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The economics of deep and machine learning-based algorithms for COVID-19 prediction, detection, and diagnosis shaping the organizational management of hospitals

JEL Classification: *E42; J33; O14*

Keywords: *deep and machine learning; COVID 19; prediction; detection; diagnosis; organizational management; hospital*

Abstract

Research background: Deep and machine learning-based algorithms can assist in COVID-19 image-based medical diagnosis and symptom tracing, optimize intensive care unit admission, and use clinical data to determine patient prioritization and mortality risk, being pivotal in qualitative care provision, reducing medical errors, and increasing patient survival rates, thus diminishing the massive healthcare system burden in relation to severe COVID-19 inpatient stay duration, while increasing operational costs throughout the organizational management of hospitals. Data-driven financial and scenario-based contingency planning, predictive modelling tools, and risk pooling mechanisms should be deployed for additional medical equipment and unforeseen healthcare demand expenses.
Purpose of the article: We show that deep and machine learning-based and clinical decision making systems can optimize patient survival likelihood and treatment outcomes with regard to susceptible, infected, and recovered individuals, performing accurate analyses by data modeling based on vital and clinical signs, surveillance data, and infection-related biomarkers, and furthering hospital facility optimization in terms of intensive care unit bed allocation.
Methods: The review software systems employed for article screening and quality evaluation were: AMSTAR, AXIS, DistillerSR, Eppi-Reviewer, MMAT, PICO Portal, Rayyan, ROBIS, and SRDR.
Findings & value added: Deep and machine learning-based clinical decision support tools can forecast COVID-19 spread, confirmed cases, and infection and mortality rates for data-driven appropriate treatment and resource allocations in effective therapeutic and diagnosis protocol development, by determining suitable measures and regulations and by using symptoms and comorbidities, vital signs, clinical and laboratory data and medical records across intensive care units, impacting the healthcare financing infrastructure. As a result of heightened use of personal protective equipment, hospital pharmacy and medication, outpatient treatment, and medical supplies, revenue loss and financial vulnerability occur, also due to expenses related to hiring additional staff and to critical resource expenditures. Hospital costs for COVID-19 medical care, screening, treatment capacity expansion, and personal protective equipment can lead to further financial losses while affecting COVID-19 frontline hospital workers and patients.

Introduction

Artificial neural network-based tools and computer vision algorithms can be harnessed in COVID-19 treatment and inpatient mortality, can be deployed in medical imaging classification and analysis of COVID-19 clinical data, and can predict COVID-19 outcomes throughout clinical decisions, diagnostic and prognostic models, enabling early disease predictions and enhancing clinician decision-making through mathematical modeling-based dynamic decision making, influencing available fund allocation and increasing operational expenses across specialized care units. Adequate fund and resource reallocation mechanisms can optimize hospital services with regard to unpredictable costs associated with mortality and morbidity, building and supporting health system financing and expenditures.

Deep learning technologies and multi-layered convolutional neural networks are instrumental in medical resource allocation and treatment, can classify medical images for COVID-19 prevention, prediction, detection, diagnosis, and monitoring and can carry out preliminary diagnosis and patient treatment analysis with regard to confirmed cases, evaluating risk factors and reducing mortality rates, forecasting COVID-19 patient evaluation and prognosis, enabling medical resource allocation for severe cases, and determining COVID-19 patient prognosis and diagnostic accuracy. Artificial neural networks and deep learning algorithms can improve patient screening for COVID-19 infection confirmation, diagnosis, and treatment, predict COVID-19 trajectory, severity, and comorbidity risk, and monitor and optimize high-risk priority patient condition and treatment by identifying risk factors based on clinical and laboratory data for treatment and triaging adjustment of COVID-19 high-risk individuals. Machine and deep learning-based COVID-19 prediction and detection algorithms can predict COVID-19 severity and mortality for intensive care unit patients based on patient data, comorbidities, and clinical symptoms, enabling streamlined clinical judgment and treatment and determining recovery, survival, and mortality rates. Artificial intelligence-based diagnostic systems and deep and machine learning algorithms can be harnessed in COVID-19 suspected infection tracking, predict intensive care unit admission and mortality by past medical history, and shape COVID-19 patient clinical evolution classification with reference to COVID-19 severity of critically ill patients, enabling early diagnosis for swift medical intervention and integrating long-term healthcare status and data predictions by computer-aided clinical decision support and predictive models.

The aim of this collective writing is to cover the economics of deep and machine learning-based algorithms for COVID 19 prediction, detection, and diagnosis shaping the organizational management of hospitals by using a methodology integrating quality assessment tools and configuring specific sections: deep and machine learning-based algorithms for optimal patient management data dynamics; machine learning algorithms and big data analytics predicting COVID-19 recovery and death by clinical risk and symptom components; machine learning and predictive modeling algorithms improving COVID-19 in hospital patient outcomes through clinical data, laboratory tests, and mortality risk prediction models; artificial neural networks and deep learning algorithms for COVID-19 detailed physiological investigations, appropriate hospital ward identification, optimal resource management, and swift treatment allocation; autonomous deep and machine learning algorithms in preliminary COVID-19 diagnosis and for early treatment patients; machine learning algorithms advancing COVID-19 patient early identification, risk factor prediction, hospital admission triaging, therapeutic measures, and treatment plan arrangements and personalized recommendations; deep and machine learning algorithms, benchmarking techniques, and predictive modeling tools detecting COVID-19 symptoms and risk factor patterns and predicting patient evolution; and deep and machine learning algorithms predicting and diagnosing COVID-19 clinical evolution through patient signs and symptoms, data classification tasks, and risk factor analysis.

