Aud Vestib Res (2021);30(3):152-159.
DOI: https://doi.org/10.18502/avr.v30i3.6528

**REVIEW ARTICLE**

# Impact of COVID-19 on the auditory and vestibular system

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Received: 10 Mar 2021, Revised: 25 Apr 2021, Accepted: 8 May 2021, Published: 15 Jul 2021

## Abstract

**Background and Aim:** The COVID-19 has affected sensory organs in a different manner. This paper aimed to review the auditory-vestibular symptoms associated with COVID-19 and it also investigated the impacts of this pandemic on hearing-impaired community.

**Recent Findings:** The existing studies related to the effects of COVID-19 on the auditory-vestibular system were reviewed and discussed in order to achieve the overall image of COVID-19 on this system. Moreover, due to the adverse effects of using a mask on the communication function of hearing-impaired people, the effects of the mask on the communication process of hearing-impaired people were also reviewed.

**Conclusion:** COVID-19 may be accompanying with some auditory and vestibular dysfunctions. Although there are few findings in this area, they showed that the induced hearing loss is often sudden in nature and it is unclear that this situation is because of the ototoxicity of virus treated drugs or not. The vertigo induced by COVID-19 can be a direct invasion of the virus or an invasion by the immune system and its association with hearing loss and tinnitus must be identified, and appropriate referrals should be considered. On the other hand, due to the adverse effects of using personal protective equipment such as masks on the communication performance of hearing-impaired people, the necessary advice and guidance in this field are provided to the medical staff.

**Keywords:** COVID-19; hearing loss; hearing-impaired; vestibular dysfunction; mask

**Citation:** Amiri M, Hasanalifard M, Delphi M. Impact of COVID-19 on the auditory and vestibular system. Aud Vestib Res. 2021;30(3):152-9.

## Introduction

On January 6, 2020, a new mutation of the coronavirus named Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV-2) was reported in Wuhan, China, and on January 30, 2020, the World Health Organization (WHO) renamed the virus to the Coronavirus Disease 2019 (COVID-19) and introduced as an emergency priority worldwide. Within a few weeks after the introduction, this disease spread rapidly in more than 200 countries and was introduced as a pandemic, according to the WHO report [1]. The virus was accompanied by a range of symptoms such as high fever, dry cough, tiredness, shortness of breath [2], loss of smell [3], etc. In a range of studies, signs of peripheral and central nervous system (CNS) disorders such as cerebrovascular diseases, visual impairment, etc., have been reported in infected people [1].

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**Neurological manifestations of COVID-19**

The family of Coronaviridae can cause respiratory, intestinal, liver, and neurological diseases with varying degrees of severity in humans and animals. Although the most prominent COVID-19 symptoms are related to respiration, there is also evidence of neurological manifestations of the virus [4].

Neurological manifestations of COVID-19 have been reported as non-specific symptoms such as vertigo, headache, and impaired consciousness. There have been reports of more severe symptoms of acute cerebrovascular disease such as ataxia and seizure; even symptoms of the cranial nerves and peripheral nervous system, including taste, olfactory, visual disorders, and neurological pain, have been mentioned [5,6].

The SARS-CoV-2 effects on nerve tissue can result from direct infection of the CNS or vascular damage due to vasculitis or vasculopathy, which is similar to the mechanism described for Varicella Zoster Virus (VZV) and Human Immunodeficiency Virus (HIV) [7]. The latter can be confirmed by the evidence that COVID-19 patients show direct signs of coagulation [8].

Due to the damage caused by this virus on the peripheral and CNS predicting the peripheral and central auditory-vestibular system in this disease is not far from the mind. Therefore, in the present study, we will review the existing studies related to the effects of COVID-19 on the auditory-vestibular system. Moreover, during the COVID-19 pandemic, there are several ways to use personal protective equipment (PPE) to reduce the possibility of disease transmission and one of them is wearing masks. Decreased acoustic transmission, reduction or prevention of lip reading and using of facial expressions, are the most problems of wearing face masks. So, due to the adverse effects of using a mask on the communication function of hearing-impaired people, we will review the effects of the mask on the communication process of hearing-impaired people.

