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REVIEW ARTICLE

# Hearing loss and COVID-19: an umbrella review

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## Abstract

**Introduction** COVID-19 can result in an extensive range of extrapulmonary, and neurological signs and symptoms such as olfactory and/or taste dysfunction, and otologic symptoms. The aim of this study was to investigate the hearing loss manifestation from COVID-19.

**Methods** The goal of this umbrella review was to examine hearing loss associated with COVID-19 disease. English literature published until October 15, 2022 in online databases including PubMed, Scopus, Web of Science, and Embase was considered for this purpose. Eligibility of the articles for subsequent data extraction was evaluated in a two-step selection process with consideration to an inclusion/exclusion criterion. This review followed the PRISMA protocol and the Amstar-2 checklist for quality assessment.

**Results** A total of four treatment strategies were used by different studies which included oral corticosteroids, intratympanic corticosteroids, combined oral and intratympanic corticosteroids, and hyperbaric oxygen therapy. Five studies investigated corticosteroid use in the forms of oral or intratympanic injection; four studies reported (complete or partial) hearing improvements after steroid treatment, while one study stated no significant improvement in hearing function. One study reported that oral corticosteroid monotherapy alone was not effective, while vestibular symptoms were ameliorated by a combination of oral prednisone, intratympanic dexamethasone injection, and hydroxychloroquine.

**Conclusion** The findings suggest that despite being one of the rare complications of COVID-19, hearing loss can impact a patient's quality of life. The most common type reported was sensorineural hearing loss, which can be diagnosed with variable techniques.

**Keywords** COVID-19 · SARS-CoV-2 · Auditory defect · Hearing damage · Hearing defect · Hearing loss

## Introduction

Severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), the cause of novel coronavirus disease-2019 (COVID-19), first emerged in Wuhan, China in late 2019. On March 11th, 2020, the World Health Organization (WHO) declared a global COVID-19 pandemic. As of 15th November 2022, SARS-CoV-2 has infected more than 630 million people and claimed the lives of almost 6.6 million patients [1–4]. COVID-19 presents with a wide range of manifestations ranging from being completely asymptomatic to acute respiratory distress syndrome (ARDS) and eventual death. Among the symptomatic cases, the main presentations include flu-like symptoms such as fever, chills, dry cough, dyspnea, fatigue, myalgia, headache, sore throat, and rhinorrhea [5].

COVID-19 can result in an extensive range of extrapulmonary, and neurological signs and symptoms such as olfactory and/or taste dysfunction (anosmia (loss of smell), ageusia (loss of taste), and dysgeusia (bad taste)), otologic symptoms, dizziness, facial nerve palsy, and long-term neurological complications [6–9]. In addition, a meta-analysis of 145,721 COVID-19 patients reported 41 different neurologic manifestations, with a pooled prevalence of fatigue, myalgia, taste impairment, smell impairment and headache being 32%, 20%, 21%, 19%, and 13%, respectively [10].

It has been shown that the angiotensin-converting enzyme 2 (ACE2) is the main functional receptor for SARS-CoV-2

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and can be found in various body tissues including the gut, blood vessels, heart, lung, brain, testis, and kidneys [11, 12]. In the nervous system, glial cells and neurons commonly express ACE2 which can be a potential target for SARS-CoV-2, and through this receptor the virus can directly or indirectly damage the nervous system [13].Previous studies have implicated viral infections, as a potential cause for both congenital and acquired hearing loss with sensorineural hearing loss being the most prevalent form. However, conductive hearing loss and mixed hearing loss have also been recorded. Viral-caused hearing loss pathogenesis is diverse and has been interpreted as direct inner ear injury due to immune-mediated damage [14]. In addition, since the beginning of the pandemic, many studies have described otologic symptoms including hearing loss, vertigo, and tinnitus among COVID-19 patients, and previous systematic reviews have explored this topic [15, 16]. In addition, in regard to audio-vestibular neurologic symptoms, a meta-analysis of 350 articles by Misra et al. found that the pooled prevalence of hearing impairment and tinnitus among COVID-19 patients was 3% and 5%, respectively [10]. Therefore, in this article, we aimed to conduct an umbrella review on COVID-19 infection and otologic manifestations including sensorineural hearing loss, conductive hearing loss, and mixed hearing loss to broaden our knowledge of their prevalence, treatment, and outcomes among COVID-19 patients.

