

# eCOVID-19: Development of ontology-based clinical decision support system for COVID-19

Vinu Sherimon<sup>1\*</sup>, Sherimon P.C.<sup>2</sup>, Rahul V. Nair<sup>3</sup>, Renchi Mathew<sup>4</sup>, Sandeep M. Kumar<sup>5</sup>, Khalid Shaikh<sup>6</sup>, Hilal Khalid Al Ghafri<sup>7</sup>, Huda Salim Al Shuaili<sup>1</sup>

<sup>1</sup>Department of Information Technology, University of Technology & Applied Sciences, Muscat, Sultanate of Oman

<sup>2</sup>Faculty of Computer Studies, Arab Open University, Muscat, Sultanate of Oman

<sup>3</sup>Medical officer (A), Emergency department, Royal Oman Police Hospital, Muscat, Sultanate of Oman

<sup>4</sup>Senior Consultant, Internal Medicine, Royal Oman Police Hospital, Muscat, Sultanate of Oman

<sup>5</sup>Specialist, Family Medicine & Tropical Medicine, Royal Oman Police Hospital, Muscat, Sultanate of Oman

<sup>6</sup>Specialist, Internal Medicine and Diabetes, Royal Oman Police Hospital, Muscat, Sultanate of Oman

<sup>7</sup>Specialist, Internal Medicine, Royal Oman Police Hospital, Muscat, Sultanate of Oman

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### \* Corresponding author:

Vinu Sherimon

Department of Information  
Technology, University of  
Technology & Applied Sciences,  
Muscat, Sultanate of Oman

Email: [vinusherimon@yahoo.com](mailto:vinusherimon@yahoo.com)

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## ABSTRACT

**Introduction:** Humankind is passing through a period of significant instability and a worldwide health catastrophe that has never been seen before. COVID-19 spread over the world at an unprecedented rate. In this context, we undertook a rapid research project in the Sultanate of Oman. We developed eCovid19 application, an ontology-based clinical decision support system (CDSS) with teleconference capability for easy, fast diagnosis and treatment for primary health centers/Satellite Clinics of the Royal Oman Police (ROP) of Sultanate of Oman.

**Material and Methods:** The domain knowledge and clinical guidelines are represented using ontology. Ontology is one of the most powerful methods for formally encoding medical knowledge. The primary data was from the ROP hospital's medical team, while the secondary data came from articles published in reputable journals. The application includes a COVID-19 Symptom checker for the public users with a text interface and an AI-based voice interface and is available in English and Arabic. Based on the given information, the symptom checker provides recommendations to the user. The suspected cases will be directed to the nearby clinic if the risk of infection is high. Based on the patient's current medical condition in the clinic, the CDSS will make suitable suggestions to triage staff, doctors, radiologists, and lab technicians on procedures and medicines. We used Teachable Machine to create a TensorFlow model for the analysis of X-rays. Our CDSS also has a WebRTC (Web Real-Time Communication system) based teleconferencing option for communicating with expert clinicians if the patient develops difficulties or if expert opinion is requested.

**Results:** The ROP hospital's specialized doctors tested our CDSS, and the user interfaces were changed based on their suggestions and recommendations. The team put numerous types of test cases to assess the clinical efficacy. Precision, sensitivity (recall), specificity, and accuracy were adequate in predicting the various categories of patient instances.

**Conclusion:** The proposed CDSS has the potential to significantly improve the quality of care provided to Oman's citizens. It can also be tailored to fit other terrifying pandemics.

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## INTRODUCTION

COVID-19 proliferated at an incredible rate over the globe. According to the World Health Organization

(WHO) report, which is updated on Oct 4, 2021, the number of confirmed cases globally is 23,46,09,003, and 47,97,368 deaths have occurred [1]. Toward the pandemic's start, individuals were locked down in

houses and were in anxiety, stress, and depression. The main concern was whether they are infected with this novel virus or the current symptoms of COVID-19. Also, because of the fear of community spread, people could not travel to hospitals to seek the necessary support. Due to the coronavirus, countries issued lockdown and travel bans [2-5] to prevent the spread.

