Bacterial co-infection and secondary infection in patients with Covid-19: A Review

By

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in partial fulfillment of the requirements for the degree of B.Sc. (Microbiology)

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Declaration

It is hereby declared that

1. The thesis submitted is our own original work while completing a degree at BRAC University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

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Approval

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Abstract-

Bacterial confections and secondary infections increase the severity of respiratory viral infections and were constant causes of mortality in influenza pandemics but have not been well characterized in patients with coronavirus disease 2019 (COVID-19). *Streptococcus pneumoniae, Haemophilus influenzae, and Staphylococcus aureus* are common microorganisms associated with co-infections. These co-infections are more common in severe cases and can have negative effects. However, due to symptoms that overlap with COVID-19, secondary infections, such as bacterial pneumonia, bronchitis, or sinusitis, can be difficult to diagnose. The complicated relationship between viral and bacterial infection affects how diseases grow, how they are diagnosed, and how they are treated. Different demographics, risk factors, and germs can cause differences in the number of people who get sick. Because symptoms often overlap, it's still hard to figure out the causative agent behind it. To close this knowledge gap, the goal of this review is to put together the most up-to-date information about bacterial-

Co-infections and secondary infections in COVID-19 patients. It states more about Secondary and co-infections are feasible, but how frequently they happen depends on a number of variables, including a person's immune system, the pathogen's severity, and hygiene habits. Due to weakened immunity, people who have been infected may be more vulnerable to secondary infections, which could result in a more serious sickness or complications. The significant findings of this review paper emphasize that bacterial co-infections and secondary infections in COVID-19 patients, influenced by various factors, can significantly worsen disease outcomes, strain healthcare systems, and contribute to antibiotic resistance, highlighting the urgent need for improved diagnostics, personalized treatments, and comprehensive public health strategies.

Keywords: COVID-19, SARS-CoV-2, bacterial co-infection, secondary infection, antibiotic therapy, multidisciplinary approach.

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Chapter 1: Introduction

The COVID-19 outbreak, which was caused by the new coronavirus SARS-CoV-2, has caused a global health crisis with problems that have never been seen before. "The presence of bacterial co-infection in COVID-19 has been a widespread concern among healthcare professionals due to clinical features that overlap with bacterial pneumonia and the increased risk of morbidity and mortality associated with bacterial co-infections **(Devi et al., 2021).** Because of this, diseases are getting worse, antibiotic resistance is going up, it's harder to detect and treat, healthcare systems are being pushed to their limits, and health gaps are getting wider. The signs and outlook for COVID-19 get worse because of these secondary infections. This makes it harder to treat COVID-19 and shows how important it is to protect world health by learning more, making more accurate diagnoses, and giving more focused treatments **(Karaba et al., 2021)**. Even though the main focus has been on the viral infection itself, a new study shows that bacterial co-infections and secondary infections have a big impact on how patients do. The goal of this study is to do a critical analysis of what is known about bacterial co-infections and secondary infections in the setting of COVID-19.

Chapter 2: Literature Review

In confessed patients with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection, which is also called coronavirus disease 2019 (COVID-19) **(Costa et al., 2022).** It was hard to get both bacteria and fungi at the same time. Because there isn't enough standardized data, estimates of the number of people with COVID-19 who also have a bacterial infection range from 3% to 30%. Recent research from the United States shows that it is not unusual for people to have both SARS-CoV-2 and another type of respiratory illness at the same time. Since many hospitals use the appearance of different respiratory disorders to figure out how likely a patient is to have coronavirus disease 2019 (COVID-19**) (Adebisi et al., 2021).** It is important to learn more about co-infections. People who were admitted to these places and thought they might have a COVID-19 infection often had signs of sepsis and were tested for bacterial infections. Most were given medicines even though there was no proof that their illness was caused by bacteria. How often and what kinds of bacterial co-infections happen, as well as whether or not they can be treated based on evidence, can be

very helpful in deciding if drugs are needed and which ones to use. This is great news for protecting rare resources and making sure medicines are used sustainably. Co-infections with bacteria, especially *Streptococcus pneumoniae* and *Staphylococcus aureus*, and viruses or fungi are a risk in past flu pandemics. During viral (influenza) pneumonitis epidemics and pandemics **(Lohia et al., 2021)**, secondary bacterial and fungus infections like *Streptococcus pneumoniae*, *Haemophilus influenzae*, *Staphylococcus aureus*, and *Aspergillus spp*. are often linked to poor patient outcomes **(Costa et al., 2022).** But no one knows if bacterial co-infections are already there when a person goes to the hospital or if they show up later after more hospital exposures. We need more information about how often people get bacterial infections in the community so we can figure out how to improve antibiotic treatment.

