Utilising a data capture tool to populate a cardiac rehabilitation registry: a feasibility study

Abstract

Background: Clinical registries are effective for monitoring clinical practice, yet manual data collection can limit their implementation and sustainability. The objective of this study was to assess the feasibility of using a data capture tool to collect cardiac rehabilitation (CR) minimum variables from electronic hospital administration databases to populate a new CR registry in Australia.

Methods: Two CR facilities located in Melbourne, Australia participated, providing data on 42 variables including: patient socio-demographics, risk factors and co-morbidities, CR program information (e.g. number of CR sessions), process indicators (e.g. wait time) and patient outcomes (e.g. change in exercise capacity). A pre-programmed, automated data capture tool (GRHANITE™) was installed at the sites to extract data available in an electronic format from hospital sites. Additionally, clinicians entered data on CR patients into a purpose-built web-based tool (REDCap). Formative evaluation including staff feedback was collected.

Results: The GRHANITE™ tool was successfully installed at the two CR sites and data from 176 patients (median age=67 years, 76% male) were securely extracted between September – December 2017. Data pulled electronically from hospital databases was limited to seven of the 42 requested variables. This is due to CR sites only capturing basic patient information (e.g. socio-demographics, CR appointment bookings) in hospital administrative databases. The remaining clinical information required for the CR registry were collected in formats (e.g. paper-based, scanned or Excel spreadsheet) deemed unusable for electronic data capture. Manually entered data into the web-tool enabled data collection on all remaining variables. Compared to historical methods of data collection, CR staff reported that the REDCap tool reduced data entry time.

Conclusions: The key benefits of a scalable, automated data capture tool like GRHANITE™ cannot be fully realised in settings with under-developed electronic health infrastructure. While this approach

remains promising for creating and maintaining a registry that monitors the quality of CR provided to patients, further investment is required in the digital platforms underpinning this approach.

Key words: cardiac rehabilitation; registry; data scraping

Introduction

The ability to quantify healthcare quality relies on the implementation of appropriate systems that can accurate capture how care is being delivered [1]. In a recent scientific statement, the American Heart Association called for the systematic redesign of cardiovascular care to enable a 'learning healthcare system' which uses information technology and data infrastructures to enhance optimal healthcare delivery [2]. In Australia, the Commission on Safety and Quality of Health Care (the Commission) promotes the use of clinical registries to systematically monitor healthcare, highlight variations in outcomes, and inform quality improvement efforts [3]. Ischaemic heart disease ranks as the highest priority area identified by the Commission that would benefit from registry development due to the high burden of disease, serious consequences associated with poor quality care and strong clinical support [4]. This follows the success of cardiac registries internationally including the Global Registry of Acute Coronary Events (GRACE)[5] and effective system-wide changes seen by countries such as Sweden which has established more than 100 health registries including some that have been maintained for more than 25 years [6].

A key component of secondary prevention of heart disease is cardiac rehabilitation (CR). Although CR is extremely effective in preventing cardiovascular recurrent events and complications [7] and recommended in clinical guidelines [8, 9], there is variability in program delivery and quality [10] some of which stems from a lack of uniform data collection and monitoring systems. The need to develop quality indicators and implement systems that collect standardised CR outcome data is recognised by several national associations internationally [11-13] including the Australian Cardiovascular Health and Rehabilitation Association's (ACRA; the Australian association of CR professionals) [14]. Specifically, ACRA recommend that all CR services collect a minimum set of data

and report on key performance indicators to promote continuous quality improvement of services and benchmarking[14]. Despite these calls, quality indicator data from CR sites are, for the most part, not systematically collected or collated. One jurisdiction in Australia, Queensland, has recently established the Queensland Cardiac Outcomes Registry (QCOR) which includes the collection of CR quality indicator variables as part of the registry and will be the first state in Australia to systematically collect CR data [15]. In the state of Victoria, the Victorian Cardiac Outcomes Registry (VCOR) [16] collects data on cardiac patients across 35 hospitals on three modules (percutaneous coronary intervention, heart failure and the early treatment of acute myocardial infarction). However, CR data are not included within VCOR.

Globally, custodians of CR registries have noted challenges, common to any registry, such as site investment or 'buy-in', privacy and security considerations, as well as limited resources for contributing data [17]. Indeed, sites are often required to manually enter data, which is time-consuming for clinical staff and increases the risk of data errors [18]. Ideally, data collection should be automated and linked to administrative databases or electronic medical records (EMRs). With advances in technology, this is becoming more feasible. Automated data capture techniques using specially-designed software can be used to extract routinely-collected data. Such software can also incorporate automated safeguards built-in to the data entry systems to ensure privacy protection. This has been previously demonstrated within primary care and other settings in Australia [19] using the GRHANITE™ (GeneRic Health Network Information for the Enterprise [20]: https://www.grhanite.com/) tool.

The aim of this manuscript was to assess the feasibility of extracting routinely-collected minimum data (as defined by the NSW division of ACRA [21]) from CR sites and hospital administration databases using the GRHANITE™ automated data capture tool in order to populate a Victorian CR Registry (VCRR).

Methods

Overarching design of VCRR

This feasibility study consisted of a 3-month (September-December 2017) data collection period involving quantitative data capture from two pilot sites and formative evaluation of the process including feedback from CR clinicians. The design of the registry was guided by technical standards outlined by the Commission [3], as illustrated in a logic model (Figure 1).

FIGURE 1

Figure 1 Clinical Quality Registries Information Model [16]. Reproduced with permission from *Logical Design for Australian Clinical Quality Registries*, developed by the Australian Commission on Safety and Quality in Health Care (ACSQHC), for use exclusively in Australia. ACSQHC: Sydney. 2012.

Acronyms: CQR: clinical quality registry; MBS: Medicare Benefits Schedule; PBS: Pharmaceutical Benefits Scheme

Selection of the minimum variables for the VCRR

The registry comprised a minimum set of variables selected from the New South Wales (NSW) ACRA association quality indicators and data dictionary which was based on expert consensus [21]. The 42 selected data elements consisted of: demographic information (e.g. sex, age), disease/condition (e.g. principal referral diagnosis) risk factors and co-morbidities (e.g. diabetes status, smoking status), intervention (e.g. number of CR sessions), process indicators (e.g. CR wait time) and individual patient outcomes (e.g. change in pre-post exercise capacity) (Table 1).