In the Sultanate of Oman, 303,769 infected cases are reported as of Oct 4, 2021, and 4096 deaths occurred [6]. In Oman, ROP was at the forefront in controlling the pandemic. ROP operates several primary health centers/satellite clinics in Oman, especially in interior places. In the medical centers orderly, nurses, and other support staff were not up to date with medical modalities to diagnose such pandemics. Also, there is not enough infrastructure in these centers compared to higher centers to diagnose coronavirus diseases. As the movement is restricted, it was difficult for the suspected coronavirus people to approach the referral hospitals in cities. In this situation, to make fast, easy diagnosis and treatment at primary health centers/ Satellite Clinics of Royal Oman Police, we developed an ontology-based clinical decision support system (CDSS) with the adoption of a teleconference facility. Medical practitioners at primary health centers/Satellite Clinics of Royal Oman Police will manage the patients as per the recommendations of the proposed intelligent CDSS with expert support through the teleconferencing system integrated with the CDSS. Thus, the travel of such patients can be avoided entirely, which will prevent the chances of community spread in any such pandemic. The system will also provide the risk assessment of affected patients with other complications such as diabetics, cardiovascular, etc.

The proposed CDSS includes a module that allows a patient (who has COVID-19 symptoms/ suspicion about the disease) to enter primary data such as body temperature, breathing difficulty, dry cough, details about any contact with infected people, travel history, etc. from their home itself. The proposed CDSS will also consider and evaluate the medical record and other medical issues/ complications of the suspected patient. Based on this data, the proposed system will provide suitable recommendations to the patient. For example, if the symptoms/condition do not match COVID-19, the system will advise symptomatic treatment. But, if it reaches the disease guidelines, the patient will be directed by the system to go to the primary health center/ Satellite Clinics.

The triage staff at the primary health center/ Satellite Clinics will check the data entered by the patient. In addition, the team will also check the vital signs and conduct swab tests, blood tests, x-ray, etc. Accordingly, symptomatic treatment will be given to the patient and will be sent home. Once the test

results are available, it is input to the proposed system. So, if the symptoms of coronavirus are confirmed in a patient, the CDSS will provide the necessary recommendations/ suggestions/ medications based on the patient's current medical condition.

In parallel, the system will monitor the condition of the in-patients based on the input (body temperature or other complications). The system will observe any changes in body temperature and will suggest suitable antibiotics, and provide alerts to the staff at the primary health center/Satellite Clinics. Further guidance and follow-up can be provided by the teleconferencing integrated with the system. Teleconferencing/videoconferencing facility with expert doctors will be utilized here, in case of any complications developed by the patient and if the specialist opinion is required. Via teleconferencing, the master specialists from the reference emergency clinics in Oman or any planet region can look at the patients and recommend further tests/meds. As proposed by the expert specialists, such cases will be alluded to the reference clinics in the capital. These systems are like supportive systems but don't replace human knowledge.

In the proposed research, we will use Ontology to represent the domain knowledge and the clinical guidelines [7]. Ontology is a conventional representation of domain knowledge. It includes concepts (related to medical knowledge), attributes, and semantic relationships between these concepts. Ontology is among the powerful tools to encode medical knowledge formally [7]. Adopting ontology in healthcare has facilitated domain experts and non-experts to perform knowledge representation tasks with great ease and without requiring any computer programming knowledge. Ontologies help to address the standard medical terms, allowing efficient knowledge sharing and reuse and supporting automatic reasoning.

The medical domain has several CDSS to assist health practitioners in diagnosing various diseases. But the proposed CDSS is different as we incorporate the guidelines of other diseases integrated with teleconferencing facility. As it is a centralized system, so the guidelines/protocols can be updated at any time, which will be relevant in the case of a new virus-like COVID-19, where the clinical research is ongoing.

In recent years, there has been an emphasis on the medical care area towards the reception of choice emotionally supportive networks in any event for routine clinical practices. Clinical decision support systems (CDSS) represent knowledge about the application domain and include some reasoning techniques to derive new information from the current information. The knowledge employed by a CDSS lies in a knowledge base.

The study described in [8] proposed the development of IDDAP, an ontology-based CDSS for diagnosing infectious diseases and for the prescription of antibiotics. Existing ontologies in a similar domain were used to construct the ontology for IDDAP. The patient will input his/her current medical conditions such as body temperature, infection sites, symptoms, etc., to the system. Based on the input data, the system will identify the type of disease and search the knowledge base to find suitable antibiotics therapy. Here, the suggestions are provided that are adaptive to the patient's case by considering several factors such as the current medical condition of the patient, other complications, drug-drug interactions, etc. Later, the patient can approach the doctors for further diagnosis.