Chapter 3: Bacterial Infections and Secondary Infections

3.1: Bacterial co-infections and secondary infections in the context of COVID-19

When it comes to COVID-19, bacterial co-infections are the second infections caused by bacteria in addition to the first infection caused by SARS-CoV-2. These bacterial co-infections happen at the same time as the main virus infection and can change how the disease progresses, how bad the symptoms are, and how well treatment works.COVID-19 patients who are hospitalized are more likely to get secondary bacterial illnesses, most often from *Staphylococcus aureus*, *Streptococcus pneumoniae*, and *Haemophilus influenzae*. Bacterial co-infection is a common side effect of many viral illnesses of the respiratory tract, and it can lead to more sickness and death **(Pal et al., 2020).**

On the other hand, secondary infection refers to infections that happen after the original SARS-CoV-2 infection has gone away is over. The most common type of second illness after a viral infection is a bacterial infection. Bacteria that were once treated with drugs may now be resistant to those drugs, making them hard to get rid of. Critically ill patients with coronavirus disease 2019 (COVID-19) may even be more likely to get a second infection because both the virus and the drugs weaken the immune system. These secondary infections can make a bad scenario even worse and could even kill the person **(Cusumano et al., 2020).**

3.2: The importance of studying these infections due to their potential impact on patient outcomes

In the circumstances of COVID-19, it is very important to look into co-infections and secondary infections because they can have a big impact on how patients do. These secondary infections may make the outlook worse by making the disease worse, making it harder to treat clinically, or both. A co-infection can be a new infection that a person gets because their immune system isn't working well, or it can be an already-present pathogen that gets worse because of a new pathogen. Stress and immune reactions are two things that can make an illness worse when they interact with each other **(Said et al., 2022).** Co-infections can be bad, neutral, or even good for how a disease turns out, depending on the amount of interactions, such as how they change the host's response or how they affect diagnostic and treatment methods **(Passerotto et al., 2023).** When two viruses are in the body at the same time, they often work against each other. If the first infection causes oxidative stress, it may be more possible that you will get another infection. The power of memory T cells to change immune responses to future co-infections can change how bad an infection is. Oxidative stress, the immune system, inflammation, and how a disease gets worse are all connected in a complicated way. For example, a person who has HIV and Mycobacterium tuberculosis at the same time might feel the effects of both diseases at the same time **(Díaz Santos et al., 2022)**.

