Comorbidities[a]			
Diabetes	33,083 (16.5%)	15,134 (17.1%)	7,772 (9.1%)
Hypertension	113,136 (56.4%)	48,823 (55.1%)	36,332 (42.5%)
Prior myocardial infarction[b]	21,876 (10.9%)	13,848 (15.6%)	1,822 (2.1%)
Prior PCI[b]	16,918 (8.4%)	5,714 (6.4%)	1,094 (1.3%)
Prior CABG[b]	5,211 (2.6%)	4,107 (4.6%)	321 (0.4%)
Prior ischemic stroke	5,714 (2.8%)	4,865 (5.5%)	2,811 (3.3%)
Peripheral artery disease	13,014 (6.5%)	7,180 (8.1%)	1,947 (2.3%)
Atrial fibrillation	26,295 (13.1%)	9,130 (10.3%)	6,198 (7.2%)
Heart failure	23,402 (11.7%)	10,773 (12.2%)	3,467 (4.1%)
Renal disease	8,019 (4.0%)	4,156 (4.7%)	1,275 (1.5%)
Chronic obstructive pulmonary disease	22,700 (11.3%)	7,144 (8.1%)	8,524 (10.0%)
Comedication[c]			
Aspirin	89,413 (44.6%)	36,927 (41.7%)	26,405 (30.9%)
Beta-blocker	76,638 (38.2%)	31,965 (36.1%)	19,349 (22.6%)
ACE inhibitor/ARB	82,894 (41.3%)	33,305 (37.6%)	26,910 (31.5%)
Calcium channel blocker	50,464 (25.2%)	22,642 (25.5%)	14,875 (17.4%)
Thiazide	28,575 (14.2%)	11,038 (12.5%)	8,008 (9.4%)
Loop diuretics	31,706 (15.8%)	11,282 (12.7%)	5,106 (6.0%)
Statin	91,107 (45.4%)	38,305 (43.2%)	29,804 (34.9%)
ADP-receptor inhibitor	11,674 (5.8%)	7,081 (8.0%)	2,936 (3.4%)
Vitamin K antagonist	14,737 (7.3%)	4,128 (4.7%)	2,167 (2.5%)
Direct oral anticoagulants	6,680 (3.3%)	2,345 (2.6%)	3,130 (3.7%)

(Continued)

Table 1 (Continued).

	CAG cohort (n=200,647)	PCI cohort (n=88,630)	CCTA cohort (n=85,512)
Glucose-lowering drug		11,847 (13.4%)	
Insulin	9,943 (5.0%)	4,648 (5.2%)	2,050 (2.4%)
Non-insulin glucose lowering drug	21,126 (10.5%)	9,354 (10.6%)	5,288 (6.2%)
Referral indication			
STEMI	31,132 (15.5%)	27,908 (31.5%)	-
NSTEMI or unstable angina pectoris	41,302 (20.5%)	25,815 (29.2%)	-
Stable angina pectoris	71,611 (35.7%)	27,957 (31.5%)	82,764 (96.8%)
Cardiomyopathy	12,659 (6.3%)	1,349 (1.5%)	2,563 (3.0%)
Valve disease	16,333 (8.1%)	389 (0.4%)	-
Other	27,610 (13.8%)	857 (1.0%)	185 (0.2%)
Coronary artery disease extent[d]			
0 vessel disease	65,091 (32.4%)	-	49,667 (58.1%)
1 vessel disease	53,802 (26.8%)	46,985 (53.0%)	9,890 (11.6%)
2 vessel disease	29,817 (14.9%)	24,326 (27.4%)	3,261 (3.8%)
3 vessel disease	28,470 (14.2%)	15,887 (17.9%)	1,499 (1.8%)
Diffuse vessel disease	22,731 (11.3%)	227 (0.3%)	15,546 (18.2%)
Missing	736 (0.4%)	1,205 (0.5%)	3,582 (4.2%)
Calcium score only	NA	NA	2,067 (2.4%)