## Methods

For this umbrella review, we focus on currently available systematic review literature investigating hearing loss occurrence in the course of COVID-19 disease. To substantiate the outcomes, this study adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist. Furthermore, methodological quality was assessed by the Amstar-2 quality assessment checklist.

### Data sources

The electronic databases used to conduct the online searches using the defined keywords included PubMed, Scopus, Web of Science, and Embase. The database search was conducted on October 15, 2022. With the purpose to identify all pertinent literature the below keywords and their plentiful combinations were used:

A. “COVID-19” OR “SARS-CoV-2” OR “Coronavirus disease 2019” OR “severe acute respiratory syndrome coronavirus 2” [Title/Abstract]
B. “Auditory defect” OR “Hearing damage” OR “Hearing defect” OR “Hearing difficulty” OR “Hearing loss” OR “Impaired hearing” OR “Hypoacusis” OR “Hearing impairment” OR “Transitory deafness” [Title/Abstract]
C. “Systematic review” [Title/ Abstract]
D. [A] AND [B] AND [C]

### Study selection

A two-step process was performed for the screening and selection of appropriate articles. First, titles and abstracts of the articles were examined for relevance in our study. Two researchers implemented this step. Second, three researchers diligently evaluated the full texts of potentially eligible publications. The inclusion and exclusion criteria for the articles are below.

Inclusion criteria: English language, systematic review, and peer reviewed prior to acceptance for publication.

Exclusion criteria: Non-human research experiments, duplicated articles, abstracts with inaccessible full texts, conference abstracts, and letters to editors.

### Data extraction

Systematic review publications fulfilling the study eligibility criteria were advanced to data extraction. Data of interest consisted of first author’s ID, publication year, searched databases and number of included papers in each publication, methods of auditory system evaluation, total number of COVID-19 patients and patients suffering from simultaneous hearing loss, type of hearing loss, and main findings in each study. This step was executed by three researchers. Throughout the data extraction process, other researchers additionally checked the selected articles/ extracted data, duplicates and possible overlaps.

### Quality and risk of bias assessment

To critically appraise the included systematic review studies, we utilized the A MeaSurement Tool to Assess Systematic Reviews 2 (AMSTAR-2). This quality assessment tool applies 16 items to individual studies. These items are visible at the bottom of the table.

## Results

### Search and selection of studies

A total of 74 papers were retrieved from the initial search strategy. After the first review of papers, 42 duplicates were identified and removed, and the titles and abstracts of the remaining 32 articles were reviewed by two independent researchers, leading to the extraction of 15 studies for full-text assessment. Next, the remaining studies were evaluated

in the full-text screening step by applying the eligibility criteria, and finally, 11 studies met the inclusion criteria and were included in the final review (Fig. 1).

## Characteristics of the included studies

Table 1 shows the quality and risk of bias assessment results of the included studies. Among the 11 eligible studies, 8 studies were systematic reviews while the remaining three studies had additional quantitative synthesis and were meta-analyses. The PubMed database was searched by all included studies ($n=11$). Moreover, the next most common databases used were: Google Scholar ($n=6$), Embase ($n=5$), Scopus ($n=5$), Web of Science ($n=4$), and Cochrane ($n=3$). Three included reviews were conducted in Italy, two in India, while the following countries each had one involved paper; UK, Canada, South Africa, Iran, USA, and China. In total, 272 articles were included in these reviews, and the number of enrolled studies of the included reviews ranged between 5 and 102 articles. A total of 116,212 COVID-19 patients were investigated in all 11 studies, and 1,064 cases of hearing loss of all three types were reported. Seven studies specified the hearing loss types, with the most common type being sensorineural hearing loss which was mentioned by six studies (132 cases), followed by conductive hearing loss which was noted by four studies (21 cases), and mixed hearing loss that was enumerated in two articles (three cases). The prevalence rate of hearing loss was reported by three studies which ranged between 0.2% and 7.6% [15, 17, 18]. Yadav et al., in their study of more than 100,000 COVID-19 patients stated that hearing loss was the least prevalent otolaryngological finding [18]. Maharaj et al., in their study of 28 COVID-19-associated hearing loss cases stated that SARS-CoV-2 would result in middle ear infections most probably through the virus spreading into the middle ear and associated neural structures, thus causing sensorineural hearing loss [16].

