Quantum Mechanical Modeling of Perpetual Immunity to SARS-CoV-2 (COVID-19) Infection

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Abstract

Survivors of SARS-CoV-2 (Covid-19) infections have a unique immune response that allows them to either delay reinfection or outsmarts the virus's whims. The emergence of new SARS-CoV-2 variants and immunization have furthered this immune response by producing high-affinity anti-SARS-CoV-2 antibodies. There is limited data on the extent to which this immune response confers protective immunity against recurrent infections, as well as the duration of this protection. Here we present the first-ever quantum mechanical model to provide an answer to this question. The model is well applicable because of the 20 nm -500 nm size range of coronavirus. We call this model the 'Quantum Perturbation Model'. The model relates the strength of the COVID-19 attack to a wave function containing information about the system (person infected by the SARS-CoV-2) and quantized energy states, which shows the chances of reoccurrence of the disease. By applying the energy corrections provided by the Quantum Perturbation Theory to the SARS-CoV-2 attack under reinfections and various pre-existing conditions we have provided possible interpretations. When pre-existing problems exist at the time of SARS-COV-2 infection, the model illustrates how the influence of COVID-19 accumulates up. The model also formulates the deficit in the intensity of the COVID-19 effect in recurrence or in the presence of other variables strengthening the body's antibody affinity and immunity to resist the virus variants.

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ABSTRACT

Survivors of SARS-CoV-2 (Covid-19) infections have a unique immune response that allows them to either delay reinfection or outsmarts the virus's whims. The emergence of new SARS-CoV-2 variants and immunization have furthered this immune response by producing high-affinity anti-SARS-CoV-2 antibodies. There is limited data on the extent to which this immune response confers protective immunity against recurrent infections, as well as the duration of this protection. Here we present the first-ever quantum mechanical model to provide an answer to this question. The model is well applicable because of the 20 nm -500 nm size range of coronavirus. We call this model the 'Quantum Perturbation Model'. The model relates the strength of the COVID-19 attack to a wave function containing information about the system (person infected by the SARS-CoV-2) and quantized energy states, which shows the chances of reoccurrence of the disease. By applying the energy corrections provided by the Quantum Perturbation Theory to the SARS-CoV-2 attack under reinfections and various pre-existing conditions we have provided possible interpretations. When pre-existing problems exist at the time of SARS-COV-2 infection, the model illustrates how the influence of COVID-19 accumulates up. The model also formulates the deficit in the intensity of the COVID-19 effect in recurrence or in the presence of other variables strengthening the body's antibody affinity and immunity to resist the virus variants.

KEYWORDS: SARS-COV-2, immunity system response, quantum mechanical modeling, quantum perturbation theory,

INTRODUCTION

The outbreak of severe acute respiratory syndrome (SARS)-like coronavirus, SARS-CoV-2, around the globe has caused ripples and spurred researchers to take alternative strategies to deal with the new SARS-CoV-2 infection (Baric et al., 2020). With 169 million cases and 3.51 million deaths worldwide, the World Health Organization (WHO), the United States Centers for Disease Control and Prevention (CDC), and the European Center for Disease Prevention and Control (ECDC) have declared COVID-19 one of the deadliest pandemics in the modern human history (Baric 2020; Lv et al., 2020). SARS-CoV-2 causes COVID-19 when it enters the body through the nose, mouth, or eyes and finds its way to our cells through its surface spike protein (Pillalamarri et al. 2021). Its entry into host cells is a key factor in viral pathogenicity, infectivity, and immunity (Li et al., 2016). Once inside the cells, SARS-CoV-2 replicates itself utilizing host cellular machinery, producing virally encoded proteins that copy its viral genetic material and induce infection (Khan et al., 2020). When a cell is infected with viruses, it ruptures (Chatterjee et al., 2021). This causes the cell to die, and the virus particles can go on to infect more cells (Lv et al., 2020; Singhal et al., 2020; Shereen et al. 2020). The virus evades our immune system by changing over time, resulting in genetic mutations in the population of circulating viral strains that dampen our immune response (Li et al., 2021). Coughing or sneezing of a COVID-19 affected person is a leading cause of the spread of this virus and the disease. The infected person can spray droplets as far as 6 feet away during a cough or sneeze (Lv et al., 2020; Shereen et al. 2020). . The latest data on the COVID-19 indicates that only 17% of people infected with SARS-CoV-2 show no symptoms and these individuals are 42% less likely to transmit the virus (Byambasuren et al., 2020).

Despite the fact that SARS-CoV-2 has the ability to hijack our immune system, we must remember that our body's natural defenses are intended to develop efficient antibodies against a specific invader (Ullah et al., 2021; Vardhana et al., 2020; Yazdanpanah et al., 2020). Our immune system remembers how it dealt with pathogens previously (Yazdanpanah et al., 2020). When an individual is re-infected with the same pathogen, our immune system recognizes it and protects us (Gasteiger et al., 2017). In the case of SARS-CoV-2 infection, recovery does provide a degree of immunity, but there have been cases where the second infection was fatal (Bi et al., 2020; Parry et al., 2020). To date, there is no information available that anyone has been infected a third time, though the possibility may exist as circulation of variants such as B.1.1.7 or B.1.1.28 has been reported in several countries (Voloch et al., 2021; Sabino et al., 2021). In the event, if a third re-infection occurs and the patient recovers, it will aid in the building of long-term immunity, eventually leading to eternal immunity, based on our existing immunology understanding.