Diabetes Mellitus Treatment Ontology (DMTO) was proposed in [9]. It was implemented using Protégé 5.0 using Web Ontology Language (OWL) 2 and Semantic Web Rule Language (SWRL). DMTO includes the standard concepts of diabetes domain, the treatment plans in the context of type 2 diabetes, and rules based on the guidelines of diabetes treatment. The proposed ontology can be implemented in distributed CDDS systems as a knowledge base.

In [10], an ontology-based system was developed to identify the risks during surgery and in perioperative situations. OntoRiDe, an ontology-based risk detector, was used to identify the risks based on Risk Identification Ontology (RIO). The module receives the existing risk situation as input, processes the ontology rules, and determines the input as a risk or non-risk situation. The module was tested to predict the risks related to cochlear implantation, and around 20 risks were identified successfully, and appropriate alerts were provided to clinical practitioners.

A telemedicine framework in the domain of oncology using case-based reasoning (CBR) is proposed in [11]. In this framework, medical reasons using conventional methods are also integrated. The details about the patient, diseases, and the corresponding treatments were modeled using ontological concepts. This data and the medical rules were reasoned using the reasoning tool, and the inferences are stored in the knowledge base. Later, appropriate tools are used to retrieve similar cases from the knowledge base. The process of CBR starts with diagnosing the current case with past cases stored in the knowledge base using an algorithm. From the set of possible treatments recommended by the system, again, the knowledge base is searched to check the treatments suggested in similar cases. The treatment supported with good evidence and the opinion of experts will be adopted.

Research given in [12] used semantic web technologies in the recommendation model

developed for differential diagnosis in the domain of diabetes and hypertension. The developed model consists of two components, one based on the evidence and the other based on proximity. The model used disease symptom ontology and patient ontology to generate the recommendations. Dynamic rules based on the clinical guidelines were developed. Data mining techniques were employed in proximity-based components to help the medical practitioners in providing predictions and in generating new diagnostic rules.

Researchers in Taiwan proposes a decision support system [13] for diabetic patients undergoing surgery. Web Ontology editor is used to design the domain ontology. User interfaces were designed to collect the patient data, and it was saved to patient ontology. The mathematical procedure called Formal concept analysis (FCA), which is based on lattice theory, was used to mine the medical records stored in the database. JENA, the rule-based reasoner, was used to reason the ontology and to infer the recommendations. The decision rules were written in JENA to generate the recommendations.

In Oman, private hospitals have approached the Ministry of Health (MoH) to offer telemedical services to beat the effect of COVID-19 [14]. MoH is planning to implement a Tele-Psychiatry program for the people in Oman who have psychological issues due to isolation or quarantine in this lockdown period [14]. Several doctors gave the opinion that telemedical facilities are helpful to reduce the cost and to ensure fast care at the doorstep of the patients, thereby ensuring social distancing. A smartphone app was announced by Oman Insurance company in partnership with TruDoc 24 x 7, the telemedicine provider in UAE [15]. This app enables the users to avail the facilities of expert doctors through telemedicine facilities. The first stage of telemedicine facility is being launched in Royal Hospital [16] for all types of diseases, ensuring fast care and consultations and reducing the possibility of the spread of infection.

## MATERIAL AND METHODS

### System Architecture

Fig 1 depicts the proposed architecture. A front-end GUI provides an interface with a questionnaire to the user, through which relevant information is collected, and predicted results are displayed. Using the application, demographic data, current health conditions, and possible risks are captured, maintained, and retrieved as the history of patients, thus tracking their visits to the health care center/clinic, along with periodic data related to relevant medical parameters (laboratory values) and their outcomes. The captured data is stored in the ontology. The system encompasses an adaptive

questionnaire that collects and makes quick recommendations and relevant information regarding COVID infection checks such as demography, contact and travel history, symptoms, test results, etc., and combines it with guidelines and symptom information to predict the risk or stage of illness. The clinical guidelines are addressed using Semantic Web Rule Language (SWRL) [17].