Notes: [a]Comorbidities were identified using a full-look back at hospital diagnoses prior to the procedure date for the CAG and the CCTA cohorts and prior to or on the procedure date for the PCI cohort. Comorbidities prior to the procedure date were identified from the Danish National Patient Registry. Information on diabetes and hypertension on the procedure date was available from the Western Denmark Heart Registry. Information on prior PCI was identified from the Danish National Patient Registry and the Western Denmark Heart Registry. [b]For the PCI cohort, prior myocardial infarction, prior PCI, and prior CABG were defined as a diagnosis more than 7 days before index PCI. [c]Comedication was defined as redemption of at least one prescription within 6 months before or on the procedure date for the CAG and the CCTA cohorts and from 6 months to 1 day before the procedure date for the PCI cohort. [d]For the PCI cohort, the extent of coronary artery disease was based on information from the most recent CAG within the past 90 days.

Abbreviations: ACE, angiotensin-converting enzyme; ADP, adenosine diphosphate; ARB, angiotensin II receptor blocker; CABG, coronary artery bypass grafting; CAG, coronary angiography; CCTA, coronary computed tomography angiography; NA, not available; NSTEMI, non-ST-segment elevation myocardial infarction; PCI, percutaneous coronary intervention; STEMI, ST-segment elevation myocardial infarction.

Coronary Computed Tomography Angiographies

CCTAs have been registered in the WDHR since 2008. Specific procedure data for CCTAs include procedure indication, type of CT scanner, heart rhythm and rate, acquisition settings, radiation dose, contrast volume, Agatston score, and CCTA result. The overall PPV for registration of CCTA variables is high (~94%).[6]

The currently available CCTA cohort includes 85,512 first-time CCTAs performed between January 2008 and May 2021 (Figure 2). This cohort comprises patients with first-time CCTAs performed due to suspicion of coronary artery disease, whereas CCTAs performed for noncoronary indications (eg, structural heart disease) are excluded. Selected characteristics of the current CCTA cohort are provided in Table 1. Additional patient and procedure characteristics are available with data from the WDHR, the Danish Civil Registration System, the Danish National

Table 2 Research Examples Based on the WDHR

Author Journal Year	Design Period Cohort	Population	Outcomes	Follow-up	Purpose	Main findings
Olesen et al Diabetes Care 2017[7]	Cohort study 2003–2012 CAG cohort	Patients undergoing CAG (n=93,866) in the WDHR	MI, cardiac death, and all-cause death	Median follow-up of 4.1 years	To examine whether patients with diabetes have the same cardiac risk as patients without diabetes in the absence of obstructive CAD	Patients with diabetes have the same risk of cardiovascular events as patients without diabetes in the absence of angiographically significant CAD.
Olesen et al Stroke 2019[8]	Cohort study 2004–2012 CAG cohort	Patients undergoing CAG (n=81,909) in the WDHR	Ischemic stroke	Median follow-up of 3.8 years	To examine the risk of ischemic stroke in patients with or without diabetes, according to CAD status	CAD and diabetes are each associated with the risk of ischemic stroke after CAG. Having both CAD and diabetes further increases ischemic stroke risk, depending on the extent of CAD.
Egholm et al Journal of the American College of Cardiology 2016[9]	Cohort study 2005–2012 PCI cohort	DES-PCI-treated patients undergoing a surgical procedure (n=22,590) and controls without IHD undergoing similar surgical procedures (n=20,232)	MI, cardiac death, and all-cause death	One-year follow-up	To evaluate surgical risk in patients treated with DES-PCI compared with nonstented controls without IHD	Patients requiring surgery within 12 months after DES-PCI have a greater risk of MI and cardiac death than controls without IHD, but the elevated risk is present only within the first month after DES-PCI.
Thrane et al The Lancet Regional Health Europe 2022[10]	Cohort study 2007–2010 and 2012–2015 PCI cohort	Patients with acute coronary syndrome treated with PCI (n=14,450) in the WDHR	MACE (MI, death, and ischemic stroke) and hospitalization for bleeding	One-year follow-up for each period	To examine the effectiveness and safety of ticagrelor implementation in patients with acute coronary syndrome treated with PCI	Implementation of ticagrelor is not associated with changes in risks of ischemic or bleeding events in patients with acute coronary syndrome treated with PCI.
Thrane et al Journal of the American College of Cardiology 2023[11]	Cohort study 2003–2018 PCI cohort	First-time PCI-treated patients undergoing primary PCI for STEMI in the WDHR	One-year trends in all-cause death	One-year follow-up for each period	To evaluate the temporal trends in 1-year, 30-day, and 31- to 365-day mortality after STEMI in Western Denmark	One-year mortality in PCI-treated patients with STEMI substantially decreased between 2003 and 2018. Approximately three-quarters of the absolute mortality reduction occurred within the first 30 days after PCI.

