

Development of a Catheterization and Percutaneous Coronary Intervention Registry with a Data Management Approach: A Systematic Review

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Abstract

Coronary catheterization is the gold standard for diagnosis and treatment of cardiovascular conditions. The development of a catheterization and percutaneous coronary intervention (CathPCI) registry considering key steps of data management has a pivotal role in coronary catheterization because it could help improve CathPCI approaches, develop equipment and devices, and minimize complications of the CathPCI procedure. Data management comprises data gathering, data processing, and information distribution. Data gathering involves the collection of data elements, including demographics, episode of care, history and relevant risk factors, visits to the catheterization laboratory, diagnosis of cardiac catheterization, estimation of the coronary arterial anatomy, percutaneous coronary intervention procedures, lesions, devices, outcomes, and discharge. Data processing is performed with respect to the number of procedures performed in different circumstances, the outcomes of the performed procedures, improvement in the healthcare approach, development of devices and equipment, and the quality of the performed procedures. Information distribution involves the sharing of information and making information accessible to researchers and clinicians, relevant health care managers, and manufacturers of medical devices and equipment. This study reviewed relevant English-language publications regarding cardiac catheterization registries, data collection, data processing, and information distribution, regardless of the date of publication.

Keywords: registry; catheterization; percutaneous coronary intervention; data collection; data processing

Introduction

According to the World Health Organization (WHO), cardiovascular diseases are the primary cause of global mortality.¹ Diagnostic cardiac catheterization and coronary angiography are considered the gold standard for the assessment of the anatomy and physiology of the heart and its associated vasculature.² Catheterization and percutaneous coronary intervention (CathPCI) is a high-cost and high-risk procedure commonly used for the diagnosis and treatment of cardiovascular diseases.³ The potential risks and complications associated with CathPCI include bleeding or infection where the catheter is inserted, damage to the arteries or heart muscle, heart attack or stroke, and reduced kidney function. However, this procedure is increasingly performed without rigorous monitoring of its safety, quality, and outcomes.⁴⁻⁶

One of the approaches that could help improve monitoring of CathPCI, thereby improving patient safety, is the management of the large amount of CathPCI data through the development and use of a registry.^{7, 8} A procedure registry, as a clinical data registry, is the result of a systematic process of data gathering, analysis, and storage that provides information about certain diagnostic or therapeutic procedures.⁹⁻¹² Such registries could help in measuring the effectiveness and quality of care, as well as monitoring the safety of procedures.^{13, 14}

With respect to CathPCI, registries have created opportunities for reviewing and monitoring the CathPCI procedure¹⁵ by managing data regarding acute hemorrhage, balloon angioplasty, stenting, various types of medications, and the time interval from the arrival of the patient to receipt of the CathPCI procedure.¹⁶⁻¹⁹ Indeed, the cardiac procedure registry in Australia led to early identification of outlier performance to ensure the maintenance of cardiac care standards and benchmarking of outcome data with feedback to clinicians and hospitals.²⁰ Similarly, the deployment of the National Cardiovascular Data Registry (NCDR) in the United States resulted in better monitoring of cardiac procedures, comparison of diagnostic and therapeutic patterns in different settings, and assessment of the safety and performance of medical equipment used for cardiac procedures.²¹

However, little research concerning CathPCI registries has been conducted, and little is known about the features of such registries from a data management perspective. This study aims to review CathPCI registries to obtain a better understanding of the steps taken for data management.

Methods

A search for relevant English-language articles, based on keywords in the title, abstract, and MeSH (Medical Subject Headings) terms, was performed in the Medline, Embase, and Cochrane databases, regardless of the date of publication. Researchers have suggested using a combination of relevant databases for adequate and efficient coverage.²² The preliminary search in these databases resulted in finding relevant articles. We reviewed the publications found in relation to cardiac catheterization registry, data collection, data processing, and data distribution. The key terms included, but were not limited to, “CathPCI,” “Data Management,” and “Registry.” Figure 1 shows the search strategy for identifying the relevant articles. The research was conducted based on three strategies. In strategy 1, keywords and MeSH terms related to CathPCI (A) were combined with terms related to data gathering (B). In strategy 2, CathPCI (A) and data processing (C) were combined to identify relevant articles addressing these two aspects. In the third strategy, terms related to CathPCI (A) were combined with terms related to information distribution (D). The results of these parts were combined using the Boolean operator “and.” Searching was supplemented by checking the bibliographies of identified articles. Articles were selected if they addressed data management with a focus on CathPCI and if at least one of their objectives dealt with data gathering, processing, and distribution in relation to percutaneous coronary intervention (PCI) registry, catheterization registry, and CathPCI registry. Studies that merely addressed clinical trial registries and cardiovascular disease registries with no focus on CathPCI procedures were excluded from the study. The reason for this exclusion was that registries for procedures are different from clinical trial and disease registries in terms of the data management approach, and the focus of the current study was a procedure registry.

