Implementation of Electronic Health Record as a Clinical Information Tool to Improve Gastric Cancer Care

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Citation: Shahmoradi L, Khorami Moghadam R, Ghazisaeedi M, Gholamzadeh M. **Implementation of Electronic Health Record as a Clinical Information Tool to Improve Gastric Cancer Care.** Applied Health Information Technology 2020; 1(1): 19-29.

Received: 3-8-2020
Accepted: 4-16-2020

Abstract

Aim: According to the high prevalence of gastric cancer in Iran, this study aimed to develop a gastric cancer electronic health record (EHR) to improve outpatient gastric cancer care.
Method: This study represented the stepwise process used to develop a web-based gastric cancer EHR to overcome the documentation problems and cancer care complications. These iterative phases included determining the required minimum data sets (MDS), designing, developing and implementation, and usability evaluation. The system functional and non-functional requirements were determined using needs assessment. The MDSs were identified through consensus by a multidisciplinary expert panel. Finally, the web-based system was implemented in PHP language.
Results: Initially, the required datasets were verified by experts. Later, an EHR-based gastric cancer system was implemented successfully to support outpatient cancer care. Based on the analysis, the functional requirements and main modules of the system were specified. The designed system reached an acceptable level of usability and performance.
Conclusion: The system was successfully implemented in the gastric cancer clinic. Implementation of an electronic health record system can not only provide ease of access to clinical information, but also improve the quality of complicated cancer care.
Keywords: Gastric, neoplasm, Electronic health record, Information

According to the World Health Organization (WHO); gastric cancers are the second most common cause of cancer deaths among all cancer types. In the same vein, gastric cancer has a high prevalence in Iran (1, 2). Accurate assessment and efficient management of cancer patients could save patients' lives and decrease mortality.

Cancer-related therapies are usually very complicated (3, 4). Thus, health care providers are faced with many challenges in dealing with cancer care programs (5, 6). These complexities include a huge amount of clinical data from different resources, continuous care, large varieties of clinical data, and difficult communication among different physicians (7-9). Cancer care involves different stages of diagnosis and treatment processes. Therefore, a multidisciplinary team is needed to coordinate all activities concerned with improving the treatment plans for cancer

patients (7). The efficient cancer care plan plays a prominent role in mortality reduction, but patient management with a large amount of clinical data makes cancer care more complex (6, 10, 11). Thus, researchers should adopt new technologies to manage cancer patient clinical data.

Electronic health record (EHR) can provide a useful platform to facilitate the sharing of health information. The EHR covers all functions of a traditional medical record with high quality (12-15). Based on the results of different studies, implementation of EHR is a useful solution in the process of care in oncology clinics (16). Moreover, pieces of evidence outline the critical role of EHR in improving cancer care and care coordination (10, 12, 17, 18). The EHR provides valuable information for physicians and researchers to manage complex circumstances such as cancer by tracking the advancement of therapeutic process (19, 20).

Due to the high prevalence of gastric cancer in Iran, developing a gastric cancer EHR can enhance clinical documentation, track conditions, and follow-up cancer patients more efficiently. Therefore, the main objective of this research was to implement a gastric cancer EHR to manage outpatient care and improve the quality of care.

Method

This developmental research was conducted in three phases as follow:

Phase 1: Determining minimum data sets

In order to determine the MDSs, a literature review was conducted to find related studies and evidences. Electronic databases, including PubMed, Scopus, and Google Scholar were searched as the world's largest abstract and indexing databases from 2005 to 2017 using the following search terms: “gastric cancer”, “gastrointestinal Neoplasms”, “stomach cancer”, and "data set". The retrieved articles were reviewed by researchers to find suitable datasets. Moreover, patients' medical records and experts' consultation were used to discover the required data sets.