Figure.: 1

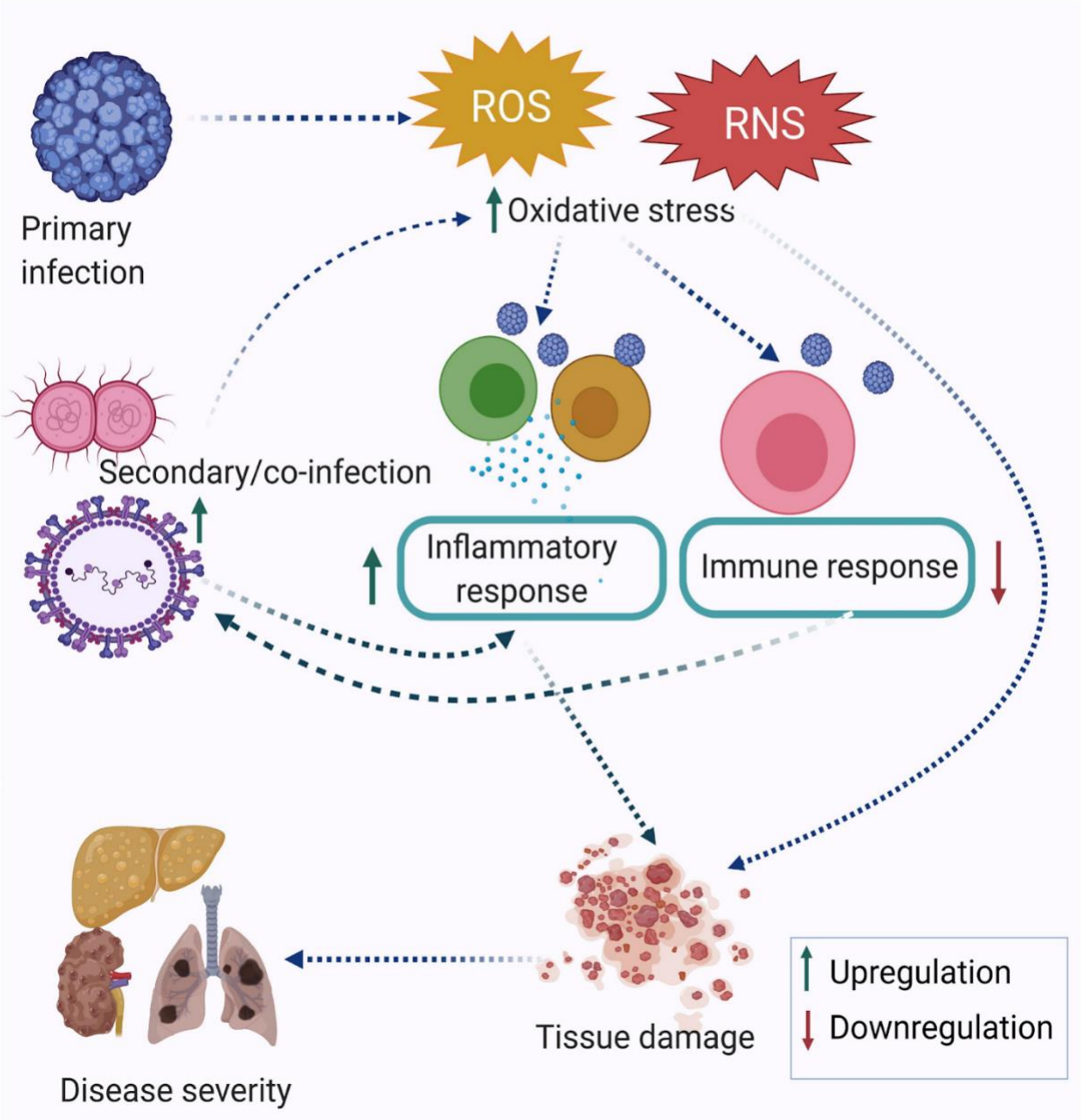

Figure 1- Co-infections enhance oxidative stress, weaken the immune system, and make symptoms of illness worse. Both the first infection and the second one cause oxidative stress, which interferes with the immune system's reaction. This leads to inflammation, damage to tissues, and sudden sickness **(Devi et al., 2021).**

Chapter 4: Prevalence and Risk Factors

4.1: The prevalence of bacterial co-infections and secondary infections in COVID-19 Patients

Between studies, the number of COVID-19 patients with bacterial co-infections and secondary infections changed a lot. Rates of co-infections and secondary infections have been found to range from low percentages to much higher percentages, depending on things like the patient's age, healthcare setting, and location. In 0.3% of cases, a proven respiratory co-infection was found, and in 1.1% of cases, a bacterial respiratory co-infection was found **(Bengoechea & Bamford, 2020)**. People with COVID-19 who were taken to the ICU with a viral illness between March 2020 and May 2020 are being studied. There were a total of 97 secondary infections. *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Klebsiella pneumoniae* were the most common reasons of illness for 57 of the 191 people. Secondary infections had a big effect on how COVID-19 patients did, as shown by the link between longer ICU stays, longer periods of mechanical breathing, and higher death rates (**Shafran et al., 2021)**. However, it's important to note that the literature doesn't always make a clear difference between co-illnesses and secondary infections. In the setting of COVID-19, more research and more standard ways of doing things are needed to learn more about how often co-infections and secondary infections are caused by bacteria.

4.2: Risk factors that contribute to susceptibility, such as age, comorbidities, and immune status

Many things affect how likely someone is to get a disease like COVID-19. Many things, like age, gender, and pre-existing health problems like high blood pressure, diabetes, obesity, and other diseases, can speed up the development of COVID-19's more serious stages, such as kidney damage and clotting problems. Lab tests like proinflammatory cytokines, lactate dehydrogenase, and C-reactive protein can show how a disease is getting worse, while lymphopenia and eosinopenia can help figure out how bad the disease is. People from lower financial backgrounds and those with weaker or overactive immune systems are more likely to get sick **(Farrell et al., 2021)**. Gender inequality and living factors like bad eating habits and not taking care of oneself also play a role. There are a lot of things that can affect the

result, such as socioeconomic status, lifestyle choices, and the quality of medical care, but cytokine storms and certain chest CT patterns do indicate serious illness. They found that in a study **(Nakagawara et al., 2022)**.