The first three authors checked all titles and abstracts to determine the eligibility of the identified articles. The fourth and fifth authors conducted a further check of the articles to ensure that the results met the selection criteria.

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) set of items for analysis was used as a guide in this study.

Background

A CathPCI registry is used for managing data related to diagnostic and therapeutic coronary catheterization performed through PCI.²³ There are numerous such registries, for example, the CathPCI registry that belongs to the NCDR in the United States,²⁴ the Melbourne Interventional Group (MIG)

registry in Australia,²⁵ the Euro Heart Survey of PCI (EHS-PCI) with Cardiology Audit and Registration Data Standards (CARDS) registry in Europe,²⁶ the British Cardiac Interventional Society's Coronary Angioplasty Register (BCIS) in the United Kingdom,²⁷ the CARDIO Agence Regionale d'Hospitalisation d'Ile de France registry in France,²⁸ the Swedish Coronary Angiography Angioplasty Registry (SCAAR) in Sweden,²⁹ the Spanish Registry of Cardiac Catheter Interventions (SRCCI) in Spain,³⁰ the German PCI Registry (ALKK) in Germany,³¹ the Austrian National CathLab Registry (ANCALAR) in Austria,³² the J-PCI registry in Japan,³³ and the K-PCI registry in South Korea.³⁴ Among the aforementioned registries, three CathPCI registries were selected for review: the NCDR registry in the United States, the MIG registry in Australia, and the EHS-PCI registry in Europe. These countries are considered pioneers in cardiovascular data management,^{35,36} and their registries are the main ones used for cardiovascular and interventional cardiology. In addition, the availability of information about these three CathPCI registries allowed their review in terms of data gathering, data processing, and data distribution. The limited access to, and the shortage of detailed information about, the CathPCI registry in other countries resulted in our decision not to include them.

The NCDR CathPCI Registry in the United States

In 1987, the American College of Cardiology developed a database to collect standardized clinical information for patients undergoing cardiac catheterization. After precise planning and the completion of this database, the initial NCDR CathPCI registry was established in 1997. Approximately 90 percent of hospitals and PCI centers in the United States use this registry. However, this registry has limitations, such as the lack of linkage with the longitudinal data of patients and medical insurance services, and the six-month interval from data gathering to information distribution.^{37,38}

In terms of realizing the expected benefits, the CathPCI registry has achieved some accomplishments, such as quality improvement and reduction of adverse consequences of this procedure. Specifically, to reduce bleeding caused by the CathPCI procedure, information gained from this registry could be used to determine the appropriate strategy, including the use of manual pressure, vascular closure devices (VCDs), or bivalirudin.³⁹ Furthermore, choosing the appropriate type of VCD via information gained through a CathPCI registry is recommended.^{40,41} Another application of the CathPCI registry deals not only with balloons but also with stents as another device used for the CathPCI procedure, and this application has been enhanced using information obtained from CathPCI data management. In recent years, different kinds of stents, including bare-metal stents, stents built with various kinds of polymers, closed-cell stents, open-cell stents, and drug-eluting stents, have been evaluated based on the CathPCI registry to select the most appropriate stent device according to the patient's condition.⁴²

Enhancement of diagnostic cardiac catheterization approaches via available data has led to the use of robots to perform the catheterization procedure. The CathPCI registry could help in modeling the movement of the catheter used by catheterization robots. The benefits of using robots are increased stability, elimination of tremors, and convenience for the specialist and operator as well as minimization of coronary lesions.⁴³ In addition, the use of machine-learning algorithms to improve the diagnostic approach of this procedure is among the benefits of applying the CathPCI registry. For instance, an algorithm that uses a novel support vector method has been designed to predict the complications of PCI.⁴⁴

Currently, data gathering for these registries is performed with web-based software.⁴⁵ Additionally, data are gathered using standardized definitions and are subjected to precise data quality control. The NCDR's CathPCI registry has introduced a data quality plan to ensure data completeness, compatibility, and accuracy. The data quality plan for this registry included a data quality report, a set of internal quality assurance protocols, and a yearly data audit program scrutinized by data quality authorities.⁴⁶ In this registry, various data elements have been generated and updated in 17 categories and subcategories by the technical committee for data collection. The data collected include patient demographics, episode of care, medical history and risk factors, visits to the catheterization laboratory, catheterization diagnosis, information on the estimation of coronary arterial anatomy, information on PCI procedures, lesions, devices, laboratory exams, outcomes, and discharge information.⁴⁷ The NCDR's CathPCI registry data processing aims to calculate the frequency of CathPCI performed in different circumstances,⁴⁸⁻⁵⁰ analyze

the outcomes of CathPCI procedures to enhance diagnostic and therapeutic approaches,^{51, 52} calculate the ratio of success and failure of CathPCI procedures with respect to medical devices in order to compare and improve medical devices,⁵³⁻⁵⁶ and assess the quality of the procedures.^{57, 58}