**COVID-19 and auditory system**

Studies show that multiple viral infections can cause damage to the auditory system and consequently hearing loss [9,10]. Hearing loss from viral infections can be congenital or acquired, unilateral or bilateral, and its severity can be mild, severe, or profound [11]. The pathophysiology of viral damage to the auditory system varies. Some viruses can directly damage the structures of the inner ear, including the organ of Corti (the location of auditory sensory receptors) and hair cells. Others cause inflammatory responses that hurt the structures of the ear. Some also increase the susceptibility to bacterial or fungal infections that lead to hearing loss, like HIV, which can weaken the immune system and cause bacterial and fungal infections, leading to hearing loss [12].

Virus-induced hearing loss is typical of the sensory-neural type and is caused by damaging the structures inside the cochlea (some viruses can also affect the auditory part of the brainstem). However, conductive hearing loss or mixed type may also occur following infections caused by certain viruses [9,10].

Primary coronaviruses such as SARS-COV-1 cause acute respiratory syndrome, and MERS-COV, the agent of Middle East Respiratory Syndrome, do not harm the auditory system (at least no cases have been reported so far) [1]. But it is not yet clear whether the new coronavirus, which causes COVID-19, affects the auditory system or not [13]. Several studies have been conducted in this field [1,13,14], and other studies are underway.

Recently has been suggested that the COVID-19 may cause damage to the organs of the inner ear, but it is unclear that in which cases, tinnitus can directly cause by SARS-CoV-2 or perhaps it is caused by stress and depression associated with the quarantine conditions and fear of disease [15].

Abdel Rhman and Abdel Wahid reported 52-year-old male with positive COVID-19 complained of sudden onset left-sided hearing loss by gradually worsening tinnitus. He had no history of head trauma or ototoxic medications during isolation. After Intra-tympanic injection of corticosteroid pure tone audiometry done that revealed improvement of hearing level [16].

A recent study published by Fidan, reported the first case of hearing loss. In this article a 35-year-

old woman with the history of otalgia and tinnitus referred to the clinic. Audiologic findings showed a conductive hearing loss in the right ear and B type in tympanogram. Radiological findings showed bilateral lung involvement in chest X-ray and positive PCR result which confirmed COVID-19 [1]. In Thailand, it has been reported that in 82 patients with COVID-19, only one elderly woman has developed hearing loss following COVID-19 infection and her hearing loss has not improved after the improvement of respiratory symptoms. There is probably a neurological disorder in her auditory system [17].

Another study was reported 20 people with COVID-19 who were between 20−50 years old and had no medical history of hearing problems before COVID-19. In this study, different auditory tests were conducted. Comparing the results of the auditory tests between corona virus group and the control group showed that patients' hearing abilities were impaired. The results of this study showed that COVID-19 infection damage cochlear hair cells, and also the absence of the main symptoms of infection with the virus (respiratory symptoms) does not necessarily mean the normal functioning of the cochlea. Pure tone thresholds at high frequencies and transient evoked otoacoustic emissions (TEOAEs) amplitude were significantly worse in patients. Outer hair cell damage was confirmed by a decrease in TEOAEs amplitude in patients compared with the control group [18].

In a study in Iran, six patients infected with COVID-19 with ages between 22−40 years old who had mild clinical symptoms including cough, fever, and respiratory disorders were evaluated. These patients had no previous reports of hearing or medical problems, but they developed hearing loss with COVID-19, and it has remained even after the disease had improved. Among these patients, four had tinnitus, two had dizziness, and all had mild to moderate hearing loss in one ear. Iranian researchers conclude that these otologic symptoms are most likely directly caused by the COVID-19. They claimed that many patients without previous auditory problems have suddenly reported hearing or balance problems in recent weeks [19].

The result of an autopsy study which was performed on several patients who died of COVID-19 showed that 2/3 of the patients had the genetic material SARS-CoV-2 in the middle ear and mastoid. According to autopsies, the substance is also found in the brainstem of dead people. The researchers claim that the neurological effects of SARS-CoV-2 may affect the auditory centers in the brain, such as the temporal lobe or brainstem [20].

According to the studies mentioned, hearing loss can occur in mild or asymptomatic cases of COVID-19. Brain imaging studies have also shown nervous damage in the temporal lobe and brainstem in COVID-19 patients. Some studies have suggested hypoxia (lack of adequate oxygen in the body's circulatory system) as a possible cause of hearing loss in patients with COVID-19 [20,21]. Because cochlear hair cells have high metabolic activity and are particularly prone to hypoxic or ischemic damage, this hypothesis is likely to be true [20].

