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Data integration in cardiac electrophysiology ablation toward achieving proper interoperability in health information systems

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Abstract:

INTRODUCTION: Providing information exchange and collaboration between isolated information systems (ISs) is essential in the health-care environments. In this context, we aimed to develop a communication protocol to facilitate better interoperability among electrophysiology study (EPS)-related ISs in order to allow exchange unified reporting in EPS ablation.

MATERIALS AND METHODS: This study was an applied-descriptive research that was conducted in 2019. To determine the information content of agreed cardiac EPS Minimum Data Set (MDS) in Iran, the medical record of patients undergoing EPS ablation procedure in the Tehran Heart Center (THC) hospital was reviewed by a checklist. Then, an information model based on Health Level Seven, Clinical Document Architecture (HL7 CDA) standard framework for structural interoperability has been developed. In this framework, using NPEX online browser and MindMaple software, a set of terminology mapping rules was used for consistent transfer of data between various ISs.

RESULTS: The information content of each data field was introduced into the heading and body sections of HL7 CDA document using Systematized Nomenclature of Medicine – Clinical Terminology names and codes. Then, the ontology alignment was designed in the form of thesaurus mapping routes.

CONCLUSION: The sensitive, complex, and multidimensional nature of cardiovascular conditions requires special attention to the interoperability of ISs. Designing customized communication protocols plays an important role in improving the interoperability, and they are compatible with the needs of future Iranian health information exchange.

Keywords:

Cardiac ablation, communication protocol, electrophysiology study, HL7 CDA, interoperability, terminology mapping

Introduction

Interoperability addresses the interconnection between information systems (ISs) to provide meaningful sharing of information.[1] Indeed, interoperability is indispensable in heath ISs (HISs) allowing their collaboration through data exchange so that valuable information is available everywhere and at any time to support treatment and monitoring of inhabitants' health.[2] HISs have different architectures, standards, and technical infrastructures. HISs work independently and do not have a uniform data structure: each software product has its individual application programs, platform, contents, and formats.[3] In this context, sharing health information is impeded, and consequently, heterogeneous HISs in each individual organization occur, leading to data redundancy and rework.[4]

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The need to exchange information between different HISs has emerged in recent years in Iran. The lack of interoperability and fragmentation of information are also some of the most important barriers to E-health acceptance in Iran government.[5,6] Given that Iran has decided to implement electronic health record (EHR), an obstacle to the widespread adoption of EHR systems is the difficulty associated with capturing structured clinical information from health-care providers who desire to document clinical notes using "free text" natural language.[7]

Designing a communication protocol is a key factor toward achieving interoperability. Two main components in communication protocols include syntactic (determining the structure and ordering of data bits of messages) and semantic (defining the semantics of data bits of messages) rules.[8,9] In other words, homogeneous terminology and capturing structured data are a precondition to interoperability and exchanging health-care information.[10] Consideration of the interoperability for creating an integrated network of systems is one of the most important requirements to achieve a comprehensive system of monitoring and controlling heart conditions.[11] The complex, sensitive, and multidimensional nature of cardiovascular conditions requires the involvement of multidisciplinary teams from different organizations. In addition, it is vital to establish multilateral and network communications, sophisticated analytics, advanced multidimensional modeling of information, and create the maximum interoperability.[9,12]

Heart diseases are a major contributor to disability and mortality in human societies. Arrhythmia is a cardiovascular disease and a common clinical problem. Currently, electrophysiology study (EPS) ablation is the first or second line for the treatment of various cardiac arrhythmias. This procedure has a remarkably high success rate and can enhance the patient's quality of life to a large extent.[13-17] Thus, it is necessary to standardize reporting and create exchange protocol of EPS ablation information. To tackle this issue, the present study proposes a communication protocol to drive interoperability among ISs involved in EPS ablation procedure.

Materials and Methods

This study was an applied-descriptive research that was conducted in 2019. The minimum data set (MDS) of cardiac electrophysiology interventions has already been designed using a combination of literature review and expert consensus approach.[18] To determine the information content of developed MDS, the medical record of patients undergoing EPS ablation in the Tehran Heart Center (THC) was reviewed by a checklist. Then, the information content was coded using selected classification or nomenclature systems. For this purpose, printed coding systems and online terminology browser (e.g., SNOMED-CT NPEX Online Browser, Regenstrief LOINC Mapping Assistant, and RxNAV (RxNORM browser (were used.