According to the policies of the registry's stakeholders, the registry information is distributed as general reports to participating hospitals, physicians, researchers, medical device companies, and even patients.⁵⁹

The MIG CathPCI Registry in Australia

The MIG is a registry and voluntary collaborative venture designed to gather data related to diagnostic and therapeutic interventions. It was established to replace the Australian Cardiac Procedure Registry in 2004 by the Centre of Cardiovascular Research and Education in Therapeutics, a research body within the Department of Epidemiology and Preventive Medicine at Monash University in Melbourne. Currently, the CathPCI registry is the only registry implemented in the MIG. The advantages of this registry involve large-scale analysis of current interventional strategies (e.g., drug-eluting stents, evaluation of new technologies, and cost-effectiveness analysis), providing a basis for multicenter clinical trials⁶⁰ to improve diagnostic and therapeutic procedures as well as the development of medical devices. The MIG CathPCI registry is linked to the Victorian Cardiac Outcomes Registry for performance improvement.⁶¹ Data collection was paper based from 2004, but beginning gradually in 2013, case reports are completed through a web-based system. A database working group and specialists within the MIG came to a consensus on the final fields of the MIG registry.^{62, 63}

Initially, some key principles were implemented in relation to controlling data quality to provide the MIG registry with accurate and reliable information. The data quality inspection officer is a person or group appointed to ensure that the data collected are accurate and meet the standards to be analyzed and eventually reported appropriately. They record the date and appropriately note any errors found. The audit forms are then sent to the MIG database and compared to the results recorded in the MIG.⁶⁴ In the MIG registry, the data collected include demographic information of patients who underwent CathPCI, admission information, history and relevant risk factors, previous interventions, the heart condition of the patient at the time of receiving CathPCI, visits to the catheterization laboratory, catheterization procedure information, characteristics and anatomical positions of the arteries that had lesions, outcomes, and discharge information.⁶⁵ The data are then analyzed to calculate the frequency of patients and CathPCI procedures for different conditions,⁶⁶ analyze outcomes of CathPCI procedures,⁶⁷⁻⁶⁹ analyze data related to improvement of diagnostic approaches,⁷⁰⁻⁷⁴ calculate the ratio of success and failure of CathPCI procedures for the purpose of comparing and improving medical devices,⁷⁵⁻⁷⁸ and determine the quality of CathPCI procedures in Australia.^{79, 80} The registry's information is distributed to the participating hospitals, physicians, researchers, and medical device companies according to their needs.⁸¹

The EHS-PCI CathPCI Registry in the European Union

Comparison and interpretation of the data from different registries in Europe is often limited and complicated because of the variety of data sets and their definitions. The European Society of Cardiology (ESC), in partnership with the Department of Health and Children in Ireland and the Irish Cardiac Society, developed data standards for clinical cardiology in 2004. The aim of this project, the Cardiology Audit and Registration data standard known as CARDS, was to reach an agreement on variables, definitions, and coding for three modules of cardiology information systems (acute coronary syndromes, CathPCI, and clinical electrophysiology). This standard was used by the ESC to develop the EHS-PCI registry for the European Union in 2005 based on the experiences of implementing CathPCI registries in different countries, including the SRCCI, the SCAAR, the BCIS, the ALKK, and registries in Switzerland and Poland.^{82, 83} To organize data collection, the registry's technical committee classified various data elements into 16 data categories and subcategories. The main data categories were demographics, episode of care, history and relevant risk factors, visits to the catheterization laboratory, catheterization diagnostic procedure, estimation of the coronary arteries anatomy, information on PCI, lesions and devices, laboratory studies, outcomes, and discharge (this category consisted of data elements related to medications at the time of discharge).⁸⁴ The data quality is assessed using web-based technology,⁸⁵

covering aspects such as checking for lost data and data accuracy.⁸⁶ In EHS-PCI registry data, processing consists of calculating the frequency of patients and the CathPCI procedures performed in different circumstances,⁸⁷ processing the outcome of the CathPCI procedure,⁸⁷⁻⁹¹ processing data related to the development of diagnostic and therapeutic approaches,⁹²⁻⁹⁵ determining the success and failure rates of CathPCI procedures with regard to medical devices used with the aim of comparing and improving medical devices,⁹⁶ and processing data in relation to the quality of CathPCI procedures performed. Based on the decision of the ESC, the reports of this registry are distributed to the participating hospitals, physicians, researchers, and medical device companies.⁹⁷

Findings

The findings of this review are presented here with a focus on data gathering, data processing and information distribution in CathPCI registries in the United States (NCDR), Australia (MIG), and the European Union (EHS-PCI).