Methods

The review software systems employed for article screening and quality evaluation were: AMSTAR (deployed in systematic review methodological quality assessment of reliable and reproducible evidence), AXIS (for cross-sectional study quality assessment), DistillerSR (for accurate evidence-based research, study design screening, intelligent workflow-based collection, and knowledge synthesis consistency), Eppi-Reviewer (study screening process through machine learning-based data collection, clustering, analysis, and synthesis), MMAT (systematic mixed studies review appraisals through methodological quality predictors for reliability optimization), PICO Portal (for collaborative knowledge synthesis and quality assessment by use of an artificial intelligence-based management tool), Rayyan (an intuitive knowledge synthesis tool for content screening and selection, data extraction procedures, synthesis and reporting, and transparent and reproducible evidence), ROBIS (for systematic review bias risk evaluation by inspecting study eligibility criteria and methodological quality deficiencies), and SRDR (a text analysis data extraction tool).

Deep and machine learning-based algorithms for optimal patient management data dynamics

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The COVID-19 pandemic led to growing hospital financial distress and losses by increased expenses and diminished revenues as a result of operational and clinical burdens and challenges with regard to medical supply and personal protective equipment shortages, additional staff training investments, outdated facilities across intensive care units, impacting the quality of care. Modeling diagnosis systems are decisive in COVID-19 time-series data and estimated, confirmed, and recovered case modeling and forecasting (Zeroual *et al*., 2020) for infected patient streamlined management. Variational autoencoder, deep learning, recurrent neural network, and gated recurrent unit algorithms can model and forecast confirmed and recovered COVID-19 cases while handling time-series data. Deep and machine learning are pivotal in COVID-19 confirmed infected, recovered, and death case modeling and forecasting in optimal patient management data dynamics. Machine learning, artificial intelligent neural network, and random forest algorithms, together with extreme gradient boosting machines, can accurately predict COVID-19 hospital admission, triaging, severity and mortality, and patient treatment and survival chances through clinical decision support tools and performance metrics (Ikemura *et al*., 2021), decreasing computation times while delivering medical care.

Visual tracking tools and deep learning algorithms configure COVID-19 estimation, screening, prediction, diagnosis, and progress assessment through medical image processing and analysis (Jamshidi *et al*., 2020), enabling effective therapeutic procedures based on clinical datasets. Artificial neural network-based tools and computer vision algorithms can be deployed in medical imaging classification and analysis of COVID-19 clinical data and symptom screening, diagnosis, and treatment, improving treatment methods. Clinical big data, gradient-based and machine learning algorithms, and image processing techniques assist in COVID-19 image-based medical diagnosis and symptom tracing by patient data collection and analysis. Deep and machine learning algorithms, computed tomography imaging, and risk stratification tools improve COVID-19 clinical care and decision-making and identify multiple risk factors (Vepa *et al*., 2021) through vital observations and demographics. Clinical decision-making tools, prognostic indicators, and multivariable predictive models can be harnessed in COVID-19 treatment and inpatient mortality by use of biochemical markers and co-morbidities. Clinical coding-based automated data extraction and machine learning-based predictive models can reduce socioeconomic factor-based mortality risk in relation to severe COVID-19 inpatient stay duration and treatment outcomes.

Artificial neural network algorithms can enable personalized prediction of treatment strategies, of targeted therapies, and of supportive measures for severe COVID-19 patients (Elham *et al*., 2022) based on specific preexisting conditions, early decision-making, laboratory results, distinct clinical prognosis, and individual prognosis assessment, improving survival outcomes. Machine learning algorithms can assist in COVID-19 mortality rate controlling and accurate outcome predictions through computational assistance and data-driven decision-making based on prognosis score-treatment identification and intensive care unit admission, laboratory, and clinical data. Artificial neural network algorithms can optimize intensive care unit admission by integrating comorbidities, demographic characteristics, predictive value parameters, laboratory biomarkers, and past medical history, predicting COVID-19 risk, clinical interventions, and patient survival.

Deep and machine learning classification algorithms and predictive models based on multiple data-driven clinical features and mining processes (Arpaci *et al*., 2021) improve patient screening for COVID-19 infection confirmation, diagnosis, and treatment. Deep reinforcement and machine learning models and computing techniques can determine early diagnosis and vulnerable groups (Pinter *et al*., 2020) through accurate spatiotemporal prediction and modeling for COVID-19 infected individuals and mortality rates. Supervised machine learning algorithms and data-driven modeling processes can be harnessed in early COVID-19 prediction, analysis, and diagnosis (Villavicencio *et al*., 2021) through data mining techniques. Mobile tracking data, computational tools, digital contact tracing processes, and machine learning classification algorithms can provide clinical decision support in COVID-19 screening, diagnosis, and forecasting (Lalmuanawma *et al*., 2020) in relation to treatment and medication of patients in severe conditions. Automated deep learning algorithms can deploy complex computational resources in diagnostic screening and interpreting imaging data for COVID-19 patients (Aslani & Jacob, 2023) in terms of detection accuracy.