***TABLE 1 ***

Table 1. Victorian Cardiac Rehabilitation Registry minimum variables

Setting and recruitment

In the state of Victoria in South East Australia, there are 136 CR programs, delivered across publicly and privately-funded hospitals and community health settings. The national association of CR professionals (ACRA) has a State-level directory of all CR facilities which was used to identify one

public and one private site to invite to participate in the study. These sites were purposively selected to ensure sample representation of: funding sources (public and private), settings (acute hospital, rehabilitation hospital), and location (metropolitan and suburban). Site 1 was a large publicly-funded program, which runs a six-week CR program for approximately 40 outpatients per week. Site 2 was a private facility primarily funded through health insurance funds and the Department of Veteran Affairs, which runs a 12-week program for approximately 15 outpatients per week. Participating sites were offered a stipend of AU$6,000 (USD$4700) to cover cost related to staff time for the set-up of automated data collection. Both CR sites agreed to participate.

Ethics approval

The study was approved by the Human Research Ethics Committee (HREC) at the University of Melbourne (HREC number: 1748609) and included a waiver of consent for individual patient data (which was de-identified). Site-specific research ethics approval was also obtained. Staff who participated in qualitative interviews provided informed consent.

Automated collection procedure (GRHANITE™)

The team at the University of Melbourne's Health and Biomedical Informatics Centre Research Information Technology Unit (led by DB) assisted in the development of the data extraction protocol and worked with the sites' Information Technology (IT) teams to create an interface regime. This required the development of a "mapping" document which linked the variables requested from the research team with the variables collected and available electronically at the sites. The overview of the study methods can be seen in Figure 2.

FIGURE 2

Figure 2 Overview of the study methods

Manual web-based data collection (REDCap)

To capture variables that were not available electronically at the sites, a secure web-based data collection form was designed using the REDCap (Research Electronic Data Capture: https://www.project-redcap.org/) software. The web-based form included three sections (Section 1: identifiable patient information; Section 2: pre-CR data; Section 3: post-CR data) and was trialled for two weeks at both sites, with feedback from the CR sites informing refinement of the data entry template. Once finalised, clinicians entered data for patients who were enrolled in the CR programs during the data collection period. The REDCap data collection forms contained mandatory fields to reduce missing data and in-built logic checks to increase the accuracy of data. Authorised staff were provided with a secure log-in which enabled access to the REDCap template; data access restrictions ensured clinicians could only view data from their site. Additional detail on REDCap is provided in Supplementary File 2.

Data extraction and linkage

CR data were extracted from the sites via the University of Melbourne's GRHANITE™ research data acquisition system. The GRHANITE™ interface was installed at both sites and scheduled to extract pre-determined variables on patients who participated in the CR program during the data collection period. GRHANITE™ enabled data to be extracted in a de-identified manner by incorporating advanced privacy-preserving hashing techniques to generate unique 'signatures'. These data were then securely transmitted to the VCRR database based on the University of Melbourne's server, with data stored in Microsoft SQL. Further details regarding data security and storage can be found in Supplementary File 1 and 2.

Data quality

The system highlighted any GRHANITE™ data extraction failures or omissions and IT representative at each site reviewed the data to ensure it was coherent before it was forwarded to the central registry. The REDCap data collection forms contained mandatory fields to reduce missing data (data must be entered before being able to move to the next section) and in-built logic checks to increase the accuracy of data. Missing patient records were assessed by comparing the number

of patients booked CR appointments in the electronic administrative database (total numbers) with number of patients manually entered into REDCap.

Formative evaluation

Semi-structured interviews were conducted within one week of the completed data collection period (December 2017) to ascertain any barriers or enablers to implementation of the CR registry. Individual interviews were held with clinical staff members involved with clinical data collection at the two pilot sites (N=3). The interviews were conducted by a member of the research team (ET). They were audio-recorded and then transcribed verbatim except to preserve anonymity.

The interview guide consisted of three parts: (i) historical approaches to data collection, (ii) barriers to measuring and collecting variables and (iii) recommendations for future registry implementation. Feedback provided by the clinicians was synthesised under the same three headings and identified barriers were coded in themes and sub-categories using content analysis[22].

Results

Characteristics of patients included in VCRR

The combined electronic and manual data revealed that across the two sites, 176 patients had a booked CR appointment, 115 patients (65.34%) completed the initial CR appointment and 48 patients (27.27%) completed the CR program (achieved patient goals and/or attended an agreed number of exercise and education sessions) within the data extraction period. The study sample was predominantly male (76%) with a mean age of 67 years and 83% spoke English as their preferred language (Table 2). The participant's sociodemographic characteristics differed across the two sites, with participants at Site 2 being 10 years older on average (74 years vs. 65 years) and having a lower baseline exercise capacity (95m less on the six-minute walk test) (Table 2).

TABLE 2

Table 2. Characteristics of patients included in VCRR

Variables available from the electronic hospital administrative databases were limited to seven (age, sex, postcode, Aboriginal and Torres Strait Islander status, preferred language, CR booking, referral date) for each of the patients. This is due to hospital administrative databases at the sites only collecting basic information on patient sociodemographic characteristics and CR appointment bookings. **Data extracted from the manual entry component (REDCap) enabled collection of all 42 variables in the minimum data set, supplementing the electronic data.**

CR Quality

The minimum variables extracted were useful in informing assessment of CR site quality in many instances (Table 3). There were site-specific differences in process indicators of care, suggesting the minimum variables are sensitive. For example, participants in Site 1 experienced a longer wait time to receive CR (44 days vs. 19 days) and were less likely to be screened for depression (54% vs. 92%). None of the identified smokers (across either site) were reported to have been referred for smoking cessation.

There was a large amount of missing and unknown data from the manual-entry source. Discrepancies existed between the number of patients booked CR appointments in the hospital administrative database (n=176) and those who attended the initial assessment and were entered into REDCap (n=115). Reasons for non-attendance to the initial session were not routinely collected and therefore unable to be ascertained for all cases. Further, many values in the post-CR assessment were reported as unknown (e.g. CR medication status was unknown for 44% of patient who completed a post-CR assessment).