Chapter 5: Common bacterial pathogens:

Co-illnesses and secondary infections with bacterial pathogens, such as SARS-CoV-2, can make the course of COVID-19 even worse. Cross-sectional studies have shown that the current SARS-CoV-2 pandemic and related co-infections have infection rates between 1% and 8%. However, there isn't much written about these subjects **(Lohia et al., 2021).**

Pathogen	**Impact on COVID-19 Patients**	**Co-Infection Incidence**	**Reference**
Streptococcuspneumoniae	Can cause serious breathing problems, especially in community-acquired pneumonia.	Low incidence ofCOVID-19	**(SaifyNabiabad et al., 2021)**
Haemophilusinfluenzae	Symptoms similar to *Streptococcus pneumoniae* when infected with the flu virus.	Bacteremia rate: 1.6% - 3.8%	**(Sun et al., 2020)**
Staphylococcus aureus	Can worsen the illness when co-infected with the flu virus, causing sepsis and skin infections.	13.3% of bacteremia cases	**(Scott et al., 2022)**
Klebsiella pneumoniae	Common nosocomial bacteria causing respiratory problems in COVID-19 patients.	Multi-resistant	**Kamaleldin et al., 2022**
Acinetobacterbaumannii	Found in pleural fluid cultures, causes ventilator-associated pneumonia.	Multidrug-resistant	**(Manna et al., 2020)**
Pseudomonas aeruginosa	Causes secondary infections, especially in hospitalized COVID-19 patients.	Can form biofilms	**(Manna et al., 2020)**

These germs are different in how they make people sick and how they cause disease. Standard treatments don't work on *Streptococcus pneumoniae*, which causes pneumonia. *Staphylococcus aureus* causes serious sepsis by releasing toxins that hurt the skin. Because of its capsular polysaccharide, the infectious *Klebsiella pneumoniae* can hide from the immune system and cause a wide range of illnesses. The dangerous illness caused by *Acinetobacter baumannii* can stay in ventilators because of biofilms. *Pseudomonas aeruginosa* can fight antibiotics and spread to new hosts by making biofilms. This may be because the focus is generally on the single pathogen that caused the outbreak and the identification of comorbidities to find groups of patients who are at risk, rather than on co-infections **(Saini et al., 2021)**

Chapter 6: Clinical Manifestation and Outcomes

6.1:How bacterial infections can complicate the clinical course of COVID-19

Bacterial illnesses can make COVID-19 worse, which makes the disease's course even more complicated. People with COVID-19 who get bacterial co-illnesses or secondary infections may see a rapid drop in their health. The high number of bacterial infections in COVID-19 deaths is likely just a side effect of the disease's late-stage pathology, which leads to different suggestions for how to treat patients. These bacterial diseases can cause several respiratory illnesses, including pneumonia **(Cong et al., 2022)**. The first piece of data that showed how important secondary bacterial pneumonia was in flu-related deaths was the isolation of bacteria from the lungs of people who had died. Also, the clinical effects can get worse because the immune system's response to multiple infections can cause an overly inflammatory reaction called a "cytokine storm," which can make the clinical effects even worse. if COVID-19 gets worse, the number of tools used and entry points for bacteria linked to ICU admission could go up **(Adebisi et al., 2021)**. The interaction between SARS-CoV-2 and bacteria shows how complicated it is for COVID-19 patients to get sick and how important it is to get the right diagnosis quickly. While SARS-CoV-2 is still going around and people are still being treated with COVID-19 **(Sturza et al., 2023)** knowing what causes bacterial infections and what happens to them will help doctors give the best care possible.