Based on the literature review and expert consultation, a five-point Likert scale questionnaire was designed, which options ranged from ‘‘strongly disagree’’ to ‘‘strongly agree’’ to identify essential data sets. The content validity index (CVI) and content validity ratio (CVR) were calculated to determine the questionnaire's content validity. Reliability of the questionnaire was assessed by split-half method and Cronbach’s alpha of 0.82. A multidisciplinary expert panel (22 experts in oncology, gastroenterology, internal medicine, and radiotherapy) was formed. These experts were required to read the questions and discuss about them until a consensus is reached. The questionnaire consisted of two parts: experts’ demographic information (nine items) and experts’ attitudes toward gastric cancer datasets (23 items). The level of consensus for each item was determined at 75%.

To identify the proper framework of EHR system, a paper-based gastric cancer care process was analyzed carefully in the study site. At this stage, one of the researchers played the role of an observer in the clinic to analyze the patient management workflow. All observations were recorded in terms of actors, tasks, and processes to recognize functional requirements of the final system. Later, the general model of the system was obtained.

Phase 2: Designing, developing, and implementing

The second phase was designing and developing an EHR-based system. A web-based platform was selected to enhance communication between clinical staff and system accessibility. The system was developed based on the PHP programming language. Next, the system prototype was developed to enhance the system usability. The demographic and

clinical data of 914 patients were entered into the system from paper-based medical records.

Phase 3: Usability evaluation

In this phase, the ISO 9241 questionnaire was administered to evaluate the system usability. This questionnaire is one of the most reliable and suitable tools applied to assess the health information system usability (21). In this study, the short version of Isometrics questionnaire was used. The questionnaire comprises of 15 items over suitability of the task (eight questions), self-descriptiveness (one question), controllability (four questions), and error-tolerance (two questions). To evaluate human-computer interactions, 10 physicians and 10 clinic staff participated. The results were analyzed and descriptive statistics were calculated using SPSS software (version 20).

Results

In the first phase of the study, based on the findings, 72% of the participants were male and 50% were assistant professors. Most of the experts (49%) had a work experience of about 10–20 years and 13.64% of them had a work experience of higher than 20 years.

The final datasets were obtained by combining the results of the literature review and consensus among experts. The required minimum dataset was approved by the expert group. After a consensus, 32 data elements were determined as essential datasets, which can be categorized into two main categories of demographic information and clinical information. The clinical information was classified into seven categories: medical history, history of the current illness, pathology information, metastasis information, treatment, death information, and habits. The highest number of items belonged to the treatment group. All approved datasets are described in Tabel 1.

In the second phase, the functional and non-functional requirements were identified based on the needs' assessment, literature review, and expert consultation; as a result, the problems and hazards of the current system were recognized by observation. Finally, general model of the final system was determined (Fig. 1).

According to the findings, the database was designed to store all demographic and clinical information of the patients and users. In gastric cancer EHR, a medical record profile was created for each patient by the system automatically. Based on two- tier architecture, the database and tables were defined on the server-side. A modular approach was applied to design the system components. According to the needs assessment, the system consists of eight main modules (Table 2).

One of the most significant aspects of the web-based system is its automatic coding section. To enhance cancer care system interoperability, EHR should use health information standards such as International Classification of Diseases Classification (ICD), Logical Observation Identifier Names and Codes (LOINC), or Systematized Nomenclature of Medicine-Clinical Terms (SNOMED-CT). The ICD is a standard vocabulary for disease, health status, and external causes of injuries. The purpose of ICD, as a database and universal standard for
identifying medical laboratory observations, is t o facilitate comparison of diseases and causes of death among nations.

Health specialists and staff can access a web-based portal for gastric cancer patients through the URL address (www.rgcancer.ir). By implementing a simple interface, users can reach the data easily. Moreover, they can access an electronic medical record for each patient in a new window. Figure 2 illustrates different screenshots from the system.

Additionally, the system had the capability of generating statistical reports and representing

statistical data in the form of charts to improve information retrieval. Hence, physicians and healthcare providers can apply this system in the context of clinical research. These reports are produced automatically.