Data Gathering in CathPCI Registries

The first step toward CathPCI data management is data gathering. The standardization of data elements and provision of clear definitions for data elements influence the data gathering process. The data element categories in the three selected registries are presented in Table 1. The details of data elements in the three registries are presented in Appendix A.

As Table 2 demonstrates, the application of web-based tools is common in the selected registries, and in these registries, checking the quality of data is part of the data gathering process.⁹⁸⁻¹⁰⁰ Key aspects of controlling data quality include ensuring the completeness and accuracy of data.¹⁰¹⁻¹⁰³

Data Processing in the CathPCI Registry

Data processing is the second step of CathPCI data management and includes the analysis of the number of procedures performed in different circumstances¹⁰⁴⁻¹⁰⁶ and procedure outcomes,¹⁰⁷⁻¹⁰⁹ processing data pertaining to improvement of diagnostic and therapeutic approaches,¹¹⁰⁻¹¹⁴ processing data relating to the development of devices,¹¹⁵⁻¹¹⁷ and assessing the quality of performed procedures,¹¹⁸⁻¹²¹ as shown in Table 3. Further details about data processing metrics are presented in Appendix B.

Information Distribution in the CathPCI Registry

Information distribution is the final step of CathPCI data management. In general, the collected information is distributed for the stakeholders of the CathPCI registry depending on the target category needs and the policies considered at the time when the registry was planned. Reports may supply the information needed for a specific study or information for the development of diagnostic and therapeutic approaches to update medical guidelines; accordingly, the reports will be distributed to researchers and physicians. Planning for a society's health requires the information contained in the registry, so this information must be distributed to the relevant healthcare system (e.g., the noncommunicable disease division of a department or ministry of health). Distribution of reports to hospital authorities, healthcare centers, and cardiac catheterization laboratories is required to evaluate and plan for improving and monitoring the quality and operations of service providers. The reports may also be distributed to medical device companies for the development of medical equipment and devices. In developing countries where medicine is evidence-based, reports may be distributed to patients to help them make decisions regarding the center providing the service and the types of devices used in the CathPCI procedure, considering the financial conditions, distance, and the quality of the procedure.¹²²⁻¹²⁴

Discussion

The development of a CathPCI registry for data management could help to improve the delivery of services to patients with heart conditions. The successful development of a CathPCI registry would lead to improvement in the quality and safety of coronary interventions, as well as the development of equipment and devices, thereby enhancing the approaches and outcomes of this diagnostic and therapeutic procedure. With respect to the three registries reviewed in the current study, the NCDR registry was

launched in 1997 and the MIG and the EHS-PCI registries were developed in 2004 and 2005, respectively.^{125–127} The main steps of CathPCI data management are the same in the reviewed registries, and this finding suggests that the NCRD might have been used as a basis for other two registries.^{128, 129} These registries include a wide range of data elements, with similarities in the main data elements. However, there are differences in relation to the data collected, as local and national needs differ. One approach that could be applied in the development of a registry is that data collection should be limited to those elements that meet certain needs to avoid unnecessary data collection.¹³⁰ Another key approach that could improve data collection is the creation of standardized data definitions to ensure consistent data collection at local, national, and international levels. Studies show that the lack of standardized definitions is a major problem, especially at a national level, which could influence data collection and reporting.^{131, 132} The standardization of data definitions provides a clear, consistent, and unambiguous approach for data gathering, ultimately leading to all related bodies having a common and shared understanding of the meaning and characteristics of the data.¹³³ The use of classification systems and terminologies, such as ICD-10-PCS and Current Procedural Terminology (CPT), could assist in the standardization of definitions for interventional cardiology, including CathPCI.^{134, 135}

All three registries benefit from web-based data collection to facilitate data collection and reporting. Data are entered via a secure, password-protected website managed by the registries. The application of Hypertext Markup Language 5 (HTML5), for instance, could facilitate data gathering by allowing the use of different devices, such as personal computers, laptops, tablets, and cell phones.^{136–138} However, problems with data collection and reporting might still be encountered because of interoperability issues.¹³⁹ Integration of CathPCI registries with electronic medical records could facilitate data collection, as the required data could be directly collected from patients' medical records electronically and transferred to the registries.^{140, 141} The use of data exchange standards, such as HL7, could eliminate integration issues.¹⁴² Another important aspect related to CathPCI registries is associated with data quality. The registries reviewed used web-based technologies to check the quality of the data, with data completeness and accuracy among the main data quality criteria used. Research suggests that accurate data can be collected through careful data cleaning and verification.¹⁴³ Indeed, quality audits in the NCDR indicate a range of 85 to 95 percent accuracy of data collection.¹⁴⁴ Data accuracy could be further improved by replacing manual data extraction and validation methods with electronic approaches.¹⁴⁵

In relation to the category of data processing, the three registries are similar. However, there are differences in relation to data processing metrics, as local, national, and research needs differ. To provide more timely and customized data processing, the NCDR introduced the NCDR dashboard, which is available to the related centers on a secure website. The dashboard allows the centers to interrogate each metric included in the data processing categories in more detail, including longitudinal data trends.^{146, 147}

Developing well-customized data processing tools like the NCDR dashboard by other registries could improve data processing according to the metrics that are established.