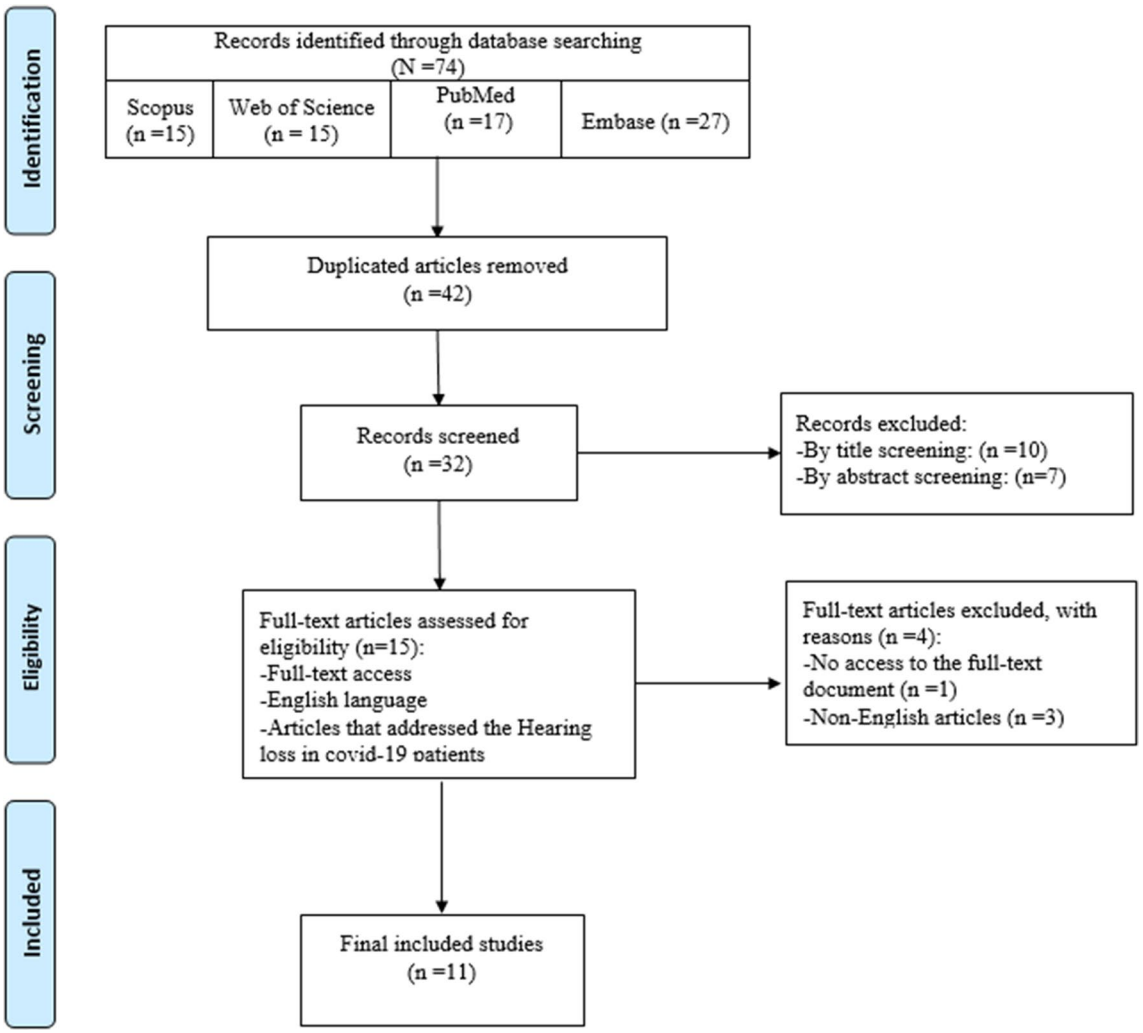


**Fig. 1** PRISMA flow diagram of study retrieval process

**Table 1** Quality assessment of included studies based on AMSTAR-2 critical appraisal tool for systematic reviews

| Articles | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Printza et al | No | No | Yes | Yes | No | No | Partial Yes | Partial Yes | No | No | No meta-analysis conducted | No meta-analysis conducted | No | No | No meta-analysis conducted | No |
| Boscutti et al | Yes | Partial Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | No meta-analysis conducted | No meta-analysis conducted | Yes | Yes | No meta-analysis conducted | No |
| da Costa et al | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | No meta-analysis conducted | No meta-analysis conducted | Yes | Yes | No meta-analysis conducted | No |
| Jafar et al | No | Yes | Yes | Partial Yes | Yes | Yes | Yes | Yes | Yes | No | No meta-analysis conducted | No meta-analysis conducted | Yes | Yes | No meta-analysis conducted | No |
| Utomo et al | Yes | Yes | Yes | Partial Yes | Yes | Yes | Yes | Yes | Yes | No | No meta-analysis conducted | No meta-analysis conducted | Yes | Yes | No meta-analysis conducted | No |
| Mohammadi et al | No | Yes | Yes | Partial Yes | Yes | Yes | Partial Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | No | No |
| Manca et al | Yes | No | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | No meta-analysis conducted | No meta-analysis conducted | No | Yes | No meta-analysis conducted | No |
| Hwa Kim et al | Yes | No | Yes | Yes | Yes | Yes | Yes | Yes | No | No | Yes | No | No | Yes | No | No |
| Jing-Wen Tan et al | Yes | Yes | Yes | Yes | Yes | Yes | Partial Yes | Yes | Yes | No | Yes | No | No | Yes | No | No |
| Keshavarz et al | No | No | Yes | Yes | Yes | Yes | Partial Yes | Yes | No | No | No meta-analysis conducted | No meta-analysis conducted | No | Yes | No meta-analysis conducted | No |
| Beigi-khoozani et al | No | No | Yes | Partial Yes | No | Yes | Partial Yes | Partial Yes | No | No | No meta-analysis conducted | No meta-analysis conducted | No | Yes | No meta-analysis conducted | No |
| Najt et al | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | No meta-analysis conducted | No meta-analysis conducted | No | Yes | No meta-analysis conducted | No |