In multiple case study reports, researchers have discovered that pre-existing chronic conditions such as heart disease, cancer, or digestive diseases are reinforcing factors for SARS-CoV-2 and that a more severe viral attack is expected in such patients. In simple words, a person with a pre-existing condition like heart disease can be affected more by the COVID-19 (Sanyaolu et al., 2020; Zheng et al., 2020; Mao et al., 2020). Based on the reported data of 76993 patients, Emami *et al.* reported that cardiovascular diseases, hypertension, smoking, diabetes mellitus, chronic obstructive pulmonary disease (COPD), malignancy, and chronic kidney disease were among the most prevalent underlying diseases among hospitalized COVID-19 patients, respectively (Emami et al., 2020).

The SARS-CoV-2 infection can damage the heart in many ways. For example, the virus may directly attack and inflame the heart muscle, affecting blood flow and the supply of oxygen to the body part. COVID-19 seems to promote the development of cardiovascular disorders, such as myocardial injury, arrhythmias, acute coronary syndrome (ACS), and venous thromboembolism (Shi et al., 2020; Dai et al., 2020; Shi et al., 2020). Children with COVID-19 have also been reported to develop hyperinflammatory shock with features akin to Kawasaki disease, including cardiac dysfunction and coronary vessel abnormalities (Dai et al., 2020). Similarly, cancer patients are also at the forefront of risk from COVID-19 and have a disproportionately high death rate (Williamson et al., 2020; Sud et al., 2020; Tillett et al., 2021; Azam et al., 2020). Clearly, some of these factors relate to immune suppression and chemotherapy and hence we can say that COVID-19 could have a more severe effect on those who have pre-existing serious disorders.

Through case studies of several COVID-19 patients, researchers discovered that re-infection and recurrence of COVID-19 is possible in patients who survived the first COVID-19 attack. According to a recent study, those who had COVID 19 had an 84 % lower chance of reinfection and a 93 % reduced risk of symptomatic SARS-CoV-2 infection (Hall et al., 2021). Clinicians and researchers presented a case study on a range of patients and investigated SARS-COV-2 infection as well as the impact of COVID-19 on patients with various conditions. They reported eleven COVID-19 patients having experienced a second clinically- and virologically confirmed acute COVID-19 episode (Bonifacio et al., 2020; Gousseff et al., 2020). Several cases of recurrence have also been reported in other parts of the world (Jiang et al., 2020).

The purpose of this study is to develop a proper model based on the Quantum Perturbation Theory that provides information and a pathway to recurrence of COVID-19 under various conditions affecting the immunity and affinity of the body.

BACKGROUND AND SIGNIFICANCE

Keeping the severity of the COVID-19 attack in the presence of a pre-existing major disease and recurrence of the attack, it is important to model the effect of SARS-CoV-2 infection and its progress. Researchers have reported various aspects of COVID-19 attack, the severity of the developed infection, and the outcomes. However, a search is still going on to find a proper model explaining how the strength of COVID-19 infection is affected by pre-existing diseases and how the strength and chances of recurrence vary under various conditions and factors.

In this paper, we developed the first Quantum Mechanical Model based on Quantum Perturbation Theory. We call it the "Quantum Perturbation Model" to model COVID-19 infections and the immune response of the affected body. The model describes how the effect of COVID-19 adds up when pre-existing major diseases exist at the time of coronavirus attack. The model also formulizes the weakness in the strength of the COVID-19 effect in recurrence or in the presence of other factors boosting the affinity and immunity of the body to resist. This quantum perturbation model is uniquely significant because the model is well suited to formulize COVID-19 because of the 20 nm -500 nm size range of coronavirus, which is exactly matching with the quantum mechanical limits of explaining the phenomenon and outcomes that cannot be explained and solved by the traditional approaches. Many phenomena and effects like single-electron tunneling in a biological system, alpha decay, electrons tunneling in physical and biological systems, and behavior of neurons have been successfully modeled and explained when all other approaches have failed. We hypothesize that a microscopic cellular event must be viewed as a quantum entity (system) in the context that it is complex and confined in space and time. These cellular events rely on a limited (unlimited) number of molecules that are densely packed and can occur within a relatively short period, leaving them accessible to the possibility that quantum mechanical processes can play an important role in biological systems.

Another unique and significant outcome of this model is that any COVID-19 patient who shows a different path of variation in the Covid-19 effect (other than predicted and prescribed by this model) has either been suffering from another underlying disease which is not been diagnosed yet or has another affinity factor which is yet to be detected.

FUNDAMENTAL MECHANISM OF PERPETUAL IMMUNITY TO SARS-COV-2 INFECTION

Our immune system is very versatile, capable of fighting a wide range of infections and possessing a memory that allows for a robust response to previously encountered pathogens. When an antigen attacks our body, the immune system responds to it through cell-mediated immunity and antibody production. Because SARS-CoV-2 is a novel virus for humans, initially it causes an innate immune response that activates an elaborate signaling cascade using proteins called cytokines (Boechat et al., 2021; Vetter et al., 2020). Within a week or two of the cytokines' storm, the adaptive system becomes active that creates natural antibodies (IgM, IgD, and IgA). These antibodies interact with the virus and eventually kill or disable it (Sette et al., 2021). The innate immune response plays a vital role in B cell development, proliferation, and isotype switching (Viau et al., 2005). When B. lymphocytes bind to SARS-CoV-2, they divide and mature into identical cells. Millions of high-affinity SARS-CoV-2 specific antibodies are released into the bloodstream and lymphatic system by these mature memory B cells. As these SARS-CoV-2 driven antibodies circulate, they bind to SARS-CoV-2 virus particles and neutralize them by changing their chemical composition, preventing them from entering other cells. Concurrent interaction with new virus strains or booster vaccinations increases the affinity of these antibodies even further. We believe that this process of SARS-CoV-2-driven B cell activation is repeated several times in order to sustain the efficiency of the anti-SARS-CoV-2 antibodies, which could lead to what is known as "perpetual immunity." Various pre-existing diseases have been linked to an increased chance of dying from COVID 19, albeit not all comorbidities carry the same risk (Callender et al., 2020) . This mechanism of perpetual immunity development is shown in Figure 1.