Previous studies have provided little information on the relationship between COVID-19 and sudden hearing loss. The mechanism by which COVID-19 can cause hearing loss is not described. Recent evidence suggests that the COVID-19, similar to the SARS-CoV-2, interacts with the angiotensin-converting enzyme (ACE2) and can attack the cochleovestibular nerve and cochlear soft tissues [20].

According the studies COVID-19-induced hearing loss appears to occur suddenly and often in young people without any previous auditory problems [13,20].

Whether hearing loss is temporary or persists after treatment is unclear due to limited studies. If the new virus follows other viruses in this case, then the hearing loss caused by COVID-19 should not be permanent. It should be noted that most cases of sudden hearing loss are viral, and most patients are treated with steroids. Patients with mild degrees of hearing loss usually recover spontaneously without the need for special treatment [9,10].

**Ototoxicity and COVID-19**

The important point is to choose the proper

treatment strategy to maximize clinical recovery and minimize adverse effects. Corticosteroids play an essential role in the treatment of sudden hearing loss [20]. On the other hand, for infections caused by this new virus, like many other viral infections, the use of corticosteroids can increase the risk of infection and delay the patient's discharge [21].

In a study, audiologists found that most drugs used to treat COVID-19 are ototoxic. These include azithromycin, Remdesivir, favipiravir, chloroquine and lopinavir, all of which have been shown to cause hearing loss and tinnitus [22]. Azithromycin has been reported to cause both reversible and irreversible sensorineural hearing loss (SNHL) and tinnitus [23].

The characteristics of SNHL and tinnitus after chloroquine or hydroxychloroquine treatment can be temporary but reports of persistent auditory and vestibular dysfunction exist the dose of chloroquine for COVID-19 infection is considerably higher than the usual dosage for malaria [24].

Data in the literature report patients that used Remdesivir and favipiravir may develop irreversible unilateral or bilateral hearing loss and tinnitus, usually after a few weeks of administration [25,26].

The severity of the drug's ototoxicity depended on the dose and duration of their use and may appear weeks or months after administration [27]. Therefore, the use of new drugs combinations in the fight against coronavirus may have ototoxic effects.

**COVID-19 and vestibular system**

Vertigo is one of the symptoms described as a clinical manifestation of COVID-19. Numerous studies that are emerging daily from different parts of the world have shown vertigo as one of the main clinical manifestations of COVID-19 [7,19,28,29]. In some studies, dizziness is reported, not true vertigo. A study published in China found that vertigo is the most common neurological manifestation of COVID-19. Vertigo develops following the neuro-invasive potential of the SARS-COV-2. In this study of 214 patients with COVID-19, found more neurological symptoms than expected. About 36.4% of patients had some neurological symptoms, and these symptoms were more common in patients with severe infection (45.5%) [29]. In another study to evaluate the prevalence of tinnitus and vertigo in a sample of 185 patients with COVID-19 using an online 10-item questionnaire, it was found that 34 patients (18.4%), 20 women and 14 men, had balance disorders after COVID-19 diagnosis. Of these, 32 patients reported vertigo (94.1%), and two (5.9%) reported acute attacks of vertigo [7].

A study was performed in Iran on six patients with auditory and balance symptoms (without the usual symptoms of COVID-19). In this study, patients (age range 22 to 40 years) had no previous medical history and had not received any ototoxic drugs. Although they did not have COVID-19 symptoms, their PCR test was positive and showed only auditory and balance symptoms, so these otologic symptoms are more likely related to COVID-19 [19].

Baig et al. hypothesized that the virus enters the nervous tissue from the blood circulation and binds to the angiotensin-converting enzyme receptors in the capillary endothelium [30]. Furthermore, direct invasion, hypoxia, hyper coagulopathy, as well as invasion by the immune system are among the hypothesized mechanisms of neuronal attack leading to vertigo [31]. Although vertigo is a non-specific symptom of COVID-19, careful examination is required to determine whether the underlying cause is acute labyrinthitis, vestibular neuritis, acute otitis media, or stroke following COVID-19 [28]. Auditory changes and balance disorders can be related to vascular damage because the structures of the inner ear are sensitive to ischemia due to the characteristics of the terminal arteries and the need for high energy. Primary and secondary vasculitis is usually associated with auditory-vestibular symptoms. Primary cardiovascular disease can also cause symptoms of vertigo [7,32]. Several viral infections, such as hepatitis B and hepatitis C, can be associated with vasculitis, and published evidence suggests that vasculitis is a clinical manifestation in COVID-19 [7,33]. Additionally, benign paroxysmal positional vertigo has been reported in 19 patients

with COVID-19. It can be hypothesized that long-term hospitalization and bed rest may be responsible for the separation of otoliths [7].