Nielsen et al European Heart Journal 2017[12]	Cohort study 2008–2012 CCTA cohort	Patients with symptoms suggestive of CAD undergoing CCTA (n=16,949)	Composite endpoint of coronary revascularization >90 days after CCTA, MI, and all-cause death	Median follow-up 3.6 years	To examine the 3.5-year prognosis of stable CAD, as assessed by CCTA in real-world practice	CAD, determined by CCTA, predicts the 3.5-year composite risk of late revascularization, MI, and all-cause death across groups according to age, sex, or comorbidity burden.
Mortensen et al Journal of the American College of Cardiology 2020[13]	Cohort study 2008–2017 CCTA cohort	Patients with symptoms suggestive of CAD undergoing CCTA (n=23,759)	Composite endpoint of CVD (MI, stroke, and all-cause death)	Median follow-up 4.3 years	To evaluate whether obstructive CAD has predictive value beyond its association with total calcified atherosclerotic plaque burden, as assessed by CAC	Plaque burden, not stenosis per se, is the main predictor of risk of CVD events and death.
Mortensen et al JAMA Cardiology 2022[14]	Cohort study 2008–2017 CCTA cohort	Patients with symptoms suggestive of CAD undergoing CCTA (n=23,759)	Proportion of individuals with obstructive CAD and a CAC score of 0	Median follow-up 4.3 years	To assess 1) the diagnostic value of a CAC score of 0 in indicating a low likelihood of obstructive CAD and 2) the implications of a CAC score of 0 and obstructive CAD across various age groups	The diagnostic value of a CAC score of 0 in ruling out obstructive CAD depends on age; the added diagnostic value is lower for younger patients.
Mortensen et al Circulation 2023[15]	Cohort study 2008–2017 CCTA cohort	Patients with symptoms suggestive of CAD undergoing CCTA (n= 23,132)	Composite endpoint of ASCVD (MI and ischemic stroke)	Median follow-up 4.3 years	To evaluate the association between LDL-C and future ASCVD events in patients with or without CAC	LDL-C appears to be almost exclusively associated with future ASCVD events in patients with evidence of CAC compared to those without.

Abbreviations: ASCVD, atherosclerotic cardiovascular disease; CAC, coronary artery calcium; CAD, coronary artery disease; CAG, coronary angiography; CCTA, coronary computed tomography angiography; CVD, cardiovascular disease; DES-PCI, drug-eluting stent by percutaneous coronary intervention; IHD, ischemic heart disease; LDL-C, low-density lipoprotein cholesterol; MACE, major adverse cardiovascular events; MI, myocardial infarction; PCI, percutaneous coronary intervention; STEMI, ST-segment elevation myocardial infarction; WDHR, Western Denmark Heart Registry.

Patient Registry, the Danish Causes of Death Registry, the Danish National Prescription Registry, and the Register of Laboratory Results for Research. Examples on its use are provided in Table 2.[12–15]

General Population Comparison Cohorts

A general population comparison cohort has been established for each of the three cohorts described above. On the date of the CAG, PCI, or CCTA procedure, each patient was matched in a 1:5 ratio by age (birth year) and sex with individuals from the Western Denmark general population. Individuals in the general population were randomly selected through the Danish Civil Registration System by linkage of CPR numbers. Using a general population cohort allows for comparison with the risk in a matched general population. For example, we have shown that patients with diabetes and a normal CAG have a similar risk of myocardial infarction as an age- and sex-matched general population.[7]

National Health Registries

The three currently available cohorts from the WDHR have been cross-linked to key national health registries in Denmark. These national registries are described below.

