Diagnosing, Managing, and Controlling COVID-19 using Clinical Decision Support Systems: A Study to Introduce CDSS Applications

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ABSTRACT

Coronavirus disease (COVID-19) as an emerging disease decreases security among people from different countries. Sense of security can be raised via quick diagnosis of COVID-19, and its management and control using clinical decision support systems (CDSS) to prevent further spread of the disease. So, the aim of this study is to identify and introduce the applications of a CDSS in the diagnosis, management, and control of COVID-19. This cross-sectional study was conducted to identify and introduce the applications of CDSS in the diagnosis, management, and control of COVID-19. Based on the results of some meetings with infectious disease specialists and a general practitioner as well as reviewing the related literature, information about COVID-19 and CDSS was obtained. Then based on the information obtained, a questionnaire was designed electronically and distributed in a two-round Delphi method among 19 experts in the three fields of medical informatics, health information management, and infectious disease specialists. According to the literature and expert opinions, 35 applications of CDSS applications were identified in the four main groups of "diagnosis", "medication", "monitoring", and "health services". Eventually, a collective agreement was reached on 30 applications in the first and second rounds of Delphi. Among all the applications, the highest means were assigned to "monitoring the vital signs" and "helping diagnose infections and damaged lung tissue through CT scan". Introducing these applications can provide general, basic knowledge of the design and implementation of clinical decision support systems in the real world to prevent irreversible complications and even many people's death.

Citation: Moulaei Kh, Bahaadinbeigy K. Diagnosing, Managing, and Controlling COVID-19 using Clinical Decision Support Systems: A Study to Introduce CDSS Applications. *J Biomed Phys Eng*. 2022;12(2):213-224. doi: 10.31661/jbpe.v0i0.2105-1336.

Keywords

Decision Support Systems; COVID-19; Coronavirus; Diagnosi; Disease Management

Introduction

The recurrence of new infectious diseases (e.g., influenza a virus subtype H1N1, severe acute respiratory syndrome (SARS), Middle East respiratory syndrome (MERS), avian influenza H5N1, Ebola) has failed to spread in the world and provided the international community with a sense of safety. However, coronavirus (COVID-19), as a highly contagious disease, has weakened this sense of safety among the countries of the world [1]. The outbreak of new COVID-19 infection quickly became a global health emergency in China during December 2019 [2, 3].

As a health state of emergency [2], COVID-19 disease causes morbid-

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Received: 13 May 2021
Accepted: 15 July 2021

ity and mortality, health system warnings, recessing of the economy, closing of schools, and psychological disorders [4]. On the other hand, patients with COVID-19 have low psychological tolerance capacity and are highly exposed to psychological disorders such as anxiety, fear, depression, and negative thoughts due to the current state of the disease in the world [5]. Also, this epidemic has induced pressure among health care providers and greatly increased healthcare costs [6]. Therefore, if the outbreak of this disease is not managed and controlled as soon as possible, patients, care providers, and even health systems will face serious problems due to the lack of medical staff and medical equipment [7]. To control and manage the disease, attention should be paid to the early symptoms of COVID-19 infection for early diagnosis. Patients should be isolated before pulmonary symptoms appear [8]. One way to help diagnose, monitor, treat, and track patients are using clinical decision support systems (CDSS) designed to help make the right decision and support all stages of the user's decision-making process. In clinical settings, CDSS provides specific knowledge, advice, and information to physicians, staff, and patients [9], predicts disease severity for the patients with COVID-19 infection [10], and is used as computer alerts and reminders, computer instructions, collection of orders, patient data reports, document patterns, and clinical trial tools [11]. CDSS includes a variety of computer and non-computer tools and interventions [12]. Computer CDSS can be designed based on electronic health records (EHRs), disease registries, computerized physician order entry (CPOE), and /or personal health records (PHR) [12].

CDSS increases patient safety (by reducing the errors and side effects), more efficient clinical management (through adherence to clinical guidelines, follow-up, and treatment reminders, etc.), reducing costs, automating managerial functions (diagnostic code selection, automated documentation, and note auto-fill), diagnostic support (by providing diagnostic suggestions based on patient data, automating output from test results), patient decision support (decision-support administered directly to patients through PHR and other systems), accurate documentation, and workflow improvement [11]. The aim of this study is to identify and introduce the applications of CDSSs for diagnosis, management, and control of COVID-19 using CDSSs.