After assigning codes, their validity and reliability were evaluated by two health information management specialists who had more than 5 years of work experience in disease coding units. Further, the external agreement method was used for re-coding the information content and comparing the primary codes with secondary codes.

In the next step, all scattered codes were mapped to integrated codes in the Systematized Nomenclature of Medicine – Clinical Terminology (SNOMED-CT) reference nomenclature system using Mind Maple software (Java software developer organization). This software is a graphic user interface to define ontologies that represent ideas, concepts, and objects in a graphical way.[19]

Finally, integrated SNOMED-CT codes were structured into CDA standard framework in order to provide structural interoperability. The CDA form was proposed as an optimal and consistent structure for transferring information in comprehensive health information exchange infrastructure of Iran.[15] Accordingly, all SNOMED-CT reference codes and terms were structured in the form of CDA body and title. Finally, the Extensive MarkUp Language (XML) rules were defined, and the final communication protocol was prepared.

Results

Defining the information content

The developed MDS of EPS ablation was divided into nonclinical and clinical data sections, 12 data classes and 61 data fields. The real information content was defined for each data element.

Coding the information content

The information content was coded using selected classification and nomenclature systems as follows: International Classification of Disease–sTenth Revision (ICD-10) or its Clinical Modification version (ICD-10-CM), International Classification of Functioning, Disability and Health (ICF), Normalized Notations for Clinical Drug (RxNORM), Logical Observation Identifiers Names and Codes (LOINC), Ninth Revision, Clinical Modification (ICD-9-CM), Diagnostic and Statistical Manual of Mental Disorders (DSM), and Read Code Classification (RCC). The SNOMED-CT covered all these terms and codes.

Evaluating the validity and reliability of codes

The evaluation of validity and reliability of codes was done through external agreement showed that from two information categories, 14 information classes, 61 data fields, 65 preference codes, and 65 reference codes (SNOMED-CT), there were 55 similarities between the initial and secondary codes (code matching), three significant differences between the initial and secondary codes, and seven minor differences (decimal level) between the primary and secondary codes. All differences between the codes were ignored at decimal level. Thus, only significant differences were the basis for evaluating the final reliability between the primary and secondary codes. Table 1 reports these differences along with the results of their final reliability assessment.

Thesaurus mapping

The general paths of mapping from the preferred thesaurus onto the reference terminology include (1) mapping administrative information onto RCC; (2) mapping disease and problem situation to ICD-10 or ICD-10-CM; (3) mapping medication terms onto RxNORM; (4) health and welfare situation mapping to ICF; (5) mapping diagnostic, medical, and surgical procedures to ICD-9-CM; (6) mapping laboratory and evaluative measures onto LOINC; and (7) mapping mental situation to DSM codes. Finally, all preferred codes are mapped to the SNOMED-CT reference codes or names [Figure 1].

Tables 2 and 3 list the data sections, data classes, data fields and their content, data field format and values, preferred codes, and reference SNOMED-CT code.

SNOMED-CT has an excellent coverage of EPS MDS, and the result of the study showed that mapping was successful by defining all scattered codes into the SNOMED-CT unit code or term.

After normalizing the information content by integrating SNOMED-CT normal names and codes, they were structured in standard formats. The HL7 CDA standard was employed for standardization of the message structure [Table 4].

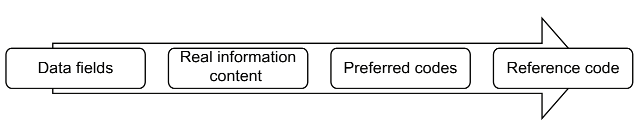

Figure 1: Triple mapping routes by MindMaple

Discussion

In this study, we have presented an extension to a previously developed MDS of cardiac electrophysiology to allow for the exchange of EPS-related data among different ISs.[18] The use of coordinated and agreed communication protocols can help overcome the challenge of data exchange between health ISs.[20,21] However, there has been little progress in computerization of EPS-associated ISs. Determining data fields, normalizing their content, ontology mapping, defining field formats, and integrating the message template structure are fundamental steps toward effective interoperability.[22,23]