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Figure 1. SARS-CoV-2 and perpetual immunity: A significant number of high-affinity antibodies are created, which outwit the virus.

QUANTUM PERTURBATION MODEL OF COVID-19 ATTACK AND IMMUNITY RESPONSE

Based on the published data regarding COVID-19 cases, a person who has recovered from a COVID-19 may be re-infected by the virus several times. However, the body's immunity system comes into play and develops resistance to the virus by producing high-affinity antibodies. When we have concurrent infections, our immune system adapts to the virus and produces a diverse repertoire of immunoglobulins (Ig) that have a higher affinity to take down the virus as described in Figure 1 (Gazumyan et al., 2012; Kumar et al., 2014). Furthermore, the strength of the body's immunity grows with additional factors such as vaccination and the number of times the virus infects. One of the most effective methods for predicting the strength and impact of SARS-CoV-2 attacks is to create a model and explain it in terms of some known parameters.

We have developed a model based on the Quantum Perturbation Theory. We call this model the 'Quantum Perturbation Model'. The model relates the strength of the COVID-19 attack to a wave function that contains information about the system (a person infected with SARS-CoV-2) and quantized energy levels that indicate the likelihood of illness recurrence.

Every measurable quantity is represented by an operator say and the state of a system are represented by a wave function ψ in Quantum Mechanics. When the operator operates on the wave function, it gives us the same wave function multiplied by certain numbers. The numbers are called *Eigen Values* and provide the measurable value of the parameter; one is interested to calculate. For example, the total energy operator is represented by Hamiltonian H. This operator operates on wave function ψ as given below (Griffith, 1994; Liboff, 2002).

$\mathbf{H\Psi = E\Psi}$ (1)

where E gives us the energy of the system.

When a quantum system perturbs the energy of the system also changes slightly. The change in energy depends upon the nature and strength of perturbation.

The rules and equations of Quantum Mechanics are applied to a system with size in nanometer (nm) or smaller. The size of coronavirus is from 20 nm up to as big as 500 nm (Williamson et al., 2020; Sud et al., 2020). This size range is very appropriate to be discovered and investigated by the laws and equations of Quantum Mechanics. Therefore, we have applied Quantum Perturbation Theory to the attack and effect of SARS-CoV-2 on humans.

Let the energy operator be given by Hamiltonian H of the Quantum Mechanical system is compatible to the full strength of the attack by coronavirus on a person then the energy eigenvalue E will give the effect of COVID-19 on the health of the person. Let us further assume that the first attack in full strength by coronavirus on a person is represented by an un-perturbed system then mathematically it can be expressed as (Griffith, 1994; Liboff, 2002; Reed, 2007),

$\mathbf{H_0\ \Psi_\nu{}^{(0)} = E_\nu{}^{(0)}\Psi_\nu{}^{(0)}}$ (2)

Where H_0 is the Hamiltonian (total strength of the coronavirus) and $\Psi_n{}^{(0)}$ is the unperturbed wave function of the system in its nth state. The energy of the unperturbed system is also called the zeroth-order correction to energy. Equation (2) gives the unperturbed zeroth-order correction in energy further simplified in equation (3).

$\mathbf{E_\nu{}^{(0)} = < \Psi_\nu{}^{(0)} — H_0 — n^{(0)} >}$ (3)

Then small perturbation is applied to find the approximate solution for the same system under a slight perturbation.

$\mathbf{H\ \Psi_\nu = E_\nu\ \Psi_\nu}$(4)

To see the effect of perturbation, we expand the Hamiltonian into a modified form,

$\mathbf{H = H\ 0 + \lambda H\ \pi}$ (5)

Where λ is a dimensionless parameter meant to keep track of the degree of "smallness". H_p is the perturbed Hamiltonian. When λ - 0, H_0 - H.

Incorporating equation (4) into equation (3), we get,

$\mathbf{(H\ 0 + \lambda H\ \pi)\ \Psi_\nu = E_\nu\Psi_\nu}$ (6)

We can easily the perturbed wave function in terms of the unperturbed wave function and the strength of perturbation λ. And the energy of the perturbed system in terms of the energy of the unperturbed system and λ. Therefore,

$\mathbf{\Psi_\nu = \Psi_\nu{}^{(0)} + \lambda\ \Psi_\nu{}^{(1)} + \lambda^2\Psi_\nu{}^{(2)} + \lambda^3\Psi_\nu{}^{(3)}}$ (7)

And $\mathbf{E_\nu = E_\nu{}^{(0)} + \lambda\ E_\nu{}^{(1)} + \lambda^2 E_\nu{}^{(2)} + \lambda^3 E_\nu{}^{(3)}}$ (8)

Putting equation (7) and equation (8) in equation (4) and collecting terms with the same exponent of λ, we can get variation or correction to the energy and wave function of the system.

$\mathbf{H}(\boldsymbol{\Psi}_{\vee} = \boldsymbol{\Psi}_{\vee}{}^{(0)} + \boldsymbol{\lambda}\ \boldsymbol{\Psi}_{\vee}{}^{(1)} + \boldsymbol{\lambda}^{2}\boldsymbol{\Psi}_{\vee}{}^{(2)} + \boldsymbol{\lambda}^{3}\boldsymbol{\Psi}_{\vee}{}^{(3)} \ldots) =$

$(\mathbf{E}_{\vee}{}^{(0)} + \boldsymbol{\lambda}\ \mathbf{E}_{\vee}{}^{(1)} + \boldsymbol{\lambda}^{2}\mathbf{E}_{\vee}{}^{(2)} + \boldsymbol{\lambda}^{3}\mathbf{E}_{\vee}{}^{(3)} \ldots)\ \boldsymbol{\Psi}_{\vee}(9)$

The first order and higher order variations or corrections to the wave function and to the energy are obtained, by solving equation (9) and analyzing the terms (Griffith, 1994; Liboff, 2002; Reed, 2007).

