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COVID-19 MANAGEMENT: INSIGHTS INTO DRUG THERAPIES, DIAGNOSTICS, AND PREVENTIVE PHARMACOLOGY

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ABSTRACT

The emergence of COVID-19 has marked one of the most significant global health crises of the 21st century. Originating in Wuhan, China in December 2019, the disease rapidly evolved into a pandemic, prompting extensive scientific investigation. This review summarizes current insights into the virology, epidemiology, diagnosis, treatment strategies, and preventive measures related to SARS-CoV-2. The disease manifests primarily as a respiratory illness and has shown a range of clinical severities, from asymptomatic infection to severe acute respiratory syndrome. As of early 2020, therapeutic approaches have been largely supportive, with antiviral trials and vaccine development rapidly advancing. This article compiles up-to-date literature from WHO reports, peer-reviewed journals, and clinical studies to provide an overview of diagnostic methods, treatment interventions including plasma therapy and antiviral drugs, and vaccination efforts. Enhanced awareness and timely interventions remain critical in curbing transmission and managing disease severity.

INTRODUCTION

Coronavirus disease 2019 (COVID-19), caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has posed a profound threat to global public health and economy since its emergence in late 2019. As a member of the Coronaviridae family, SARS-CoV-2 is an enveloped, single-stranded RNA virus characterized by its high transmissibility and ability to cause a spectrum of clinical outcomes—from mild respiratory illness to severe pneumonia, acute respiratory distress syndrome (ARDS), multi-organ failure, and death. The virus spreads primarily through respiratory droplets and contaminated surfaces, but airborne and fomite transmissions have also been confirmed under certain conditions.

The rapid and widespread transmission of COVID-19 led the World Health Organization (WHO) to declare it a pandemic in March 2020. Unlike previous coronavirus outbreaks (SARS-CoV in 2002 and MERS-CoV in 2012), SARS-CoV-2 exhibits unique virological features such as its high basic reproduction number (R_0), asymptomatic transmission, and prolonged incubation period. As of 2025, COVID-19 has infected over 800 million people globally, prompting an urgent need for diagnostics, treatment options, and preventive strategies.

From a pharmacological perspective, the pandemic has catalyzed unprecedented global efforts in drug repurposing, novel antiviral development, and accelerated vaccine innovation. A wide array of pharmacological agents—including remdesivir, favipiravir, corticosteroids, monoclonal antibodies, and immunomodulators—have been explored for therapeutic efficacy. In parallel, the emergency use authorization (EUA) of multiple vaccines, including mRNA-based platforms (e.g., Pfizer-BioNTech, Moderna) and vector-based vaccines (e.g., Oxford-AstraZeneca), has significantly altered the trajectory of the pandemic.

This review aims to present a comprehensive summary of the epidemiological trends, current diagnostic tools, approved and experimental treatment modalities, and public health strategies employed in the prevention and control of COVID-19. Particular emphasis is placed on the pharmacological developments that have shaped the medical response to this novel infectious disease.

2. LITERATURE REVIEW

The COVID-19 pandemic has catalyzed global advancements in diagnostic technologies, therapeutic protocols, and preventive strategies. Multiple studies have proposed the integration of machine learning and deep learning frameworks in the diagnosis of COVID-19, particularly using chest X-ray and CT imaging. For instance, Sharma and Singh [1] utilized VGG16 architecture to enhance X-ray-based diagnostics, while Romdhane *et al.* [2] incorporated multi-scale convolutional neural networks with attention mechanisms to improve CT image detection accuracy.

Similarly, studies such as those by R.A.M and S.R [6], and Zhong *et al*. [7], have reinforced the effectiveness of CNN-based models in predicting disease severity and aiding early diagnosis.

Bharizadeh *et al*. [3] detailed the role of molecular diagnostics and immunoassays as vital tools in pandemic response, with emphasis on RT-PCR and serological tests. These methods remain the gold standard in SARS-CoV-2 detection [10], [11]. The early transmission dynamics and viral load behavior have been explored in works by Li *et al*. [12] and Zou *et al*. [5], laying a foundational understanding for intervention design. The World Health Organization's dashboard [13] continues to provide real-time epidemiological updates essential for public health planning. Drug repurposing and antiviral therapy formed the backbone of early pharmacological interventions. Ibrahim *et al*. [8], [14] presented a comprehensive network meta-analysis comparing drug efficacy in mild to moderate COVID-19 cases, highlighting agents like remdesivir, corticosteroids, and monoclonal antibodies. Reviews by Reche *et al*. [9], [15] and Li *et al*. [18] provide further insight into the progression of antiviral therapies, while others discuss future therapeutics based on molecular docking and in vivo models [19], [20].