TABLE 3

Table 3. CR process indicators

CR Staff Perceptions of Data Capture Processes

Feedback from the two sites revealed that the manual entry component was straight-forward, easy to use, and quicker than traditional forms of data collection (i.e., clinician-selected variables

entered into an Excel spreadsheet; Table 4). The training provided was perceived as sufficient and staff felt in-built features such as mandatory fields enabled them to feel more confident about the data quality. Staff expressed desire to have the capacity to search more easily for entered patient data (a feature that is available in REDCap but was not highlighted during the training session) and additional information about the rationale/evidence for some of the selected minimum variables. All interviewees wanted to continue using REDCap and preferred this approach over traditional methods; as described by the CR co-ordinator at Site 2 "*I just can see that REDCap is the bright new future that we can start to get the cardiac rehab product out there with consistency between programs… Because at the moment we can all say that we are doing cardiac rehab and we can all be members of ACRA but I don't know what you're providing and you don't know what I am doing unless you are there".*

Five main barriers were identified regarding historic methods of measuring and entering variables (see Supplementary file 3): i) workload and competing responsibilities (e.g. time constraints), ii) environmental context and resources (e.g. information technology issues, and not having access to a quiet and secure space to enter data); iii) patient factors (e.g. patient needs/concerns conflicting with data collection requirements); iv) care delivery processes and co-ordination (e.g. referrals getting lost because sent via post/fax) and v) outcome expectations (e.g. reduced confidence in data because of measurement errors).

***TABLE 4 ***

Table 4. Feedback from sites on web-based data entry

Discussion

To our knowledge, this was the first study to assess the feasibility of utilising a data capture tool to automatically extract minimum CR registry variables within public and private facilities. While CR sites collected large amounts of clinical data, the majority of these data (i.e., 83% of the 42

variables) were not readily-available in an appropriate electronic format rendering automated data extraction unfeasible. Until such time that the current infrastructure in public and private CR settings in Australia develops, the key benefits of scalable, automated data capture tools like GRHANITE™ will remain unrealised. While this approach remains promising for creating and maintaining a registry that monitors the quality of CR provided to patients, further investment is required in the digital platforms underpinning this approach including ensuring electronic platforms are i) accessible to CR sites, ii) fit for purpose and, iii) capturing high quality data. In the interim, a web-based data collection tool housed on the REDCap system can enable standardised data to be collated from various CR sites with known limitations associated with manual data entry. These key findings are discussed further below.

Greater emphasis must be placed on ensuring CR staff have access to EMRs[9]. In general, allied health and community-based settings have had low-levels of adoption of electronic health infrastructure compared to acute settings and primary care [23]. To ensure more timely access, national associations such as ACRA, the Cardiac Society of Australia and New Zealand (CSANZ) and the National Heart Foundation (NHF) need to facilitate advocacy efforts at the local, state and national-level for improved electronic infrastructure within the CR setting. For example, ACRA could provide guidance to CR co-ordinators and managers to push the agenda within local settings; enhanced CR representation on state-based cardiac clinical networks could drive the issue at a state-level; and the development of a national strategic plan and committee could be established with the aim of improving monitoring of CR and enhancing national efforts.

Future digital health investments will be driven by specific business needs and the identification and demonstration of local and system-wide benefits[24]. Consequently, a clear business case for enhanced monitoring of CR is required which details the digital requirements necessary to fulfil the current gap. Additionally, the workplace will likely need to up-skill to ensure adequate digital capability. Well-developed and robust change management is a crucial factor in deploying new

systems and clinicians must be involved in the process and actively champion health technology activities [24].

Ideally, as EMR uptake increases, all CR minimum variables would be available electronically, and a registry could be pre-filled. In other countries CR registries have begun to simultaneously link with administrative electronic databases to enable auto-filling of data (e.g. the Danish registry and Canadian registry) [17, 25]. In states where different EMR systems are being implemented, flexible tools like GRHANITE™ will be crucial in enabling interoperability of data across various systems (including public and private) whilst adhering to privacy and security concerns.

Ultimately, the success of data capture through EMRs will depend on multiple factors, including minimum variables being: i) clearly defined, ii) entered consistently across sites, iii) of sufficient reliability/validity, and iv) extractable. The CR field can begin to prepare for this now by ensuring quality indicators are clearly defined and comparable across states.

In the interim, CR data collection can be improved via the use of a standardised web-based tool housed on platforms such as the REDCap system. REDCap had multiple advantages including: i) ease of implementation without any need for the sites' IT departments, ii) usable at both public and private CR sites, iii) secure and password-protected access, iv) straight-forward and quick data entry, v) in-built functions (e.g. mandatory fields, character limits, drop down options, automated reports) to enhance data quality and completeness, vi) available for use at no costs for affiliated research institutes. Further, REDCap was supported by those entering the data who expressed an interest in continuing beyond the study period.

Use of the web-based tool, however, could be enhanced. For example, future studies should incorporate data quality checks early in the data collection period that include a comparison of enrolled and entered patient data to ensure such data match and reasons for missing data are ascertained. In Australia CR sites often refer patients to more convenient programs (e.g. closer to home); such information needs to be captured on all patients so that reasons for non-attendance

276 can be more accurately documented. Additionally, unknown data requires additional clarification.
277 For example, post-CR medication status had larger amounts of unknown responses than other
278 variables and is potentially not being checked at post-CR interviews. Automated alerts could be in-
279 built for this variable to clarify the reason for the unknown information.

280 **Study limitations**

281 We acknowledge that this study has limitations. Due to the small sample size and Victorian
282 setting, results from this feasibility study may not be generalizable to other settings and saturation
283 of themes in the staff interviews were not realised. Additionally, the 'snap-shot' method of data
284 collection meant that many patients had not completed CR at the time of data extraction. Further,
285 enhanced methods are required to ensure all who enrolled into the CR programs were captured
286 even if they did not attend the initial assessment session to reduce reporting bias towards CR
287 attenders.