First Order correction to wave function:

$\boldsymbol{\Psi}_{\vee}{}^{(1)} = [?]\ \{< \boldsymbol{\Psi}_{\vee}{}^{(0)}\mathbf{.H}\ \boldsymbol{\pi}\mathbf{.}\boldsymbol{\Psi}_{\vartheta}{}^{(0)} > /\ (\ \mathbf{E}_{\vartheta}{}^{(0)} - \mathbf{E}_{\vee}{}^{(0)}\ )\ \}\ \boldsymbol{\Psi}_{\vee}{}^{(0)}\ (10)$

First Order energy correction:

$\mathbf{E}_{\vee}{}^{(1)} = < \boldsymbol{\Psi}_{\vee}{}^{(0)}\mathbf{.H}\ \boldsymbol{\pi}\mathbf{.}\boldsymbol{\Psi}_{\vee}{}^{(0)} > / < \boldsymbol{\Psi}_{\vee}{}^{(0)}\mathbf{.}\boldsymbol{\Psi}_{\vee}{}^{(0)}>\ (11)$

Second Order energy correction:

$\mathbf{E_n}^{(2)} = [?]\{—<\ _{\mathbf{n}}{}^{(0)}—\mathbf{H\ p}—_{\mathbf{j}}{}^{(0)}>—^{\mathbf{2}}\ /\ (\ \mathbf{E_j}^{(0)} - \mathbf{E_n}^{(0)}\ )\}\ (12)$

Similarly, we can obtain 3rd order, 4th order and high order corrections to the energy of the system.

It must be noted that the perturbation energies are very small as compared to the original total energy of the system. In addition, every higher-order perturbation contributes less energy as compared to the energy contribution by lower-order perturbation.

The size match of SRAS-CoV-2 with the range where quantum phenomena appear makes it possible to study various scenarios of COVID-19 using Quantum Perturbation Theory. In this work, the energy corrections provided by the Quantum Perturbation Theory are applied to the corona various attack under various conditions.

RESULTS AND DISCUSSION

To apply Quantum Perturbation Theory to a person affected by COVID-19, we consider the following cases.

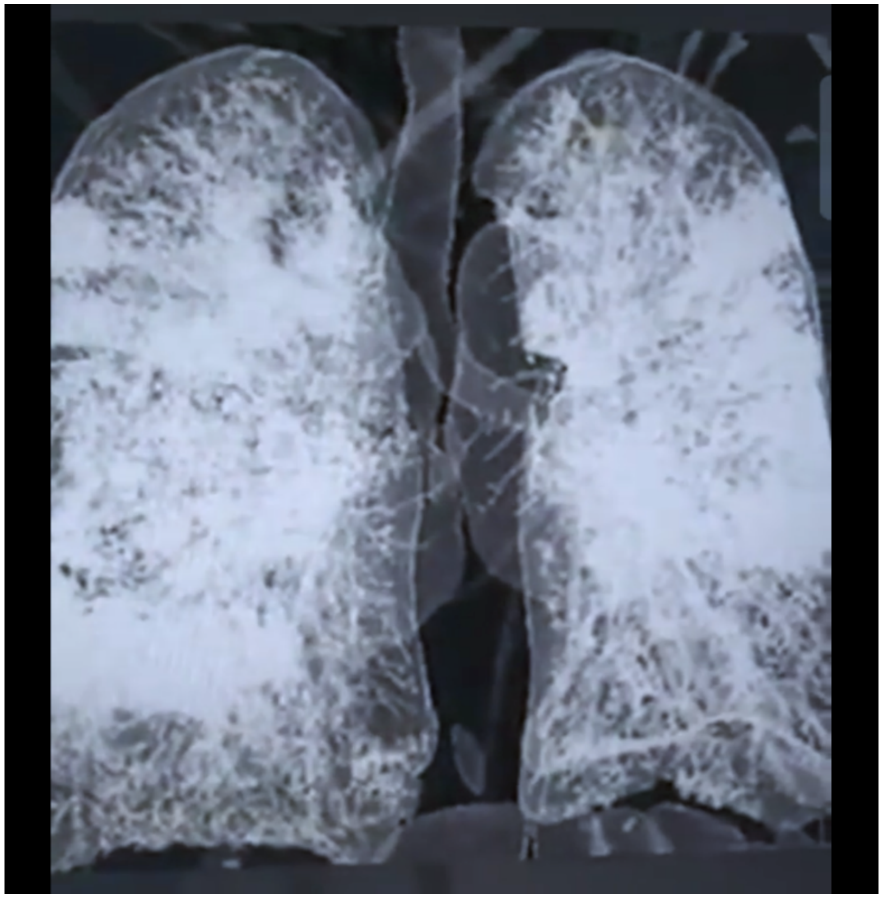
Case 1: SARS-CoV-2 attack on a healthy person.

Upon SARS-CoV-2 attacks on a healthy person with no pre-existing condition, the total strength of the virus attack on this healthy person is represented by the unperturbed Hamiltonian **H 0** and its maximum effect on the patient is given by the total energy, given by

$\mathbf{E}_{\vee}{}^{(0)} = < \boldsymbol{\Psi}_{\vee}{}^{(0)}\ —\mathbf{H_0}—\mathbf{n}^{(0)}>$

This equation shows that the energy is directly proportional to the Hamiltonian. It concludes that the stronger the viral attack on a healthy person, the sicker the person becomes and the longer the person remains a COVID-19 patient.