| Addison et al | Yes | No | Yes | Yes | No | No | Partial Yes | Yes | Yes | No | No meta-analysis conducted | No meta-analysis conducted | No | No | No meta-analysis conducted | No |
| O'Byrne et al | Yes | Partial Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | No meta-analysis conducted | No meta-analysis conducted | Yes | No | Yes | No |
| Hyun Kim et al | Yes | Yes | Yes | Yes | Yes | Yes | Partial Yes | Yes | Yes | Yes | Yes | No | No | Yes | No | No |
| Feng et al | Yes | No | Yes | Partial Yes | Yes | Yes | Yes | Yes | Yes | Yes | No meta-analysis conducted | No meta-analysis conducted | Yes | Yes | No meta-analysis conducted | No |
| Xavier-Santos et al | Yes | No | Yes | Yes | Yes | No | No | Yes | No | Yes | No meta-analysis conducted | No meta-analysis conducted | No | Yes | No meta-analysis conducted | No |
| Helman et al | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | No meta-analysis conducted | No meta-analysis conducted | Yes | Yes | No meta-analysis conducted | No |
| Zeng et al | No | Yes | Yes | Partial Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | No |
| De Luca et al | No | No | No | Yes | Yes | Yes | Yes | Yes | No | No | No meta-analysis conducted | No meta-analysis conducted | No | Yes | No meta-analysis conducted | No |

**Table 1** (continued)

| Articles | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Van Kessel et al | No | No | No | Partial Yes | Yes | Yes | Yes | Yes | Yes | No | No meta-analysis conducted | No meta-analysis conducted | No | Yes | No meta-analysis conducted | No |
| Salamanna et al | Yes | No | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No meta-analysis conducted | No meta-analysis conducted | Yes | Yes | No meta-analysis conducted | No |
| Willi et al | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No meta-analysis conducted | No meta-analysis conducted | Yes | Yes | No meta-analysis conducted | No |

Items of quality assessment by AMSTAR-2 tool:

[1]Did the research questions and inclusion criteria for the review include the components of PICO?

[2]Did the report of the review contain an explicit statement that the review methods were established prior to conduct of the review and did the report justify any significant deviations from the protocol?

[3]Did the review authors explain their selection of the study designs for inclusion in the review?