Soft computing epidemiological models, multi-layered perceptron neural networks, particle swarm and grey wolf optimizers, machine learning algorithms, and adaptive network-based fuzzy inference systems can assist in COVID-19 informed decisions, control measure enforcement, and mortality rate estimation in intensive care units (Ardabili *et al*., 2020) with regard to susceptible, infected, and recovered patients through temporal nonstationarity data processing and prediction modeling. Auto-regressive integrated moving average models, deep learning-based time series techniques, and stacked long short-term memory networks can predict COVID-19 symptomatic, confirmed, recovered, and death cases by infection status forecasting, data pre-processing, collection, simulation, scenario planning, performance modeling, correlation analysis, and feature extraction (Devaraj *et al*., 2021) to enhance patient diagnosis, treatment, and monitoring throughout healthcare system facilities.

Machine learning algorithms and big data analytics predicting COVID-19 recovery and death by clinical risk and symptom components

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Intensified inpatient services and COVID-19 hospitalization spending threaten financial performance, solvency, and well-being, as such public health emergencies lead to high occupancy rates to enable patient engagement and care, affecting the expenditure and revenue management. Machine learning and random forest algorithms integrate socio-demographic and clinical data (Patel *et al*., 2021) with reference to COVID-19 severity of critically ill patients and intensive care unit prediction for healthcare resource allocation. Federated deep and machine learning algorithms can accurately predict infectious cases, performance time, and recovery rates (Abdul Salam *et al*., 2021) by use of chest X-ray images in COVID-19 case data, identification, and classification. Suspected and confirmed case spatio-temporal spread estimation and risky area identification contribute to COVID-19 diagnosis and treatment (Yeşilkanat, 2020) by use of random forest machine learning and decision tree algorithms. Regressor machine learning models, random forest feature selection algorithms, and big data analytics (Malki *et al*., 2020) can forecast COVID-19 spread, confirmed cases, and infection and mortality rates. Machine learning algorithms can use clinical data to predict prolonged hospitalization stay (Ebinger *et al*., 2021), identifying and classifying critically ill patients.

Machine learning algorithms can optimize infection control, individualized patient care, and pathological conditions, articulating targeted treatments, and decreasing symptomatic cases and hospitalizations (Rahimi *et al*., 2021) in relation to susceptible, exposed, confirmed, quarantined, recovered, and death cases, predicting epidemiology and disease transmission levels through control measures. K-nearest neighbor, logistic regression, long short-term memory, adaptive and extreme gradient boosting, support vector machine, random forest, artificial and convolutional neural network, decision tree algorithms, feature engineering modeling, and synthetic oversampling techniques (Solayman *et al*., 2023) are pivotal in COVID-19 prediction, detection, control, prognosis, and treatment based on symptoms and health conditions.

Machine learning algorithms and big data analytics can predict COVID-19 recovery and death by clinical risk and symptom components, and demographic data (Iwendi *et al*., 2022), improving the clinical diagnosis. Decision tree, random forest, and machine learning regression algorithms can predict COVID-19 confirmed, recovered, and death cases, disease severity and transmission, and medical equipment allocations (Majhi *et al*., 2021), performing accurate analyses by data modeling, enabling and monitoring infection avoidance and adequate preventive care. Decision tree, machine learning, and k-nearest neighbor algorithms, together with artificial neural networks and partial least squares discriminant analysis (Cobre *et al*., 2021), can predict COVID-19 diagnosis and severity based on laboratory test results. Cloud computing and machine learning algorithms can track and predict the COVID-19 cumulative incidence, spread, and mortality rate (Tuli *et al*., 2020) through mathematical modeling-based dynamic decision making. Machine learning algorithms facilitate efficient COVID-19 screening and diagnosis for infection risk detection (Zoabi *et al*., 2021), triaging patients effectively and reducing healthcare system burdens.

Random forest, logistic regression, k-nearest neighbor, gradient boosting, and support vector machine algorithms can predict COVID-19 progression severity and mortality risk (Das *et al*., 2020) based on vital and clinical signs, surveillance data, and infection-related biomarkers that are also relevant in patient triaging and in accurate prognosis of confirmed cases. Machine learning prediction algorithms, random forest classifier parameters, and prognostic tools can predict intubation likelihood in COVID-19 high-risk suspected or diagnosed patients (Arvind *et al*., 2021) based on clinical and laboratory data, comorbidities, physiologic patterns, and vital measurements, improve triaging and diagnostic accuracy, and reduce mortality.

Machine learning algorithms and naïve Bayes classifier can predict mortality risk in COVID-19 patients, disease progression, and prognostic feature data-driven selection (Halasz *et al*., 2021) for data-driven appropriate treatment and resource allocations in optimal clinical scenarios. Deep and machine learning algorithms, recurrent neural and long short-term memory networks, and time-series datasets (Alassafi *et al*., 2022) can predict COVID-19 cases and subsequent deaths. Decision tree algorithms and conventional logistic regression models can predict intensive care unit outcomes related to COVID-19 admission, diagnosis, and prognosis (Elhazmi *et al*., 2022), by identifying risk factors based on clinical and laboratory data. Recurrent and convolutional neural networks can predict and control COVID-19 confirmed cases and disease spread rates (Verma *et al*., 2022) by time series data analysis. Linear regression, time series forecasting, and support vector regression algorithms can analyze and predict COVID-19 progression and spreading (Gothai *et al*., 2023), integrating computerized data tracking suspected, confirmed, recovered, and death cases, while modeling historical outcomes.