In the third phase, all software errors were fixed and resolved in an iterative process. Algorithms, queries, and web server accuracy can be assessed through performance testing. Since the system should be tested in a real environment to measure its performance (22), the system was implemented as a pilot application in the setting. The syntax, semantic, and logical errors of the software were determined through performance testing. The obtained results were rational and acceptable.

Usability evaluation is an essential process in health information systems to ensure the system's capability to meet the users' requirements. To this end, the experts' viewpoints were collected and analyzed. Distribution frequency of answers to each question was considered and the required revisions were applied in the usability evaluation survey using SPSS v.20.

Table 3 represents the frequency of answers to each question. The findings indicated that the majority of users (72.3%) were strongly agree, 18% were agree, 7.75% were disagree, and 0.05% of users were strongly disagree. Overall, the analysis of evaluation results among the five ISO usability criteria indicated that the mean score of suitability for the task, self-descriptiveness, controllability, and error tolerance were about 25.62%, 25%, 25.02%, and 20.61%, respectively. The findings indicated that the highest mean score was related to the suitability of the task.

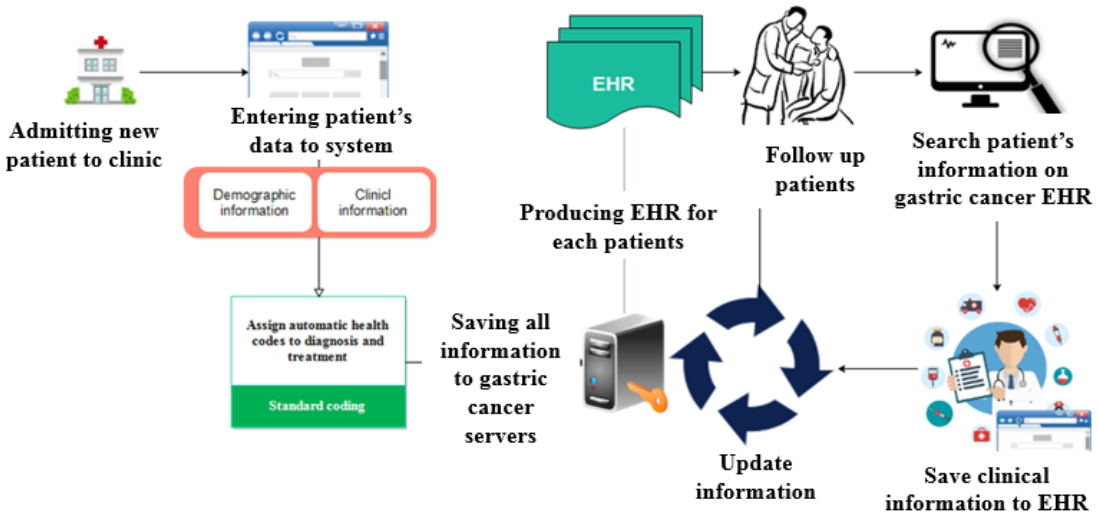