One of the causes of vertigo in COVID-19 is vestibular neuritis, also known as vestibular neurolabyrinthitis or acute peripheral vestibulopathy; it is usually a benign, limited disease with vertigo, nausea, vomiting, and sometimes gait disorders. It is a viral or post-viral inflammatory disorder that affects the vestibular portion of the eighth cranial nerve [34]. According to Guan et al., the most common finding (83%) among patients with COVID-19-related neurological disorders is lymphocytopenia [2]. Interestingly, lymphocytopenia is associated with more severe symptoms of the central nervous system, including acute stroke, intracerebral hemorrhage, seizures, and encephalitis [29]. The neurotropic nature of the SARS-CoV-2 may produce a wide range of neuropathic effects and affect the neural plexus responsible for hearing and balance [19]. However, as notice in the previous sections, it should be noted that ototoxic drugs such as azithromycin, hydroxychloroquine, which are widely used for COVID-19, may also be effective in causing COVID-19-related hearing or balance disorders [19].

However, the reported prevalence of auditory-vestibular symptoms in COVID-19 patients is very low. It is not yet clear whether this indicates the rarity of these symptoms or whether researchers are focusing more on life-threatening symptoms.

It is emphasized that vertigo and dizziness should not be taken easily because these are of the most clinically significant manifestations among COVID-19 patients. In parallel, correlation with other auditory-vestibular manifestations such as hearing loss and tinnitus should be identified. After treatment of persistent vertigo caused by COVID-19, it is necessary to refer to the Ear Nose and Throat Department for a detailed examination. Besides, vestibular rehabilitation therapy, which has shown promising results, is recommended for patients with COVID-19 with persistent vertigo [28].

## COVID-19 and hearing-impaired people

### *Hearing loss and clinical challenges during COVID-19 pandemic*

COVID-19 has created many challenges in health care centers in all countries of the world. During quarantine in most countries, most elective surgeries and outpatient consultations were canceled. Meanwhile, patients with neurotological disorders faced difficulties in accessing appropriate medical services. According to the British Society of Otology, most ear surgeries (except emergencies) were delayed until the end of the pandemic. Moreover, quarantine has had side effects on mental health, and symptoms such as stress, anxiety, depression, insomnia, etc. have been reported in many people. In this disturbing scenario, it is very important to pay attention to people with disabilities such as hearing-impaired people [35].

Currently, in the United States, 14.1% of people over the age of 18 (approximately 27.7 million) have hearing loss [36]. Since hearing loss is currently reported in 72.4% of people over 65 years old and due to the high number of hospitalized elderly people during the pandemic, attention to this group of people is very important [37].

During the COVID-19 pandemic, there are several ways to use PPE to reduce the possibility of disease transmission, such as a mask, keep a physical distance, avoiding crowds, working from home, washing hands frequently, and avoiding contact with hands. On the other hand, in medical centers, the patient cannot be accompanied by his companions in departments such as the ICU, and therefore it is said that the use of masks has reduced clear empathetic communication in patients [38].

### *Impacts of face masking on hearing-impaired communication*

One of the most important problems for hearing-impaired people during the COVID-19 pandemic is the adverse effects of using masks on their communication performance, especially in medical centers and public places [38,39]. As mentioned earlier, in most hospitals, it is not possible to accompany the families of hearing-impaired people with them, and this has negative effects

on patient safety, health care quality, and speech perception, thus reducing the communication performance of hearing-impaired people [36]. Among the most important causes of inadequate and inappropriate communication of hearing-impaired people in such cases are the following:

1) Decreased acoustic transmission as a result of distortion in speech or reduced speech intensity. It has recently been shown that different types of masks can act as a low-pass filter and reduce the high-frequency content (2 to 7 kHz) of the speaker's speech. It has been found that in medical masks, a decrease of about 3 to 4 dB occurs, and in filtered masks such as the N95 mask, a decrease of about 12 dB occurs in the speaker intensity [38]. As a result, both hearing loss and mask reduce the high-frequency content of speech stimuli and reduce speech clarity in hearing-impaired people. This problem, especially with the addition of background noise, aggravates the communication problems of hearing-impaired people and even, in some cases, makes communication impossible [38].