[4]Did the review authors use a comprehensive literature search strategy?

[5]Did the review authors perform study selection in duplicate?

[6]Did the review authors perform data extraction in duplicate?

[7]Did the review authors provide a list of excluded studies and justify the exclusions?

[8]Did the review authors describe the included studies in adequate detail?

[9]Did the review authors use a satisfactory technique for assessing the risk of bias (RoB) in individual studies that were included in the review?

[10]Did the review authors report on the sources of funding for the studies included in the review?

[11]If meta-analysis was justified did the review authors use appropriate methods for statistical combination of results?

[12]If meta-analysis was performed did the review authors assess the potential impact of RoB in individual studies on the results of the meta-analysis or other evidence synthesis?

[13]Did the review authors account for RoB in individual studies when interpreting/ discussing the results of the review?

[14]Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review? If they performed quantitative synthesis did the review authors carry out an adequate investigation of publication bias (small study bias) and discuss its likely impact on the results of the review?

[15]Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?

### Audiological evaluation methods

Generally, 13 types of audiological evaluation methods were utilized to evaluate auditory function among subjects, and 10 studies specified their applied tests. These tests were as follows: pure tone audiometry ($n=6$), otoacoustic emissions ($n=6$), tuning fork tests ($n=2$), hearing handicap inventory ($n=2$), tinnitus handicap inventory ($n=2$), auditory brainstem response ($n=2$), dizziness handicap inventory ($n=1$), and suppression head impulse paradigm ($n=1$).

### Treatments and outcomes

A total of 4 treatment strategies were used by different articles as follow: oral corticosteroids, intratympanic corticosteroids, combined oral and intratympanic corticosteroids, and hyperbaric oxygen therapy. Five studies investigated corticosteroid use in the forms of oral or intratympanic injection; four studies reported (complete or partial) hearing improvements after steroid treatment [19–22], while one study stated no significant improvement in hearing function [15]. One study reported that oral corticosteroid monotherapy alone was not effective, while vestibular symptoms were ameliorated by a combination of oral prednisone, intratympanic dexamethasone injection, and hydroxychloroquine. They also reported that a combination of prednisolone, vitamin B, folic acid, and proton pump inhibitors resulted in complete resolution of hearing loss [21]. Meng et al. concluded that intratympanic injections were safer and probably more effective compared with systemic corticosteroid use [22].

### Radiological findings

One study reported the following MRI findings: inner ear damage, bilateral intra-labyrinthine hemorrhage, bilateral cochlear inflammation, and cochlear fibrosis [23]. Details about the included studies and clinical characteristics of COVID-19 patients with hearing loss are shown in Table 2.

## Discussion

Since the outbreak of COVID-19, many atypical symptoms have been reported accordingly. Even though the primary site of SARS-CoV-2 is the lung, it can cause various extrapulmonary symptoms, for example, sensory and neural complications such as sudden onset olfactory and gustatory dysfunction, otologic signs (e.g., tinnitus, vertigo, and hearing loss), nonspecific symptoms, and long-term neurological complications [26]. Sudden sensorineural hearing loss with no other symptoms may be one of the earliest complications associated with COVID-19, with an incidence rate of 0.2–7.6%; hence all patients with hearing loss or acute vestibular disease should be screened for SARS-CoV-2 infection [27–29]. In this study, we aimed to conduct an umbrella review of current evidence based on the systematic reviews and meta-analyses that examined hearing loss as a complication of COVID-19. Findings from this review may assist decision-makers to have a better understanding of possible pathologies and determination of appropriate medical treatment plan.

### Hearing loss classification and diagnosis

There are three types of hearing loss, sensorineural hearing loss, conductive hearing loss, and mixed hearing loss. To differentiate between them, first, we must confirm the genuine existence of hearing loss. The studies in the present review applied various techniques to confirm that the patient had hearing loss. The tests used to verify hearing loss included: pure tone audiometry, otoacoustic emissions, tuning fork tests, hearing handicap inventory, auditory brainstem response, and suppression head impulse paradigm. However, pure tone audiometry was the most frequent test used to diagnose hearing loss. These results are supported by Meng et al., where pure tone audiometry was reported as the most common method for audiological assessment [30].