288 **Implications and future recommendations**

289 The transition to digital health systems holds great potential for enhancing clinical care within
290 the CR setting. However, many jurisdictions have been slow to adopt e-health infrastructure limiting
291 the application of tools like GRHANITE™. Key organisations need to advocate for EMRs in CR
292 programs so that automated data-capture technologies can increase the viability of CR registries in
293 the future. Efforts must also focus on preparing the field for the digital transition and preparing a
294 clear business case delineating the local- and system-wide benefits and the digital requirements so
295 systems are built in a way that is fit for purpose.

296 In the interim, a web-based data entry tool shows promise as an approach that should be
297 explored further and could enable the monitoring of CR quality across the private and public sector.

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299 **References**

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Selection of the minimum variables for the VCRR

The registry comprised a minimum set of variables selected from the New South Wales (NSW) ACRA association quality indicators and data dictionary which was based on expert consensus [21]. The 42 selected data elements consisted of: demographic information (e.g. sex, age), disease/condition (e.g. principal referral diagnosis) risk factors and co-morbidities (e.g. diabetes status, smoking status), intervention (e.g. number of CR sessions), process indicators (e.g. CR wait time) and individual patient outcomes (e.g. change in pre-post exercise capacity) (Table 1).

***TABLE 1 ***

Table 1. Victorian Cardiac Rehabilitation Registry minimum variables

Setting and recruitment

In the state of Victoria in South East Australia, there are 136 CR programs, delivered across publicly and privately-funded hospitals and community health settings. TACRA he national association of CR professionals (ACRA) has a State-level directory of all CR facilities which was used to identify one public and one private site to invite to participate in the study. These sites were purposively selected to ensure sample representation of: funding sources (public and private), settings (acute hospital, rehabilitation hospital), and location (metropolitan and suburban). Site 1 was a large publicly-funded program, which runs a six-week CR program for approximately 40 outpatients per week. Site 2 was a private facility primarily funded through health insurance funds and the Department of Veteran Affairs, which runs a 12-week program for approximately 15 outpatients per week. Participating sites were offered a stipend of AU$6,000 (USD$4700) to cover cost related to staff time for the set-up of automated data collection. Both CR sites agreed to participate.

Ethics approval

The study was approved by the Human Research Ethics Committee (HREC) at the University of Melbourne (HREC number: 1748609) and included a waiver of consent for individual patient data

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(which was de-identified). Site-specific research ethics approval was also obtained. Staff who participated in qualitative interviews provided informed consent.

Automated ~~Data~~ collection procedure (GRHANITE™)

The team at the University of Melbourne's Health and Biomedical Informatics Centre Research Information Technology Unit (led by DB) assisted in the development of the data extraction protocol and worked with the sites' Information Technology (IT) teams to create an interface regime. This required the development of a "mapping" document which linked the variables requested from the research team with the variables collected and available electronically at the sites. The overview of the study methods can be seen in Figure 2.

FIGURE 2

Figure 2 Overview of the study methods

Manual ~~Amendment to the study protocol to add a manual data entry component~~ web-based data collection (REDCap)

~~In order to~~ To capture variables that were not available electronically at the sites, a secure web-based data collection form was designed using the REDCap (Research Electronic Data Capture: https://www.project-redcap.org/) software. ~~The amendment was approved by the University of Melbourne's HREC in July 2017.~~ The web-based form included three sections (Section 1: identifiable patient information; Section 2: pre-CR data; Section 3: post-CR data) and was tr~~a~~ialled for two weeks at both sites, with feedback from the CR sites informing refinement of the data entry template. Once finalised, clinicians entered data for patients who were enrolled in the CR programs during the data collection period. The REDCap data collection forms contained mandatory fields to reduce missing data and in-built logic checks to increase the accuracy of data. Authorised staff were provided with a secure log-in which enabled access to the REDCap template; d~~. D~~ata access restrictions ensured

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clinicians could only view data from their site. Additional detail on REDCap is provided in Supplementary File 2.

Data extraction and linkage

CR data were extracted from the sites via the University of Melbourne's GRHANITE™ research data acquisition system. The GRHANITE™ interface was installed at both sites and scheduled to extract pre-determined variables on patients who participated in the CR program during the data collection period. GRHANITE™ enabled data to be extracted in a de-identified manner by incorporating advanced privacy-preserving hashing techniques to generate unique 'signatures'. These data were then securely transmitted to the VCRR database based on the University of Melbourne's server, with data stored in Microsoft SQL. Further details regarding data security and storage can be found in Supplementary File 1 and 2.

Data quality

The system highlighted any GRHANITE™ data extraction failures or omissions and IT representative at each site reviewed the data to ensure it was coherent before it was forwarded to the central registry. The REDCap data collection forms contained mandatory fields to reduce missing data (data must be entered before being able to move to the next section) and in-built logic checks to increase the accuracy of data. Missing patient records were assessed by comparing the number of patients booked CR appointments in the electronic administrative database (total numbers) with number of patients manually entered into REDCap.

Formative evaluation

Semi-structured interviews were conducted within one week of the completed data collection period (December 2017) to ascertain any barriers or enablers to implementation of the CR registry. Individual interviews were held with clinical staff members involved with clinical data collection at the two pilot sites (N=3). The interviews were conducted by a member of the research team (ET). They were audio-recorded and then transcribed verbatim except to preserve anonymity.

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The interview guide consisted of three parts: (i) historical approaches to data collection, (ii) barriers to measuring and collecting variables and (iii) recommendations for future registry implementation. Feedback provided by the clinicians was synthesised under the same three headings and identified barriers were coded in themes and sub-categories using content analysis[22].

Results

Characteristics of patients included in VCRR

The combined electronic and manual data revealed that across the two sites, 176 patients had a booked CR appointment, 115 patients (65.34%) completed the initial CR appointment and 48 patients (27.27%) completed the CR program (achieved patient goals and/or attended an agreed number of exercise and education sessions) within the data extraction period. The study sample was predominantly male (76%) with a mean age of 67 years and 83% spoke English as their preferred language (Table 2). The participant's sociodemographic characteristics differed across the two sites, with participants at Site 2 being 10 years older on average (74 years vs. 65 years) and having a lower baseline exercise capacity (95m less on the six-minute walk test) (Table 2).