The role of artificial intelligence in COVID-19 management extends beyond diagnostics to include predictive analytics and hospital management systems. Malhotra *et al*. [21], Rangkuti *et al*. [22], and Allahabadi *et al*. [23] explored AI-driven models to assess disease progression, triage patients, and monitor lung compromise levels. Tsang *et al*. [24] developed an automated multiplexing system capable of detecting COVID-19 and other respiratory infections simultaneously—demonstrating the shift toward comprehensive, multi-pathogen diagnostics.The Internet of Things (IoT) has also played a significant role. Palli *et al*. [25] proposed a remote healthcare platform for quarantine and telemedicine management. Lu *et al*. [26] and Ting *et al*. [28] emphasized the potential of self-supervised and transfer learning to increase COVID-19 detection accuracy using minimal annotated data. Meanwhile, reviews like those by Niveriya *et al*. [27] discuss the synergy between AI, diagnostics, and pharmaceutical delivery systems in pandemic control.

In terms of prevention, rapid vaccine development has been one of the most impactful strategies. Although not extensively covered in the above references, the foundational virology work by Phan *et al*. [4] and studies on viral load and transmissibility [5], [12] were instrumental in guiding vaccine targeting and clinical trial designs.

Altogether, these studies underscore the importance of integrating biomedical diagnostics, AI tools, and evidence-based pharmacological treatments to manage and mitigate the impact of COVID-19. Babu et al. [30] discussed the increasing concerns of microplastic accumulation in terrestrial and aquatic ecosystems. Their study emphasized recycling strategies, management techniques, and the long-term sustainability challenges associated with microplastic waste. The work contributes to environmental protection by identifying gaps in current waste-handling technologies and proposing eco-friendly alternatives. Rubala et al. [31] reviewed the histopathological impacts of environmental pollutants on living systems. The authors highlighted pathological changes caused by toxic exposure, underlining the importance of biomonitoring and early detection for preventive healthcare. This paper provides critical insights into toxicology and biomedical research.

Ramya et al. [32] analyzed the growth trends and economic implications of *Penaeus monodon* aquaculture. Their review identified key market drivers, sustainability challenges, and socio-economic benefits, suggesting that aquaculture plays a significant role in food security and economic stability in coastal regions. Geetha et al. [33] presented a comprehensive review of ecotourism, emphasizing its applications in biodiversity conservation and environmental education. The study suggested that ecotourism can promote awareness while balancing ecological protection with economic benefits, making it a vital tool for sustainable development. Swetha et al. [34] provided a concise review of mosquito control measures, ranging from biological methods to chemical interventions. Their findings underline the importance of integrated vector management (IVM) in reducing mosquito-borne diseases, thus supporting global public health initiatives. Mahalakshmi et al. [35] explored the health risks associated with inhalation of volatile paint fumes. Their review highlighted respiratory consequences such as reduced lung function and long-term pulmonary disorders, stressing the necessity for safety regulations and protective measures for workers and exposed populations.

3. METHODOLOGY

This review was conducted using a systematic and integrative literature collection approach to ensure comprehensive coverage of pharmacological, diagnostic, and preventive aspects of COVID-19. Peer-reviewed publications, meta-analyses, systematic reviews, clinical trials, World Health Organization (WHO) reports, and official health authority guidelines were considered.

3.1 EPIDEMIOLOGY OF COVID-19

The epidemiology of COVID-19 has evolved rapidly since the initial outbreak in Wuhan, China, in late 2019. The virus, SARS-CoV-2, demonstrated an exceptionally high transmission rate due to its airborne spread, long incubation period, and capacity for asymptomatic transmission. Early cases were linked to zoonotic exposure at a seafood market, followed by rapid global dissemination driven by human-to-human transmission via respiratory droplets, aerosols, and contaminated surfaces.

By early 2020, the World Health Organization (WHO) declared COVID-19 a Public Health Emergency of International Concern and later a pandemic. As of mid-2025, COVID-19 has caused over 800 million confirmed cases and millions of deaths globally. Epidemiological models revealed significant variations in transmission dynamics influenced by population density, mobility patterns, and public health interventions.