The Danish National Patient Registry

The Danish National Patient Registry contains records of all hospital inpatient diagnoses since 1977 and outpatient specialty clinic and emergency department diagnoses since 1995. Diagnoses are classified according to the *International Classification of Diseases* (ICD) 8th revision from 1977 to 1993, and the 10th revision from 1994 onward. The Danish National Patient Registry also contains data on surgical procedures performed since 1996, coded according to the Nordic Medico-Statistical Committee System (NOMESCO). The registry has been described in detail previously.[16]

The validity of the coding of commonly used cardiovascular diagnoses ascertained from the Danish National Patient Registry is generally high. For example, coding of the diagnosis of myocardial infarction (ICD-10 I21) has shown a high PPV of 97% for first-time myocardial infarction and 75% for myocardial infarction after PCI in prior validation studies.[17,18] The coding of ischemic stroke diagnosis (ICD-10 I63) has been reported to have a PPV of 97%.[19] For nontraumatic bleeding diagnoses, an overall PPV of 94% has been estimated.[20]

The Danish Register of Causes of Death

The Danish Register of Causes of Death collects information from death certificates in Denmark since 1943.[21] Until 2007, registration of cause of death was performed centrally at the National Board of Health, according to the medical information on death certificates. Since 2007, the registration of cause of death has been coded by the medical doctors who verify the death and issue the death certificate. All deaths have been classified according to ICD-10 codes since 1994. Death certificates state the underlying cause of death. Including as many as three of the following contributory causes is optional: contributory cause I, cause of immediate events that led to the death; contributory cause II, conditions that might have contributed to the death; and contributory cause III, other conditions. The quality of the data on causes of death depends on the coding performed by the National Board of Health and the accuracy of the physicians preparing the death certificates.

The Danish National Prescription Registry

The Danish National Prescription Registry has registered detailed information on all redeemed prescriptions at Danish pharmacies since 1995. Core variables include prescription dispensing date, package size, strength, and the Anatomical Therapeutic Chemical (ATC) code. The ATC system, developed by the World Health Organization, classifies drugs according to their active substances and therapeutic intent. The registry has been described in detail.[22]

Register of Laboratory Results for Research

The Register of Laboratory Results for Research is a nationwide register that collects routine individual-level biomarker results from general practitioners and hospitals. Core variables of the registry include the patient identification number; date and time (hour and minute) of the sampling; code (using the International System of Nomenclature, Properties, and Units [NPU]); the name of the biomarker; test results, with corresponding units, as well as lower and upper reference limits; and an identification code for the laboratory and the requisitioner. The registry has variable temporal geographical coverage, because the data collection started in different calendar periods in the five Danish regions (North Denmark Region, Central Denmark Region, and Region of Zealand, 2013; Capital Region of Denmark, 2014; and Region of Southern Denmark, 2015). The registry has been described in detail elsewhere.[23]

Research Examples

Examples of research based on the WDHR are provided in Table 2.[17–25]

Other International Cardiovascular Registries

The Swedish Coronary Angiography and Angioplasty Registry (SCAAR) was formed in 1998 and is part of the Swedish Web system for Enhancement and Development of Evidence-based care in Heart disease Evaluated According to Recommended Therapies (SWEDEHEART), which was developed in 2009 after merging four national registries on coronary artery disease.[24] SWEDEHEART is a nationwide, multicenter (n=74 hospitals) registry covering 100% of patients undergoing CAGs, PCIs, and cardiac surgery, 60% of all patients with acute coronary syndrome, and 100% of patients with acute coronary syndrome admitted to coronary care units.[24] The degree of patient capture in the registry is higher for younger patients with acute coronary syndrome and for those with ST-segment myocardial infarction. The registry can be linked with other national health registries in Sweden.