Figure 2 depicts a comparison of healthy lungs and lungs damaged by COVID-19 during its initial onslaught. The graphic, which is an x-ray imaging of a patient's lungs, depicts how COVID-19 affects and damages the lungs of a healthy individual.



(b)

Figure 2. Comparison of (a) healthy lungs, and (b) lungs affected by Covid-19 in its first attack.

Case 2: SARS-CoV-2 attack on a healthy person with pre-existing conditions.

If SARS-CoV-2 infects a person who has a pre-existing condition like heart disease or Asthma, it will make the person sicker and affect them more than if they did not have a pre-existing condition. Quantum Perturbation Theory describes that in this case, the total effect of COVID-19 on the person attacked by the virus will be the sum of unperturbed energy and the first-order correction of energy. Thus, mathematically

Strength of Covid-19 attack on a person with pre-existing disease$\mathbf{E} = \mathbf{E_n}^{(0)} + \mathbf{E_n}^{(1)}$

$\mathbf{E} = < \boldsymbol{\Psi_\nu}^{(0)}$ —$\mathbf{H_0}$—$\mathbf{n}^{(0)}> + < {}_{\mathbf{n}}{}^{(0)}$—$\mathbf{H\ p}$—${}_{\mathbf{n}}{}^{(0)} > / < {}_{\mathbf{n}}{}^{(0)}$—${}_{\mathbf{n}}{}^{(0)}>$ (13)

Similarly, if a person has two chronic conditions and is infected with coronavirus, the viral infectivity with the two pre-existing diseases will be,

$\mathbf{E} = \mathbf{E_n}^{(0)} + \mathbf{E_n}^{(1)} + \mathbf{E_n}^{(2)}$

Which gives,

$\mathbf{E} = < \boldsymbol{\Psi_\nu}^{(0)}$ —$\mathbf{H_0}$—$\mathbf{n}^{(0)}> + < {}_{\mathbf{n}}{}^{(0)}$—$\mathbf{H\ p}$—${}_{\mathbf{n}}{}^{(0)} > / < {}_{\mathbf{n}}{}^{(0)}$—${}_{\mathbf{n}}{}^{(0)}>$

$+$ [?] $\{$—$< {}_{\mathbf{n}}{}^{(0)}$—$\mathbf{H\ p}$—${}_{\mathbf{j}}{}^{(0)}>$—$^{\mathbf{2}} / (\mathbf{E_j}^{(0)} - \mathbf{E_n}^{(0)})\}$ (14)

Thus, the existence of any number of pre-existing diseases will increase the effect of COVID-19 infection and the extra risk is proportional to the order of perturbation.

An important point worth noting here is the fact that every higher-order perturbation contributes less energy than the lower-order perturbation. Each additional disease is represented by a higher order of perturbation. This results in a significant outcome that, if an individual is affected by the COVID-19 and has one pre-existing disease, then the effect is represented mathematically by the addition of first-order correction to the energy. Similarly, if another person has two existing diseases, then the effect of COVID-19 will be increased by the sum of first-order energy correction and second-order energy correction. Since second-order energy is less than the first order that means doubling the pre-existing disease in a person will not double the COVID-19 effect but the effect on the person will be less than double. This could be most probably attributed to the fact that in the presence of two pre-existing diseases as compared to one when coronavirus attacks then the immunity system of the person will be more active and will fight stronger. As a result, the COVID-19 effect will be less than double. The effect of COVID-19 on a healthy person and on patients with one or more pre-existing chronic diseases is given in Figure 3.

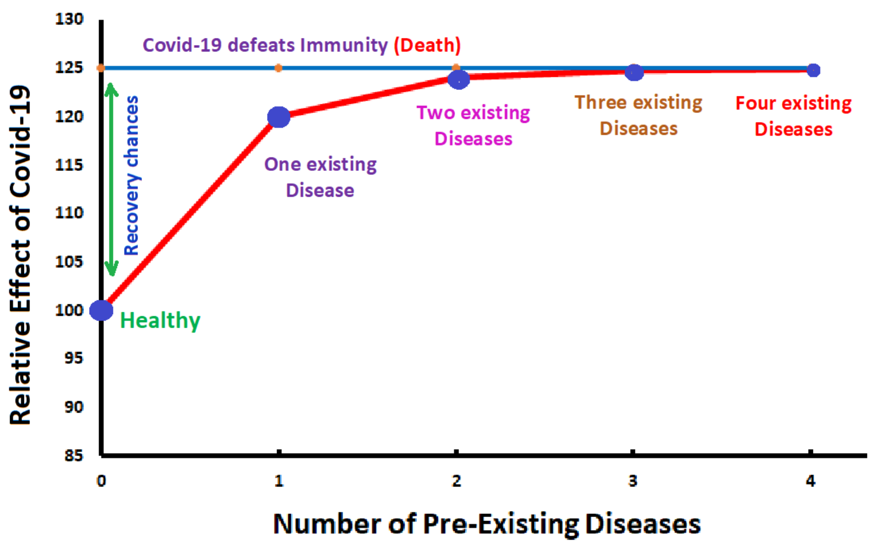


Figure 3. Increase in the chances of death by COVID-19 with pre-existing diseases.

Case 3: Role of age on the first-time effect of COVID-19.