The most common type of hearing loss was sudden sensorineural hearing loss, which can be defined as the sudden beginning of sensorineural hearing loss without a particular etiology, with at least three consecutive frequency losses $\geq 30$ dB within 72 h [30]. Jafari et al. reported unilateral sudden sensorineural hearing loss as the most common type of hearing loss, and only one case report on conductive hearing loss [26]. The occurrence of post-COVID-19 sensorineural hearing loss can be explained by three different mechanisms. Specifically, (1) neuritis caused by the direct invasion of the cochlear nerve by the virus, (2) involvement of cochlea and peri lymphatic tissue that can cause inflammation of cochlea, and (3) the immune reaction caused by the cross reaction between the inner ear and viral antigens [31].

### Treatment

It is well known that excessive release of inflammatory cytokines (cytokine storm), especially IL-6 in SARS-COV-2 infection, can cause disease symptoms; therefore, suppression of these reactions is necessary [32]. Based on the results of the present review, the most common type of treatment was corticosteroids due to their suppressive effects on the immune response mentioned above. As an initial treatment, intravenous or intratympanic glucocorticoids can be used for patients separately or in combination. Chandrasekhar et al. investigated the difference between intratympanic

**Table 2** Study characteristics, clinical features, audiological evaluation methods, and treatment strategies of COVID-19 patients from the 11 included studies

| First Author/ Year | Country | Searched databases | Included studies | COVID-19 patients | Patients with HL | Type of HL | Treatment | Outcomes and Prognosis | HL Prevalence | Method of auditory evaluation | Other findings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Almufarrij 2021 [17] | UK | PubMed, Embase, Web of Science, Google Scholar, Cochrane Library | 56 articles including: 28 case reports/ series and 28 cross-sectional studies | – | 28 | 14 cases of SNHL, 9 cases of CHL, 1 case of Mixed HL | – | – | Pooled estimate prevalence of HL was 7.6% | Audiometry | Asymptomatic SARS-CoV-2 group had significantly poorer hearing thresholds<br>The pooled estimate prevalence of tinnitus was 14.8%<br>The pooled estimate prevalence of otalgia was 13.1%<br>The prevalence of hyperacusis and phonophobia were 35% and 27–30%, respectively |
| Yadav 2022 [18] | India | PubMed, Embase and Cochrane Central Register of Controlled Trials | 102 | 100,856 | 862 | N/A | – | – | Prevalence of HL was 0.2% | N/A | HL was the least common otolaryngological manifestation |
| Umashankar 2021 [20] | India | PubMed, science direct, J-GATE, Google Scholar | 7 articles including: 6 case reports and 1 case-series | 11 | 11 | 10 cases of SNHL, 1 case of CHL | Use of steroids either in the form of intratympanic or oral caused improvement in hearing thresholds post-treatment | Outcome measures revealed amelioration in hearing thresholds after treatment | – | Otoscopy, PTA, Immittance Audiometry, WRS tympanometry, TFT (Rinne and Weber), speech recognition scores, OAE, and tinnitus evaluation | One case had bilateral moderate SNHL, and the 9 remaining cases had unilateral SNHL<br>Tinnitus was reported by 9 papers<br>No middle ear pathology was observed on otoscopic examination |