The growing use of E-health technologies increases the attention to semantic interoperability.[24,25] Semantic interoperability is related to unified, coordinated, consistent, unambiguous, and semantic harmonization of information for all systems and users. EHR semantic interoperability is urgently needed for systems to improve health-care quality.[26,27] Semantic interoperability consists of metadata, value set defining, data format, data rules, and the terminology binding.[9,26] Thesaurus mapping is a technical function for data integration through transformation of multiple terms into a unified term or code.[28] Indeed, mapping can be used as a means for representing the ontology domain contributing to achievement of semantic interoperability.[10] SNOMED-CT has been proposed as reference terminology for Iranian EHR (SEPASS project) interoperability.[29,30] The use of this terminology will enhance the data quality criteria.[25] The present study used the selected classifications or nomenclatures to normalize EPS ablation data; finally, all contents were integrated into the SNOMED-CT unique codes.

Syntactic interoperability means that the data collection and validation processes are integrated into consistent message frameworks.[9,31] Reference models, XML-based CDA, reference model of classes and archetypes, distinct ontologies, terminology mapping, and use of reference archetypes for exchanging documents have been introduced as a component of the messaging standards for EHR in Iran.[32]

The SNOMED-CT standard lexicon and HL7 CDA framework have been suggested for Iran's E-Health.[29,30] Accordingly, in this study, the content of data fields was integrated through preferred

Table 1: Assessment of reliability codes

Category	Information class	Data element	Information (record) content	Coding system	Primary code	Secondary code	Final evaluation
Clinical	Diagnostic/problems	Final diagnosis	Systolic heart failure stage D	ICD10	I52.9	I50.0	I50.0
Clinical	Heart conduction status	Ventricular tachycardia	Recurrent ventricular tachycardia	ICD10	I40.8	I47.2	I47.2
Clinical	Laboratory	Diagnostic procedure	Electronic Cardiogram (ECG)	LOINC	34537-9	34534-8	34534-8

Table 2: Nonclinical minimum data set description for information exchange of cardiac electrophysiology interventions

Data classes/items	Case sample	Response format	Vocab code	Preferred codes	References code
Demographic					
Name, Surname	Entity name	String	RCC	XaLva	371484003
Father name	Entity name	String	RCC	XaLvs	371484008
Physician name	Entity name	String	RCC	Xalvx	371484012
Birthdate	yyyy/mm/dd	Integer	RCC	9155	184099003
Age	52 y	Integer	RCC	X24Ai	28288005
Place of birth	Geographical location	String	RCC	XaG3t	315446000
Gender	Female	Binary	RCC	X768C	248152002
Male Female					
Marital status	Married	Categorical	RCC	XE0oa	87915002
Single					
Married					
Widow					
Other					
Education level	Diploma	Categorical	RCC	13Z46	342341000000108
Illiterate					
Under diploma					
Diploma					
Bachelor					
Master of science or above					
Unspecified					
Identifier number					
Medical Record Number	xx-xx-xx	Numerical	RCC	Xn73J	398225001
National ID number	XXX-XXXXXX-X	Numerical	RCC	XE2Hj	422549004
Physician ID	XX XXXX - XX	Numerical	RCC	Xn21JE	118522005
Insurance ID	XXXX XXXX	Numerical	RCC	XE2Hj	456281000000100
Contact information					
Postal code	xxxxx-xxxxx	Numerical	RCC	9158	184102003
Home address	Province-city-street-alley-house no	String	RCC	XaDvP	184097001
Phone number	(+98 xxx-xxx-xxxx)	Number	RCC	XaZ4q	824551000000105
Patient disposition					
Admission type	Admission to community hospital	String	RCC	XaAMr	305337004
Admission date	yyyy/mm/dd	Integer	RCC	Xa0ck	399423000
Discharge type	Discharge by physician	String	RCC	XaAiJ	306416004
Discharge date	yyyy/mm/dd	Integer	RCC	Xa0ck	442864001
Discharge status	Discharge to home	String	RCC	XaApt	306689006

classification or nomenclature systems for local purposes, followed by mapping into SNOMED-CT reference codes and names in order to achieve the macro levels of interoperability.