Machine learning and predictive modeling algorithms improving COVID-19 inhospital patient outcomes through clinical data, laboratory tests, and mortality risk prediction models

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Hospital frontline staff compensations through bonus pay implementation for increased hours lead to heightened wage and labor expenditures, affecting increasingly financially vulnerable hospitals and health systems through intensive care unit treatment and bed capacity expansion by significant investment needed. Artificial neural networks, swarm intelligence and time-series prediction algorithms, cloud computing technologies, and fuzzy inference systems can assist in COVID-19 diagnosis and spread control, forecasting, simulation, and modeling (Zivkovic *et al*., 2021) by determining suitable measures and regulations across intensive care units with regard to confirmed cases. Internet of Things devices, deep and machine learning algorithms, medical image recognition tools, and cloud, edge, and fog computing technologies can configure COVID-19 suspected and infected detection and tracking by use of monitoring and prognosis systems (Kallel *et al*., 2022) through real-time streaming symptom data collection and processing, enabling early disease predictions and enhancing clinician decision-making.

Computationally-efficient mortality prediction models can deploy patient data in terms of clinical features and decision-making processes, comorbidities, and laboratory findings (Subudhi *et al*., 2021) for treatment and triaging adjustment of COVID-19 high-risk individuals. Machine learning and prognostication algorithms can identify COVID-19 high-risk individuals and predict intensive care unit admission and mortality by past medical history. Tree-based supervised machine learning algorithms can configure prognostic and diagnostic models with regard to COVID-19 intensive care and mortality risk, supporting clinical decision-making (Ustebay *et al*., 2023) by use of computed tomography images, demographics and clinical data, laboratory blood test features, and hospitalized patient comorbidities. Artificial neural network-based COVID-19 prognostic predictions and decision tree-based algorithms use clinical data to determine patient prioritization and mortality risk.

Artificial neutral networks, supervised machine learning techniques, support vector machine model, and logistic regression analysis can be harnessed in COVID-19 containment, prediction, diagnosis, infection, and recovery (Muhammad *et al*., 2021), diminishing the massive healthcare system burden. Deep and machine learning algorithms, decision tree and naïve Bayes modeling, and data mining tools can be leveraged in COVID-19 infection, prediction, diagnosis, and prognosis through demographic and clinical data. Machine learning, naïve Bayes, and random forest algorithms can predict intensive care unit admission and mortality through data-driven decision making and risk stratification models in COVID-19 hospitalized individuals (Moulaei *et al*., 2022), reducing medical errors and increasing patient survival rates. Random forest algorithms and data mining tools enable patient identification and predict COVID-19 mortality, supporting clinical decision-making in critical condition treatment. Machine learning and predictive modeling algorithms can improve COVID-19 in hospital patient outcomes through clinical data, laboratory tests, and mortality risk prediction models, assisting in qualitative care provision and optimizing patient survival likelihood.

Artificial neural network, machine learning, and random forest algorithms can optimize patient survival by accurate clinical decision-making, prognostic assessment, and healthcare resource allocation (Fernandes *et al*., 2021) through incorporating COVID-19 clinical and demographic data. CatBoost, extra trees, and extreme gradient boosting algorithms can predict COVID-19 outcomes throughout clinical decisions, diagnostic and prognostic models, and screening and treatment procedures for severe condition risk patterns, associated with intensive care unit admission, mechanical ventilation intubation, and death. Multipurpose prognostic and machine learning algorithms can predict negative COVID-19 prognostic outcomes such as subsequent clinical deterioration throughout hospital admission and monitoring.

Evolutionary algorithms and data mining tools can detect and forecast COVID-19 cases and severity and mortality risk, trace contacts, and articulate social control (Alballa & Al-Turaiki, 2021), improving critical patient health outcomes and clinical decision making. By using symptoms and comorbidities, vital signs, clinical and laboratory data and medical records, and demographics and imaging findings, deep and machine learning algorithms can forecast, detect, and diagnose COVID-19 infections, predict mortality risk and severity, and assess early high-risk patient identification and intensive care unit admission. Artificial neural networks and supervised learning techniques can be harnessed in COVID-19 suspected infection tracking, early high-risk patient identification, screening, diagnosis, severe condition monitoring, in-hospital mortality risk prognosis, intensive care unit admission prediction, treatment administration, and vaccines.

Artificial neural networks and deep learning algorithms for COVID-19 detailed physiological investigations, appropriate hospital ward identification, optimal resource management, and swift treatment allocation

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Increasing long-term revenue losses and financial costs are associated with COVID-19 patient treatments, medical equipment and supplies, uncompensated care, screening and testing, and hospitalizations. Gradient boosting and support vector machine, decision tree, k-nearest neighbor, and random forest algorithms can predict COVID-19 confirmed patient infectious status and clinical outcomes with regard to mortality risk and suitable treatment by routine patient data analysis (Aktar *et al*., 2021), furthering hospital facility optimization in terms of intensive care unit bed allocation. Deep and machine learning algorithms can accurately predict COVID-19 health condition and patient severity due to pre-existing comorbidities, optimize care delivery and resource distribution, and decrease mortality risks by use of real-time clinical data sets. Artificial neural networks and deep learning algorithms can predict COVID-19 trajectory, severity, and comorbidity risk, improve patient care decision making processes through clinical data and physical sign parameters, and facilitate detailed physiological investigations, appropriate hospital ward identification, optimal resource management, and swift treatment allocation.