It has also been reported and is widely accepted that people of old age are affected more severely by the COVID-19 as compared to the younger population. This situation is also modeled by the Quantum Perturbation theory. However, the reverse Quantum Perturbation effect applies to this scenario in which the unperturbed term represents the effect of COVID-19 on the old people above the age of 80. The first-order correction to energy term represents the next lower age population and so on. The lower effect of COVID-19 on young age people could be attributed to their immunity, which decreases in strength with age, keeping all other factors the same. Mathematically, the varying effect with age is given by the following equations.

The effect of COVID-19 on very old age people is represented by the unperturbed energy term$\mathbf{E_n}^{(0)}$. The effect on the next lower age group is modeled by the first-order energy correction term given as

$$\mathbf{E}_{\vee}{}^{(1)} = < \Psi_{\vee}{}^{(0)}{}_{.}\mathbf{H}\ \pi_{.}\Psi_{\vee}{}^{(0)} > / < \Psi_{\vee}{}^{(0)}{}_{.}\Psi_{\vee}{}^{(0)}>$$

The decreasing effect on the next lower ag population is given by the second-order energy correction term given below.

$\mathbf{E_n}^{(2)} = [?]$

$\{—< {}_{\mathbf{n}}^{(0)}—\mathbf{H\ p}—_{\mathbf{j}}^{(0)}>—^{2}\ /\ (\ \mathbf{E_j}^{(0)} - \mathbf{E_n}^{(0)}\ )\}$

Figure 4 represents the effect of COVID-19 on the increasing age of the affected population. Age effect has been observed in many case studies and is one of the leading causes of early vaccination of elderly people in the USA.

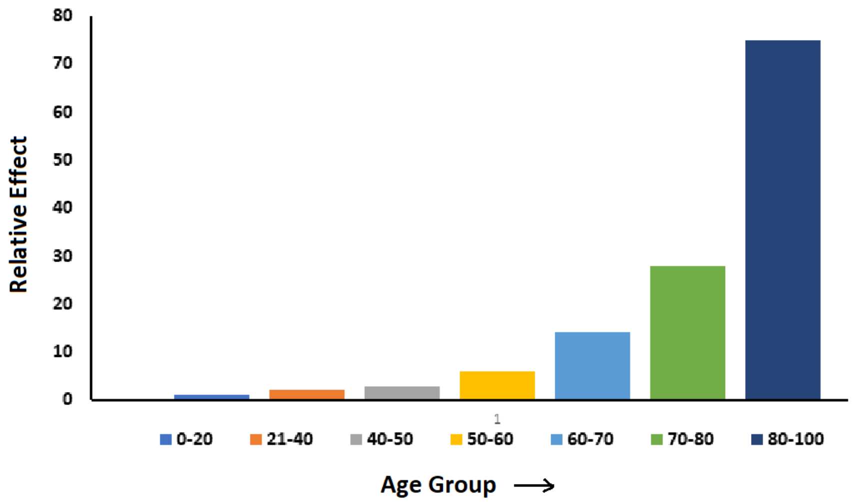


Figure 4. The effect of age of a patient on the severity of the impact of COVID-19 attack.

Case 4: SARS-CoV-2 attack on a vaccinated person for the first time or reinfecting a patient for the second time.

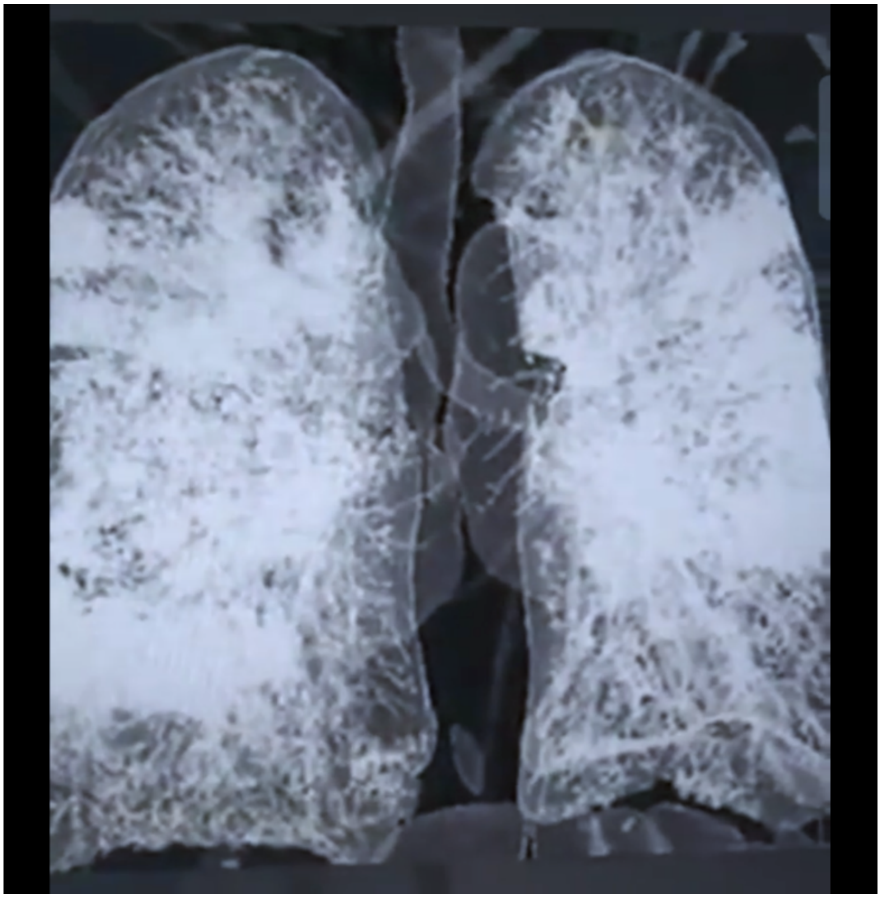
What would happen if a person has recovered from COVID-19 and received a vaccine against the virus? Another significant finding, according to Quantum Perturbation Theory, is a link between repeated COVID-19 attacks and immunity responses.