Figure 1: The general model of the gastric cancer EHR

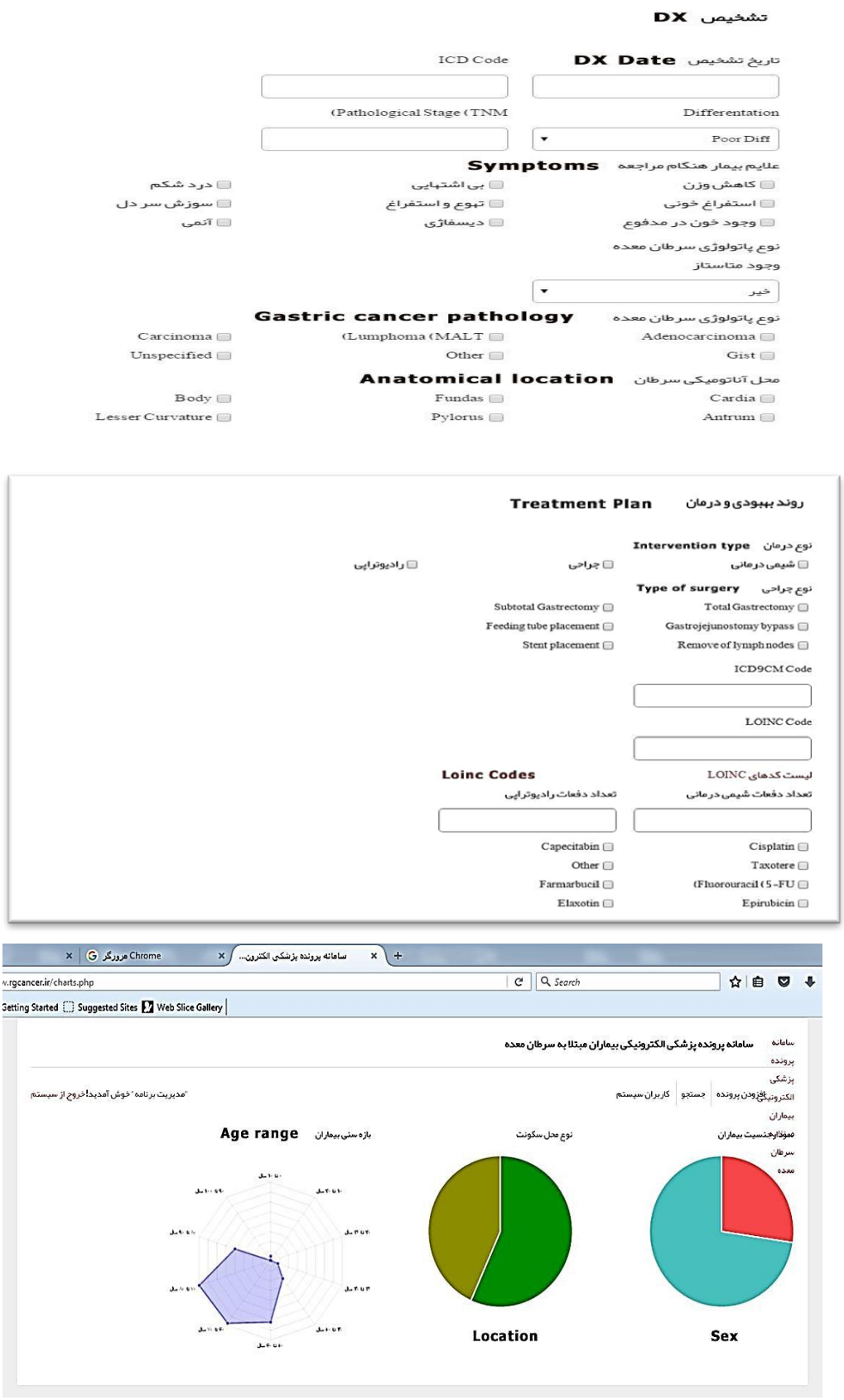

Figure 2. Some screenshots the gastric cancer EHR

Table 1: Approved minimum data sets of gastric cancer EHR

Category		Subcategory
Demographic Information		Patient 'name
		Medical record number
		National code
		Date of birth and age
		Gender
		Marital status
		Contact information
		Type of residence (urban, rural)
		Native or non-native
Clinical Information	Medical history	The individual history of cancer
		The family history of cancer
		The history of Helicobacter pylori
		Blood group
	History of the current illness	Date of first cancer diagnosis
		Problem lists at the time of referral (weight loss, anorexia, abdominal pain, vomiting, nausea, heartburn, stool circulation, dysphagia, anemia)
		Patient' age at diagnosing time
	Pathology information	Type
		Anatomic site
	Metastasis information	Metastatic cancer or non-metastatic cancer
		The anatomic site of Metastasis
		Differentiation stage of tumors
	Treatment	Treatment plan or protocol
		Surgical plan or type
		Number of chemotherapy cycles received (with start and stop dates of chemotherapy)
		Number of radiation plan received
		Name of chemotherapy regimen (specific chemotherapy names, dose (per m^2, etc.) and schedule)
	Death information	Cause of death
		Date of death
	Habits	History of smoking
		Alcohol consumption
		Opium consumption
		Consumption of salt and ghee