The British Cardiovascular Intervention Society (BCIS) PCI registry registers clinical characteristics, indications, procedural details, and outcomes of nearly all patients (~95%) undergoing PCI in the UK since 1994.[25] In 2017–2018, only 6 of 118 PCI centers in the UK did not participate in the registry since private hospitals are not obliged to participate.[25] Following discharge, data on all-cause mortality can be tracked via linkage to the Office of National Statistics.[25] However, cause of death and postdischarge data on complications and outcomes are not collected.[25]

The Korea Acute Myocardial Registry (KAMIR) is a nationwide, multicenter (n=55 hospitals) registry of patients with acute coronary syndrome in South Korea initiated in 2005.[26] Due to several limitations in the registry, including the lack of long-term follow-up, the KAMIR was expanded to the national, multicenter (n=22 hospitals) KAMIR-National Institutes of Health (NIH) in 2011.[26] The KAMIR-NIH covers a small proportion of the total amount of PCI centers (n=173) in South Korea.[27]

Other cardiovascular registries include the National Cardiovascular Data Registry in the U.S.,[28] the Global Registry of Acute Coronary Events (GRACE) and Canadian Registry of Acute Coronary Events (CANRACE) in Canada,[29] the Japan Acute Myocardial Infarction Registry (JAMIR),[30] the China Acute Myocardial Infarction (CAMI) Registry,[31] the Acute Myocardial Infarction in Switzerland (AMIS) registry,[32] and the Northern New England Cardiovascular Disease Study Group.[33]

Strengths and Weaknesses

Strengths of the WDHR include the comprehensiveness of data on patient and procedural characteristics since 1999, the high registration completeness, and the high quality of registrations in the registry. Furthermore, the WDHR is a population-based registry that can be linked to multiple national health registries in Denmark using the unique CPR number, providing long-term individual-level follow-up with minimal loss to follow-up. Finally, the Danish healthcare system provides universal healthcare, limiting selection bias.

The current cohorts have several limitations based on the WDHR and linked national health registries. First, the WDHR data registration is not 100% complete, especially not in the early years following the registry's creation. However, more recently, the WDHR data registration has been estimated to be approximately 98% complete.[6] Assuming that data are missing at random, researchers may use multiple imputation or other statistical methods to account for missing data when complete case analysis is required.[34] Second, there is some variation in the data quality of the registries linked to the WDHR. For instance, the cause of death depends on the coding on the death certificate by the medical doctor who verifies the death, which can be difficult to determine, especially due to Denmark's low autopsy rate.[21] Moreover, data quality may have changed over time. Two of the most common measures of data quality are validity and completeness. Key measures of validity include sensitivity, specificity, and predictive value.[35] Validity may have increased for some diagnoses within the past decades, given the continuous improvements in diagnostic criteria and procedures.[3] Variable completeness may also have improved, with an increased focus on a more complete registration of even mild hospital diagnoses due to different incentives. Fortunately, several validation studies have indicated high or sufficient positive predictive values for many key outcome variables used in cardiovascular research in the main Danish registries;[17–20] however, completeness is seldom reported, and validation studies may require an update. Third, researchers should be aware of registry initiation and possible left censoring and left truncation.[35,36] For example, the Register of Laboratory Results for Research initiated data collection for the Region of Southern Denmark in 2015, and data from this registry before 2015 are left truncated for this region. However, data linkage to other registries may compensate for the lack of coverage and completeness. For instance, diabetes can be identified with data on hemoglobin A_{1c} level obtained from the Register of Laboratory Results for Research, but the disease may also be identified based on redemption of a glucose-lowering drug prescription as registered in the Danish National Prescription Registry or an inpatient or outpatient hospital diagnosis of diabetes as registered in the Danish National Patient Registry. Finally, the WDHR only covers 55% of the Danish population, including both urban and rural areas, and, thus, may not be considered representative of the Danish population.

Conclusions

In conclusion, the WDHR serves as a valuable, continually updated research tool, offering extensive patient and procedural data for cardiovascular studies. This review highlights three well-defined cohorts on CAG, PCI, and CCTA, each of which is supported by data from the WDHR and enriched by linkage with additional Danish healthcare registries. The integration of comprehensive clinical data within these cohorts facilitates robust, large-scale studies, with the potential to drive advancements in cardiovascular care. By providing a clear structure of available data, these cohorts support both ongoing and future research projects that can inform and enhance patient care practices.