Limitations of the Study

This study focused only on CathPCI registries in three countries with no time frame for the studies because of the limited access to, or the shortage of detailed information about, CathPCI registries in other countries. However, the three CathPCI registries in the United States, Australia, and the European Union were reviewed in detail. In addition, the current study included only relevant studies in English because of language barriers. Reviewing non-English-language studies could give a more in-depth analysis of CathPCI registries in relation to data management. However, a combination of different databases was used for searching the literature, which helped to reduce the risk of not including relevant studies.

Conclusion

The development of a CathPCI registry considering the key steps of data management has a pivotal role to play in coronary catheterization. A registry could help improve CathPCI approaches, develop equipment and devices, and minimize complications of the CathPCI procedure. Improving data collection

and processing approaches is necessary to use this registry efficiently and effectively. Because data gathering occurs over time, checking data quality to create valid and accurate reports is essential.

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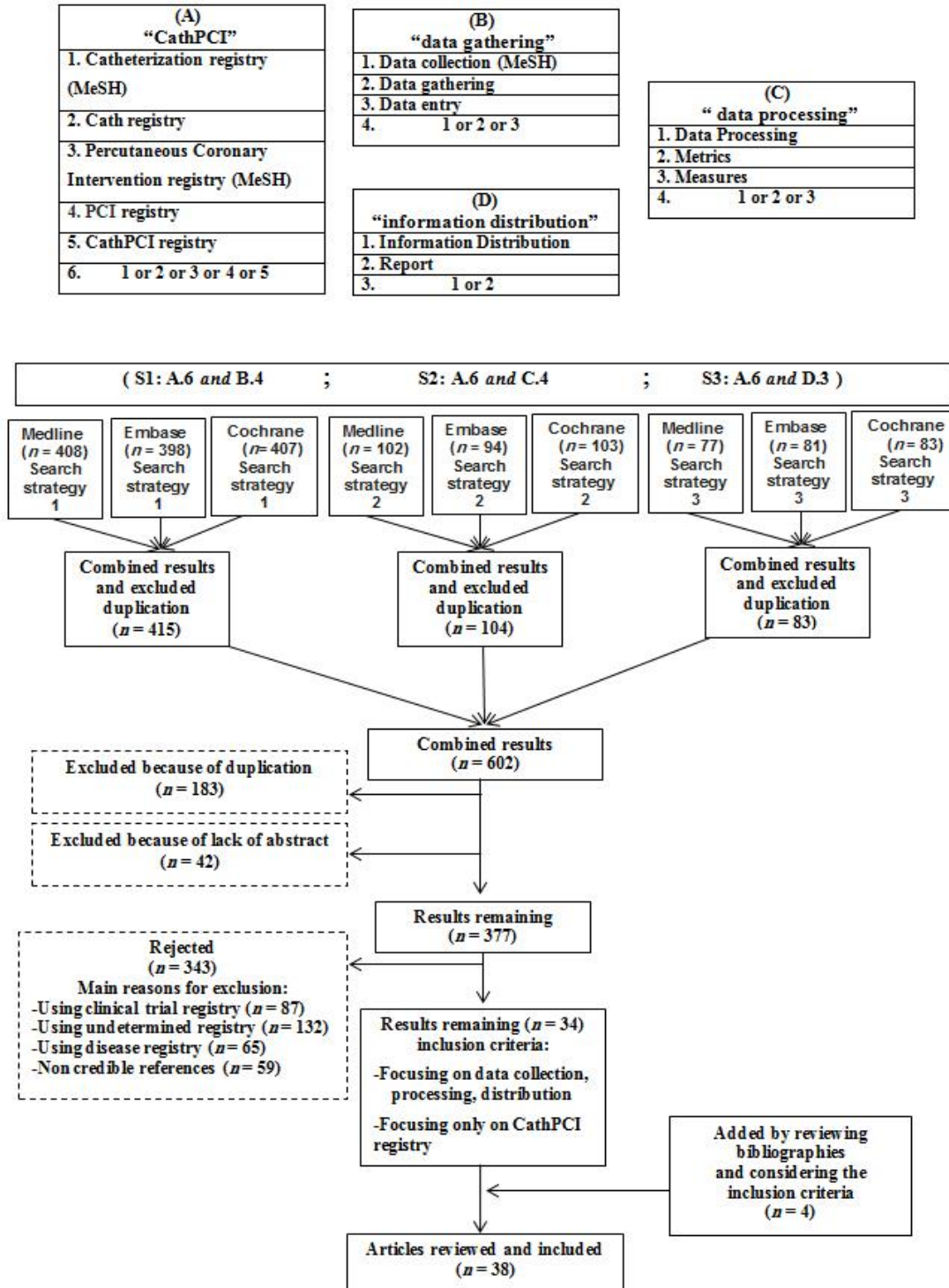
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Figure 1

Search Strategies and Search Flow



Abbreviation: CathPCI, catheterization and percutaneous coronary intervention.