Automatic deep learning classification algorithms can detect COVID-19 infection from deep convolutional neural network computer vision-based chest X-ray images for reliable accurate screening and effective diagnosis (Akter *et al*., 2021) through automated image categorization and classification. Deep learning techniques, convolutional neural networks, and image classification algorithms and enhancement techniques can classify medical images for COVID-19 symptom detection. Deep and machine learning algorithms and image recognition, computer vision, and natural language processing tools shape COVID-19 identification, classification, and diagnosis (Nassif *et al*., 2022) with regard to recovered case and death rate prediction, tracking, and monitoring. Deep and machine learning algorithms, speech signal classification and digital image processing tools, and forecast modeling techniques are pivotal in COVID-19 prevention, screening, detection, diagnosis, and treatment for infection severity identification.

Deep and machine learning, random forest, specialized convolutional neural network, support vector machine, and regression algorithms, together with data science can integrate X-ray and computed tomography images, time series analysis and forecasting, and text and clinical data (Meraihi *et al*., 2022) for COVID-19 prevention, prediction, detection, diagnosis, and monitoring in relation to confirmed and death cases. Machine learning and neural network algorithms can track high-risk and infected patients, make accurate predictions, determine and assign health care priorities, optimize timely treatment, and forecast disease spreading dynamics (Quiroz-Juárez *et al*., 2021) with regard to confirmed and suspected COVID-19 cases based on patient data, comorbidities, and clinical symptoms. Supervised artificial neural networks can detect high-risk COVID-19 individuals by analyzing clinical manifestations, patient demographic data, and laboratory test findings, articulating treatment process clinical stages for hospitalized patients requiring swift medical attention. Machine learning, artificial neural network, and patient classification algorithms are instrumental in medical resource allocation and treatment for suspected and confirmed

COVID-19 individuals through real case detection rates, clinical decision making, high-risk patient identification, mortality risk assessments, and computed survival probability.

Machine and deep learning and convolutional neural network algorithms employ image processing techniques in computerized tomography scan and X-ray image processing for abnormality determination and localization (Al Shehri *et al*., 2022) to enable accurate and timely early disease detection and precise and reliable patient symptom analysis in COVID-19 case detection, diagnosis, and monitoring. Machine and deep learning-based COVID-19 prediction and detection algorithms, big data analytics, and feature engineering and image augmentation techniques can carry out preliminary diagnosis and patient treatment analysis by integrating computerized tomography scan and X-ray image processing. Feature engineering, k-means clustering, and decision tree algorithms assist COVID-19 automatic detection, diagnosis, and treatment (Shahin *et al*., 2022) through computed tomography-lung screening and laboratory results. Deep learning, radial basis function, and support vector machine algorithms and big data analytics are instrumental in medical image processing and computer-aided diagnosis systems for computed tomography scans and X-ray pictures.

Survival analysis and computational techniques can detect COVID-19 patient period of stay, discharge time, and recovery duration for confirmed cases through predictive modeling, decision tree, and support vector machine algorithms (Nemati *et al*., 2020), evaluating risk factors and reducing mortality rates and hospital overloads. Deep and machine learning algorithms can enable COVID-19 patient selection and progression prediction, while enhancing disease prevention and control (Fang *et al*., 2021) by medical history, clinical information, prognostic factors, physical examination outcome, computed tomography features, and laboratory test analysis. Deep learning algorithms can forecast COVID-19 progression, diagnosis, and treatment based on early warning systems, medical resource allocation, clinical data, computed tomography scans, patient early deterioration, and symptom severity identification to determine and enhance treatment strategies.

Autonomous deep and machine learning algorithms in preliminary COVID-19 diagnosis and for early treatment patients

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Hospitals face substantial COVID-19-related financial challenges and revenue decline by increased screening, treatment, and support service costs by healthcare worker shortages and patient surges. Deep learning convolutional neural networks can predict COVID-19 by harnessing computerized tomography and chest X-ray images (Babukarthik *et al.*, 2020) in terms of searching and classification accuracy automation in reduced computation time. Autonomous deep and machine learning algorithms in preliminary COVID-19 diagnosis and for early treatment patients can be used for exponential case volume increase through cloud computing tools, determining identification rate and classification accuracy for early stage COVID-19 prediction and diagnosis. Deep and machine learning algorithms can improve contact tracking, treatment, medication, intelligent computation and viable therapeutic techniques, and drug and vaccine development (Tiwari *et al.*, 2022) by determining the volume of confirmed cases, recoveries, mortality rates, and death cases brought about by COVID-19, assisting in prediction, prognosis, and diagnosis. Decision tree and clustering algorithms optimize COVID-19 prediction, detection, diagnosis, screening, and forecasting in relation to patient clinical data clusters, risk evaluations, specific remedies, and health conditions by medical imaging with an effective accuracy rate by integrating social data mining and processing by type and nature and physiological and personalized features.