TABLE 2

Table 2. Characteristics of patients included in VCRR

Variables available from the electronic hospital administrative databases were limited to seven (age, sex, postcode, Aboriginal and Torres Strait Islander status, preferred language, CR booking, referral date) for each of the patients. This is due to hospital administrative databases at the sites only collecting basic information on patient sociodemographic characteristics and CR appointment bookings. ~~The remaining clinical information selected for the CR registry minimum data set were collected on paper-based records and manually transferred by clinicians onto an Excel spreadsheet or scanned into patient records and deemed unusable for electronic data capture.~~

~~*Amendment to the study protocol to add a manual data entry component*~~

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In order to capture variables that were not available electronically at the sites, a secure web-based data collection form was designed using the REDCap (Research Electronic Data Capture: https://www.project-redcap.org/) software. The amendment was approved by the University of Melbourne's HREC in July 2017. The web-based form included three sections (Section 1: identifiable patient information; Section 2: pre-CR data; Section 3: post-CR data) and was trailed for two weeks at both sites, with feedback from the CR sites informing refinement of the data entry template. Once finalised, clinicians entered data for patients who were enrolled in the CR programs during the data collection period. The REDCap data collection forms contained mandatory fields to reduce missing data and in-built logic checks to increase the accuracy of data. Authorised staff were provided with a secure log-in which enabled access to the REDCap template. Data access restrictions ensured clinicians could only view data from their site. Additional detail on REDCap is provided in Supplementary File 2.

Combining electronic data and REDCap data extracts via GRHANITE™

The GRHANITE™ data capture software was configured to extract data from both the electronic data (from hospital administrative databases) and manually entered clinical data (from REDCap) into the study database hosted on the University of Melbourne's server and secured within the University's IT infrastructure. The unique 'signatures' generated by GRHANITE™ enabled anonymous record linkage between the electronic and manually entered data. Data extracted from the manual entry component (REDCap) enabled collection of all 42 variables in the minimum data set, supplementing the electronic data. The overview of the amended study methods can be seen in Figure 2.

FIGURE 2

Figure 2 Overview of amended study methods

Characteristics of patients included in VCRR

The combined electronic and manual data revealed that across the two sites, 176 patients had a booked CR appointment, 115 patients (65.34%) completed the initial CR appointment and 48

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~~***TABLE 2***~~

~~**Table 2.** Characteristics of patients included in VCRR~~

CR Quality

The minimum variables extracted were useful in informing assessment of CR site quality in many instances (Table 3). There were site-specific differences in process indicators of care, suggesting the minimum variables are sensitive. For example, participants in Site 1 experienced a longer wait time to receive CR (44 days vs. 19 days) and were less likely to be screened for depression (54% vs. 92%). None of the identified smokers (across either site) were reported to have been referred for smoking cessation.

There was a large amount of missing and unknown data from the manual-entry source. Discrepancies existed between the number of patients booked CR appointments in the hospital administrative database (n=176) and those who attended the initial assessment and were entered into REDCap (n=115). Reasons for non-attendance to the initial session were not routinely collected and therefore unable to be ascertained for all cases. Further, many values in the post-CR assessment were reported as unknown (e.g. CR medication status was unknown for 44% of patient who completed a post-CR assessment).

TABLE 3

Table 3. CR process indicators

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CR Staff Perceptions of Data Capture Processes

Feedback from the two sites revealed that the manual entry component was straight-forward, easy to use, and quicker than traditional forms of data collection (i.e., clinician-selected variables entered into an Excel spreadsheet; Table 4). The training provided was perceived as sufficient and staff felt in-built features such as mandatory fields enabled them to feel more confident about the data quality. Staff expressed desire to have the capacity to search more easily for entered patient data (a feature that is available in REDCap but was not highlighted during the training session) and additional information about the rationale/evidence for some of the selected minimum variables. All interviewees wanted to continue using REDCap and preferred this approach over traditional methods; a~~-~~s described by the CR co-ordinator at Site 2 "*I just can see that REDCap is the bright new future that we can start to get the cardiac rehab product out there with consistency between programs… Because at the moment we can all say that we are doing cardiac rehab and we can all be members of ACRA but I don't know what you're providing and you don't know what I am doing unless you are there".*

Five main barriers were identified regarding historic methods of measuring and entering variables (see Supplementary file 3): i) workload and competing responsibilities (e.g. time constraints), ii) environmental context and resources (e.g. information technology issues, and not having access to a quiet and secure space to enter data); iii) patient factors (e.g. patient needs/concerns conflicting with data collection requirements); iv) care delivery processes and co-ordination (e.g. referrals getting lost because sent via post/fax) and v) outcome expectations (e.g. reduced confidence in data because of measurement errors).

***TABLE 4 ***

Table 4. Feedback from sites on web-based data entry

Discussion

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To our knowledge, t~~T~~his was the first study to assess the feasibility of utilising a data capture tool to automatically extract minimum CR registry variables within public and private facilities ~~in Australia~~. While CR sites collected large amounts of clinical data, the majority of these data (i.e., 83% of the 42 variables) were not readily-available in an appropriate electronic format rendering automated data extraction unfeasible. Until such time that the current infrastructure in public and private CR settings in Australia develops, the key benefits of scalable, automated data capture tools like GRHANITE™ will remain unrealised. While this approach remains promising for creating and maintaining a registry that monitors the quality of CR provided to patients, further investment is required in the digital platforms underpinning this approach including ensuring electronic platforms are i) accessible to CR sites, ii) fit for purpose and, iii) capturing high quality data. In the interim, a web-based data collection tool housed on the REDCap system can enable standardised data to be collated from various CR sites with known limitations associated with manual data entry. These key findings are discussed further below.