Table 1

Data Element Categories in the Reviewed Registries

Data Element Category	Registry		
	NCDR	MIG	EHS-PCI (CARDS)
Patient demographics	✓	✓	✓
Episode of care	✓	✓	✓
Medical history and risk factors	✓	✓	✓
Visits to catheterization laboratory	✓	✓	✓
Clinical evaluation leading to the procedure	✓	✓	✓
Procedure information	✓	✓	✓
Mechanical ventricular support	✓	✓	✓
Arterial access	✓	✓	✓
Information of catheterization diagnosis	✓	✓	✓
Coronary arteries anatomy	✓	✓	✓
Information on PCI	✓	✓	✓
Procedure medication	✓	✓	✓
Laboratory studies	✓	✓	✓
Outcomes	✓	✓	✓
Discharge	✓	✓	✓
Discharge medication	✓	✓	✓

Abbreviations: CathPCI, catheterization and percutaneous coronary intervention; National Cardiovascular Data Registry (NCDR); EHS-PCI (CARDS), Euro Heart Survey of PCI with Cardiology Audit and Registration Data Standards; MIG, Melbourne Interventional Group; PCI, percutaneous coronary intervention.

Table 2

Data Gathering Technology and Data Quality Control in the Reviewed Registries

Category Reviewed	Registry		
	NCDR	MIG	EHS-PCI (CARDS)
Data gathering technology	Web-based	Web-based	Web-based
Data completeness control	✓	✓	✓
Data accuracy control	✓	✓	✓

Abbreviations: National Cardiovascular Data Registry (NCDR); EHS-PCI (CARDS), Euro Heart Survey of PCI with Cardiology Audit and Registration Data Standards; MIG, Melbourne Interventional Group; PCI, percutaneous coronary intervention.

Table 3

Data Processing Categories in the Reviewed Registries

Data Processing Category Reviewed	Registry		
	NCDR	MIG	EHS-PCI (CARDS)
Calculation of the frequency of CathPCI performed in different circumstances	✓	✓	✓
Processing related to CathPCI procedures outcomes	✓	✓	✓
Processing related to enhancement of diagnostic and therapeutic approaches	✓	✓	✓
Processing related to improvement of the devices	✓	✓	✓
Processing related to quality of the services	✓	✓	✓

Abbreviations: CathPCI, catheterization and percutaneous coronary intervention; National Cardiovascular Data Registry (NCDR); EHS-PCI (CARDS), Euro Heart Survey of PCI with Cardiology Audit and Registration Data Standards; MIG, Melbourne Interventional Group; PCI, percutaneous coronary intervention.

Appendix A

Details of Data Elements in the Reviewed Registries

Data Elements	Registry		
	NCDR	MIG	EHS-PCI (CARDS)
Patient demographics	✓	✓	✓
Last name	✓	✓	✓
First name	✓	✓	✓
Middle name	✓	✓	✓
Patient identification number	✓	✓	✓
Date of birth	✓	✓	✓
Sex	✓	✓	✓
Race	✓	-	-
Episode of care	✓	✓	✓
Date of admission/arrival	✓	-	✓
Time of admission/arrival	✓	✓	✓
Postcode	✓	✓	-
Admit source	✓	✓	-
Insurance status	✓	✓	-
Insurance number	✓	✓	-
Medical history and risk factors	✓	✓	✓
Smoking status	✓	✓	✓
History of hypertension	✓	✓	✓
History of dyslipidemia	✓	✓	-
History of hypercholesterolemia	-	-	✓
Family history of coronary artery disease	✓	✓	-
History of previous myocardial infarction	✓	✓	✓
History of congestive heart failure	-	✓	✓
History of valvular heart disease	-	-	✓
Previous valvular surgery	✓	✓	-
Date of most recent valvular surgery	-	✓	-
Previous PCI	✓	✓	✓
Date of most recent PCI	✓	✓	-
Previous coronary artery bypass grafting	✓	✓	✓
Date of most recent coronary artery bypass grafting	✓	✓	-
Height	✓	✓	✓