COVID-19 machine learning forecasting models and deep learning techniques deploy real-time data dashboards, network visualization, and risk assessment, tracking, prediction, diagnosis, prognosis, and treatment tools (Rahimi *et al.*, 2021) with regard to exposed, quarantined, susceptible, registered, confirmed, infected, hospitalized, recovered, and deceased cases. Machine, logistic regression, artificial neural network, supervised, and unsupervised learning algorithms can be leveraged in COVID-19 case prediction, assessment, and triage for accurate clinical diagnosis, risk estimation, and decision making (Kwekha-Rashid *et al*., 2023) by analyzing elaborate imaging and text data.

Historical data-based COVID-19 clinical prediction and modeling techniques further early diagnosis and treatment (Alakus & Turkoglu, 2020) through personalized risk scores for healthcare resource prioritization. COVID-19 predictive algorithm-based clinical decision making systems together with artificial, convolutional, and recurrent neural networks can serve in laboratory finding data, interpretation, and treatment. Deep and machine learning algorithms, computer-aided clinical decision support and predictive models, and laboratory data enable accuracy score and performance in COVID-19 infection detection and forecasting. Deep and machine learning algorithm-based early COVID-19 detection and classification assess symptom abnormality severity and progression by clinical symptoms and tests and medical imaging techniques (Desai *et al*., 2020), and thus personalized therapies improve patient outcomes. Deep and machine learning algorithms can be harnessed as COVID-19 clinical decision support tools in effective therapeutic and diagnosis protocol development due to medical imaging big data processing.

Gradient boosting and support vector machine classifier algorithms can be pivotal in COVID-19 early triage decisions and mortality risk assessment and prediction (Elham *et al*., 2022) based on measurable predictors, past medical histories, prognostic factors, routine laboratory outcomes, and demographic characteristics. Random forest and logistic regression algorithms can predict COVID-19 severity and mortality for intensive care unit patients based on preexisting conditions, laboratory outcomes, and clinical data to enhance appropriate treatment through computer-aided diagnosis. K-nearest neighbor, extreme gradient and adaptive boosting, and random forest algorithms can be leveraged in COVID-19 screening and diagnosis across hospital settings (Goodman-Meza *et al*., 2020), according to patient demographic and laboratory characteristics, in clinical practice. Stochastic gradient descent, support vector machine, iterative imputation, multilayer perceptron, and logistic regression algorithms can assess epidemiologic, screening, clinical, testing, laboratory and imaging features for diagnostic accuracy in relation to early available data, enabling rapid clinical decision making.

Machine learning algorithms advancing COVID-19 patient early identification, risk factor prediction, hospital admission triaging, therapeutic measures, and treatment plan arrangements and personalized recommendations

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Increase in hospital inpatient volumes brought about serious revenue and margin decreases together with forgone medical care and cancelled services throughout the healthcare infrastructure due to COVID-19 fund distribution. Deep learning technologies and multi-layered convolutional neural networks can enable COVID-19 accurate prevention, screening, suspicious case early detection, prognosis, diagnosis, control, progression, treatment, and isolation (Zhang *et al.*, 2022) by integrating epidemiology, computerized tomography preliminary screening of infected patients, clinical classification and symptoms, biomedical image analysis performance, data computing and modeling, signal processing, and laboratory tests. Extremely randomized tree, random forest, extreme gradient boosting, k-nearest neighbor, bootstrap aggregating, support vector machine, and recursive feature elimination algorithms, deep and machine learning techniques, and principal component analysis can assist COVID-19 patients in terms of severity and mortality risk prediction in intensive care units (Sayed *et al.*, 2021), saving hospital resources and carrying out early medication actions with X-ray images as early symptom detection and diagnosis, while monitoring and optimizing high-risk priority patient condition and treatment by large dataset-based image local feature extraction.

Machine learning algorithms can forecast and triage COVID-19 positive patients and initial hospital encounters accurately (Burdick *et al.*, 2020), preventing emergency intubations and reducing false positive results by clinical decision support and early warning scoring systems. Sparse data tolerant algorithms and data balancing techniques can forecast COVID-19 patient evaluation and prognosis (e.g., patient condition deterioration and intensive care unit emergency transfer risks), mechanical ventilation requirements, and critical illness development by automatic vital sign and lab assessments and scoring system decisions. Machine learning algorithms can predict COVID-19 hospitalized individual resource distribution, decrease false positive alerts and emergency intubation risks, enable planned ventilation procedures, and improve patient care. Machine learning algorithms can detect and predict severe COVID-19 admission status and patient deterioration risk throughout hospital stay (Assaf *et al*., 2020), optimize patients triage and diagnostic accuracy and performance, and prioritize medical resources and adequate clinical care based on medical history recording, decision supporting tools, and vital sign measurement.

Linear regression, supervised deep and machine learning, decision tree, and time-series forecasting algorithms can predict and analyze COVID-19 confirmed cases and transmission and are instrumental in prevention, screening, diagnosis, and treatment (Malki *et al*., 2021), determining recovery, survival, and mortality rates and patient discharge time due to clinical data. Short-term forecasting techniques and cloud- and regression-based machine learning algorithms can model, forecast, and assess COVID-19 prevention development, cumulative confirmed cases, volume of fatalities, and effective treatment based on infected case data and social interaction parameters (Satu *et al*., 2021), configuring smart healthcare prediction models to enhance clinical outcomes, real-time decision making, and medical resource allocation.