Material and Methods

The present study was conducted in the following two phases:

Phase 1: Identifying and introducing CDSS applications to manage, control, and monitor the patients infected with COVID-19

Four steps were taken to collect, extract, and classify data about COVID-19 disease as follows: 1) we held two half-hour online sessions via Skype with two infectious disease physicians and a general practitioner. These physicians had experience attending hospitals serving patients with coronavirus (COVID-19) with sufficient knowledge of COVID-19, 2). 2) various studies and about COVID-19 were studied [3, 13-18] and all data about this disease (signs, symptoms, and complications) were extracted and included in a data extraction form, 3) one of the medical informatics specialists who had experience in designing and presenting the CDSSs was asked to classify the different applications of CDSSs to groups and subgroups of each category, based on the signs and symptoms obtained during an online consultation session, and 4) 50 applications (including main groups and subgroups) were reviewed and modified during two online consultation sessions with two infectious physicians, a general practitioner, and one medical informatics specialist during one day. Finally, 35 applications were selected to include in the questionnaire.

Phase 2: Final approval of CDSS applications identified and introduced by experts

In this step, a questionnaire was used to collect data in a two-stage Delphi method with two parts: 1) the specialists' demographic information and 2) 35 questions about the identified CDSS applications for further management, diagnosis, control, and monitoring COVID-19 patients. Numerical data from one to five were assigned to score each question (a five-point Likert scale). The questionnaire's face and content validity were confirmed by two infectious disease and internal medicine physicians, one general practitioner, and two medical informatics specialists. Based on the received comments, some unrelated and equivalent items were excluded from the questionnaire. The reality of the questionnaire was analyzed using Cronbach's Alpha (0.930).

In the next step, the questionnaire was distributed and since COVID-19 was spread in different cities of Iran with some challenges such as distance and high-cost traveling, distributing the questionnaire was impossible among the experts in person; thus, the questionnaire was designed in the electronic format. The questionnaire's link was sent to the experts in the three fields of medical informatics, health information management, and infectious disease physicians. Inclusion criteria for the experts in medical informatics and health information management included experience in designing or implementing CDSSs or working with these pre-established systems in treatment centers. Furthermore, working in specialized hospitals related to COVID-19 considered the inclusion criteria for infectious disease specialists. Since in most Delphi studies the number of experts is15 to 20, in this study random sampling was conducted and 19 experts in medical informatics, health information management, and infectious disease specialists were selected to participate in the study. The Delphi method is a structured process for collecting and classifying the knowledge available to a group of experts, done by distributing questionnaires among these people and controlled feedback on the answers and comments received [19].

In the first round of the Delphi study, the questionnaire was distributed and collected among the experts on November 12-16, 2020. One month after the Delphi first round (December 16, 2020), the questionnaire was electronically redistributed and collected between the same specialists in the second round of Delphi. Besides, in order to identify other important applications from the perspective of experts, an open-ended question about "other applications, challenges, and suggestions" was considered.

After collecting the questionnaires, the Delphi first-round data were entered in SPSS software (version 23) and, then the frequency and mean scores of each data were calculated and analyzed. Experts' opinions were analyzed after calculating the standard deviation (SD) and mean scores for each application in Delphi first round. To decide about any identified application, a consensus level was considered in the first step. Therefore, some of the CDSS applications with the mean score of less than 50 percent were ignored in the first round, applications with the mean score from 50 to 75 percent in Delphi second round were included, and applications with a mean score of more than 75 percent, without requiring to re-evaluate in Delphi second round, were considered as a final data element of CDSS applications [20].

Technical presentation

Table 1 shows the frequency distribution of the demographic of the experts participating in the study. The female participants' frequency in all the three expert groups was more than that of males. The most age group of the participants ranged from 36 to 45 years old.