Slotwiner *et al*. developed a cardiac implantable electronic devices protocol and defined syntactic as well as semantic interoperability requirements including controlled vocabulary, specification of data element, agreement on data management framework, and structured reporting.[9] The cardiac electrophysiology experiment protocol for data sharing interoperability in the Quinn *et al*. study includes (1) use of standard templates, (2) codification of reporting, (3) proposal of a draft for Minimum Information about a Cardiac Electrophysiology Experiment, (4) content normalization through metadata, data dictionary, and classification, (5) synchronization of data flow models through mapping, and (6) adoption of message standards.[11] van der Velde *et al*. integrated data from remote monitoring systems into the hospital EHR system based on HL7/XML communication protocol.[33] The present study defined the information patterns for EPS ablation information exchange in CDA XML standard format.

Our study method had four major strengths. First of all, we derived the core data elements based on expert consensus through rigorous qualitative analysis. In addition, the data field format, content format, and preferred codes were determined for local uses. Second, we also mapped the data elements from different clinical terminologies to unique SNOMED-CT reference codes. The adoption of standard nomenclature such as

Table 3: Clinical MDS description for the information exchange of cardiac electrophysiology interventions

Data classes/items	Case sample	Response format	Vocab code	Preferred codes	References code
Diagnostic/problems					
Primary diagnosis	Functional heartburn	String	ICD10	R12	722876002
Sign and symptom	Paroxysmal nocturnal dyspnea Palpitations	String	ICD10	R06.0 R00.2	55442000 80313002
Chief Compliant	Chest pain at rest	String	ICD10	R07.3	9267009
Final diagnosis	Systolic heart failure stage D	String	ICD10	I50.0	120851000119104
Comorbidities	Diabetes mellitus type 1	String	ICD10	E10.6	46635009
Past medical History					
Non cardiovascular personal history	PHx of diabetes mellitus type 1 PHx of urinary stone	String	ICD10	Z86.3 Z87.4	472970003 161548009
Cardiovascular personal history	PHx angina pectoris	String	ICD10	Z86.7	161504004
Cardiovascular Familial History	No FHx of Cardiovascular disease	String	RCC	115451	160270001
Non-Cardiovascular Familial History	FHx of neoplasm of lung	String	ICD10	Z80.1	297247000
Personal history of cardiovascular procedures (Invasive or non- invasive)	No history of procedure	String	RCC	ZVu3S	416128008
Personal history of non-cardiovascular procedures (Invasive or non- invasive)	Extracorporeal Shock Wave Lithotripsy (ESWL) of the kidney	String	ICD9 CM	98.51	24376003
Personal history of drug treatment	Tamsulosin Insulin lispro	String	Rx NORM	C0257343 C0043031	372509005 372756006
Social history	Social exclusion	String	ICD10CM	Z60.4	105412007
Physical Examination					
Heart rate <60 bpm, Between 60-100 bpm, Over than 100 bpm, Unknown	Normal heart rate	Categorical	RCC	Xa7s1	76863003
Blood pressure Systolic. <120 mm Hg, 120-129 mm Hg, 130-139 mm Hg , >140 mm Hg, Unknown Diastolic. <80 mm Hg, 80-89 mm Hg, >90 mm Hg, Unknown	Normal systolic blood pressure, 120-129 mm Hg Maximum diastolic blood pressure, x >90 mm Hg	Categorical	RCC	Ua1FM XaF4R	2004005 314452008
Heart murmur Yes No	Functional heart murmur	Binary	ICD10	R01.0	59935001
Waist circumference <35 inches, 35-40 inches , >41 inches, Unknown	Measurement of waist circumference declined, <35 inch.	Categorical	RCC	Xa041	698484006
Lung (pulmonary) examination Clear or normal, Rales, Decreased breath sounds or dullness, Rhonchi, Wheezing	Superficial crackling rales Constant wheezing	Categorical	ICD10	R09.8 R06.2	63642005 867311000000104
BMI level <18.5 kg/m^2, 18.5-24.9 kg/m^2, 25-29.9 kg/m^2, >30 kg/m^2, Unknown	Body Mass Index 25-29 , Overweight	Categorical	ICD10	E66.9	162863004
LAB test					
Routine tests name	Complete Blood Count (CBC)	String	LOINC	24317-0	26604007
Specialized tests name	Brain Natriuretic Peptide measurement (BNP)	String	LOINC	30934-4	390917008
Test date	yyyy/mm/dd	Integer	RCC	Xa0ck	804081000000104
Test result/interpretation	Primary hypercholesterolemia	String	ICD10	E78.0	238076009
Heart conduction status					

Contd...