6.2: The impact on respiratory symptoms, disease severity, and patient outcomes

Bacterial co-infections or secondary infections are often the cause of respiratory symptoms, worsening of the disease, and worse results for COVID-19 patients.COVID-19 usually makes people cough and hurt their muscles and heads. People often have upper respiratory signs like a sore throat or trouble smelling or tasting. Coughing and shortness of breath are common symptoms of pneumonia, which can be deadly and may be made worse in some people by other bacterial infections. These respiratory signs may be able to predict how the patient will do in the hospital. In the later stages of the disease, when the immune system can't fight off both pathogens as well as it should, inflammation gets worse, tissue damage happens, and the lungs don't work as well **(Llor & Bjerrum, 2014).** This double curse could lead to a faster drop in health, a higher rate of hospitalization, and a greater need for critical care and breathing machines. According to a report by **(Lohia et al., 2021),** an increase in COVID-19 patients coming to the hospital with serious illnesses has led to a lack of intensive care beds and a strain on hospital resources.

These infections are a huge clinical problem that needs close monitoring, quick treatment, and good management to make sure the patient gets better.

Flowchart of hospitalized adults in COVID-NET with bacterial and viral infections:

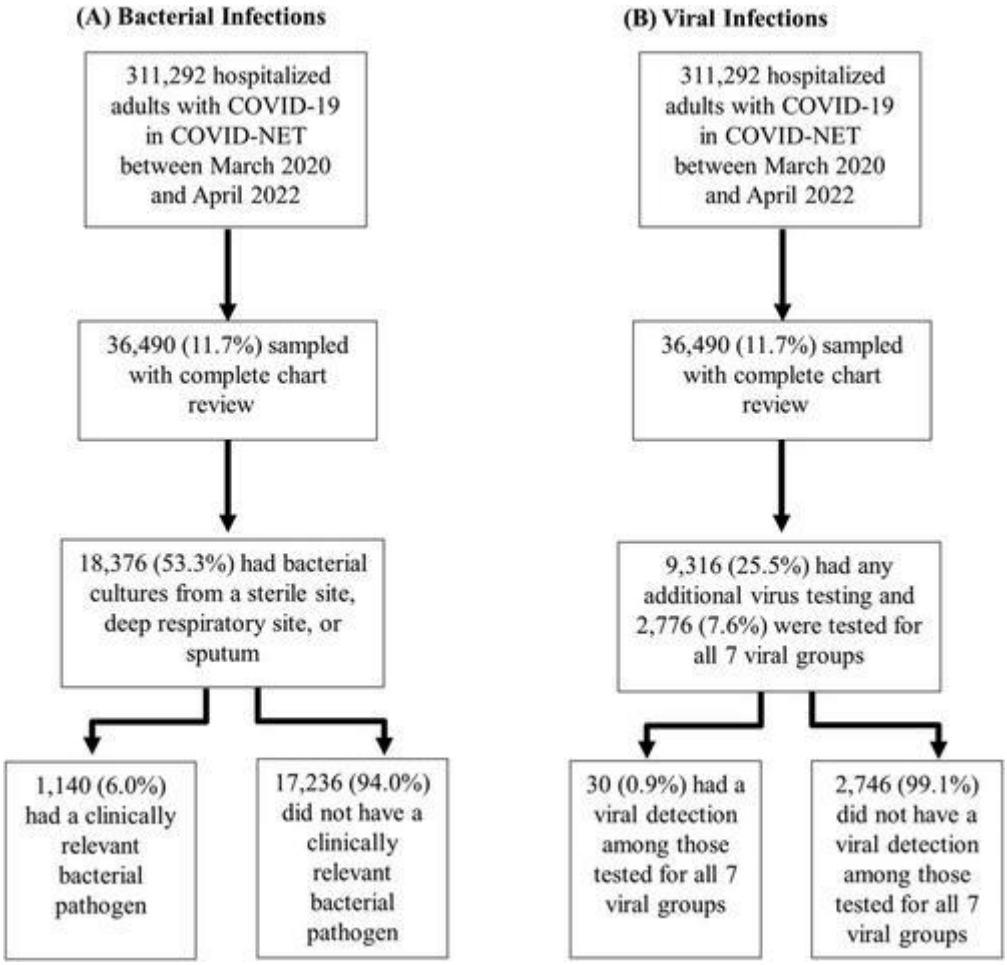

FIGURE 2: Flowchart of hospitalized adults in COVID-NET with bacterial and viral infections:

A flowchart of hospitalized people with COVID-NET who have bacterial or viral infections is shown. Data is shown both as unweighted numbers and as ratios based on those numbers. The seven viral families are respiratory syncytial virus (RSV), rhinoviruses/enterotoxin (EV), influenza (A, B, or unknown), adenoviruses, human metapneumovirus (HMPV), parainfluenza (serotypes 1-4), and common human coronaviruses **(Shah et al., 2023)**.