According to Table 2, from 35 applications classified into the four major categories of "diagnosis", "medication", "monitoring", and "health services", 30 applications were finally confirmed based on research experts' opinions. In the first round of Delphi, the mean score of

Table 1: Demographic information of the experts participating in the study

Variable		Frequency (%)		
		Medical informatics Experts (n= 12)	Health Information Management Experts (n= 3)	Infectious disease specialists (n= 4)
Gender	Male	5(41.6)	1(33.3)	1(25.0)
	Female	7(58.3)	2(66.6)	3(75.0)
Age	25-35	1(8.33)	1(33.3)	0
	36-45	9(75.0)	1(33.3)	2(50.0)
	46-55	2(16.66)	1(33.3)	1(25.0)
	>50	0	0	1(25.0)
Education	MSc	2(16.66)	1(33.3)	2(50.0)
	PhD Student	7(58.3)	1(33.3)	2(50.0)
	PhD and above	3(25.0)	1(33.3)	3(75.0)
Experience working with clinical decision support systems (By year)	1-2	10(83.3)	3(100)	1(25.0)
	3-5	1(8.3)	0	0
	>5	1(8.3)	0	0
Number of designed clinical decision support systems	0	0	3(100)	3(75.0)
	1-2	9(75.0)	0	1(25.0)
	3-5	2(16.66)	0	0
	>5	1(8.33)	3(33.3)	0

Table 2: Groups and subgroups accepted/rejected from Delphi in the first and second stages

Data primary groups	Number of the subgroup or applications	First round of Delphi			Second round of Delphi			No of final subgroup or applications
		<50%	50-75%	>75%	<50%	50-75%	>75%	
Diagnosis	9	0	1	8	1	0	0	8
Medication	8	0	1	7	1	0	0	7
Monitoring	3	0	0	3	0	0	0	3
Health services	15	0	3	12	3	0	0	12

five applications was between 50 and 75 that were included in the Delphi second round and four applications with a mean score of less than 70% were excluded.

As shown in Table 2, all the applications contributing to the diagnosis of corona disease are listed in the main "diagnosis" group. Irrational use of the medicines does not help the patient and society's health and may lead to serious problems and even death due to side effects and complications [21]. So, in the "medication" group, all applications related to CDSSs which can decrease errors and complications associated with drug management and safety were included. The "monitoring" group was devoted to recording the patient's symptoms and signs to regularly monitor these patients' conditions. Besides, in the "health services" group, all the services provided to the patients with COVID-19 using CDSS to improve diagnosis, treatment, control, and prevention processes were devoted. Among these groups, the most and the lowest subgroups were related to "health services" (with 15 subgroups) and "monitoring"(with three subgroups), respectively.

Table 3 shows all subgroups or applications for each group with their mean and standard deviation (SD). Accordingly, the "monitoring" group was the only group, in which all three subgroups in the Delphi first round had a mean score of more than 75%. The subgroup of "diagnosis by designing a social networking robot (like telegram robots) for initial screening" was the only subgroup of the "diagnosis" group, finally excluded from the study with a mean score of less than 75%. In the "medication" group, the subgroup of "managing the treatment of depression and prescribing antidepressants", according to the experts' opinion, was excluded from the identified applications.

In the "health services" group, the three subgroups of "alerting in case of improper nutrition", "automatic assessment of disease risks by the family physician", and "assessing and diagnosing disabilities in older people with COVID-19" were finally excluded from the identified CDSS applications based on the experts' opinions. Among all the applications of CDSSs, the highest mean was identified for the subgroups of "monitoring the vital signs" and "helping diagnose infections and damaged lung tissue through CT scan".

Besides, in the open-ended question about "Other applications, challenges, and suggestions", the experts pointed out that due to the existing infrastructure challenges in Iran, some of these items are not possible to implement; moreover, facing the health staff with these systems used for the specific and almost unrecognized COVID-19 disease can induce confusion. Therefore, studying the facilities and infrastructure located in any hospital or organization dedicated to the patients with COVID-19 should be strongly considered. Experts also point out that COVID-19 can spread very quickly among people. Thus, using remote diagnostic systems and CDSS for physicians and patients is needed more than ever, and conducting such research in this period can be very useful and efficient. In addition to decision support systems, it would be better to discuss databases related to this disease.