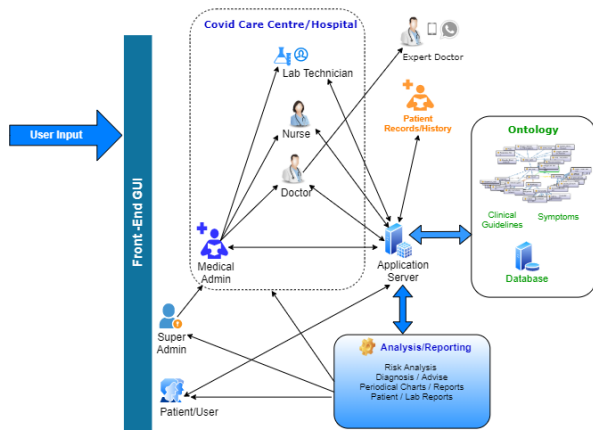


Fig 1: System Architecture

The Online Questionnaire for General Users, Covid Care Centre/Hospital Information Collection, Lab Testing, Diagnosis and Treatment, Analysis and Reporting, Clinical Guidelines and Symptoms form the essential core of the system. The symptoms and the guidelines contain symptoms. Their relations help the Clinicians and Medical Practitioners supplement additional information and quickly identify and relate the chances or risk of novel Coronavirus infection. By interpreting symptoms, lab findings, and observations, they can predict /diagnose/ recommend/ make quick decisions. The Analysis and Reporting of symptoms support estimating the state of General Public Health during a given period based on different parameters and criteria.

**Data collection**

We collected information about the symptoms, causes, risks, test details, related health problems, future problems, severity, etc. the corona virus from primary and secondary sources. Main data was collected from the medical team of ROP hospital, and the secondary data was collected from the articles published in reputed journals. The data identified with the dangers of Covid in patients with different difficulties like diabetics, cardiovascular, and so forth, was also acquired from medical doctors. Because of the gathered data, a survey was prepared. Several online meetings were conducted with the medical team, to design and validate the questionnaire.

**Clinical guidelines**

In the beginning, several versions of guidelines were issued by the Ministry of Health (MoH), Oman, such as the *National Clinical Management Protocol for Hospitalized Patients with COVID-19* and *ICU protocol for the management of COVID-19*. We referred to the updated guidelines, titled COVID-19 Infection Guideline-10 for Hospitals, Primary and Private Health Care Institutes (updated in April 2020), to develop our system. In addition, we incorporated "ROP hospital protocol for the treatment of adult COVID patients and SARS-CoV-2 algorithm Version 11.0" guidelines issued by the Ministry of Health (MOH), Directorate-General for Diseases Surveillance & Control, for Hospitals, Primary and Private Health Care Institutes in our system.

**Ontology design**

Ontologies foster semantic interoperability [7]. We have used Protégé [18], the open-source ontology editor developed by Stanford University in collaboration with the University of Manchester. The taxonomy of the ontology developed is given in Fig 2. The significant terms in the COVID-19 domain are added as the main classes of the ontology. The observed symptoms of COVID-19 are included as sub-classes of the *Symptom* class. LabTest class includes different mandatory lab tests for COVID-19 suspected patients. Initially, based on the background history, symptoms, and other risk factors, the system categorizes the patients into *Suspected*, *Non-suspected*, *Probable*, and *Confirmed* cases of COVID-19. Then based on the physical examination, vital signs, lab test results, x-ray results, the system categorizes the patient into one of the sub-classes of *ClinicalDiagnosis* class (Fig 2). *The treatment and Recommendation* class include the treatment and recommendation based on the patient category. Fig 3 displays the relations between the classes defined in the ontology. Data properties that link individuals to data values are given in Fig 4.

