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Review Article

Ear Symptoms Related To COVID-19 or Vaccine: A Systematic Review and Meta-Analysis

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Abstract

Purpose: We conducted a meta-analysis by searching and analyzing literature studies published through December 1, 2023, executing to assess the Event Rates (ERs) of vertigo, tinnitus, hearing loss, earache and aural fullness by confirmed coronavirus disease 2019 (COVID-19) or its vaccine.

Methods: A database (PubMed, Embase, Web of Science) search for studies released up to December 01, 2023 was conducted. The ERs of potential ear illness of take notice of crowd papers of COVID-19 or COVID-19 vaccine draw our focus, we as well as paid attention to uncommon ear symptoms described in person with COVID-19. The information retrieved from the respective papers were evaluated and summarized.

Results: We accepted 91 study's that met the eligibility criteria. The comprehensive assessment of ERs based heavily on retrospective review of common symptoms in ear of COVID-19 patient was 13% (95% confidence interval [CI]: 0.09-0.18), 10% (95% CI: 0.06-0.15), 8% (95% CI: 0.05-0.12), 5% (95% CI: 0.02-0.08) and 13% (95% CI: 0.06-0.22) for vertigo, tinnitus, hearing loss, earache and aural fullness, respectively. The ERof vertigo, tinnitus, and hearing loss after COVID-19 vaccine injection were 7% (95% CI: 0.05-0.11), 6% (95% CI: 0.01-0.15) and 2% (95% CI: 0.00-0.06), in proper order.

Conclusions: Our findings suggest that COVID-19 or COVID-19 vaccine can cause vertigo, tinnitus, hearing loss, earache and aural fullness. Besides, it can cause some less common but not insignificant ear symptoms, such as hemorrhage of the membranous labyrinth, otitis media. This phenomenon should be of great concern to ear nose throat surgeon.

Keywords: COVID-19; Vaccine; Vertigo; Tinnitus; Hearing Loss; Earache; Aural Fullness

Introduction

The coronavirus disease 2019 (COVID-19), a new flu, first identified in December 2019 and subsequently transmit worldwide. The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the COVID-19, spread to almost every corner of the globe, causing social unrest and anxiety [1]. Resulting in a declaration of the pandemic as an international public hygiene emergency by The World Health Organization [2]. COVID-19 initially manifests as fever, sore throat, cough, and dyspnea, the main clinical manifestations of respiratory illness. Yet, over the course of the pandemic, other symptoms such as abdominal pain, chest and muscle pain, loss of smell, deafness, and headache have been also identified as clinical features of COVID-19 [3, 4]. It is catholic accepted what the pre-pandemic will never return unless highly effective vaccines that can prevent a wide range of associated symptoms strategy and global vaccination programme are implemented successfully and urgently [5]. But a series of cases have reported ear symptoms after COVID-19 vaccination [6-8]. This phenomenon should be paid enough attention and explore the morbidity caused by COVID-19 vaccines and provide data support for further improving the symptom relief rate of COVID-19 vaccines. Since the pandemic beginning, the olfactory and gustatory manifestations of COVID-19 have been extensively exist and COVID-19 has also been reported to affect the auditory and vestibular systems, but relevant meta-analyses on this topic are limited. For early detection of ear symptoms in people infected with COVID-19 or vaccinated and prevent further spread of the disease, otolaryngologists must keep a close eye on ear symptoms.

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Methods

Search Strategy

As this stage, we seek database, such as PubMed, Embase and Web of Science from the database of establishment to December 01, 2023, by using the keywords "COVID-19," "SARS-CoV-2," "vaccines," "COVID-19 vaccine," "SARS-CoV-2 vaccine," "BNT162," "mRNA-1273," "ChAdOx1 COVID-19 vaccine," "PittCoVacc," "Pifer-BioNtech", "AstraZenec", "Aikewei", "Moderna"Janssen" "Ad26.COV2.S vaccine ," "EpiVacCorona vaccine," "hearing loss," "auditory dysfunction," "hearing impairment," "deafness," "tinnitus," "vestibular dysfunction," "dizziness," "vertigo," "otologic symptoms," and "earache." Each keyword was retrieved and integrated them using Boolean operators.

Inclusion/Exclusion Criteria

This meta-analysis considers cross-sectional, retrospective and questionnaire in English papers reporting vertigo, tinnitus, hearing loss, earache and aural fullness in confirmed COVID-19 cases or COVID-19 vaccine. Participants in this study were those who presented with ear symptoms after contracting COVID-19 or getting vaccination to against COVID-19, no exact confines were placed on age or on the diagnostic tools used to test for SARS-CoV-2. The outcomes of the review were the ERs for vertigo, tinnitus, hearing loss, earache and aural fullness. Studies of symptoms entirely caused by anxiety were excluded. Books, case reports, case series, letters, editorials, notes commentaries and cases report that included a small number of cases (≤ 10 cases) were excluded. Endnote (version X7) survived to manage all retrieved references and remove duplicates. The final paper was screened through three procedure: duplicates removed, title and abstract screening and full-text screening to obtain research, which met the inclusion criteria's. When it is uncertain whether the exclusion criteria are met, the abstract is initially screened, and then filtering the full text. All three phases were performed by three reviewers without interference. When there were different viewpoints during screening, they were discussed with each other. Ultimately, a completely consistent view was achieved among the reviewers.