Discussion

In the present study, 30 subgroups of applications of the CDSSs in the diagnosis, management, and control, and monitoring of the patients with COVID-19 were identified. According to the study findings, among these subgroups, "health services", with a variety of services, could be most useful in diagnosis, manage, control, and monitor patients with COVID-19. The main "monitoring" group can also have the least applications to manage, control, and monitor these patients. Also, the highest mean was related to the subgroups "monitoring the vital signs" and "helping diagnose infections and damaged lung tissue through CT scan".

Results of Sutton et al. [11] study confirmed

Table 3: Main groups and subgroups related to the applications of clinical decision support system (CDSS) in diagnosis, management, and control of COVID-19

Main group	Subgroups (applications)	First round of Delphi: Mean± standard deviation (SD)	First round of Delphi: Accepted / review	Second round of Delphi: Mean± standard deviation (SD)	Final acceptance or rejection
Diagnosis	Diagnosis through signs and symptoms	4.37 ±0.76	√		√
	Helping diagnose infections and damaged lung tissue through computerized tomography scan	4.58±0.83	√		√
	Diagnosing patients' fever by smart devices or wearables	4.11±0.87	√		√
	Diagnosis by designing a social networking robot (like telegram robots) for initial screening	3.26±0.93	*	3.16±1.38	×
	Helping diagnose and monitor patients through communication-oriented spatial decision support system (SDSS) for: the target group is mostly communication-oriented CDSS, internal teams of physicians and nurses, and other treatment staff. Examples of types of communication-oriented CDSS are chat and instant messaging software, online collaboration, and net meeting software.	3.89±0.87	√		√
	Diagnosis and treatment of the disease through document-based CDSSs (for example, using an info button to search web pages and find documents to provide new documentation for physicians)	4.00±0.81	√		√
	Automatic assessment of disease risks in families to identify and diagnose people affected in a family to help family physicians hospitalize or quarantine individuals at home	4.32±0.67	√		√
	Diagnosis and control of respiratory diseases caused by COVID-19 and specialized support for spirometry	4.16±0.83	√		√
	Interpreter based on CT images obtained from patients' lungs to diagnose and control the disease	4.37 ±0.68	√		√
Medication	Reminder in prescribing medication	3.84 ±1.46	√		√
	Warning at the time of prescribing the drug at the wrong time	3.95 ±1.35	√		√
	Warning in case of drug allergies	4.16 ±0.83	√		√
	Estimation of drug dose	4.05 ±0.91	√		√
	Prohibiting the prescription of illegal and counterfeit drugs	4.16 ±1.06	√		√
	Preventing drug interactions	4.32±0.82	√		√
	Providing medication advice after discharge	4.11±0.87	√		√
	Managing the treatment of depression and prescribing antidepressants	2.74±1.09	*	3.26±0.93	×
Monitoring	Tracking and monitoring patients in the hospital using radio-frequency identification (RFID) technology	4.16±0.89	√		√
	Monitoring the vital signs (body temperature, pulse rate (heart rate), blood pressure, respiration rate, and oxygen saturation) of patients in ICU	4.63±0.59	√		√
	Continuously monitoring patients' breathing and body temperature by smart devices or wearables	4.58±0.60	√		√

Main group	Subgroups (applications)	First round of Delphi		Second round of Delphi	Final acceptance or rejection
		Mean± standard deviation (SD)	Accepted / review	Mean± standard deviation (SD)	
Health services	Helping accommodate and hospitalize patients quickly in hospitals and medical centers by spatial decision support system (SDSS)	4.42±0.69	√		√
	Helping identify high-risk locations to prevent the provision of services through mobile hospitals by SDSS	4.16±0.76	√		√
	Modeling patient behavior and using models to investigate the effect of treatment measures on patient survival	4.11±1.10	√		√
	Automated patient reporting system to provide a report of patients' physical and psychological condition in order to make the right treatment decision	3.95±0.91	√		√
	Providing treatment suggestions to reduce the side effects of the disease	4.11±0.73	√		√
	Remote monitoring and management of patients by physicians through the reception of symptoms such as fever, cough, shortness of breath, and acute respiratory problems	3.89±1.37	√		√
	Providing reminders to move patients from the ICU to other departments	3.95±1.07	√		√
	Automatic reminder to help with the patient discharge process	4.11±0.93	√		√
	Patient classification using signs and symptoms related to COVID-19	4.37±0.68	√		√
	Grade disease severity to help hospitalization or home quarantine based on processing CT images of the lungs	4.53±0.61	√		√
	Accessing the patient's medical history to make the right decision	4.26±1.09	√		√
	Alerting in case of improper nutrition	3.71±1.31		3.73±1.43	×
	Electronic assessment of COVID-19 risk to prevent the disease	4.21±0.91	√		√
	Automatic assessment of disease risks by family physician	3.16±1.38	*	3.26±1.17	×
	Assess and diagnose disabilities in older people with coronavirus	3.26±1.19	*	3.71±1.31	×