2) Reduce or prevent lip reading and use of facial expressions

3) Unpleasant feeling of simultaneous use of masks and hearing aids or cochlear implants. In a study in Italy, 59 hearing-impaired people with an average age of 60 years old were asked to rate the degree and severity of their communication problems when going to medical and emergency centers as non-problematic, mild, moderate, and severe. Of these, 13.6% reported no problems, and the rest reported mild (24.5%), moderate (37.3%), and severe (23.7%) problems [35].

*Impacts of social distancing on hearing-impaired communication*

Another health care strategy in the COVID-19 pandemic is social distancing. It is also having important effects on the audibility of the speech stimulus. As we know, as the distance from the sound source increases, the sound intensity is reduced. Based on the logarithmic scale of decibels, sound with an intensity equal to half the intensity of the output source is equivalent to a decrease of about 3 dB or more. According to the inverse square law, as the distance doubles, the intensity decreases by a quarter of its original volume. So, if the distance is doubled, a decrease in sound intensity of about 6 dB occurs. If the normal distance between two people during conversations is 1.5 to 3 feet, by social distancing, which emphasizes a distance of at least 6 feet between two people (it means two or even four times the distance compared to normal), the level of sound pressure is reduced about 6 to 12 dB. This will certainly not have good consequences for hearing impaired people [36].

Furthermore, in most medical centers, such as hospitals, due to the high background noise (this noise is due to various devices in the wards as well as due to loud speaking and it is usually around 65 dB SPL) and high level of reverberations due to surfaces, communication becomes more difficult for both the hearing-impaired patient and the staff. This can be a problem, especially in cases where medical staff have hearing problems or the patient is very old [35,36].

Therefore, to ensure effective empathetic communication, medical staff can use the following strategies when dealing with hearing-impaired people [35,36,39].

- Reduce background noise
- Get the patient's attention
- Ask the patient about the communication method used by him
- Make sure the hearing impaired people use their hearing aid
- Speaking louder and somewhat slower
- Rephrase statements instead of repeating similar words, shouting, pronouncing words thicker, etc.
- Take turns when speaking
- Optimize positioning (for example, talking face to face, not walking while talking, etc.)
- Use of low-tech methods (such as using paper and pen or clear partitions)
- Using high-tech methods (such as using Wi-Fi-enabled tablets or video chat apps on smartphones)
- Use of video conferencing platforms (such as telemedicine, unmasked, without PPE)
- Use clear masks or masks with a transparent part on the front of the lips to improve

visibility and symptoms related to facial expression and lip-reading)
- Use personal sound amplification products
- Use loaner hearing aids or FM systems along with a microphone lanyard
- Use scribes or professional to help hearing-impaired staff

Using masks with a plastic panel around the lips is probably one of the least expensive ways to communicate in these cases [35,36,39]. However, medical staff should be fully aware of the communication strategies with hearing impaired people during the COVID-19 pandemic to provide the best services to this group [37,38]. Also, parents of hearing-impaired children must be encouraged and motivated to use the online rehabilitation classes instead of face-to-face ones. So, they must inform that during the pandemic, the rehabilitation programs become more family-based and they must aware of the online programs availability and use them [39].

## Conclusion

COVID-19 may be accompanying with some auditory and vestibular dysfunctions. Although there are few findings in this area, but the results showed that COVID-19 may suddenly cause hearing loss in young people without any previous auditory problems and due to the small number of studies available in the field of hearing loss and COVID-19, it is unclear that this situation is because of the ototoxicity of virus treated drugs or not and whether the development of hearing loss is temporary or persists after treatment. Given that most cases of sudden hearing loss are viral and most patients are treated with steroids, it seems that patients with mild hearing loss usually recover spontaneously without the need for special treatment. Other manifestations associated with COVID-19 is vertigo. The origin and causes of vertigo can be a direct invasion of the virus, hypoxia, vestibular neuritis, or an invasion by the immune system. COVID-19 induced vertigo should be taken seriously, and its association with other auditory-vestibular manifestations such as hearing loss and tinnitus must be identified, and appropriate referrals to an otolaryngologist and audiologist should be considered for these patients. On the other hand, due to the adverse effects of using personal protective equipment such as masks on the communication performance of hearing-impaired people, it is recommended that the necessary advice and guidance in this field are provided to the medical staff.

## Conflict of interest

The authors declared no conflicts of interest.

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