Table 2: Different modules of the system

Module	Description
Login module	Only authorized users can enter the system after a successful login.
The dashboard	The user can see the abstraction of the records.
Adding a patient's information	Clinical data entered through five main axes: demographic information, present medical condition, treatment plan, and information about hereditary and environmental factors.
History module	The patient's medical and family history which was related to the type of gastric cancer (in three subsets of gastric cancer) entered separately in this section, as well as the presence or absence of a history of Helicobacter pylori infection.
Diagnosis module	The items include the date of diagnosis, the ICD-10 code of diagnosis, the degree of differentiation, the pathological stage (TNM), and symptoms of the patient, the presence or absence of metastasis, anatomical location of the tumor, pathology details, and anatomical location of metastases.
Recovery and treatment module	Information such as chemotherapy protocol information, surgical and treatment codes, cause of departure, death information, and cause of death are stored here.
Searching module	Users can search for desired patients in this section.
Reports	This section provides a variety of reports from quantitative data in graphical charts. Additionally; the user can view pathology results in the form of a scanned image.
Automatic coding section	The three categories of standard coding systems such as the International ICD according to the ICD-10, surgical or therapeutic procedures coding system based on the ICD-9-CM, and the LOINC coding system were applied. The automated coding process developed in this system to assign accurate diagnosis codes to intervention and protocols.

ICD: Classification of Diseases Classification; *ICD-9-CM*: International Classification of Diseases, Version 9, Clinical Modification; *LOINC*: Logical Observation Identifier Names and Codes.

Table 3: Results of usability evaluation

Category	Question	Completely agree	Agree	No opinion	Disagree	Completely disagree
Suitability for the task	The way in which data is entered is suited to the tasks I want to perform with the software.	15(75%)	5(25%)	-	-	-
	I perceive the arrangement of the fields on-screen as sensible for the work I do with the software.	16(80%)	3(15%)	1(5%)	-	-
	Too many different steps need to be performed to deal with a given task.	16(80%)	2(10%)	2(10%)	-	-
	The way in which data is output is suited to the tasks I want to perform.	12(60%)	8(40%)	-	-	-
	The software is well suited to the requirements of my work.	16(80%)	4(40%)	-	-	-
	I can easily adapt the software for performing new tasks.	10(50%)	10(50%)	-	-	-
	The presentation of the information on the screen	14(70%)	6(30%)	-	-	-

Category	Question	Completely agree	Agree	No opinion	Disagree	Completely disagree
	supports me in performing my work.					
	The function implemented in the software supports me in performing my work.	15(75%)	3(15%)	2(10%)	-	-
Self-descriptiveness	It is easy to retrieve information about a certain entry field.	15(75%)	5(25%)	-	-	-
Controllability	The software makes it easy for me to switch between different menu levels.	12(60%)	6(30%)	2(10%)	-	-
	The software lets me return directly to the main menu from any screen.	20(100%)	-	-	-	-
	When selecting menu items, I can speed things up by directly entering a letter or a command code.	14(70%)	6(30%)	-	-	-
	The software allows me to interrupt functions at any point, even if it is waiting for me to make an entry.	12(60%)	6(30%)	2(10%)	-	-
Error-tolerance	When I attempt to perform a destructive operation (e.g. deletion of data etc.), I am always first prompted to confirm the action.	15(75%)	5(25%)	-	-	-
	My impression is that very little effort is involved in correcting mistakes.	15(75%)	3(15%)	2(10%)	-	-

Discussion

Due to the complexity of gastric cancer care and clinical documentation, we applied a new approach by EHR implementation to facilitate cancer care management. LeBlanc et al. (23) believed that using EHR in oncology clinics could potentially lead to a significant improvement in cancer care. Kwon et al. (24) emphasized that implementation of EHR enhanced the evidence-based practices for treatment adherence and cancer care improvement.