*: Review in Delphi second round; √: Final accepted; ×: Final rejection, CT: Computerized Tomography, ICU: Intensive Care Unit

the present study findings, i.e. the function ranges provided by CDSS are very broad and involve all aspects of diagnosis, alert systems, disease management, drug administration, drug control, and other cases. Moreover, Reeves et al. [22] investigated electronic-based clinical decision support processes related to COVID-19 and demonstrated that in a CDSS, different facilities can be used to support screening processes or outpatient testing, emergency care, and emergency testing in order to support clinical decision-making during ordering. This is possible by providing screening criteria, sample acquisition information, personal protective equipment requirements, and expectations about the turnaround time of the test results for review and convenient decision-making by service providers [22].

Another study [23] stated that Ebola virus disease (EVD) is infectious, contagious, and highly deadly for humans with unknown treatment without enough knowledge. Therefore, designing a clinical decision support system can help users and health staff diagnoses and manage the disease. Wong et al. [24] developed a web-based decision support system to diagnose Ebola disease due to problems such as high mortality rates, its rapid spread and contagion, late diagnosis or diagnostic errors, shortage of the specialist, and the fewer number of physicians than patients. Using the patient's symptoms, this system could diagnose the presence or absence of EVD and the probability that the patient is infected with this disease. Since no drug or vaccine was proven with 100% safety for COVID-19 and this disease rapidly spreading around the world, non-drug proceedings are essential to decrease the incidence of the corona disease. Thus, according to Oluwagbemi et al. [23] and Wong et al. [24], CDSS can compensate for some of these shortcomings by rapidly diagnosing and evaluating the status of the affected patients in order to decrease the hospital bed occupancy, reduce the costs, and prevent further outbreaks of the epidemic disease. Besides, patients can be classified based on the severity of complications, signs and symptoms, global COVID-19 protocol, and CT images taken from damaged lung tissue (for hospitalization in the wards, ICUs, or home quarantine). The discussion about image processing in the domain of coronavirus and CDSS is significant. Since different tissues in the lung have different characteristics, image segmentation techniques can be used to diagnose the infection and damaged parts in different parts and accelerate the diagnosis process. MERS-CoV is another airborne disease that easily spreads with high mortality. Sandhu et al. [25] designed a smart system to predict and prevent the spreading of the MERS-CoV infection using a global positioning system (GPS) to show each MERS-CoV patient on Google maps, identifies the infected people in order to quarantine and prevent the traffic of non-infected citizens in high-risk areas. Based on the present study findings and citing Sandhu et al.'s study, location-based CDSSs are used to identify high-risk locations to prevent servicing provided by field hospitals.

The system designed in Anakal and Sandhya's [26] study could help physicians instantly to diagnose COPD accurately, classify different stages of the disease, and prevent drug interactions. According to the findings of the present study, designing a clinical decision support system for medication to alert the patients, estimate the drug dosage, prevent prescribing the unauthorized and counterfeit drug and drug interactions, and provide post-discharge medication advice can be very helpful in preventing many dangerous complications, and even death of the patients with COVID-19, and also improve the treatment processes. Bennett et al. [27] stated that medication errors play a significant role in causing morbidity and mortality, and more than half of the adverse effects of diseases at the training hospital were related to medication. However, designing a CDSS for reminding and feedbacks can improve different behaviors of medication management among service providers and patients as this type of CDSS improves prevention and clinical guidelines. According to Marcilly et al. [28], adverse drug events are also the most common adverse events occurring during the care process and can lead to increased hospital stay time and treatment costs, medical complications, and even death.