Machine learning algorithms can advance COVID-19 patient early identification, risk factor prediction, hospital admission triaging, therapeutic measures, treatment plan arrangements and personalized recommendations, and prognosis and diagnosis aid systems (Xu *et al*., 2021), enabling medical resource allocation for severe cases based on computed tomography image data, clinical symptoms, comorbidities, and vital signs. Artificial intelligence-based diagnostic systems and deep and machine learning algorithms can build COVID-19 prediction models based on clinical manifestations and risk factors in relation to proper care delivering and critical case mortality rates. Decision tree and machine learning algorithms can predict COVID-19 triaging, progression, severe patient identification in hospital admission, and critical illness development by computed tomography diagnosis and prognosis due to clinical decision support systems, laboratory findings, and dataset analysis.

Deep and machine learning algorithms, benchmarking techniques, and predictive modeling tools detecting COVID-19 symptoms and risk factor patterns and predicting patient evolution

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Public health system investments can reduce hospital pressures, as increasing COVID-19 infection rates and hospital care expenditures have exacerbated financial losses while exceeding expected reimbursements. Deep and machine learning techniques and multilayer perceptron neural networks can predict COVID-19 severity (Alotaibi *et al*., 2021) by past medical history, demographic and testing data, clinical characteristics, and laboratory findings for critical patient early treatment, reducing mortality. Artificial neural networks, Bayesian regularization, and genetic algorithms can assess COVID-19 severity at an early stage through initial screening processes, increasing patient survival rate. Support vector machine and decision trees algorithms can identify, screen, and triage COVID-19 high risk patients in terms of mortality by real-time clinical data for treatment measures. Random forest regression and fuzzy logic algorithms can sort and treat COVID-19 patients for appropriate clinical management and effective medical facility and resource allocation.

Artificial neural network, k-nearest neighbor, and support vector machine algorithms can predict COVID-19 medical conditions, mortality risk, and priority in patient triaging and hospitalization (Pourhomayoun & Shakibi, 2021), reducing delays in specific care provision and adverse events by inspecting pre-existing conditions and physiological data. Decision tree, logistic regression, and random forest algorithms can integrate physiological conditions and symptoms to determine medical decision making and health status for confirmed cases after hospital admission through data-driven predictive analytics. Extreme gradient boosting algorithms, data mining tools, and conventional logistic regression methods can evaluate COVID-19 hospitalized cases of severe and critical patients in intensive care units with regard to specific risk factors and treatment decisions (Pan *et al*., 2020), as early disease prognosis can curtail mortality rates by integrating vital signs, medical records, feature screening, clinical data, and laboratory test results.

Decision, boosted, and bagged tree algorithms can forecast COVID-19 spread and cases accurately and improve risk management (Alali *et al*., 2022) due to medical resource availability. XGBoost, support vector regression, and random forest algorithms can predict cumulative COVID-19 recovered and confirmed cases through temporal and spatial dynamic modeling. Gaussian process regression networks and kernel-based machine learning and Bayesian optimization algorithms can mitigate COVID-19 transmission and handle available resources by time-series data and forecasting. Whale optimization, grey wolf, long-short term memory, and deep learning algorithms, together with artificial convolutional neural networks and image recognition tools, can accurately predict COVID-19 infection, diagnosis, and medical resource allocation by laboratory results based on prevention and control (Su *et al*., 2023), enabling streamlined clinical judgment and treatment and decreasing medical resource waste. Extreme gradient boosting algorithms and machine learning modeling can identify COVID-19 high-risk mortality patients and optimize triaging and resource allocation and diagnostic swiftness and accuracy (Kar *et al*., 2021) based on initial clinical state, vital physiological parameters, comorbidities, and laboratory data and predictors.

Deep and machine learning algorithms, benchmarking techniques, and predictive modeling tools can configure COVID-19 clinical diagnostic process (Andrade *et al*., 2022) by detecting disease symptoms and risk factor patterns and predicting patient evolution. Multilayer perceptron, decision tree, and k-nearest neighbor algorithms can shape COVID-19 patient clinical evolution classification, pattern identification and classification, vital prognosis, hospital consultations, and treatment recommendations. Extreme gradient and categorical boosting algorithms can forecast mechanical ventilation and high mortality rate for COVID-19 hospitalized patients (Yu *et al*., 2021) by use of resource allocation data, demographics, past medical history, laboratory values, and vital signs for specific treatments, determining severe disease progression risks. Mortality prediction algorithms and clinical scoring systems can assess COVID-19 real-time clinical data, care decisions, length of stay, and therapy escalation needs.

Deep and machine learning algorithms predicting and diagnosing COVID-19 clinical evolution through patient signs and symptoms, data classification tasks, and risk factor analysis

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Reduced revenues and financial resources shape constant hospitals and health system pressures in terms of medical and surgical inpatient hospital service delays, interruptions, and cancellations across emergency departments and clinics, operating rooms, and intensive care units. Robust forecasting techniques, deep and machine learning algorithms, and data mining tools can be leveraged in COVID-19 transmission, prevention, detection, containment, and alleviation (Mohan *et al*., 2022), improving prediction accuracy, integrating long-term healthcare status and data predictions, and determining patient moving patterns, infection, and mortality rates. Time series-based predictions, recurrent neural networks, and machine learning algorithms integrate forecasting values for COVID-19 confirmed, recovery, and death cases. Machine learning-based forecasting algorithms, in terms of support vector machine, linear regression, exponential smoothing, and least absolute shrinkage and selection operator, can determine the volume of infected cases, recoveries, and deaths (Rustam *et al*., 2020), shaping disease prognosis and predicting COVID-19 risk. Deep neural networks and risk score systems can forecast COVID-19 intensive care unit patient admission, triaging, and progression, disease severity, and in-hospital mortality (Li *et al*., 2020), by assessing demographic information, laboratory data and tests, imaging findings, chronic comorbidities, symptoms, and vital signs that can indicate critical illness likelihood.