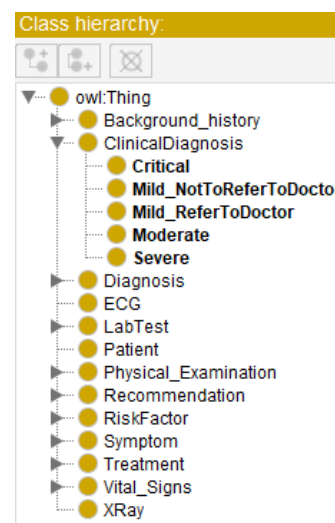


Fig 2: Classes & Subclasses



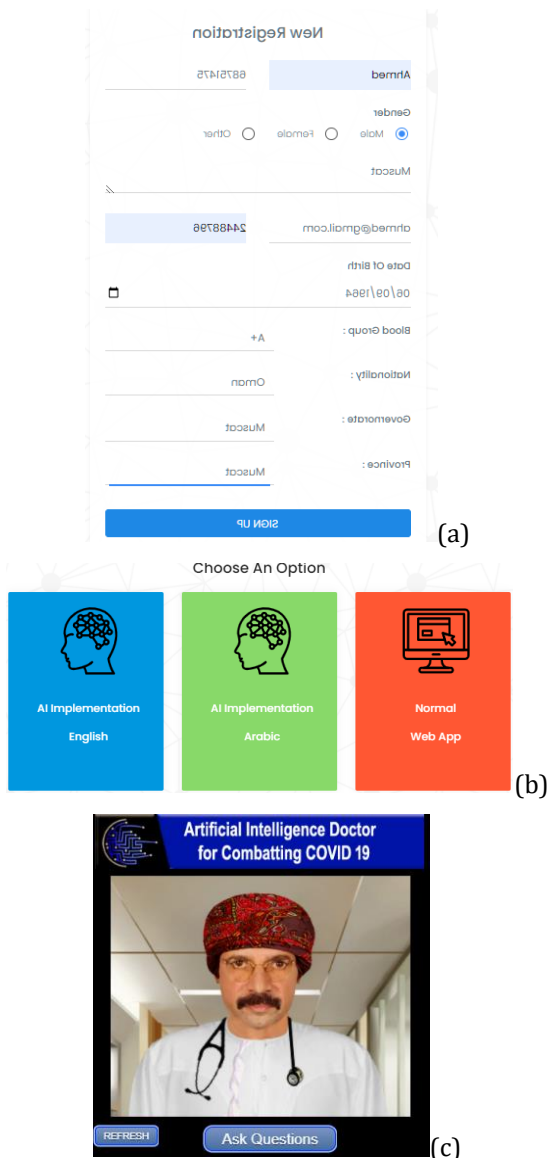


Fig 6: (a) Registration form (b) Option UI (c) Voice-driven interface

If the user chooses a voice-driven interface (English), the AI doctor screen pops up, and the questions will be asked by the humanoid once the *Ask Questions* button is triggered by the user (Fig 6 c). Fig 7 shows the normal web interface of the COVID-19 Symptom Checker. The questions are divided into three categories – Symptoms, Background history, and Risk factors.

In the main application, separate interfaces exist for different categories of medical staff. Once the suspected patient visits the satellite clinic, the triage staff will enter the vital details and other readings. The triage staff interface is shown in Fig 8 (a). The triage staff can view the patient history, and examine the patient to enter all the vital sign values. Fig 8 (b) shows the doctor interface. A doctor can view the pre-assessment done in the triage, patient history, lab results, X-ray results, etc. The lab staff is provided with a separate interface to input the test values.

According to the lab results and X-ray results, the patient is automatically put into one of the categories – mild, moderate, severe, and critical. The category will be shown in the doctor’s screen. The doctor can get support from AI radiology assistants to analyse the Xray images. Fig 9 shows the interface of AI-based X-ray analysis.

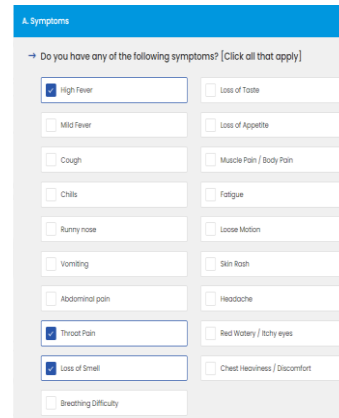


Fig 7: Questionnaire

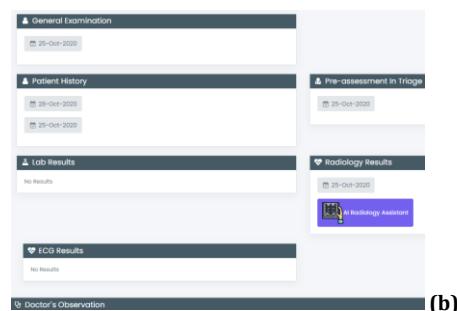
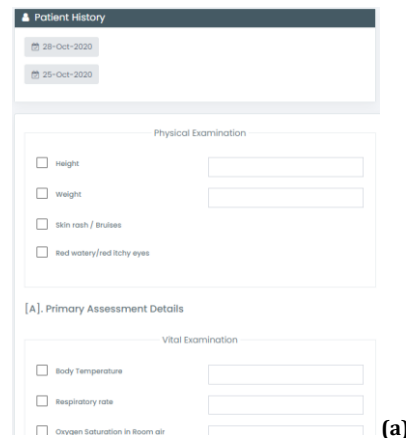