An initial objective of this research was to improve gastric cancer care. Consequently, EHR-based gastric cancer was developed in the oncology clinic to enhance patient management and documentation. In a similar study in Japan, an EHR system was implemented to manage patients with gastric cancer at outpatient clinics to improve documentation. The results showed that developing such a system would be beneficial to improve the quality of care (25).

The development process included design, development, implementation, and evaluation. The system development method was adapted from the standard process of software development life cycle. The design phase began with a need analysis. The needs assessment was performed by direct observation. Since one of the research questions is about specifying the required datasets, the analysis phase continued with dataset determination. A multi-disciplinary committee of experts in related fields was chosen to improve the finding appropriate datasets in terms of gastric cancer. Gastric

cancer minimum datasets were ascertained through the combination of literature review and expert consensus meetings. The final datasets obtained through this study were matched with the datasets described by the American Society of Clinical Oncology (ASCO) (26). In addition, the development of gastric cancer minimum datasets enhanced reporting and information administration.

Based on our findings, interoperability is the most challenging subject in developing the EHR system. Data codification could be used by applying the health data standards to optimize health data exchange and information retrieval (21). According to Fasola et al. (22), standardization of the cancer care process can improve patient assessment, cancer care management, physician's communication, and epidemiological research in oncology practice. Thus, health data standards and automatic coding were considered as the main module of EHR system to produce a structured medical record for each patient.

The web-based platform was selected in this study to improve the coordination of cancer care among healthcare providers. According to Gastonia (21) and Fraccaro (22), a web-based approach could facilitate frequent follow-up and accessibility. Application of a web platform not only can solve the limitation of paper-based medical records, but also can provide sharing information among clinicians.

The third question in this research was about system evaluation. The gastric cancer EHR was implemented in the study site to assess its usability and high-quality performance. Through performance testing, the system design and specifications were significantly improved to avoid severe obstacles. In this regard, we can meet expectations of the users to some extent before final implementation. For example, we improved the search module after conducting performance testing. Later, the search module was changed, which was divided into a simple search and an advanced search to enhance system performance.

In terms of usability, the usability evaluation showed that the system met users' requirement and satisfaction. Among isometric criteria, task suitability received the highest score in this study. Other researches also emphasized the importance of task suitability to improve system usability (27-29).

The key strength of this study is the experts' collaboration in all development phases through the iterative and incremental processes. The user and staff involvement can lead to system development based on the users' expectations (30). However, because this system is only for the management of outpatients with gastric cancer, it is one of the weaknesses of this system.

This study was encountered with certain limitations. Given the limited number of participants, our findings cannot be generalized to other studies in the context of cancer care. So, more research is required to better investigate the long-term effects of the EHR system. In this regard, a randomized control trial research should be conducted to evaluate the effect of the designed system on cancer care. Development of a system for inpatient is suggested for the future researchers. The findings can be integrated to outpatient care system to improve patient management.

Conclusion

The designed system was implemented successfully in the gastric cancer outpatient clinic and was utilized in the routine cancer care process. The system not only can promote patient management, but also can improve better clinical decision-making by healthcare professionals. The EHR evaluation verified the system performance and usability. The usability evaluation showed that patient information management and documentation could be improved through system implementation.

Furthermore, it facilitates access to medical records due to its simple interface design.

Disclaimer Statements

- **Acknowledgments:** Special thanks go to Razi clinic in Rasht at Guilan due to their cooperation in conducting this research.
- **Conflict of interests:** None
- **Financial support or sponsorship:** This study was approved by Tehran University of Medical Sciences (M.Sc. thesis, No: 280/3/f/71)
- **Protection of Human and Animal Subjects:** These subjects were not included in the project.
- **Authors' contributions:** All of the authors have contributed to writing the article. The corresponding author made the final proofreading

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