~~Enhancing access and use of EMRs~~

Greater emphasis must be placed on ensuring CR staff have access to EMRs[9]. In general, allied health and community-based settings have had low-levels of adoption of electronic health infrastructure compared to acute settings and primary care [23]. To ensure more timely access, national associations such as ACRA, the Cardiac Society of Australia and New Zealand (CSANZ) and the National Heart Foundation (NHF) need to facilitate advocacy efforts at the local, state and national-level for improved electronic infrastructure within the CR setting. For example, ACRA could provide guidance to CR co-ordinators and managers to push the agenda within local settings; enhanced CR representation on state-based cardiac clinical networks could drive the issue at a state-level; and the development of a national strategic plan and committee could be established with the aim of improving monitoring of CR and enhancing national efforts.

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~~Within Victoria (and likely other states)~~Future~~,~~ digital health investments will be driven by specific business needs and the identification and demonstration of local and system-wide benefits[24]. Consequently, a clear business case for enhanced monitoring of CR is required which details the digital requirements necessary to fulfil the current gap. Additionally, the workplace will likely need to up-skill to ensure adequate digital capability. Well-developed and robust change management is a crucial factor in deploying new systems and clinicians must be involved in the process and actively champion health technology activities [24].

~~Ensuring EMRs are fit for purpose~~

Ideally, as EMR uptake increases~~s develop in Australia~~, all CR minimum variables would be available electronically, and a registry could be pre-filled. In other countries CR registries have begun to simultaneously link with administrative electronic databases to enable auto-filling of data (e.g. the Danish registry and Canadian registry) [17, 25]. In states where different EMR systems are being implemented, flexible tools like GRHANITE™ will be crucial in enabling interoperability of data across various systems (including public and private) whilst adhering to privacy and security concerns.

Ultimately, the success of data capture through EMRs will depend on multiple factors, including minimum variables being: i) clearly defined, ii) entered consistently across sites, iii) of sufficient reliability/validity, and iv) extractable. The CR field can begin to prepare for this now by ensuring quality indicators are clearly defined and comparable across states.

~~Monitoring CR in settings with under-matured electronic platforms~~

~~Many states are a long way from having fully integrated electronic health systems. Between 2004-2013 Victoria invested over $300 million to reform the IT ecosystem with the HealthSMART initiative which was eventually abandoned due to a 'one-size-fit-all approach' being unsuccessful[21]. Consequently, the responsibility of developing digital solutions was placed back on health services providers resulting in a wide range of clinical information systems implemented to~~

~~varying degrees across hospitals and health centres[22]. Many CR sites have no access to EMRs and as demonstrated in this feasibility study are relying on paper-based data collection methods.~~

In the interim, CR data collection can be improved via the use of a standardised web-based tool housed on platforms such as the REDCap system. REDCap had multiple advantages including: i) ease of implementation without any need for the sites' IT departments, ii) usable at both public and private CR sites, iii) secure and password-protected access, iv) straight-forward and quick data entry, v) in-built functions (e.g. mandatory fields, character limits, drop down options, automated reports) to enhance data quality and completeness, vi) available for use at no costs for affiliated research institutes. Further, REDCap was supported by those entering the data who expressed an interest in continuing beyond the study period.

Use of the web-based tool, however, could be enhanced. For example, future studies should incorporate data quality checks early in the data collection period that include a comparison of enrolled and entered patient data to ensure such data match and reasons for missing data are ascertained. In Australia CR sites often refer patients to more convenient programs (e.g. closer to home); such information needs to be captured on all patients so that reasons for non-attendance can be more accurately documented. Additionally, unknown data requires additional clarification. For example, post-CR medication status had larger amounts of unknown responses than other variables and is potentially not being checked at post-CR interviews. Automated alerts could be in-built for this variable to clarify the reason for the unknown information.

Study limitations

We acknowledge that this study has limitations. Due to the small sample size and Victorian setting, results from this feasibility study may not be ~~are not~~ generalizable to other settings and saturation of themes in the staff interviews were not realised. Additionally, the 'snap-shot' method of data collection meant that many patients had not completed CR at the time of data extraction. Further, enhanced methods are required to ensure all who enrolled into the CR programs were

captured even if they did not attend the initial assessment session to reduce reporting bias towards CR attenders.

Implications and future recommendations

The transition to digital health systems holds great potential for enhancing clinical care within the CR setting. However, many jurisdictions have been slow to adopt e-health infrastructure limiting the application of tools like GRHANITE™. Key organisations need to advocate for EMRs in CR programs so that automated data-capture technologies can increase the viability of CR registries in the future. Efforts must also focus on preparing the field for the digital transition and preparing a clear business case delineating the local- and system-wide benefits and the digital requirements so systems are built in a way that is fit for purpose.

In the interim, a web-based data entry tool shows promise as an approach that should be explored further and could enable the monitoring of CR quality across the private and public sector.

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Table 1. VCRR minimum variables

CORE DATA		
Person identifying information	1.	Name
	2.	Medicare number
	3.	Patient Unit Record number
	4.	Date of birth
	5.	Sex
	6.	Postcode
	7.	Culturally and linguistically diverse (CALD)
	8.	Aboriginal and Torres Strait Islander status
Provider organization	9.	Service provider name
CQR SPECIFIC DATA		
Disease/condition	10	Principal CR referral diagnosis
Risk factors and co-morbidities (for risk adjustment)	11	Interventions/complications (e.g. PCI, CABG)
	12	Diabetes diagnosis
	13	Smoking status
	14-18	Prescribed medications (i. oral antiplatelet, ii. Beta-blockers, iii. ACE-I/ARB, iv. lipid-lowering, v. sublingual nitrate)
	19	Waist circumference
	20	Exercise capacity
Intervention	21	CR program model
	22	CR referral date
	23	CR commencement date
	24	Number of CR sessions attended
	25	CR completion status

	26	Reason for CR withdrawal (if applicable)
Process indicators of evidence based care	27	CR wait time (CR commencement date – CR referral date)
	28	Screened for depression
	29	Positive cases for depression referred for management
	30	Current/recent smokers referred or provided with smoking cessation advice
	31-35	Prescribed medications (i. oral antiplatelet, ii. Beta-blockers, iii. ACE-I/ARB, iv. lipid-lowering, v. sublingual nitrate)
	36	Provided a symptom-management plan
	37-40	Referred for ongoing care (i. General Practitioner, ii. specialist/Cardiologist, iii. CR follow-up, iv. Phase 3 CR or equivalent)
Individual patient outcome measures	41	Pre-post change in exercise capacity
	42	Pre-post change in waist circumference