Support vector machine and naive Bayes algorithms are pivotal in medical image identification, classification, and diagnosis (Andrade *et al*., 2022), optimizing COVID-19 prediction and screening by clinical decision support for severity risk forecasting. Deep and machine learning algorithms can predict and diagnose COVID-19 clinical evolution through patient signs and symptoms, data classification tasks, and risk factor analysis. Data mining techniques, convolutional neural network, and artificial intelligence algorithms can determine COVID-19 patient prognosis and diagnostic accuracy, shaping clinical evolution and hospital discharge probability by real-time data analysis. Random forest, feature engineering, extreme gradient and adaptive boosting, and extra trees algorithms can estimate COVID-19 severity prediction (Laatifi *et al*., 2022) by use of real-time patient data, comorbidities, medical records, and laboratory tests for determining high priority hospital admission. COVID-19 prediction, detection, and diagnosis can be performed by use of generative artificial intelligence tools, extensive reality and digital twin technologies, and bio-inspired optimization algorithms.

COVID-19 patient data and diagnostic modelling can guide clinical decision making and datasets in terms of morbidity and mortality prediction by computed tomography images and deep learning algorithms in relation to severe cases (Ning *et al*., 2020), enabling early diagnosis for swift medical intervention based on laboratory test results. Deep learning and logistic regression algorithms, convolutional neural networks, and image recognition tools can predict COVID-19 disease severity and clinical outcomes for patient screening, triage, diagnosis, isolation, and treatment by including pathophysiological features, robust clinical findings, and risk factors to enable timely medical interventions. Decision tree, multi-layer perceptron, random forest, linear and vector auto-regression, XBoost, and support vector machine algorithms can screen, track, and forecast COVID-19 cases for high-risk patient diagnosis (Rahman *et al*., 2021) by determining symptoms and critical conditions for confirmed, recovered, and dead individuals, while enabling optimal resource distribution and medical equipment. Machine learning and contact tracking algorithms, forecasting and screening tools, medical imaging techniques, and data science processes can further COVID-19 patient clinical diagnosis for early detection and precise forecasting of confirmed, recovered, and death cases.

Holt–Winter algorithms, seasonal autoregressive integrated moving average algorithms, random forest, and decision tree algorithms can predict and control the COVID-19 transmission (Saba *et al*., 2021) and thus diminish infected and dead cases by efficient big data processing and time series analysis. Polynomial regression, autoregressive integrated moving average, support vector machine, and k-nearest neighbor algorithms can forecast and model COVID-19 confirmed and recovered, and death cases, decreasing hospital burdens. K-nearest neighbor, support vector machine, artificial neural network, and random forest algorithms can track, predict, and manage COVID-19 transmission dynamics (Naeem *et al*., 2021) by time-series datasets, medical care structures, and treatment procedures for confirmed, recovered, and death cases.

Conclusions

Financial pressures and challenges are associated with hospital and health system revenues falling sharply as a consequence of cancelled medical services. Publicly operated and critical access hospital financial losses negatively affect routine diagnostic services and inpatient care across healthcare infrastructures by COVID-19 hospitalization and treatment costs. Declining hospital finances and negative operating margins, increased overtime and labor costs, and cancelled and delayed procedure-related total revenue losses articulate COVID-19-related financial impact with regard to hospital and health systems. Postponed or delayed medical care, uncompensated care elevation, medical supplies and equipment costs, and declining hospital margins and revenues affect financially vulnerable publicly operated and critical access hospitals.

Autonomous deep and machine learning algorithms are pivotal in COVID-19 prediction, detection, control, prognosis, can enhance patient diagnosis, treatment, and monitoring throughout healthcare system facilities, enabling effective therapeutic procedures based on clinical datasets, triaging patients effectively, and reducing healthcare system burdens. Deep and machine learning algorithms can predict and diagnose COVID-19 clinical evolution by analyzing clinical manifestations, patient demographic data, and laboratory test findings, being instrumental in medical image processing and computer-aided diagnosis systems. Deep and machine learning algorithms can accurately predict COVID-19 hospital admission, triaging, severity and mortality based on clinical and laboratory data, comorbidities, physiologic patterns, and vital measurements through real-time streaming symptom data collection and processing, prioritizing medical resources and adequate clinical care. Deep and machine learning algorithms can forecast, detect, and diagnose COVID-19 infections, assessing epidemiologic, screening, clinical, testing, laboratory and imaging features, detecting disease symptoms and risk factor patterns, and predicting COVID-19 hospitalized individual resource distribution. Deep learning algorithms can enable patient identification and accurate and timely early disease detection, and predict COVID-19 diagnosis and severity, evaluating real-time clinical data based on laboratory test results.

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