Determining a suitable technical architecture for COVID-19 information exchange infrastructure: A case for Iran

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Abstract

Introduction: Improving the quality, safety and effectiveness of health care services is the most important advantages of using the Public Health Information Exchange (PHIE) infrastructure. This infrastructure has three centralized, decentralized, and hybrid architectures. This study sought to identify the most appropriate technical architecture for the coronavirus disease (COVID-19) Information Exchange (CoVIE) based expert panels.

Materials and methods: In order to identify the desired CoVIE technical architecture, a qualitative approach was used and a number of meetings were held with experts in Health Information Technology and Management (HITM) and Health Informatics fields working at Iran, Tehran and Shahid Beheshti University of Medical Sciences (IUMS, TUMS and SBUMS). Basic concepts, including the type of technical architecture and exchange context, were categorized and discussed in terms of themes, sub-themes, and codes. Finally, the results were evaluated using content analysis and descriptive statistics.

Results: The universities of Iran and Tehran had chosen hybrid model in national context and Shahid Beheshti University selected regional centralized model as the optimal technical architecture for CoVIE.

Conclusion: Hybrid model with implementation at national context was selected for CoVIE in Iranian health system. Implementation of this architecture improves the effective management of information exchange in the context of CoVIE.

Keywords: COVID-19, Public Health Information Exchange (PHIE), Technical architecture, Hybrid model, Centralized model, Decentralized model

Introduction

Public health information exchange (PHIE) deals with the sharing of information between health care facilities through communication networks (1, 2). The HIE aims to facilitate the access and retrieval of information in order to provide safe, timely, efficient, effective, and patient-centric treatment (3). The high quality, safety, and effectiveness of care services are the major benefits of exchanging health information (4, 5). Prior to establishment of comprehensive PHIE models, the health sector faced difficulties in delivering high quality services and in meeting the needs of patients (4, 6, 7). Lack of information, poor documentation, inaccessibility of existing knowledge, and

mere reliance on individuals' memory, prevented the delivery of high quality healthcare services (8, 9). Policymakers, researchers, healthcare providers, and industry groups suggested the exchange data interoperability based on HIE infrastructure to address these problems (4).

From a technical point of view, exchanging health information models are categorized into three types: Centralized, decentralized, and hybrid (decentralized and decentralized) models (10) .It is important to identify the optimal PHIE model and implement it in a context which is compatible with current situation of organization (11, 12). Communication context is the area that information is managed in order to achieve interoperability (12). These contexts include three local, regional, and national areas for PHIE (13).

Coronavirus disease (COVID-19) is a highly contagious disease that rapidly spreads to other countries. The World Health Organization (WHO) has recently declared the COVID-19 as a public health emergency (14-16). Given the significant burdens associated with COVID-19, decision was made to adopt information technology and data infrastructures to bolster efficient research, surveillance, and treatment of this emerging outbreak (17, 18).

Selecting a technical architecture for COVID-19 Information Exchange (CoVIE) on the each context, may be vary depending on organizations' strategic planning, quality promotion criteria, security requirements, stakeholder expectations and their desire for independence, level of service complexity, internal health network infrastructure, and cultures and policies governing the health care system (10, 11, 19, 20). Stakeholders in different geographic areas adopt HIE architecture according to their local conditions, infrastructure, facilities, and needs (11).

In Iran, due to the insistence on manual and traditional methods of recording health information and lack of a coordinated and integrated infrastructure for information sharing between different levels of health care organizations, the process of efficient sharing information at high level faced with challenges (21). These conditions have led to islanding performances of health care systems and other related organizations; practically, they have adversely affected the inter-organizational cooperation(21, 22).

This study used experts' survey to identify the most optimal technical architecture for CoVIE in Iran. It will pave the way for establishment of a customized and integrated infrastructure for exchanging COVID-19 information in order to improve interoperability between different information systems.

Materials and methods

This research is a qualitative study that conducted in 2019. At first, the meetings were held with experts including faculty members working in Health Information Management and Health Information Technology departments at three of the top universities in Iran in the field of medical sciences, including Iran, Tehran and Shahid Beheshti universities where the best of the above mentioned experts are working.

The CoVIE architecture in present study included suitable communication models and contexts. In total, 17 experts were surveyed in three separate sessions. The results were recorded using audio recordings and notes. The data was analyzed using qualitative (content analysis) and quantitative (descriptive statistics) methods. At first step, the content analysis was done. The results were categorized into 3 theme, 9 sub-themes, and 17 codes. The axial coding was then used to correlate the concepts. A total of 24 subcategories were extracted from 4 main categories in interview content. Finally, the

results were evaluated by descriptive statistics.

Results

The number of participants in each expert session at the universities of Iran, Tehran and Shahid Beheshti was five, six and six experts, respectively. The demographic characteristics of participants and their workplace are presented in Table 1.