Chapter 7: Diagnosis and Detection

7.1: Various diagnostic methods and techniques used to identify bacterial co-infections and secondary infections.

Various diagnostic methods and techniques are employed to identify bacterial co-infections and secondary infections in the context of COVID-19:

Clinical evaluations: this is important in psychology because they help figure out what's wrong with a patient and guide choices about how to treat them. The clinical assessment uses several tools to do fair evaluations of people and figure out what's wrong with them. Once the root cause(s) of the patient's condition(s) have been found through a full clinical evaluation, the best course of treatment can be chosen. In the same way, doctors use clinical measures to find signs of bacterial co-infections, such as worsening respiratory symptoms, high fever, a high white blood cell count, and abnormalities in chest imaging. If a person gets a coronavirus, their breathing system can fail and their lungs can be badly hurt **(Sieswerda et al., 2020).**

Laboratory Tests: Molecular studies that extract viral components and antibody testing that show a prior infection response are the two main types of tests utilized to diagnose COVID--19. Testing for antibodies can show past infection, whereas molecular testing can diagnose individual patients and aid in the control of an epidemic. Similarly, a complete blood count (CBC) and inflammatory markers like C-reactive protein (CRP) and procalcitonin can help determine the presence or absence of a bacterial infection **(Sidpra et al., 2020)**. Successive infections might contribute to a rise.

Chest Imaging: Chest X-rays are a popular way to find out if someone has coronavirus disease 2019 (COVID-19) and to track its progress while being treated. CT imaging looks are linked to different clinical scenarios, such as early vs. advanced stages, asymptomatic vs. symptomatic people, and severe vs. not-severe situations. However, it is still not clear what role it plays in COVID-19 as a screening and diagnostic tool **(Sidpra et al., 2020).**

Sputum and Blood Cultures: When a patient has a bacterial super infection on top of a respiratory viral infection, blood and sputum cultures often find common bacteria like *Streptococcus pneumoniae*, *Pseudomonas aeruginosa*, Klebsiella pneumoniae, Enterobacter and *Citrobacter spp*., and *Haemophilus influenzae* (Sidpra et al., 2020).

Serological Tests: Serological testing can find antibodies to certain germs, which can show if someone is sick or has been sick in the past. Healthcare workers need to know what the limits of SARS-CoV-2 serological tests are. Laboratory experts may be able to tell them this. For a full diagnosis, clinical details and imaging tests should be added to the results of serological tests **(Mirzaei et al., 2020).**

7.2: Challenges in differentiating between viral and bacterial etiologies

Diagnosing COVID-19 can be challenging due to its similarities with other infections. Symptoms like fever, cough, and fatigue overlap with bacterial illnesses. Viral pneumonia can further complicate matters. **(*The Covid-19 Vaccination Programme:*, 2022).** Bacteria and viruses can interact, aiding each other's spread. To distinguish viral from bacterial infections, a patient's history and proper diagnostic tests are crucial. Co-infections with both SARS-CoV-2 and bacteria are common during the pandemic, leading to antibiotic overuse. A comprehensive approach involving infectious disease experts, lab tests, and clinical evaluation is necessary for accurate diagnosis. **(Ibrahim, 2020).**

Chapter 8: Antibiotic Use and Resistance

One study looked at the use of antibiotics and bacterial infections in COVID-19 patients between June 2020 and March 2021. Since the last time this was looked at, the number of drug prescriptions has dropped by a lot, from 82.3% to 39.7%. On the "Watch" list of the World Health Organization were widely used antibiotics. The most often recorded resistant organism was *Staphylococcus aureus*, which had a bacteremia rate of 10.5% **(Bengoechea & Bamford, 2020)**. Before starting drug treatment, doctors should look for signs of infection, such as worsening symptoms, increased inflammatory markers, and radiographic abnormalities that suggest bacterial co-infections. Also, doctors should always be on the lookout for bacterial superinfections. This is especially important when dealing with patients who are nearing the end of their lives **(Aydemir et al., 2022)**. Doctors shouldn't be afraid to

start targeted antibiotic treatment as soon as it's needed. Taking antibiotics was linked to the need for more air. Antibiotics should be given to people with COVID-19 just in case there are signs of a bacterial infection **(Bazaid et al., 2022).**