Table 3: Contd...

Data classes/items	Case sample	Response format	Vocab code	Preferred codes	References code
Sinus node function	Normal sinus rhythm	Categorical	RCC	X76Jd	64730000
Normal sinus rhythm					
Sinus arrhythmia					
Sinus bradycardia					
Sinus arrest					
Sinus node dysfunction					
Sick sinus syndrome					
Atrioventricular (AV) conduction		Categorical	ICD10	I44.7	418341009
Normal AV conduction	Atrioventricular conduction disorder				
Short PR interval					
AV block					
AV abnormality following surgery					
Congenital complete heart block					
Isorhythmic dissociation					
Paroxysmal AV block					
Pre-excitation (Delta wave)					
Intraventricular (IV) conduction	Bundle -Branch Block (BBB)	Categorical	ICD10	I45.4	6374002
Normal					
Left anterior/posterior fascicular block					
Bundle -Branch Block (BBB)					
Intraventricular conduction delay					
IV conduction abnormality following surgery					
Supraventricular tachycardia (SVT)	Supraventricular tachycardia with functional bundle branch block	Categorical	ICD10	I47.1	233900001
Normal					
Atrial tachycardia (AT)					
Atrial fibrillation (AF)					
Sinus tachycardia (ST)					
Inappropriate ST					
Postural orthostatic tachycardia					
AV node re-entry					
Junctional tachycardia					
Ventricular tachycardia (VT)	Recurrent ventricular tachycardia	Categorical	ICD10	I47.2	708124001
Normal					
Recurrent					
Persistent					
Paroxysmal					
Incessant					
Ablation procedure					
Indication of catheter ablation	Stroke prophylaxis	Categorical	RCC	XaINu	135875009
Symptoms reduction					
Desire for drug-free life style					
Stroke prophylaxis					
Sudden death prophylaxis					
Frequent ICD discharges Other					
Sedation type		Categorical	RCC	X70q9	426155000
Minimal Sedation	Induction of deep sedation				
Moderate Sedation					
Deep sedation					
General Anesthesia Other					

Contd...

Table 3: Contd...

Data classes/items	Case sample	Response format	Vocab code	Preferred codes	References code
Target of ablation Pulmonary Vein Isolation Surgical Ablation Ablation of the atrioventricular node Ablation for Supraventricular tachycardia's Ablation for Ventricular Tachycardia Other	Ablation of atrioventricular node	Categorical	RCC		428663009
Source of energy Non- irrigated Radiofrequency Radiofrequency with closed irrigation Radiofrequency with open irrigation Ultrasound ablation Microwave ablation Laser balloon Cry thermal ablation Duty-cyded Radiofrequency energy Other	Open irrigation radiofrequency ablation operation for arrhythmia	Categorical	RCC	X011d	233163003
Drug Prescription					
Current Prescription	Digoxin	String	Rx NORM	C0025854	387461009
Allergy/adverse effects Yes No	Drug allergy	Binary	ICD10	Z88.8	416098002
Allergy/adverse effects name	Allergy to antibiotic	String	ICD10	Z88.1	109991000119100
Compliance assessment Yes No	Drugs - partial non-compliance	Binary	ICD10CM	Z91.12	275928001
Administration Route Oral (O), Sub Lingual (SL), Inhalation (INH), Topical (TOP), Intra Muscular (IM), Suppository (SUPP), Other	Oral form	Categorical	RCC	XaljJ	26643006
I. Post procedure complication					
Minor complication Yes No	No complication	Binary	RCC	X0006	88797001
Major complication Yes No	Complication associated with cardiac implant	Binary	ICD10	T82.1	473036007
Complication name	Infective endocarditis as complication of ablation	String	ICD10	T82.7	461416009

ESWL=Extracorporeal shock wave lithotripsy, CBC=Complete blood count, BNP=Brain natriuretic peptide, AV=Atrioventricular, IV=Intraventricular, BBB=Bundle branch block, SVT=Supraventricular tachycardia, AT=Atrial tachycardia, AF=Atrial fibrillation, ST=Sinus tachycardia, VT=Ventricular tachycardia, ICD-10=International Classification of Disease-Tenth Revision, PR=P wave Rate, BMI=Body mass index, LONIC=Logical Observation Identifiers Names and Codes