SARS-CoV-2 has undergone multiple mutations, leading to variants of concern (e.g., Alpha, Delta, Omicron), each exhibiting different degrees of infectivity, immune escape, and clinical severity. This genetic variability has affected vaccine efficacy, diagnostic sensitivity, and pharmacological response, underscoring the need for real-time genomic surveillance and adaptable therapeutic strategies.

3.2 DIAGNOSIS OF COVID-19

Early and accurate diagnosis of COVID-19 is essential for infection control and timely clinical management. The standard diagnostic method remains reverse transcription-polymerase chain reaction (RT-PCR), which detects viral RNA from nasopharyngeal swabs with high sensitivity and specificity. However, challenges such as false negatives due to low viral load or sampling errors necessitate supplementary techniques.

Rapid antigen tests, although less sensitive, have enabled point-of-care testing and mass screening, particularly in resource-limited settings. Serological assays detecting IgM/IgG antibodies provide retrospective evidence of infection but are not suitable for early diagnosis. In addition to molecular techniques, chest imaging (X-ray, CT) has been extensively utilized to assess lung involvement. Recent studies have shown the integration of AI-based tools with imaging modalities significantly improves diagnostic accuracy and speed [1], [2], [7]. Advanced models, such as CNN and VGG16, have demonstrated high performance in distinguishing COVID-19 pneumonia from other pulmonary conditions [6], [22].

Emerging diagnostic platforms, including CRISPR-based biosensors, loop-mediated isothermal amplification (LAMP), and multiplex detection systems, offer rapid and sensitive alternatives to conventional tests, enhancing diagnostic readiness for future variants and pandemics [24], [26].

3.3 TREATMENT AND PHARMACOLOGICAL INTERVENTIONS

Therapeutic strategies for COVID-19 have evolved through multiple clinical trial phases and drug repurposing efforts. In the early stages of the pandemic, treatment was largely supportive focused on oxygen therapy, mechanical ventilation, and symptomatic relief. Subsequently, several pharmacological agents were evaluated under emergency use authorization.

Antiviral agents, such as remdesivir and favipiravir, have been used to inhibit viral replication. Molnupiravir and nirmatrelvir-ritonavir (Paxlovid) have shown promise in reducing viral load and hospitalization rates in high-risk patients [8], [9], [15].

Corticosteroids (e.g., dexamethasone) have become standard care in severe COVID-19 cases to reduce hyperinflammation and

cytokine storm syndromes. Monoclonal antibodies (e.g., casirivimab/imdevimab) have been developed to provide passive immunity, particularly in immunocompromised individuals.

The role of immunomodulators, such as tocilizumab and baricitinib, has been extensively studied in managing cytokine-mediated lung injury. These drugs have shown efficacy in reducing mortality and need for mechanical ventilation in critically ill patients [18], [19].

Parallel to therapeutic development, mRNA vaccines (Pfizer-BioNTech, Moderna) and adenovirus vector vaccines (Oxford-AstraZeneca, Sputnik V) were developed at unprecedented speed and played a vital role in global disease control. Their pharmacokinetics, safety profiles, and immunogenicity have been extensively reviewed, and booster strategies have been adapted to address waning immunity and emerging variants.

4. RESULTS

This review analyzed and compared diagnostic methodologies, therapeutic regimens, and preventive strategies reported in 30 high-impact studies and clinical trials conducted between 2020 and 2025. The collective findings reveal that: RT-PCR remains the most sensitive and specific diagnostic tool for SARS-CoV-2 detection. However, rapid antigen tests and AI-assisted radiological analysis (e.g., CNN, VGG16) have improved large-scale screening efficiency in various settings. In terms of therapeutic pharmacology, antiviral agents like remdesivir, molnupiravir, and nirmatrelvir/ritonavir (Paxlovid) have shown efficacy in reducing viral load and disease progression in mild to moderate cases.Corticosteroids and IL-6 inhibitors (e.g., tocilizumab) have significantly reduced mortality in severe COVID-19 cases. Machine learning-based diagnostic tools demonstrated high accuracy in COVID-19 detection from chest X-rays and CT images, especially in areas with limited RT-PCR access. Vaccine development has been the most significant preventive breakthrough. mRNA-based vaccines (Pfizer-BioNTech, Moderna) and viral vector vaccines (Oxford-AstraZeneca, Sputnik V) demonstrated high protection against severe disease, with booster doses enhancing immunity against variants of concern. The results consistently indicate that the integration of advanced diagnostics, evidence-based pharmacological interventions, and adaptive immunization strategies have substantially improved COVID-19 management globally.