Misusing antibiotics is a big problem in healthcare in general and in COVID-19 treatment in specific. When once-treatable illnesses become immune to treatment because of a change in a pathogen like a virus, bacteria, parasite, or fungus, the chance of disease transmission, bad outcomes, and death goes up **(Muralidar et al., 2020)**. Overusing antibiotics is one of the main reasons for antimicrobial resistance, which leads to more severe illnesses, longer stays in the hospital, and higher death rates. Overusing antibiotics is tied to unintended consequences, inappropriate medicalization, and more use of health care, especially when it happens in primary care settings **(Suleiman et al., 2023)**. Also, the creation of new antibiotics has slowed down a lot, which has made the growth of bacteria that are resistant to drugs a major public health issue.COVID-19 has made things worse by making people use antibiotics when they don't need to stop the spread of bacteria that are resistant to antibiotics, it is important to treat bacterial illnesses quickly and not use drugs too much **(Mahmoudi, 2020)**.

Chapter 9: Clinical management and guidelines:

9.1: Current clinical guidelines and recommendations for managing bacterial co-infections in COVID-19 patients

Antibiotics should be used carefully by people with COVID-19 because there are special rules for dealing with bacterial co-infections. In situations where COVID-19 pneumonia is thought to be the cause, antibiotic decisions should be made in line with institutional pneumonia management and procalcitonin guidelines while waiting for test results. Current standards say that patients with COVID-19 and likely bacterial co-infections should be cautiously treated with antibiotics. If cultures and tests show that no germs are to blame after 48 hours, the antibiotics can be stopped **(Egyir et al., 2020)**. The same procedures should be used to treat secondary respiratory infections as for healthcare-associated pneumonia and ventilator-associated pneumonia. People with COVID-19 who have signs of a bacterial lung infection are told to take antibiotics for five days after their symptoms get better. bigger prospective studies are needed right away to confirm these results and make sure antibiotics

aren't used too much during the pandemic. The goal is to give good care while keeping drug resistance and side effects to a minimum. The key to good management is for doctors to talk to each other, stick to established diagnostic methods, and teach patients **(Elsayed et al., 2021)**.

9.2: The importance of individualized treatment plans and the role of multidisciplinary teams

Individualized treatment plans are important in healthcare because they take each patient's medical history, current state, preferences, and possible risks into account. Because people are trying to stop the virus from spreading, people with chronic diseases aren't getting or are only getting some of the medicines and treatments they need. Due to the long-term nature of heart failure, patients need care and support that is constant and tailored to them. People who have less access to health care may be more likely to get sick or die as a result **(Daher Nashif, 2021)**. This method makes sure that each patient gets care that is right for them, which is better for their health and for their experience. In one of the papers, researchers look at how well online MDTs worked during the COVID-19 outbreak in 2009. Twenty-four clinicians and radiologists were asked what they thought about virtual MDTs, and their answers showed that they are seen as safe and effective options. AI workflows could be added to virtual MDTs, which would make them even more useful. Even though communication and security are issues, virtual MDTs offer benefits like coordinated conversations and picture viewing **(He et al., 2021)**. Teams of medical experts from many different fields work together to make comprehensive care plans. Their unique skill sets allow for more thorough treatment, better decision-making, and a fuller knowledge of complicated cases **(Gomes & Higginson, 2006)**. This leads to better patient outcomes and a more patient-centered approach to healthcare.

Chapter 10: Impact on Public Health

10.1: The broader implications of bacterial co-infections and secondary infections on public health systems

COVID-19 is one example of a viral respiratory illness that has become harder to treat because of bacterial co-infections and secondary bacterial infections **(Zhu et al., 2020)**. This is a big problem for public health systems. These problems can put a strain on healthcare

systems because they lead to longer hospital stays, more expensive treatments, and more patient tracking **(Sang et al., 2021)**. Antimicrobial resistance is a worldwide problem that is made worse by the wrong use of antibiotics. This can happen when bacteria co-infections are not treated well. Public health efforts must focus on the right ways to manage bacterial co-infections and secondary infections to keep antibiotics working for a variety of health conditions **(Langford et al., 2020)**. These are major risk factors for how bad respiratory viral infections like COVID-19 can be.

10.2: Strategies for preventing and controlling these infections to mitigate their impact

When you have a viral respiratory infection like COVID-19, there are many ways to avoid and treat bacterial infections and diseases caused by bacteria.