However, a clinical decision support system with alert capabilities or recommendations for physicians can allow them to make decisions based on the known side effects of medications, their interactions, and potential contraindications. Medication CDSS improves the quality of physicians' prescriptions, decreases medication errors, prevents drug side effects, checks real-time orders through a medical knowledge base, and supports physicians' treatment decisions, and alerts for physicians [29].

Monitoring the patients with COVID-19 disease in the hospital using RFID technology and with, monitoring the vital signs in the patients with COVID-19 disease in ICU, and monitoring checking breathing and body temperature of the patients with COVID-19 disease continuously using breathing and temperature sensors are examples of CDSS applications, by which the diagnosis, management, control, and monitoring of patients with CO-

VID-19 are provided. Paksuniemi et al. [30] designed a system to monitor vital signs of the patients in the operating room and used sensors to monitor the breathing rate, oxygen saturation, ECG, heart rate, temperature, and blood pressure in monitoring the patient status and making for the right decision medical staff. Using sensors monitoring vital signs such as blood pressure, glucometer, and heart rate cause patients and healthcare professionals to make right and accurate decisions [31] and prevent risks by providing "alerting" or emergency messages [32].

Finally, according to the findings of the "health services" group and its subgroups, this section can cover not only simple services such as an automatic reporting system for patients' status with COVID-19, but also complex services such as modeling the patient behavior based on different parameters. Fernandes et al. [9] also noted that the scope of CDSS services is not just one-dimensional, but can be used to meet different related clinical needs, ensuring accurate diagnosis and on-time screening to prevent drug side effects or manage the pain.

Overall, CDSSs have a variety of applications in different clinical decisions and care tasks for the patients with COVID-19 and can be actively used to provide quality services and can be used to eliminate unnecessary testing, increase patient safety with COVID-19, and prevent potentially dangerous and costly complications. A CDSS can also help health care providers diagnose accurately by analyzing patient data (symptoms and signs). On the other hand, a ubiquitous CDSS for health monitoring provides mobile health services and helps physicians and health care providers monitor patients' conditions anytime, anywhere with the help of wireless networks. Another application identified as spatial decision support system resulting accommodating, hospitalizing patients quickly in hospitals and medical centers, and identifying high-risk locations.

One of the research limitations is that no same research in the field of CDSSs and COVID-19 was conducted yet. Therefore, further studies in this field are recommended. Besides, to prove the role of CDSSs in the management and control of COVID-19, CDSSs should be designed and implemented in the real world, and then the impact of these systems on control, management, and the further prevalence of COVID-19 should be also investigated.

Conclusion

In this study, focusing on COVID-19, CDSS applications in the management and control of this disease was identified and introduced. Thirty subgroups of CDSS applications were identified in 4 classes: "diagnosis", "medication", "monitoring", and "health services". This range of applications can provide basic and background knowledge about designing and implementing the CDSSs for COVID-19 in the real world. The use of CDSS to diagnose, manage, and control can prevent the risk of irreversible complications and even many deaths, decrease unnecessary treatments and diagnostic costs, minimize the time for diagnostic processes, improve clinical performance and patient-related outcomes, and by identifying, diagnosing, and treating these patients, the further prevalence of COVID-19 will be prevented.

Acknowledgment

The authors would like to thank all experts who freely participated in this study.

Authors' Contribution

Kh. Moulaei was involved in the writing, development of the methodology, reviewing, and editing of the overall research and results. K. Bahaadinbeigy contributed to the writing, reviewing, analyzed the results, and was responsible for the funding acquisition and supervision. Also, both authors read, modified, and approved the final version of the manuscript.

Ethical Approval

Ethics approval (IR.KMU.REC.1399.329) was acquired from the Ethics Committee of Kerman University of Medical Sciences.

Informed consent

The expert's participation was voluntary, and the individuals were free to withdraw from the study at any time. Informed consent for participation was acquired from the experts.

Conflict of Interest

None

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