Fig 8: (a) Interface of the triage staff (b) Interface of doctor



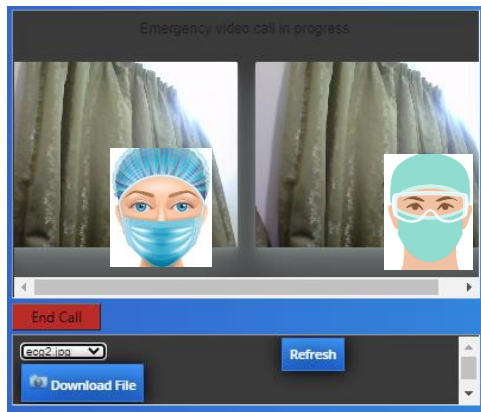


Fig 14: Teleconferencing to seek expert opinion

### System Evaluation

Our CDSS was tested by the specialist doctors from the ROP hospital, and based on their suggestions and recommendations, the user interfaces were modified and simplified. The evaluation of the clinical efficacy was tested by the team using different categories of test cases.

Table 1: Test cases

Category	Collected number of cases	Samples used for evaluation
Mild	22	19
Moderate	15	14
Severe	12	10
Critical	12	11

The doctors carried out a simulated environment to input the symptoms and other test values. The system recommendations and the treatment suggestions were analyzed later and compared with the manual diagnosis of doctors. We used *precision*, *recall (sensitivity)*, *specificity* to check the performance of our CDSS. Table 2 shows the confusion matrix with four possible outcomes.

Table 2: 2x2 Confusion matrix

	Actual: Positive	Actual: Negative
Predicted: Positive	True Positive	False Positive (Type I error)
Predicted: Negative	False Negative (Type II error)	True Negative

### Mild case

In this category, out of 19 samples, the actual number of mild cases were 8. 7 cases were predicted correctly (true positive) as mild cases and 9 non-mild cases were predicted correctly (true negatives) as non-mild cases. 2 non-mild cases were mispredicted as a mild case and 1 mild case was predicted incorrectly as a non-mild case.

Table 3: Confusion matrix-Mild case

	Actual: Positive	Actual: Negative
Predicted: Positive	7	2
Predicted: Negative	1	9

### Moderate case

In this category, out of 14 samples, the actual number of moderate cases were 7. All the 7 cases were predicted correctly (true positive) as mild cases and 6 non-moderate cases were predicted correctly (true negatives) as non-moderate cases. 1 non-moderate case was predicted incorrectly as a moderate case and none of the moderate case was mispredicted as a non-moderate case.

Table 4: Confusion matrix-Moderate case

	Actual: Positive	Actual: Negative
Predicted: Positive	7	1
Predicted: Negative	0	6

### Severe case

In this category, out of 10 samples, the actual number of severe cases were 5. 4 cases were predicted correctly (true positive) as severe cases and 4 non-severe cases were predicted correctly (true negatives) as non-severe cases. 1 non-severe case was predicted incorrectly as a severe case and 1 severe case was predicted incorrectly as a non-severe case.

Table 5: Confusion matrix-Severe case

	Actual: Positive	Actual: Negative
Predicted: Positive	4	1
Predicted: Negative	1	4

### Critical case

In this category, out of 11 samples, the actual number of critical cases were 6. 5 cases were predicted correctly (true positive) as critical cases and 5 non-critical cases were predicted correctly (true negatives) as non-critical cases. No cases were mispredicted as critical cases and 1 critical case was predicted incorrectly as a non-critical case.

Table 6: Confusion matrix-Critical case

	Actual: Positive	Actual: Negative
Predicted: Positive	5	0
Predicted: Negative	1	5

Fig 15 shows the overall measures of precision, sensitivity (recall), specificity, and accuracy in predicting mild, moderate, severe, and critical cases.