Weight	✓	✓	✓
Dialysis requiring	✓	✓	-
History of chronic renal failure	-	-	✓
Cerebrovascular disease	✓	✓	-
History of stroke	-	-	✓
History of peripheral arterial disease	✓	✓	✓
Chronic lung disease	✓	✓	-
Type of chronic lung disease	-	✓	-
Diabetes mellitus	✓	✓	✓
Type of diabetes therapy	✓	✓	✓
Functioning renal transplant	-	✓	-
Obstructive sleep apnea	-	✓	-
Clinical evaluation leading to the procedure	✓	✓	✓
Coronary artery disease presentation	✓	✓	✓
Heart failure within two weeks, New York Heart Association (NYHA) class	✓	✓	-
Angina classification within 2 weeks	-	-	✓
Cardiomyopathy or LV systolic dysfunction	✓	✓	✓
Cardiogenic Shock within 24 hours	✓	✓	✓
Standard exercise stress test	✓	-	-
Stress echocardiogram	✓	-	-
Stress testing w/SPECT Myocardial Perfusion Imaging (MPI)	✓	-	-
Stress testing w/Cardiac Magnetic Resonance (CMR)	✓	-	-
Procedure information			
Procedure date	✓	✓	✓
Procedure time	✓	-	-
Diagnostic catheterization	✓	✓	✓
CathPCI for treatment	✓	✓	✓
Fluoroscope time	✓	-	-
Fluoroscope dose	✓	-	-
Contrast	✓	✓	-
Mechanical ventricular support			
Intra-aortic balloon pump	✓	✓	✓
Other mechanical ventricular support	✓	-	-
Drug-eluting stent	-	✓	✓
Closed-cell stent	-	✓	✓
Open-cell stent	-	✓	✓
Rotational atherectomy	-	✓	✓
Arterial access	✓	✓	✓

Arterial access site	✓	✓	✓
Closure method	✓	✓	✓
Information of catheterization diagnosis	✓	✓	✓
Operator's name and ID	✓	-	-
Left heart catheterization	✓	✓	✓
Cardiac transplant evaluation	✓	✓	✓
Catheterization type	-	✓	-
Prescription after procedure	✓	✓	✓
Coronary arterial anatomy	✓	✓	✓
Artery stenosis in left main	✓	✓	✓
Artery stenosis in prox Left Anterior Descending (LAD)	✓	✓	✓
Artery stenosis in mid/distal LAD, diagonal branches	✓	✓	✓
Artery stenosis in Circumflex artery segment (Circ), Obtuse Marginal(OM), Left Posterolateral Descending Artery (LPDA), Left Posterolateral (LPL) branches	✓	✓	✓
Artery stenosis in Right Coronary Artery (RCA), Right Posterior Descending Artery (RPDA), Right Posterolateral(RPL), Acute Marginal (AM) branches	✓	✓	✓
Artery stenosis in ramus	✓	✓	✓
Information of PCI	✓	✓	✓
Pre-CathPCI left ventricular ejection fraction	✓	✓	✓
CathPCI indication	✓	✓	✓
Subsequent electrocardiogram with STEMI date/time	✓	✓	✓
Reason for delay in CathPCI	✓	-	-
Procedure medication	✓	✓	✓
Medication fondaparinux	✓	✓	✓
Medication low molecular weight heparin	✓	✓	✓
Medication unfractionated heparin	✓	✓	✓
Medication aspirin	✓	✓	✓
Medication bivalirudin	✓	✓	✓
Medication direct thrombin inhibitor	✓	✓	✓
Medication GP IIb/IIIa	✓	-	-
Medication clopidogrel	✓	✓	✓
Medication prasugrel	✓	✓	✓
Medication ticagrelor	✓	-	-
Laboratory studies	✓	✓	✓
CK-MB pre/post-procedure	✓	✓	✓
Troponin I pre/post-procedure	✓	✓	✓
Troponin T pre/post-procedure	✓	✓	✓
Creatinine pre/post-procedure	✓	✓	✓

Hemoglobin pre/post-procedure	✓	✓	✓
Outcomes	✓	✓	✓
Myocardial infarction	✓	✓	✓
Cardiogenic shock	✓	✓	✓
Heart failure	✓	✓	✓
CVA/stroke	✓	✓	✓
Tamponade	✓	✓	✓
New requirement for dialysis	✓	✓	✓
Other vascular complications requiring Rx	✓	✓	✓
RBC/whole blood transfusion	✓	✓	✓
Bleeding event within 72 hours	✓	✓	✓
Size of hematoma	✓	✓	✓
Discharge	✓	✓	✓
Coronary artery bypass graft	✓	✓	✓
Post-procedure left ventricular ejection fraction	✓	✓	✓
Discharge date	✓	✓	✓
Discharge status	✓	✓	✓
Hospital status	✓	✓	✓
Discharge medication	✓	✓	✓
Medication angiotensin converting enzyme inhibitor	✓	✓	✓
Medication angiotensin receptor blocker	✓	✓	✓
Medication aspirin	✓	✓	✓
Medication beta blocker	✓	✓	✓
Medication lipid-lowering agents, statin	✓	✓	✓
Medication lipid-lowering agents, non-statin	✓	✓	✓
Medication clopidogrel (P2Y12)	✓	✓	✓

Abbreviations: CathPCI, catheterization and percutaneous coronary intervention; National Cardiovascular Data Registry (NCDR); EHS-PCI (CARDS), Euro Heart Survey of PCI with Cardiology Audit and Registration Data Standards; MIG, Melbourne Interventional Group; PCI, percutaneous coronary intervention.