**Table 2** (continued)

| First Author/ Year | Country | Searched databases | Included studies | COVID-19 patients | Patients with HL | Type of HL | Treatment | Outcomes and Prognosis | HL Prevalence | Method of auditory evaluation | Other findings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fancello 2021 [23] | Italy | PubMed and Embase | 15 articles including: 13 case reports and 2 case-series | 20 cases with audio-vestibular symptoms mean age: 42.4 ± 35.1 years the male to female ratio was 7:13 | 15 | 15 cases of SNHL | Two cases were treated with oral prednisone two cases were treated with intratympanic steroid injections three cases were treated with combined oral and intratympanic corticosteroids | Among four cases with available outcomes, three had experienced full recovery, one partial improvement, and one no improvement in SNHL | – | PTA | Five cases had isolated SNHL, seven cases had SNHL with tinnitus, and three subjects had SNHL with tinnitus/vertigo MRI findings: inner ear damage, a bilateral intralabyrinthine hemorrhage, and bilateral cochlear inflammation, cochlear fibrosis. One patient, not responsive to corticosteroid therapy, underwent a cochlear implant |
| Jafari 2021 [15] | Canada | PubMed, Scopus, Wiley | 12 articles included in the meta-analysis: 2 single-group prospective, 4 cross-sectional, and 6 retrospective studies and 28 case reports/ case series | 3938 | 33 cases of HL, of which 19 cases were including in the meta-analysis | Case-reports/ case series: 8 SNHL, 1 CHL, 1 Mixed HL, and 4 non-specified HL | – | – | Event rate of HL was 3.1% | HHI | According to the results of the meta-analysis, the event rate of HL (3.1%), tinnitus (4.5%), and dizziness (12.2%) were statistically significant in COVID-19 patients Prevalence rate of HL was 3.1% |
| Maharaj 2020 [16] | South Africa | PubMed, Embase, Web of Science, Scopus, BMJ best practice, Google scholar and Cochrane Database | 7 articles including: 5 case reports and 2 case series | 28 the male to female ratio was 1:1 age ranged between 20 to 60 years | 28 | 25 cases of SNHL, 1 case of CHL, 1 case of Mixed HL | – | – | – | PTA and TEOAE | SARS-CoV-2 is a probable cause of middle ear infections and SNHL, secondary to the spread of the virus into the middle ear and related neural structures |

**Table 2** (continued)

| First Author/ Year | Country | Searched databases | Included studies | COVID-19 patients | Patients with HL | Type of HL | Treatment | Outcomes and Prognosis | HL Prevalence | Method of auditory evaluation | Other findings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Maleki 2022 [24] | Iran | PubMed, Web of Science, and Google | 26 articles including: 11 case reports, 7 cross sectional, 2 retrospective, 1 cohort, 1 case–control, 1 case series, 1 survey, and 1 observational | 5543 | 5 | 5 cases of SNHL | – | – | – | Audiometry, Tympanometry, Imaging, HHI, THI, TEOAE, VEMP, and Otoscopy | In nine included articles, HL (Mostly SNHL) was considered as a symptom or complication of COVID-19<br>The prevalence of audio-vestibular symptoms according to the pooled estimates were as follows:<br>dizziness (17.8%), tinnitus (8.1%), and vertigo (2.8%)<br>symptoms such as otalgia, fullness, instability, auditory hallucinations, and Bell's palsy were also reported |
| McIntyre 2021 [21] | USA | PubMed and Google Scholar | 7 case reports | 7 | 7 | 7 cases of SNHL | Two cases were treated with oral prednisone and two cases were treated with combined oral and intratympanic corticosteroids | One case no improvement was observed in oral prednisone monotherapy<br>One case oral corticosteroid, vitamin B, folic acid complex, proton pump inhibitors use resulted in complete resolution of HL<br>One cases combined oral and intratympanic corticosteroids resulted in Near-resolution of HL | - | Audiometry, tympanometry, TFT (Rinne and Weber) | Corticosteroid and intratympanic dexamethasone injection would improve vestibular symptoms |

**Table 2** (continued)

| First Author/Year | Country | Searched databases | Included studies | COVID-19 patients | Patients with HL | Type of HL | Treatment | Outcomes and Prognosis | HL Prevalence | Method of auditory evaluation | Other findings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Meng 2022 [22] | China | PubMed, Scopus, Web of Science, and Embase | 16 articles including: 13 case reports and 3 case-series studies | 23<br>11 males and 12 females<br>average age: 43.1 years | 23 | 23 cases of SNHL | Glucocorticoids (orally, intravenously, or intramuscularly via systemic and/or intratympanic), hyperbaric oxygen therapy (HBOT) and oral mesoglycan, | Two patients (8.7%) recovered completely<br>12 patients (52.2%) recovered partially<br>1 (4.3%) case improved slightly<br>6 (26.1%) patients did not improve | – | PTA, ABR, ENoG, WRS, Tympanometry, VHI, VNG, TFT, THI, DHI | The time from COVID-19 confirmation to the SNHL onset ranged from a few days to 2 months<br>only 4 cases (17.4%) presented with HL symptoms solely, while the concomitant symptoms included tinnitus (n = 14, 60.9%), vertigo (n = 3, 13.0%), dizziness (n = 2, 8.7%), ear pain (n = 1, 4.0%), and peripheral facial nerve palsy (n = 1, 4.0%)<br>Two cases had intra-labyrinthine hemorrhage in MRI<br>Corticosteroids are the preferred medication to treat COVID-19-related SSNHL<br>intratympanic administration may be considered to reduce the side effects of the drug |