Mild category resulted in 88% sensitivity, and 82% specificity. Moderate category resulted in 100% sensitivity, and 86% specificity. Severe category resulted in 80% sensitivity, and 80% specificity. Critical category resulted in 83% sensitivity, and 100% specificity. All the results were found satisfactory.

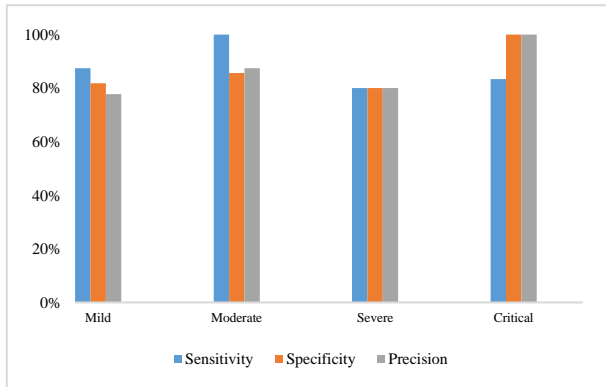


Fig 15: Performance metrics

## CONCLUSION

The creation of eCOVID-19, an ontology-based clinical decision support system (CDSS) with teleconference capacity for easy, fast diagnosis and treatment at the Royal Oman Police's (ROP) main health centers/Satellite Clinics, was described in this paper. The research's main product is an intelligent CDSS that can assist basic health centers and satellite clinics in Oman in diagnosing coronavirus without the assistance of experienced medical practitioners. The CDSS and the Artificial Intelligence-powered Symptom Checker (Arabic & English) are the two key systems we have developed. The CDSS incorporates an Artificial Intelligent X-ray Analysis module that predicts whether COVID-19 features will be traced after an X-ray. The proposed CDSS includes a teleconferencing feature that allows doctors from the referral hospital or elsewhere in the world to consult

with specialists.

To check for COVID-19 symptoms, the public can use our Symptom Checker, available in Arabic and English. People can go to primary health facilities / Satellite Clinics in different Wilayat's of Oman to obtain treatment if our CDSS is deployed at primary centers, rather than going to specialist hospitals. Also, because our system in basic health centers would be able to diagnose the condition properly, we will be able to avoid crowding in specialist hospitals and hence community spread. Only the most complicated cases will be directed to the Sultanate of Oman's specialty institutions. Unnecessary referral cases can be avoided, allowing referral hospitals' resources to be more effectively utilized. The proposed CDSS can be used efficiently to improve the quality of care for Oman's inhabitants. It can likewise be customized to suit other startling pandemics.

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## AUTHOR'S CONTRIBUTION

All authors contributed to the literature review, design, data collection and analysis, drafting the manuscript, read and approved the final manuscript.

## CONFLICTS OF INTEREST

The authors declare no conflicts of interest regarding the publication of this study.

## FINANCIAL DISCLOSURE

No financial interests related to the material of this manuscript have been declared.

## REFERENCES

- World Health Organization. WHO coronavirus (COVID-19) dashboard [Internet]. 2019 [cited: 2021 Oct 4]. Available from: <https://covid19.who.int>
- Atalan A. Is the lockdown important to prevent the COVID-19 pandemic? Effects on psychology, environment and economy perspective. *Ann Med Surg (Lond)*. 2020; 56: 38–42. PMID: 32562476 DOI: 10.1016/j.amsu.2020.06.010 [[PubMed](#)]
- Times News Service. Lockdown measures bear fruit as COVID cases drop in Oman [Internet]. 2021 [cited: 2021 Oct 3]. Available from: <https://timesofoman.com/article/104560-lockdown-measures-bear-fruit-as-covid-cases-drop-in-oman>
- Liu S, Ermolieva T, Cao G, Chen G, Zheng X. Analyzing the effectiveness of COVID-19 lockdown policies using the time-dependent reproduction number and the regression discontinuity framework: Comparison between countries. *Engineering Proceeding*. 2021; 5(1): 8.
- Yang X. Does city lockdown prevent the spread of COVID-19? New evidence from the synthetic control method. *Glob Health Res Policy*. 2021; 6(1): 20. PMID: 34193312 DOI: 10.1186/s41256-021-00204-4 [[PubMed](#)]
- Woldometer. Oman COVID [Internet]. 2019 [cited: 2021 Oct 4]. Available from: <https://www.worldometers.info/coronavirus/country/oman>
- Akerkar R. Foundations of the semantic web: XML, RDF & ontology. Alpha Science International Ltd;