Data Sharing Statement

According to Danish law, patient data are not directly available to third parties. Applications for data access from national health registries may be requested from the Research Service at the Danish Health Data Authority (e-mail: forskerservice@sundhedsdata.dk) and requires approval from the Danish Data Protection Agency (e-mail: www.datatilsynet.dk/english/the-danish- data-protection-agency/introduction-to-The-danish-data-protection-agency). Applications for data access from the WDHR may be requested from OPEN (website: www.open.rsyd.dk/projekter/vestdansk-hjertedatabase) and requires approval from a Danish region.

Ethics Approval

No ethics committee approval was required for this study.

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.

Funding

This study was supported by the Department of Cardiology, Aarhus University Hospital, Aarhus, Denmark. The funding source had no influence on the study design, the collection, analysis, and interpretation of the data, the writing of the report, or the decision to submit this manuscript for publication.

Disclosure

KKWO and MHA are supported by the Danish Cardiovascular Academy, which is funded by the Novo Nordisk Foundation (grant nos. NNF20SA0067242 and PHD2023001-HF, respectively) and The Danish Heart Foundation. BLN has received unrestricted research support from the Novo Nordisk Foundation. MM has received lecture and/or advisory board fees from AstraZeneca, Bayer, Boehringer-Ingelheim, Bristol-Myers Squibb, and Novo Nordisk; research grants from Philips, Bayer, and Novo Nordisk; a travel grant from Novo Nordisk; has ongoing research contracts with Janssen, Novo Nordisk, and Philips; and is a minor shareholder in Novo Nordisk, Eli Lilly & Company, and Verve Therapeutics. MHA is a minor shareholder in Novo Nordisk. The Department of Clinical Epidemiology, Aarhus University Hospital, receives funding for other studies from companies through research grants to (and administered by) Aarhus University. None of those studies have any relation to the present study. The authors report no other potential conflicts of interest in this work.