4.1 Diagnostic tools: sensitivity and application

Multiple diagnostic approaches have been employed globally to manage COVID-19 cases, each varying in sensitivity, specificity, and operational feasibility. RT-PCR remains the gold standard, while rapid antigen tests are faster but less sensitive. Recent AI-based imaging analysis, especially using deep learning models like CNN and VGG16, has shown high diagnostic accuracy in radiographic interpretation [1], [2], [6], [22].

Table 1. Comparison of Diagnostic Tools for COVID-19

Method	Sensitivity (%)	Specificity (%)	Time to Result	Remarks
RT-PCR	95–98	98–100	4–6 hours	Gold standard, high accuracy
Rapid Antigen Test	60–85	90–98	15–30 minutes	Useful for mass screening
Chest CT	88–94	80–85	~1 hour	Detects lung abnormalities early
AI-enhanced X-ray	90–95	90–94	~10 minutes	Promising support tool, fast interpretation
Serological (IgG/IgM)	70–90	85–95	30–60 minutes	Useful for past exposure surveillance

4.2 Therapeutic Interventions

Drug repurposing and antiviral development have been central to COVID-19 management. Remdesivir, Paxlovid, and Molnupiravir showed moderate efficacy in reducing viral load and hospital stay duration in mild to moderate cases [8], [14], [15]. Corticosteroids like dexamethasone significantly reduced mortality in severe patients [9], [18].

Table 2. Summary of Pharmacological Treatments for COVID-19

Drug/Therapy	Mechanism	Indicated For	Outcome
Remdesivir	RNA polymerase inhibition	Mild-moderate COVID-19	Reduced recovery time
Dexamethasone	Anti-inflammatory (corticosteroid)	Severe/ICU patients	Reduced mortality (~35%)
Molnupiravir	Inhibits viral replication	Mild-moderate risk groups	Lowered hospitalization risk
Paxlovid (Nirmatrelvir)	Protease inhibition	High-risk outpatients	89% reduced risk of severe disease
Monoclonal antibodies	Passive immunity	Early infection, high risk	Effective in early intervention
Tocilizumab	IL-6 receptor blocker	Cytokine storm cases	Improved survival in severe inflammation

4.3 Preventive Pharmacology and Vaccine Strategies

Preventive strategies were dominated by rapid vaccine development using mRNA, viral vector, and inactivated virus platforms. Booster doses and variant-specific formulations were introduced to combat immune escape. The pharmacodynamics and efficacy data have shown long-term protection, especially against severe disease.

Table 3. Summary of COVID-19 Vaccine Platforms

Vaccine	Platform	Doses Required	Efficacy (Severe Disease)	Booster Available
Pfizer-BioNTech	mRNA	2 (+ booster)	~95%	Yes
Moderna	mRNA	2 (+ booster)	~94%	Yes
Oxford-AstraZeneca	Viral vector	2	~82%	Yes
Johnson & Johnson	Viral vector	1 (+ booster)	~66%	Yes

Vaccine	Platform	Doses Required	Efficacy (Severe Disease)	Booster Available
Covaxin (Bharat Biotech)	Inactivated virus	2	~78%	Yes
Sputnik V	Viral vector	2	~91.6%	Yes

CONCLUSION

The COVID-19 pandemic has underscored the critical importance of rapid diagnostics, repurposed pharmacological interventions, and large-scale preventive strategies. Diagnostic approaches have evolved from conventional PCR to AI-assisted imaging and point-of-care rapid tests, enabling quicker clinical decisions. Antiviral therapies and immunomodulators, though varying in effectiveness, have significantly reduced mortality in targeted patient groups.

Preventive pharmacology through vaccination has been the most effective tool in curbing severe disease outcomes and healthcare burden. However, the emergence of new variants demands continuous surveillance, booster strategies, and the development of next-generation antivirals.

In conclusion, an integrated approach combining accurate diagnostics, timely drug therapy, and robust preventive pharmacology is key to current and future pandemic preparedness. Ongoing innovations in artificial intelligence, nanomedicine, and immunopharmacology will likely shape the post-pandemic medical landscape.

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