Appendix B

Details of Data Processing Metrics in the Reviewed Registries

Data Processing Metrics	Registry		
	NCDR	MIG	EHS-PCI (CARDS)
Calculation of the frequency of CathPCI performed in different circumstances	✓	✓	✓
Total PCI procedures	✓	✓	✓
Total diagnostic catheterization and PCI procedures during same lab visit	✓	–	✓
Total number of patients	✓	✓	✓
Total non-ST-segment elevation myocardial infarction (non-STEMI) PCI procedures performed	✓	✓	✓
Total STEMI PCI procedures performed	✓	✓	✓
Count of procedures with arterial access site = femoral or brachial or radial	✓	✓	✓
Processing related to CathPCI procedure outcomes	✓	✓	✓
Proportion of patients with post-procedure revascularization	–	–	✓
Proportion of patients with post-procedure myocardial infarction (when routinely collecting post-PCI biomarkers)	✓	✓	✓
Proportion of patients with post procedure myocardial infarction (when not routinely collecting post-PCI biomarkers)	✓	✓	–
Proportion of diagnostic catheterization procedures with vascular access site injury requiring treatment or major bleeding	✓	✓	✓
Proportion of patients with post-procedure cardiac tamponade	–	–	✓
Proportion of patients with post-procedure hemorrhagic bleeding	–	✓	✓
Proportion of patients with post-procedure stroke	✓	✓	✓
Proportion of CathPCI procedures with transfusion of whole blood or red blood cells	✓	✓	✓
Proportion of patients with emergency coronary artery bypass graft	✓	✓	✓
PCI in-hospital observed/expected mortality ratio	✓	✓	–
PCI in-hospital observed mortality ratio (patients with STEMI)	✓	✓	–
PCI in-hospital expected mortality ratio (patients with STEMI)	✓	–	–

PCI in-hospital observed/expected mortality ratio (patients without STEMI)	✓	-	-
PCI in-hospital observed rate of bleeding events	✓	✓	✓
PCI in-hospital expected rate of bleeding events	✓	-	-
Processing related to enhancement of diagnostic and therapeutic approaches	✓	✓	✓
Count of diagnostic catheterization procedures with all native coronary artery territories <50%	✓	-	-
Proportion of elective PCIs with prior positive stress or imaging study	✓	-	-
Proportion of PCI procedures with creatinine assessed pre- and post-PCI procedure	✓	✓	✓
Proportion of patients with aspirin prescribed at discharge	✓	✓	✓
Proportion of patients with statins prescribed at discharge	✓	✓	✓
Proportion of patients with a P2Y12 inhibitor prescribed at discharge (patients with stents)	✓	✓	✓
Proportion of evaluated PCI procedures that were inappropriate according to Appropriate Use Criteria guidelines	✓	-	-
Proportion of evaluated PCI procedures that were appropriate according to Appropriate Use Criteria guidelines	✓	-	-
Proportion of PCI procedures not classifiable for Appropriate Use Criteria reporting	✓	-	-
Processing related to improvement of the devices	✓	✓	✓
Proportion of CathPCI with vascular closure devices	✓	-	-
Proportion of PCI with stent	✓	✓	✓
Proportion of PCI with drug-eluting stent	-	✓	✓
Proportion of PCI with closed-cell stent	-	-	✓
Proportion of PCI with open-cell stent	-	-	✓
Proportion of PCI with only balloon	-	✓	-
Proportion of PCI with rotational atherectomy	-	✓	-
Processing related to quality of the services	✓	✓	✓
Median time to immediate PCI for STEMI patients (in minutes)	✓	✓	-
Median time from emergency department arrival at STEMI transferring facility to emergency department arrival at STEMI receiving facility among transferred patients	✓	✓	✓
Median time from emergency department arrival at STEMI transferring facility to immediate PCI at STEMI receiving facility among transferred patients (in minutes)	✓	-	✓

Median Fluoroscope time for CathPCI procedures	✓	✓	-
Median post-procedure length of stay (in days) for PCI patients with STEMI	✓	-	-

Abbreviations: CathPCI, catheterization and percutaneous coronary intervention; National Cardiovascular Data Registry (NCDR); EHS-PCI (CARDS), Euro Heart Survey of PCI with Cardiology Audit and Registration Data Standards; MIG, Melbourne Interventional Group; PCI, percutaneous coronary intervention.