SNOMED-CT is suggested for the EHR as it captures clinical information at the level of details required by clinicians for the provision of care in most health-care disciplines and settings.[7] Furthermore, we leveraged HL7 CDA, functioning as a standard for the exchange of clinical documents, which should be readable by computers and humans. Finally, this study presented a practical model of real presentation of information exchange communication protocol for EPS ablation. Nevertheless, this work had a basic limitation due to the lack of comprehensive and systematic information exchange infrastructure in Iran's health system; therefore, it was not possible to implement and evaluate the proposed protocol. Further research is suggested to improve the interoperability, hoping to implement a comprehensive and interoperable E-health system for Iran.

Conclusion

Interoperability leads to a common understanding and subsequently optimal use of information. Customized communication protocols are a way to achieve interoperability between health ISs. The complex and multidimensional aspects of cardiovascular diseases and their increasing prevalence in human societies have doubled the need for the use of interoperable information exchange infrastructures. Sharing the data of cardiac electrophysiology interventions (EPS ablation and device implantation) is categorized into two major classes including communication: (1) between implantable

Table 4: HL7 CDA framework for information exchange of cardiac electrophysiology interventions

Document heading
Doc title: Cardiac electrophysiology interventions information exchange
Doc author: Physician
Doc custodian: Tehran heart center
Doc receiver: Iranian ministry of health (SEPASS project)
Doc target: Interoperable EPS consistent reporting
Doc name: EPS ablation reporting
Doc date of creation: September 2, 2018
Doc content standard: SNOMED-CT
Document body - administrative
Demographical information
Patient name: Zohreh Jamshidi
Sex: 248152002
Age: 28288005
Date of birth: October 01, 1964
Socioeconomically information
Education level: 342341000000108
Religion: 28010004
Nationality/race: 297553001
Contact information
Phone number: +98 912 xxxxx Postal code: 57896-23511
Identification information
Patient identifier (National ID): 011-52148-2
Medical record number: 02-29-01
Insurance ID: 44785233
Patient disposition
Admission type: 305337004
Admission date: August 21, 2018
Discharge type: 306416004
Discharge status: 306689006
Discharge date: August 24, 2018
Document body- clinical
Diagnosis/problem
Primary diagnosis: 722876002
Final diagnosis: 120851000119104
Chief compliant: 9267009
Comorbidities: 46635009
Past medical history
Cardiovascular personal history: 161504004
Noncardiovascular personal history: 472970003, 161548009
Cardiovascular familial history: 160270001
Noncardiovascular familial history: 297247000
Personal history of cardiovascular procedures: 416128008
Personal history of noncardiovascular procedures: 24376003
Physical examination
Heart rate: 76863003
Blood pressure: 2004005, 314452008
Heart murmur: 59935001
Waist circumference: 698484006
Lung (pulmonary) examination: 63642005, 867311000000104
BMI level: 16286300
Laboratory test
Routine tests name: 26604007
Specialized tests name: 390917008
Test date: August 23, 2018
Test result/interpretation: 238076009
Heart conduction status
Sinus node function: 64730000
AV conduction: 418341009
IV conduction: 6374002
SVT: 233900001 VT: 708124001
Ablation procedure
Indication of catheter ablation: 135875009
Sedation type: 426155000T
arget of ablation: 428663009
Source of energy: 233163003
Prescription
Current Rx: 387461009
Allergy/adverse effects: 416098002
Compliance assessment: 275928001
Withdrawal cause: 224973000
Administration route: 26643006
Complication
Minor/major complication: 473036007
Complication name: 461416009, 762667005

Contd...

Table 4: Contd...

SNOMED-CT=Systematized Nomenclature of Medicine - clinical terminology, AV=Atrioventricular, IV=Intraventricular, SVT=Supraventricular tachycardia, VT=Ventricular tachycardia, EPS=Electrophysiology study, BMI=Body mass index

devices and ISs and (2) across various ISs. In addition, the design of communication protocols is categorized into two dimensions: information and technical protocols. In this study, we mapped EPS data elements to a coding system and HL7 CDA template. Further research is required to investigate the information and technical requirements for exchange of information between implanted intracardiac devices and ISs. The technical aspects of communication protocols also warrant further research.

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Conflicts of interest

There are no conflicts of interest.

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