In order to facilitate the classification and analysis of data, the main themes, synonyms, and sub-themes were extracted from research content (Table 2).

The findings are presented in two ways: a) Qualitative findings from separate meetings and b) Frequency of findings of three sessions. The themes were categorized based on identification of PHIE model and their implementation from experts' opinions.

a) Qualitative findings from separate meetings

This section summarizes all findings from experts' interviews which were recorded during each session through audio recordings and notes. At the beginning of meeting, from five experts of IUMS, two experts suggested the centralized model as suitable technical architecture for CoVIE in Iran. They argued that Centralized model benefits such as, "integrated information management" (IE3) and "applicability at large geographical areas" (IE5). But in continuation of discussion, all participants agreed on selecting the hybrid model, and finally considered national information exchange context as suitable for implementing the hybrid model. In conclusion, the hybrid architecture and national context were selected. Their reasoning for selecting hybrid model were "information access management" (IE1), "customer satisfaction management" (IE2), "incremental and gradual implementation " (IE2), "proper integration" (IE3), "acceptable security and privacy" (IE4), "high interoperability " (IE5), and "information independence and conflict resolution" (IE5). Also their reasoning for selecting national context for implementing hybrid architecture was "central management leverage for Iran" (IE2) and "centralized policymaking at Ministry of Health" (IE4).

Table 1. Demographic characteristics of surveyed experts.

Row	University	Code	Sex	Age	Education field / degree	Work experience (years)
1	Iran university	IE1	Female	41	PhD of Medical Informatics	8
2		IE2	Female	51	PhD of Health Information Management	24
3		IE3	Male	53	PhD of Health Information Management	25
4		IE4	Male	47	PhD of Medical Informatics	9
5		IE5	Male	38	PhD of Health Information Management	5
6	Tehran university	TE1	Female	42	PhD of Health Information Management	15
7		TE2	Male	34	PhD of Health Information Management	9
8		TE3	Female	39	PhD of Health Information Management	12
9		TE4	Female	43	PhD of Health Information Management	18
10		TE5	Male	52	PhD of Health Information Management	23
11		TE6	Male	36	PhD of Medical Informatics	4
12	Shahid Beheshti university	BE1	Male	47	PhD of Health Information Management	7
13		BE2	Female	39	PhD of Health Information Management	11
14		BE3	Male	54	PhD of Health Information Management	24
15		BE4	Female	42	PhD of Health Information Management	28
16		Code	Male	57	PhD of Medical Informatics	6
17		IE1	Female	61	PhD of Medical Informatics	15

Table 2. Themes, synonyms, and sub-themes extracted from research content.

Theme	Synonyms	Sub-theme
Centralized model	Central model Indirect model Database based model Centralized model	Centralized model contexts' categorization geographical segmentation Implementation of a central database in each province's local health information organizations (centralized local architecture) implementation a central database at the level of the categorized provinces (centralized, inter-regional or regional architecture) Implementation of a central and national database at macro level (national centralized architecture)
Decentralized model	Indirect model Peer to peer model Decentralized model Decentralization model Direct model Not central model	Decentralized model contexts categorization by geographical segmentation Peer-to-peer communication between all centers in each province (decentralized local architecture) Peer-to-peer communication between all centers at the level of categorized provinces (decentralized inter-provincial or regional architecture) Establishment of a national health information network for peer-to-peer connection of all centers at macro level (national decentralized architecture)
Hybrid model	Integrated Model Dual model Linked model Mixed model Complex model Multiple model	Classification of hybrid model contexts by geographical segmentation Communication across all provincial centers and creation of a central database to store a copy of all information (local hybrid architecture) Communication across all provincial centers and creation of a central database to store a copy of all information (inter-provincial or regional hybrid architecture) Communication between all centers at macro level and create a central database to store a backup of all information (national hybrid architecture)

All experts were unanimously opposed to using decentralized model because of "costly and time - consuming direct cabling" (IE1), and "disrupting information integration and islanding of operation" (IE5).

Similar findings were obtained from experts of TUMS. All experts firmly considered the hybrid architecture in national context as suitable for Iranian CoVIE. From their point of view, the centralized model could not meet health care organization requirements in Iran due to "mere dependency on a central database" (TE1), "perpetual accessibility risks" (TE4), and "conflicts due to integrated data storage" (TE3). One expert quoted that "The culture and spirit of interaction between health care organizations have not yet reached the suitable level that enable a centralized model to be executed effectively" (TE2). According to one expert, the decentralized model (TE5) can overcome all above problems, but the problem of this model is the "high cost of implementing it" (TE3) and "time-consuming direct cabling between all organizations "(TE1). The consensus among experts at Tehran University of Medical Sciences on selecting hybrid model achieved due to its "cost effectiveness" (TE2), "high flexibility" (TE3), "optimal information management" (TE4), "greater adaptation to complex and up-to-date healthcare needs" (TE5), and "improvement in Interoperability" (TE6).