Acronyms: ACE-1: angiotensin-converting enzyme; ARB: angiotensin receptor blockers; CR: cardiac rehabilitation

Table 2. Characteristics of patients included in the VCRR

	SITE 1 Freq (%); Mean [SD] n=131	SITE 2 Freq (%); Mean [SD] n=45	Total Freq (%); Mean [SD] n=176	Missing %
Male	99 (75.57)	35 (77.78)	134 (76.14)	0
Age (years)	64.96 [11.82]	74.11 [9.21]	67.30 [11.88]	0
Aboriginal or Torres Strait Islander	1 (0.76)	0 (0)	1 (0.57)	0
English not preferred language	30 (22.90)	0 (0)	30 (17.04)	0
Referral indication				34.65*
STEMI	20 (15.26)	4 (8.89)	24 (13.64)	
NSTEMI	14 (10.68)	1 (2.22)	15 (8.52)	
CT surgery	37 (28.24)	9 (20.00)	46 (26.14)	
Interventions				34.65*
Non-elective PCI	19 (14.50)	4 (8.89)	23 (13.07)	
Elective PCI	30 (22.90)	6 (13.33)	36 (20.45)	
CT surgery	37 (28.24)	4 (8.89)	41 (23.29)	
Diabetic	25 (19.01)	7 (15.55)	32 (18.18)	34.65*
Smoker	8 (6.11)	1 (2.22)	9 (5.11)	34.65*
Exercise capacity†	480.50 [93.22]	383.91 [126.89]	456.61 [110.11]	47.16*

Acronyms: CT: cardiothoracic; Freq: frequency; NSTEMI: non-ST elevated myocardial infarction; PCI: percutaneous coronary intervention; SD: standard deviation; STEMI: ST-elevated myocardial infarction.

*Manually entered data had missing variables; † six-minute walk test

Table 3. Process indicators of evidence based care

Process indicator	SITE 1 Freq (%); Mean [SD] n=89[†]	SITE 2 Freq (%); Mean [SD] n=26[†]	Total Freq (%); Mean [SD] n=115[†]	Unknown/ missing[*] Freq (%) n=115[†]
CR wait time (days)	44.26 [22.53]	19. 21 [19.46]	38.94 [24.13]	2 (1.74)
Screened for depression	48 (53.93)	24 (92.31)	72 (62.61)	43 (37.39)
Positive case for depression referred	1 (2.38)[‡]	2 (22.22)[‡]	3 (5.88)[‡]	43 (84.31)[‡]
No. of smokers	8 (8.99)	1 (3.85)	9 (7.83)	2 (1.74)
Smokers referred for cessation	0 (0)[§]	0 (0)[§]	0 (0)[§]	3 (33.33)[§]
Post-CR medications				
Antiplatelet	21 (23.60)	20 (76.92)	41 (35.65)	74 (64.35)
Beta-blockers	18 (20.22)	12 (46.15)	30 (26.09)	75 (65.22)
ACE-I/ARB	14 (15.73)	10 (38.46)	24 (20.87)	75 (65.22)
Lipid-lowering	21 (23.60)	13 (50.00)	34 (29.57)	75 (65.22)
Sublingual nitrate	11 (12.36)	5 (19.23)	16 (13.91)	75 (65.22)
Provided a symptom - management plan	48 (53.93)	22 (84.61)	70 (60.87)	45 (39.13)
Referred for ongoing care	44 (49.44)	24 (92.31)	68 (59.13)	47 (40.87)

Acronyms: ACE-1: angiotensin-converting enzyme; ARB: angiotensin receptor blockers; CR: cardiac rehabilitation; Freq: frequency; SD: standard deviation.

*These data were part of a prospective 3-month snap-shot, as such not all data were known at the time of data extraction highlighting issues using these data to compare sites; [†]Denominator = number of patient records entered into REDCap; [‡] Denominator = number of patients screened positive for depression; [§]Denominator = number of identified smokers

Table 4. Feedback from sites on use of web-based data entry

How sites were traditionally collecting clinical information about CR participants

- paper-based medical notes or hard copy worksheets
- data manually transferred into an Excel spreadsheet when time allowed
- collected variables were determined individually by the sites and relied on clinician knowledge of CR 'best practice' and influenced by management requirements

Identified issues with traditional methods of data collection

- time consuming
- unnecessary data collected (i.e. not used in analysis or reporting)
- analysis of data in Excel was challenging
- unable to compare data across sites
- collected data was influenced by patient needs, time constraints and perceived importance of the clinical information

Experience using the REDCap web-based standardized templates

- straight-forward and easy
- data entry was quick
- training was sufficient
- appreciated quick responses if any questions arose
- reports more professional compared to Excel

Future use of the REDCap web-based templates

- potential to improve the consistency between CR programs
- expressed desire to continue using REDCap
- staff wanted to be able to search more easily for previously entered patients
- additional evidence/rationale behind why certain variables were selected as the minimum data is required
- would like available data to be automatically imported from hospital databases
- would like to enter data during the patient assessment (e.g. via an I-Pad)