- 2009.
8. Shen Y, Yuan K, Chen D, Colloc J, Yang M, Li Y, et al. An ontology-driven clinical decision support system (IDDAp) for infectious disease diagnosis and antibiotic prescription. *Artif Intell Med.* 2018; 86: 20-32. PMID: 29433958 DOI: 10.1016/j.artmed.2018.01.003 [[PubMed](#)]
  9. El-Sappagh S, Kwak D, Ali F, Kwak KS. DMT0: A realistic ontology for standard diabetes mellitus treatment. *J Biomed Semantics.* 2018; 9(1): 8. PMID: 29409535 DOI: 10.1186/s13326-018-0176-y [[PubMed](#)]
  10. Uciteli A, Neumann J, Tahar K, Saleh K, Stucke S, Faulbrück-Röhr S, et al. Ontology-based specification, identification and analysis of perioperative risks. *J Biomed Semantics.* 2017; 8(1):36. PMID: 28877732 DOI: 10.1186/s13326-017-0147-8 [[PubMed](#)]
  11. Sene A, Kamsu-Foguem , Rumeau P. Telemedicine framework using case-based reasoning with evidences. *Comput Methods Programs Biomed.* 2015; 121(1): 21-35. PMID: 26001421 DOI: 10.1016/j.cmpb.2015.04.012 [[PubMed](#)]
  12. Mohammed O, Benlamri R. Developing a semantic web model for medical differential diagnosis recommendation. *J Med Syst.* 2014; 38(10): 79. PMID: 25178271 DOI: 10.1007/s10916-014-0079-0 [[PubMed](#)]
  13. Bau CT, Chen RC. Huang CY. Construction of a clinical decision support system for undergoing surgery based on domain ontology and rules reasoning. *Telemed J E Health.* 2014; 20(5): 460-72. PMID: 24730353 DOI: 10.1089/tmj.2013.0221 [[PubMed](#)]
  14. Oman Observer. Hospitals mull offering telemedicine services [Internet]. 2020 [cited: 2021 Oct 4]. Available from: [https://www.omanobserver.om/article/13847/CORONAVIRUS/hospitals-mull-offering-telemedicine-](https://www.omanobserver.om/article/13847/CORONAVIRUS/hospitals-mull-offering-telemedicine-services)
  15. TAS News Service. Covid-19: You can now get access to doctors in Oman through this app [Internet]. 2020 [cited: 2021 Oct 4]. Available from: <https://www.thearabianstories.com/2020/04/08/covid-19-you-can-now-get-access-to-doctors-in-oman-through-this-app>
  16. Muscat Daily. Telemedicine adopted to reduce infection [Internet]. 2020 [cited: 2021 Oct 4]. Available from: <https://www.muscatdaily.com/2020/04/22/telemedicine-adopted-to-reduce-infection>
  17. Horrocks I, Patel-Schneider PF, Boley H, Tabet S, Grosz B, Dean M. SWRL: A semantic web rule language combining OWL and RuleML [Internet]. 2004 [cited: 2021 Oct 4]. Available from: <https://www.w3.org/Submission/SWRL>
  18. Protégé [Internet]. 2016 [cited: 2021 Oct 4]. Available from: <https://protege.stanford.edu>
  19. O'Connor M, Das AK. SQWRL: A query language for OWL. *International Conference on OWL: Experiences and Directions.* ACM; 2009.
  20. Teachable machine. 2019 [cited: 2021 Oct 4]. Available from: <https://experiments.withgoogle.com/teachable-machine>
  21. Shukla N, Fricklas K. *Machine learning with TensorFlow.* Manning Publications; 2018.
  22. NIH chest X-ray dataset [Internet]. 2019 [cited: 2021 Oct 4]. Available from: <https://cloud.google.com/healthcare/docs/resources/public-datasets/nih-chest>
  23. WebRTC API [Internet]. 2005 [cited: 2021 Oct 4]. Available from: [https://developer.mozilla.org/en-US/docs/Web/API/WebRTC\\_API](https://developer.mozilla.org/en-US/docs/Web/API/WebRTC_API)