The findings from experts at SBUMS were somewhat different from findings of two other universities. Four experts preferred the centralized model. They cited the "integrating information for complex and multidimensional analysis" (BE1), "improving epidemiological surveying processes" (BE3), "experiencing Iranian electronic health (e-Health) record system" (BE5), and "need for cost savings" (BE6) as the most important reasons for selecting this

model in Iran. The experts did not reach a consensus on information exchange context; every expert agreed on a particular context. Four experts agreed with regional centralized model, one agreed with national hybrid model, and one agreed with the local decentralized model. Experts stated that: "Since other countries have been successful in establishing regional organizations to manage information systems and integrating all of them into a national information infrastructure, the regional contexts will be more efficient for HIE infrastructure management" (BE4). This is one of the reasons that the hybrid model was not selected by experts at Shahid Beheshti University: "The hybrid model requires more sophisticated technologies and increases the information exchange problems due to separation of message text from its identifiers" (BE3). The table 3 summarizes expert statements on each of HIE architectures.

Table 3. Participants' statements in discussing about information exchange architectures for health information exchange (HIE).

Model	Summary of participants' statements on HIE models	Frequency
Centralized model	Dependency on a single database	TE1, BE3
	Complex and comprehensive analysis	IE6, BE1
	Integrated information management"	IE3
	Vulnerability to hackers	TE4, BE6
	Lower updating	TE4
	Creating interference and conflict between organizations	TE2, IE1, BE5
	Risks of perpetual availability	TE4, BE4
	Accurate and efficient quick search	IE1, IE3 , BE2
Decentralized model	High cost	IE1, TE3
	Fast exchange of information without interference	BE3
	Disparate standards for information	IE1, IE5, BE4
	Islanding operation	IE1
	Suitable for large geographical areas	IE5, TE4
	Business continuity despite failure of a subset	BE4, BE6
Hybrid model	Cost effectiveness	IE1, TE2, TE4
	Gradual and incremental execution	IE2, BE6
	Information independence and conflict resolution	IE5, TE3
	High Interactivity	IE1 , IE2, TE3, TE4
	Acceptable security and privacy	IE4, TE3
	Proper integration	IE3, BE4
	Customer satisfaction management	IE2
	High flexibility	TE3, BE1
	Managing information access	IE1
	Increasing communication complexity	BE3

b) Frequency of findings from three meetings

The three meetings highlighted that from the perspective of experts, the hybrid model is suitable for Iranian HIE. From 114 words that used to represent HIE models in three sessions, 55 items were the hybrid model, 38 items were centralized model, and 21 items were the decentralized model. From 17 participated experts, 12 experts selected the hybrid model (70.58%), four experts selected the centralized model (23.52%), and one expert selected the decentralized model (5.9%). However except the experts at SBUMS who did not archive consensus, the experts at other two universities selected the national and macro contexts as suitable for exchanging information. The repetition rate

of terms representing the three models and the frequency of their selection in sessions were analyzed. Table 4 shows the frequency and repetition rate of selecting these terms.

Table 4. Repetition rate of terms representing CoVIE models and frequency of selecting them.

Terms representing three models	Repetition rate	Frequency (in percentage)
Centralized (central, indirect, and database-based) model	38	23.52
Decentralized (indirect, peer-to-peer, not central, and direct) model	21	5.9
Hybrid (integrated, dual, interconnected, mixed, complex, and multiple) model	55	70.58

Discussion

Rapidly distribution of accurate information is an effective approach to better the public health potential to handle COVID-19 outbreak. It is a main prerequisite to providing real-time information to researchers, epidemiologists, clinicians, managers and policy makers(20, 23). The lesson of the previous widespread prevalence of corona like diseases (such as SARS and MERS) and recently Covid-19, have reinforced the need to expand the Public Health Information System (PHIS) infrastructures for the active control and monitoring of this disease. In this situation, the design and implementation of customized Public Health Information Exchange (PHIE) and surveillance programs is necessary (24-26).

Improvement information exchange among health care stakeholders enabled the health care organizations to provide their services based on COVID-19 requirements and novel scientific evidence(24, 25). Iran lacks a comprehensive PHIE platform(21, 27). Characteristics of Iran health care structure require to adopt new information technologies and design of an effective and customized e-health infrastructure, especially for monitoring and control of the public health hazards(28). The establishment of a system in accordance with social and cultural conditions is one of the foremost issues to establishment of e-health infrastructure that demand major attention from health care policy-makers(29, 30).