References

1. Global burden of 288 causes of death and life expectancy decomposition in 204 countries and territories and 811 subnational locations, 1990-2021: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet*. 2024. doi:10.1016/S0140-6736(24)00367-2
2. Global incidence, prevalence, years lived with disability (YLDs), disability-adjusted life-years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries in 204 countries and territories and 811 subnational locations, 1990-2021: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet*. doi:10.1016/S0140-6736(24)00757-8
3. Schmidt M, Schmidt SAJ, Adelborg K, et al. The Danish health care system and epidemiological research: from health care contacts to database records. *Clin Epidemiol*. 2019;11:563–591. doi:10.2147/CLEP.S179083
4. Pedersen CB. The Danish Civil Registration System. *Scand J Public Health*. 2011;39(7 Suppl):22–25. doi:10.1177/1403494810387965
5. Schmidt M, Pedersen L, Sørensen HT. The Danish Civil Registration System as a tool in epidemiology. *Eur J Epidemiol*. 2014;29(8):541–549. doi:10.1007/s10654-014-9930-3
6. Schmidt M, Maeng M, Madsen M, Sørensen HT, Jensen LO, Jakobsen CJ. The Western Denmark Heart Registry: its Influence on Cardiovascular Patient Care. *J Am Coll Cardiol*. 2018;71(11):1259–1272. doi:10.1016/j.jacc.2017.10.110
7. Olesen KKW, Madsen M, Egholm G, et al. Patients With Diabetes Without Significant Angiographic Coronary Artery Disease Have the Same Risk of Myocardial Infarction as Patients Without Diabetes in a Real-World Population Receiving Appropriate Prophylactic Treatment. *Diabetes Care*. 2017;40(8):1103–1110. doi:10.2337/dc16-2388
8. Olesen KKW, Madsen M, Gyldenkerne C, et al. Diabetes Mellitus Is Associated With Increased Risk of Ischemic Stroke in Patients With and Without Coronary Artery Disease. *Stroke*. 2019;50(12):3347–3354. doi:10.1161/STROKEAHA.119.026099
9. Egholm G, Kristensen SD, Thim T, et al. Risk Associated With Surgery Within 12 Months After Coronary Drug-Eluting Stent Implantation. *J Am Coll Cardiol*. 2016;68(24):2622–2632. doi:10.1016/j.jacc.2016.09.967
10. Thrane PG, Olesen KKW, Würtz M, et al. Effectiveness and Safety of Ticagrelor Implementation in Patients with Acute Coronary Syndrome undergoing Percutaneous Coronary Intervention: a Cohort Study in Western Denmark. *Lancet Reg Health Eur*. 2022;14:100301. doi:10.1016/j.lanepe.2021.100301
11. Thrane PG, Olesen KKW, Thim T, et al. Mortality Trends After Primary Percutaneous Coronary Intervention for ST-Segment Elevation Myocardial Infarction. *J Am Coll Cardiol*. 2023;82(10):999–1010. doi:10.1016/j.jacc.2023.06.025
12. Nielsen LH, Bøtker HE, Sørensen HT, et al. Prognostic assessment of stable coronary artery disease as determined by coronary computed tomography angiography: a Danish multicentre cohort study. *Eur Heart J*. 2017;38(6):413–421. doi:10.1093/eurheartj/ehw548
13. Mortensen MB, Dzaye O, Steffensen FH, et al. Impact of Plaque Burden Versus Stenosis on Ischemic Events in Patients With Coronary Atherosclerosis. *J Am Coll Cardiol*. 2020;76(24):2803–2813. doi:10.1016/j.jacc.2020.10.021
14. Mortensen MB, Gaur S, Frimmer A, et al. Association of Age With the Diagnostic Value of Coronary Artery Calcium Score for Ruling Out Coronary Stenosis in Symptomatic Patients. *JAMA Cardiol*. 2022;7(1):36–44. doi:10.1001/jamacardio.2021.4406
15. Mortensen MB, Dzaye O, Bøtker HE, et al. Low-Density Lipoprotein Cholesterol Is Predominantly Associated With Atherosclerotic Cardiovascular Disease Events in Patients With Evidence of Coronary Atherosclerosis: the Western Denmark Heart Registry. *Circulation*. 2023;147(14):1053–1063. doi:10.1161/CIRCULATIONAHA.122.061010
16. Schmidt M, Schmidt SAJ, Sandegaard JL, Ehrenstein V, Pedersen L, Sørensen HT. The Danish National Patient Registry: a review of content, data quality, and research potential. *Clin Epidemiol*. 2015;7:449–490. doi:10.2147/CLEP.S91125
17. Egholm G, Madsen M, Thim T, et al. Evaluation of algorithms for registry-based detection of acute myocardial infarction following percutaneous coronary intervention. *Clin Epidemiol*. 2016;8:415–423. doi:10.2147/CLEP.S108906
18. Sundbøll J, Adelborg K, Munch T, et al. Positive predictive value of cardiovascular diagnoses in the Danish National Patient Registry: a validation study. *BMJ Open*. 2016;6(11):e012832. doi:10.1136/bmjopen-2016-012832
19. Krarup LH, Boysen G, Janjua H, Prescott E, Truelsen T. Validity of stroke diagnoses in a National Register of Patients. *Neuroepidemiology*. 2007;28(3):150–154. doi:10.1159/000102143
20. Thaarup M, Nielsen PB, Olesen AE, et al. Positive Predictive Value of Non-Traumatic Bleeding Diagnoses in the Danish National Patient Register. *Clin Epidemiol*. 2023;15:493–502. doi:10.2147/CLEP.S400834
21. Helweg-Larsen K. The Danish Register of Causes of Death. *Scand J Public Health*. 2011;39(7 Suppl):26–29. doi:10.1177/1403494811399958
22. Pottegård A, Schmidt SAJ, Wallach-Kildemoes H, Sørensen HT, Hallas J, Schmidt M. Data Resource Profile: the Danish National Prescription Registry. *Int J Epidemiol*. 2017;46(3):798–798f. doi:10.1093/ije/dyw213
23. Arendt JFH, Hansen AT, Ladefoged SA, Sørensen HT, Pedersen L, Adelborg K. Existing Data Sources in Clinical Epidemiology: laboratory Information System Databases in Denmark. *Clin Epidemiol*. 2020;12:469–475. doi:10.2147/CLEP.S245060
24. Jernberg T, Attebring MF, Hambraeus K, et al. The Swedish Web-system for enhancement and development of evidence-based care in heart disease evaluated according to recommended therapies (SWEDEHEART). *Heart*. 2010;96(20):1617–1621. doi:10.1136/hrt.2010.198804
25. Rashid M, Ludman PF, Mamas MA. British Cardiovascular Intervention Society registry framework: a quality improvement initiative on behalf of the National Institute of Cardiovascular Outcomes Research (NICOR). *Eur Heart J Qual Care Clin Outcomes*. 2019;5(4):292–297. doi:10.1093/ehjqcco/qcz023