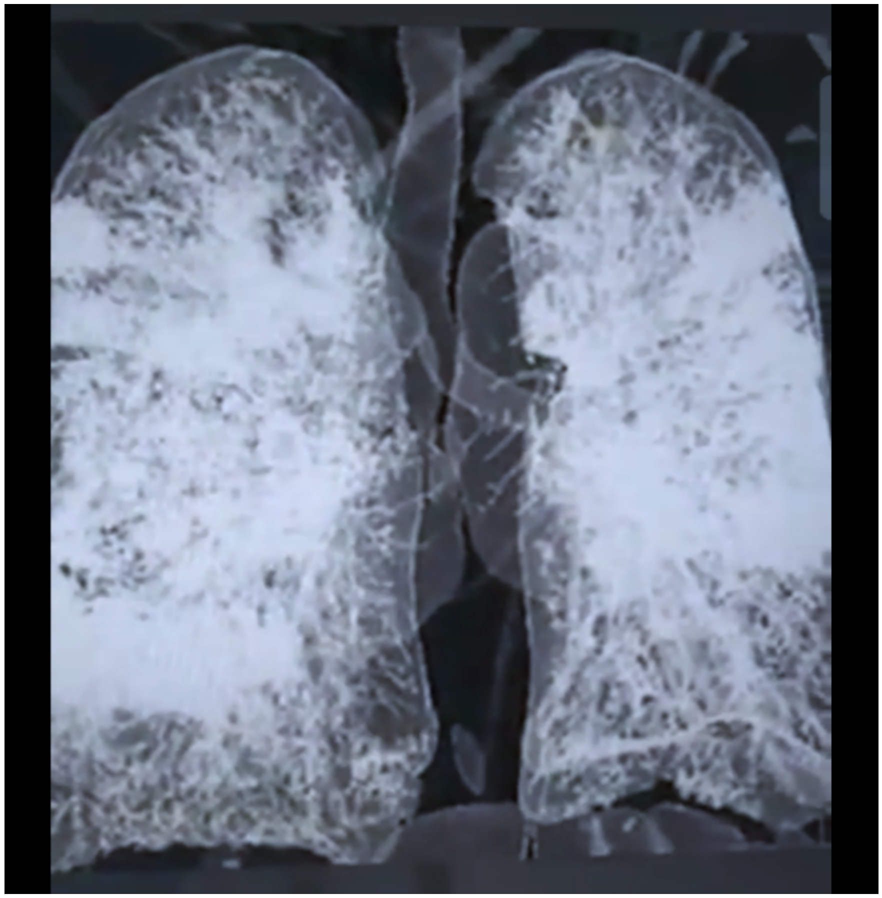
Assume that a person has recovered from the first attack of coronavirus and is suffering for a certain time from COVID-19. Quantum Perturbation Theory prescribes that this person can be affected by the COVID-19 again. However, this time the attack may not be as severe as the first time because the body has developed an affinity and the immunity system has got the strength and has already recognized the virus to resist strongly. The reduced effect of COVID-19 on this person is given by the first-order correction to the energy of the perturbed system. There would not be an unperturbed energy effect this time. Since the first-order correction to the energy is very small, therefore, the second attack on a person will be very weak as well and the person will recover soon. Mathematically, the effect of COVID-19 on a person being suffered the second time is given mathematically by,

Strength of second attack of COVID-19 attack on a person$\mathbf{E_n}^{(1)} = <\ \boldsymbol{\Psi}_{\nu}{}^{(0)}{}_{.}\mathbf{H}\ \ \pi_{.}\boldsymbol{\Psi}_{\nu}{}^{(0)}\ >\ /\ <\ \boldsymbol{\Psi}_{\nu}{}^{(0)}{}_{.}\boldsymbol{\Psi}_{\nu}{}^{(0)}>$

If a person got a vaccine against coronavirus, then this person can still be suffered from COVID-19. In this situation, like the above case of second attack, the effect of COVID-19 will be weak and is represented by the first-order correction to the energy$\mathbf{E_n}^{(1)} = <\ \boldsymbol{\Psi}_{\nu}{}^{(0)}{}_{.}\mathbf{H}\ \ \pi_{.}\boldsymbol{\Psi}_{\nu}{}^{(0)}\ >\ /\ <\ \boldsymbol{\Psi}_{\nu}{}^{(0)}{}_{.}\boldsymbol{\Psi}_{\nu}{}^{(0)}>$

Figure 5 shows how the effect of Covid-19 is tremendously reduced after vaccination.





(b)

Figure 5. Comparison of (a) Covid-19 effect on lungs of a non-vaccinated healthy person, to (b) the effect of Covid-19 on the lungs of a vaccinated person.

Case 5: SARS-CoV-2 second-time attack on a vaccinated person.

What would be the case of a person who has recovered from SARS-CoV-2 and got a vaccine against the virus? Quantum Perturbation Theory describes that it is still possible that the person may be affected by the SARS-CoV-2 again. However, this time the attack will be very weak, even weaker than the person described in case 3. Mathematically, the effect of SARS-CoV-2 on this person is given by the second-order correction to the energy of the perturbed system. Thus, the strength of coronavirus attack on a vaccinated person for the second time is given by,

$\mathbf{E_n}^{(2)}=$ [?] $\{—<{}_n^{(0)}—\mathbf{H\ p}—{}_j^{(0)}>—^{2}\ /\ (\ \mathbf{E_j}^{(0)} - \mathbf{E_n}^{(0)}\ )\}$

Since $En^{(2)} < \mathbf{E_n}^{(1)}$, therefore, the person will get better very quickly. This reduction in the COVID-19 attack could be attributed to the fact that the body has developed much higher affinity than the previous time and the immunity system has got even higher strength because of two factors: the vaccine and the second attack of SARS-CoV-2. Similarly, by adding any additional factor which can further boost the affinity and the resistance of the immunity system, the strength of coronavirus will further decrease and will be given by the very small 3rd order correction to the perturbed energy. Thus, Quantum Perturbation Theory suggests that multiple times suffering from SARS-CoV-2 is not impossible but every additional time or if any extra factor which boosts the body or organ affinity (like a vaccine) the strength of the attack will decline sharply.