Figure 1

Click here to download high resolution image

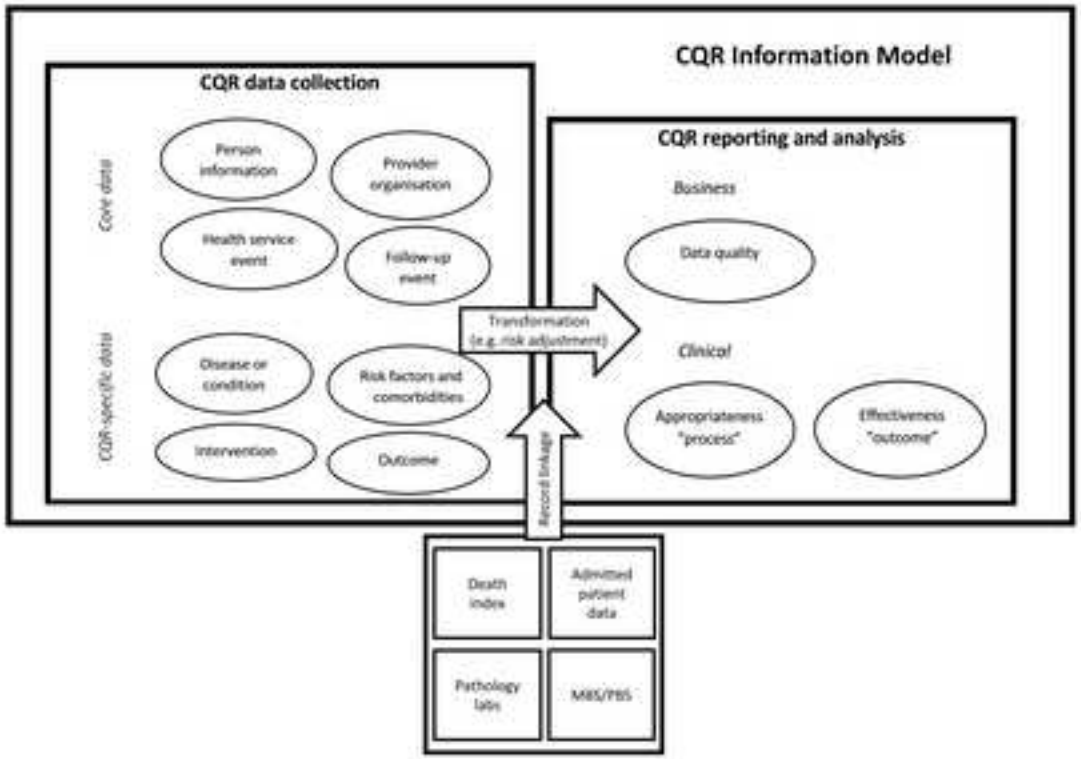
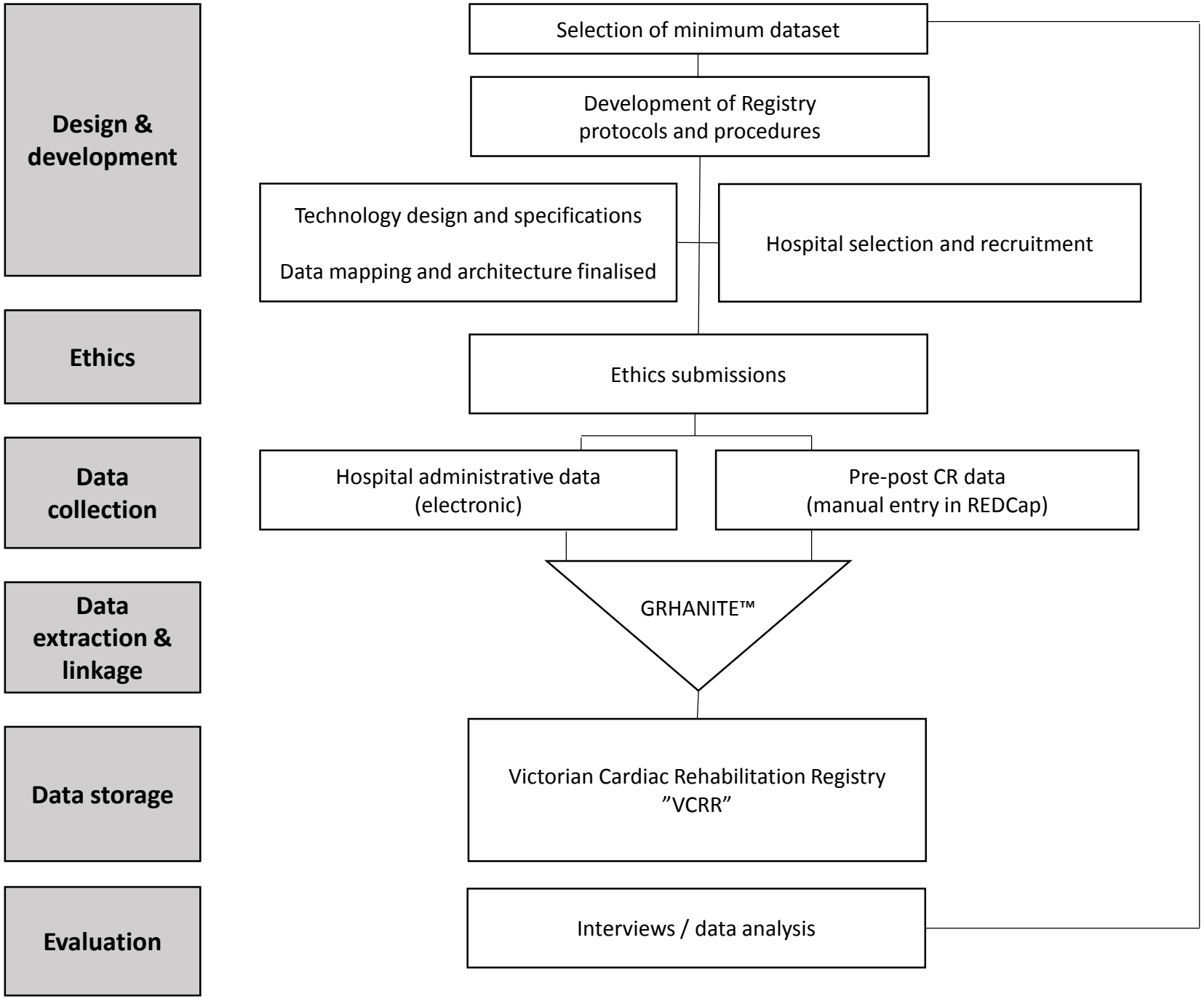


Figure 2


Design & development
Selection of minimum dataset
Development of Registry protocols and procedures
Technology design and specifications
Data mapping and architecture finalised
Hospital selection and recruitment
Ethics
Ethics submissions
Data collection
Hospital administrative data (electronic)
Pre-post CR data (manual entry in REDCap)
Data extraction & linkage
GRHANITE™
Data storage
Victorian Cardiac Rehabilitation Registry ”VCRR”
Evaluation
Interviews / data analysis

Supplementary Material

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