Vaccination Programs: Co-illnesses and secondary infections can be avoided by getting more people vaccinated against bacterial diseases that can be avoided, like influenza and pneumococcal. The vaccination program worked because there was strong leadership, teamwork between many groups, and a commitment to openness and fairness **(Islam et al., 2021)**. People in underserved areas were tried to reach, and the program's focus on ease and fairness made it possible for everyone to use. Lessons learned in areas like data use, local cooperation, and building trust can help improve health services like vaccines, screenings, and disease management **(Karaba et al., 2021).**

Hygiene and Infection Control: Viral and bacterial illnesses can be stopped in their tracks if hospitals and the general public follow strict rules about cleaning and preventing infections. Since stricter infection control measures were put in place **(Cusumano et al., 2020)**, both enveloped and non-enveloped viruses have decreased greatly and steadily. This is because the spread of respiratory viruses in hospitals has been cut down. Personal protective equipment (PPE), disinfection procedures, and daily hand washing are all part of this effort to stop the spread of disease.

Surveillance and Data Collection: To learn more about the effects of viral respiratory illnesses, it is important to set up surveillance systems to track how often people with these illnesses also have bacterial co-infections and get new infections. Better surveillance is important if you want to find cases and stop a pandemic from spreading **(Jeong et al., 2022)**.

This knowledge can be used to help public health programs and resources be more effective.

Patient Education: It is very important to let patients, medical workers, and the general public know about the possibility of co-infections and secondary infections caused by bacteria. Many studies have been done on different parts of the outbreak in many different areas of medicine **(Li et al., 2020)**. More than 100 manuscripts about COVID-19 have been sent to the journal Patient Education and Counseling (PEC). These manuscripts cover topics like the responses and behaviors of patients, families, and the general public, as well as suggestions and treatments for improving health communication about COVID-19 **(Díaz Santos et al., 2022)**. Spreading information about how to practice good hygiene, how to recognize the signs of a bacterial infection, and when and how to use antibiotics can help prevent and manage infections better.

By using these methods to prevent and control bacterial co-illnesses and secondary bacterial infections, public health services can help patients get better, save money on health care, and slow the spread of antibiotic resistance.

Future Directions and Research Gaps

Future research needs to be done on a large scale to find out more about the frequency, risk factors, and effects of bacterial co-infections with COVID-19. There needs to be a better way to tell the difference between viral and bacterial infections, better ways to treat them, and more knowledge about how they will affect survivors in the long run. It is important to characterize viral and bacterial strains and use the right preclinical models. Because of COVID-19, it's important to keep a close eye on how drug resistance changes **(Bengoechea & Bamford, 2020)**. Collaboration between different experts is needed for a comprehensive study that guides prevention, diagnosis, and treatment to improve patient outcomes and lessen the effect on public health as a whole. By understanding how co-infections affect global health during and after the pandemic **(Zhang & Shaw, 2020)**. We might learn more about how viruses and bacteria interact inside the host's nasal mucosa.

Targeted treatments have a lot of potential because they can be aimed at specific molecular targets, like key pathways or virulence factors that are involved in co-infections. To lower the risk of co-infections even more, preventive steps like better immunization techniques and infection control should be put in place. Due to how widespread the pandemic danger is, new

treatments, vaccines, and anti-viral drugs must be made as soon as possible **(Asmarawati et al., 2021)**.In the complicated COVID-19 landscape, strong clinical study is needed to figure out how to deal with and lessen the effects of bacterial co-infections.

Conclusion

In this review, it is pointed out how important bacterial co-infections and secondary infections are for COVID-19 patients because they make COVID-19 and its effects worse. The chance of developing bacterial co-infections or secondary infections varies depending on factors like age, underlying medical conditions, and the severity of the initial COVID-19 infection. It is crucial to highlight that not all COVID-19 patients will do so.

Factors like age, underlying medical conditions, and the severity of the initial COVID-19 infection. It is crucial to highlight that not all COVID-19 patients will do so. These supplementary infections can be severe and can need additional care, including. Antibiotics. In order to prevent these infections, one must practice proper hygiene, which includes routine hand washing, wearing masks to stop the spread of Covid-19, and receiving vaccinations when necessary. In addition, medical professionals should regularly monitor COVID-19 patients for indications of these illnesses and provide appropriate treatment as needed.

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