**Table 2** (continued)

| First Author/ Year | Country | Searched databases | Included studies | COVID-19 patients | Patients with HL | Type of HL | Treatment | Outcomes and Prognosis | HL Prevalence | Method of auditory evaluation | Other findings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| De Luca 2022 [25] | Italy | PubMed, Scopus, Google Scholar | 16 | 5582 | 9 | 9 cases of CHL | – | – | – | ABR, TEOAE, DPOAE, PTA, vHIT, SHIMP | 3.2% patients had mild CHL associated with nasopharyngeal inflammation, which improved over the course of follow-up<br>Vertigo prevalence was 7.2%<br>Audio and vestibular symptoms after COVID-19 infection were persistence |
| De Luca 2021 [19] | Italy | PubMed, Scopus, Google Scholar | 19 articles including:<br>12 case reports, two case series, four prospective studies, and one retrospective study | 204 | 16 audiometry confirmed SNHL<br>27 self-reported or subjective HL cases | 16 cases of SNHL | Among 16 SNHL:<br>Nine cases were treated by oral steroids<br>one subject with intratympanic steroid<br>three patients were treated by oral steroid and intratympanic corticosteroids combination<br>One patient, with no improvement had cochlear implant | Among 16 SNHL:<br>Three patients completely recovered<br>five had a partial improvement | – | PTA, tympanometry and cochleo-stapedial reflexes testing, OAE, and contralateral suppression of OAE | Tinnitus was reported by four patients. Two patients suffered from vertigo, two had nausea or vomiting, and one was affected by ear fullness<br>Oral and intratympanic corticosteroid injection leads to hearing improvement |

*HL*, hearing loss; *CHL*, conductive hearing loss; *SNHL*, sensorineural hearing loss; *SSNHL*, Sudden sensorineural hearing loss; *THI*, Tinnitus Handicap Inventory; *VEMP*, Vestibular evoked myogenic potential; HHI, hearing handicap inventory; *PTA*, Pure tone audiometry; *OAE*, Otoacoustic Emissions; *TEOAE*, Transient Evoked Otoacoustic Emissions; *DPOAE*, Distortion Product Otoacoustic Emissions; *ABR*, auditory brainstem response; *ENoG*, Electroneuronography; *WRS*, word recognition scores; *VHI*, Voice Handicap Index; *VNG*, Video Nystagmography; *TFT*, tuning fork tests; *DHI*, dizziness handicap inventory; *SHIMP*, Suppression head impulse paradigm

and systemic intravenous steroids on sensorineural hearing loss, and they found that intratympanic steroids (often in combination with systemic steroids) had no overall merit to systemic steroids and led to similar results [33]. Nonetheless, this theory might be incorrect, and some findings are debatable. For instance, Tsuda et al., stated that although the two treatments have no significant difference in outcomes, intratympanic steroid therapy has few to almost nothing systemic side effects. Perforation of the tympanic membrane was reported in only one of the 21 patients, suggesting it could be used in outpatient clinics. However, intravenous steroids require hospitalization to prevent causing severe side effects such as insomnia, increased blood pressure, etc. [34]. Other treatment plans include hyperbaric oxygen therapy and cochlear implantation, which can be used when patients do not respond to steroid therapy [35].

### Limitations

This study has several limitations. First, the number of studies selected for review in this paper is limited, as the focus was on hearing loss in COVID-19 patients. Second, in some studies, hearing loss may have already existed before the SARS-CoV-2 infection. Lastly, more research is needed with a more extensive study population to provide adequate knowledge.

## Conclusions

Despite being one of the rare complications of COVID-19, hearing loss can impact a patient's quality of life. Sensorineural hearing loss is the most common type and it can be diagnosed with various techniques. However, pure tone audiometry is the most frequent technique used. The initial treatment plan may include steroids administered via intravenous or intratympanic. However, some studies preferred intratympanic to intravenous steroids due to the fewer systemic side effects. If patients do not respond to steroids there are various other treatment plans that can be used.

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## Declarations

**Conflict of interest** The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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