Figure 6 provides a systematic decrease in the effect of SARS-CoV-2 in such circumstances.

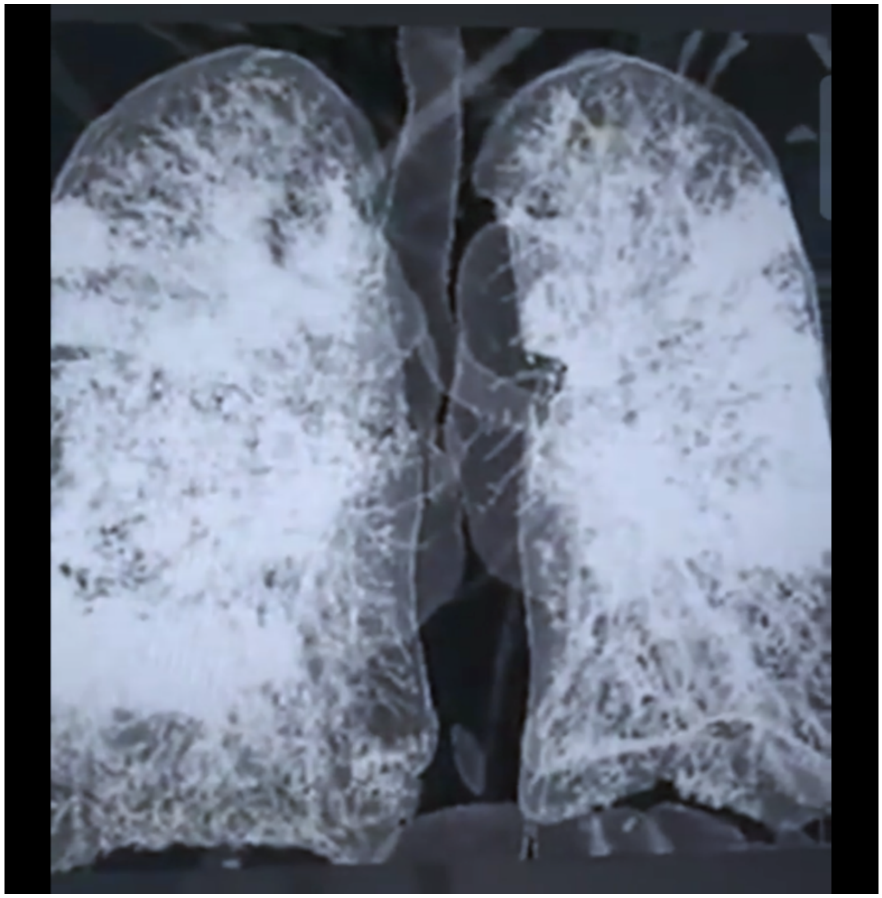


Figure 6. The role of affinity factors like vaccine and recurrence on the effect of SARS-CoV-2.

The present work provides a quantum mechanical approach to variations in the Covid-19 effect. Any person who shows a different path of variation in the Covid-19 effect has either got another underlying disease that is not diagnosed yet or has another affinity factor that is yet to be detected. It is also worth noting that we have not looked into the effect of a time interval between two attacks in the event of multiple SARS-CoV-2 attacks. In the present work, we have used time-independent quantum perturbation theory. To account for the time interval between two attacks, time-dependent quantum perturbation theory must be considered.

Another important fact and information this model provides is an approach to underlying disease, which is either not detected, or ignored during Covid-19 patients' studies. Assume that a patient reports one pre-existing disease when affected by Covid-19 then the first-order energy perturbation term should be applied to the patient. If it is found that the effect of Covid-19 is severe than this model predicts then that indicates that the patient has a second underlying disease as well which is either unreported or ignored. Therefore, the quantum perturbation model of Covid-19 can also predict a hidden underlying disease, which can affect the body's immunity to Covid-19.

CONCLUSION

To enter human cells, SARS-CoV-2 uses the angiotensin-converting enzyme 2 (ACE2) receptor. The virus replicates inside the cell by releasing its single-strand RNA genome into the cytoplasmic compartment. B cells initiate an early response by generating anti-SARS-CoV-2 specific IgA, IgG, and IgM antibodies.

The specificity of these antibodies increases with reinfection, immunization, and exposure to new variants. The antibody maturation cycle is repeated indefinitely, with each cycle producing new and higher affinity antibodies. When a larger number of people are re-infected or vaccinated and survive, herd immunity develops. Age and pre-existing conditions have an impact on this process as well. Being a new pandemic with very little understood, It is very important to put it in a standard model based on universal ideas and scope. Quantum Perturbation Theory is used in the present work to successfully model the effect of SARS-CoV-2 and its variation as a function of various factors. Images of Covid-19 patients at various stages are included. The Quantum Modelling provides a strong base and interprets mathematically why the effect of Covid-19 does not change linearly and follows exponential variation with each factor developing affinity against the virus. The Quantum Model will open a unique way of understanding the effect, prevention, and control of pandemic diseases.

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