CoVIE platform should be designed in such a way that facilitates the sharing of information between different health care organizations in accordance with structure of healthcare(31, 32). It is necessary to conduct a proper and targeted planning through accurate identification of criteria's and factors influencing the implementation of components of this system (27, 33). Various technical, legal, resource, political, cultural, and security criteria influence on the selecting of information exchange model in COVID-19 interoperability (9, 10, 23, 29). Analyzing of first section findings was concluded that hybrid model is capable for centralized storage and peer-peer exchange(3) and can be used for efficiently to exchange health information in Iran. This model operates based on decentralized capacities' using Record Locator Services (RLS)(3, 4).

The decentralized model is not efficient for operating in large geographic environments and its implementation is expensive, especially in the case of PHIE and massive disease outbreak. At present study, the critics of centralized model focused on conflict over information ownership, difficulty of updating, and risks of continuing business. Most advocators of hybrid model acknowledged the cost-effectiveness and qualitative improvements in information management process of this model. Execution of hybrid model is gradual and incremental and it is highly flexible in using latest technologies. "Using key identifiers and read-only access to information play an

important role in maintaining information integrity", based on one experts opinion.

In this study, the data exchange context consisted of local, regional, and national areas. Analyzing of second section findings, it was concluded that using the national context where information is managed at macro level, is more compatible with e-health implementation in Iran. This context enables the coordinated information management; that requires integrated technical architecture and legal agreements(12). At present study, the national context was recognized as a suitable platform for exchange information in CoVIE infrastructure because of the low cost for implementation, integrated infrastructure and using same standards. "Because of harmony in laws and regulations of all provinces, it is more suitable to implement the HIE model in national context", said one expert. Therefore In this study, hybrid model and national context were selected as suitable technical architecture for exchange of COVID-19 information in Iranian health system. In this regard, the findings of similar studies are provided to highlight on the scientific basis of findings in this study.

Ubri et al. (2009) introduced the hybrid model as applicable in US e-health infrastructure because of its high potential in optimizing information sharing. They also stated that the decentralized model is inefficient due to its high cost and complexity in exchange information in EHR infrastructure(34). In present study, the hybrid model was also considered suitable for exchange health information due to its high cost-effectiveness, efficient management of information sharing process, and enhancement of security. In addition, the information sharing process is best managed.

McCarthy study (2014) introduced the hybrid and centralized architectures as suitable technical infrastructures for exchange health information in Beacon communities(35). Pirnezhad et al (2007) emphasized on the efficiency of hybrid model in exchange health information. They believed that suitable management of information sharing process depends on using a hybrid model(11). Covich et al (2011) stated that decentralized model is not suitable for exchange information in HIE(19). Barrow and their colleague (2011) determined the centralized architecture as the first priority to share health information. They also introduced the hybrid model suitable for HIE(36). In present study, the hybrid and centralized model had the highest priority in respectively.

The High cost of direct cabling between all institutions at macro level in decentralized model was one of the main reasons for disapproval it. In addition, this model is not able to meet the complex and up-to-date requirements of healthcare industry. The following disadvantage was mentioned by many experts about centralized model creating interference and conflict over information ownership in organizations. Therefore, the benefits of centralized model can be yielded through training and helping to improve the culture and spirit of inter-organizational partnership; facility of integration and macro analysis is the most important benefits.

Larry et al. (2010) stated that in US, decentralized model was used in early 1990s, the centralized model was used from 1990 to 2000, and since 2000, the use of hybrid has increased(4). In report by Champagne (2013), most of the surveyed organizations used centralized and hybrid model for exchange health information (36%); only 28% of surveyed organizations adopted the decentralized model (22). In present study, it was concluded that hybrid model is of higher priority for exchange COVID-19 information; 70.58% of experts were interested in this model. In this study, the decentralized model had the least importance for exchange information (about 6%). Rudin

et al (2009) considered the strategic interests of organizations and the expectations of stakeholders of service quality as the criteria for selecting HIE technical architecture(10). Adoption of PHIE architecture may be different depending on expectations, needs, and features of target population and cultural, financial, technical, political, and ethical features(37). The research team assumed that participated experts are aware from general features of health system and above criteria's. These factors also affecting on the selection of suitable technical architecture for exchange COVID-19 information, have not been directly addressed in present study.

Conclusion

Selecting the hybrid model in national context may be effective in meeting the COVID-19 information exchange requirements. This means having a centralized database at national level that manages key identifiers of records and distributes read-only information to its stakeholders. In addition, all organizations communicate with each other by an intermediary organization. Furthermore, possible conflicts between organizations regarding information ownership will be reduced and stronger management of health information will be achieved. Implementation and maintenance of national hybrid infrastructure will be cost-effectiveness without need to peer-peer connection (decentralized model). On the other hand, the problems related to storage, security, business continuity, and updating of information in central database (centralized model) will be resolved.

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Competing interests

None declared.

Ethical approval

Not required.

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