26. Kim JH, Chae SC, Oh DJ, et al. Multicenter Cohort Study of Acute Myocardial Infarction in Korea - Interim Analysis of the Korea Acute Myocardial Infarction Registry-National Institutes of Health Registry. *Circ J*. 2016;80(6):1427–1436. doi:10.1253/circj.CJ-16-0061
27. Shin DH, Kang HJ, Jang JS, et al. The Current Status of Percutaneous Coronary Intervention in Korea: based on Year 2014 & 2016 Cohort of Korean Percutaneous Coronary Intervention (K-PCI) Registry. *Korean Circ J*. 2019;49(12):1136–1151. doi:10.4070/kcj.2018.0413
28. Brindis RG, Fitzgerald S, Anderson HV, Shaw RE, Weintraub WS, Williams JF. The American College of Cardiology-National Cardiovascular Data Registry (ACC-NCDR): building a national clinical data repository. *J Am Coll Cardiol*. 2001;37(8):2240–2245. doi:10.1016/s0735-1097(01)01372-9
29. Bajaj RR, Goodman SG, Yan RT, et al. Treatment and outcomes of patients with suspected acute coronary syndromes in relation to initial diagnostic impressions (insights from the Canadian Global Registry of Acute Coronary Events [GRACE] and Canadian Registry of Acute Coronary Events [CANRACE]). *Am J Cardiol*. 2013;111(2):202–207. doi:10.1016/j.amjcard.2012.09.018
30. Honda S, Nishihira K, Kojima S, et al. Rationale, Design, and Baseline Characteristics of the Prospective Japan Acute Myocardial Infarction Registry (JAMIR). *Cardiovasc Drugs Ther*. 2019;33(1):97–103. doi:10.1007/s10557-018-6839-1
31. Xu H, Li W, Yang J, et al. The China Acute Myocardial Infarction (CAMI) Registry: a national long-term registry-research-education integrated platform for exploring acute myocardial infarction in China. *Am Heart J*. 2016;175:193–201.e3. doi:10.1016/j.ahj.2015.04.014
32. Radovanovic D, Erne P. AMIS Plus: Swiss registry of acute coronary syndrome. *Heart*. 2010;96(12):917–921. doi:10.1136/hrt.2009.192302
33. Nugent WC. Building and supporting sustainable improvement in cardiac surgery: the Northern New England experience. *Semin Cardiothorac Vasc Anesth*. 2005;9(2):115–118. doi:10.1177/108925320500900202
34. Hughes RA, Heron J, Sterne JAC, Tilling K. Accounting for missing data in statistical analyses: multiple imputation is not always the answer. *Int J Epidemiol*. 2019;48(4):1294–1304. doi:10.1093/ije/dyz032
35. Sørensen ST, Kristensen FP, Troelsen FS, Schmidt M, Sørensen HT. Health registries as research tools: a review of methodological key issues. *Dan Med J*. 2023;70(4):A12220796.
36. Cain KC, Harlow SD, Little RJ, et al. Bias due to left truncation and left censoring in longitudinal studies of developmental and disease processes. *Am J Epidemiol*. 2011;173(9):1078–1084. doi:10.1093/aje/kwq481