Data Collection Process and Data Items

Two investigators who analyse the database search independently and arrange data in the article. Disagreements among three raters were agreed upon through discussion and negotiation. The following data were enumerated using tabular collection: author, study design, country, vaccine, No. of pts (overall), reported ear symptoms and NIH (Table1,2). The present data about COVID-19 or vaccine was conducted on the basis of the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines [9].

Risk of Bias in Individual Studies

3 boffin non-interfering assessed the quality of each paper of the literature employ the National Institutes of Health (NIH) Quality assessment tool. The quality level of evidence was listed as follows: poor, fair, or good.

Data Analysis

We performed a meta-analysis of ear illness ERs in person who infect COVID-19 and figured out the morbidity with the 95% Confidence Interval (CI). The meta-analysis was using single-arm ratios analysis of ear symptoms due to COVID-19 was performed with STATA (version 16.0). To prevent confusion bias caused by a low sample size, papers with a sample capacity of less than 10 were eliminated. Heterogeneity was assessed using the Cochran Q test and the I2 statistic. Heterogeneity was confirmed (I2 > 50% and $P < 0.1$ in the Cochran Q test), when statistical heterogeneity was high (I2 > 50%), pooled data carrying out a random model. When statistical heterogeneity is low (I2 < 50%), the fixed exact model was applied to analyze the data. Forest plots were used to estimates of ERs and 95% CI for ear symptoms caused by COVID-19 or COVID-19 vaccine [10].

Results

Characteristics of the Included Studies

The PRISMA (Figure 1) chart shows article inclusion and exclusion process. 2342 released paper were selected from databases (n = 2319) and other sources (n = 23). A total of 825 published articles remained after removing duplicates. After an initial review of the titles and abstracts of each article, 152 articles were thinked eligible for the full-text review criteria. After the full-text screening, all 91papers were included in the present systematic review. The included reports were all graded for quality according to the NIH quality assessment tool. Most of the them were retrospective studies.

Ear Symptoms

This meta-analysis indicated that common ear symptoms were vertigo, tinnitus, hearing loss, earache, aural fullness among patients which diagnosed with COVID-19, while some studies reported rare symptoms such as otitis media, hemorrhage of the membranous labyrinth. The pooled prevalence of vertigo after COVID-19 from 40 researches was 13% (CI: 0.09-0.18; I2 = 98.55%) (Figure 2). Twenty-five studies reported COVID-19-induced tinnitus with an ER of 10% (CI: 0.06-0.15; I2 = 98.08%) (Figure 3). Thirty-one studies reported hearing loss with a pooled prevalence of 8% (CI: 0.05-0.12; I2 = 98.18%) (Figure 4). This meta-analysis showed that the most common ear symptom caused by COVID-19 vaccine was also vertigo, tinnitus, hearing loss, however, earache or aural fullness although reported, is not a frequent symptom. While 4 cross-sectional, 3 retrospective and 1 online survey reported earache with a prevalence of 5% (CI: 0.02-0.08; I2 = 88.32%) (Figure 5).The prevalence of aural fullness from 8 researches was 13% (CI: 0.06-0.22; I2 = 98.45%) (Figure 6). The prevalence of vertigo with COVID-19 vaccine in 27 included studies was 7% (CI: 0.05-0.11; I2 = 99.96%) (Figure 7). The 27 included studies included a wide range of vaccines, such as Moderna, Pfizer, Comirnatry Astra Zeneca, BNT162b2 mRNA, mRNA-1273, BBIBP-CorV, ChAdOx1 nCoV-19. Among the cross-sectional studies included, retrospective studies calculated that the ER of COVID-19 vaccine-induced tinnitus was 6% (CI: 0.01-0.15; I2 = 99.76%) (Figure 8). Among the 5 cross-sectional studies included, 2 retrospective studies calculated that the ER of COVID-19 vaccine-induced hearing loss was 6% (CI: 0.00-0.06; I2 = 99.03%) (Figure 9).

Reporting Bias

It is well known that publication bias exists, we inspected it solely for vertigo, tinnitus, hearing loss and earache using Egger's and Begg's tests, yet, none of tests showed statistically significant findings.

Quality Appraisal

Despite the relatively low quality of the research design relative to the level of evidence admissible at the trial. In total, 12, 39, and 10 studies about COVID-19 patients were regarded as showing good, fair, and poor quality. In addition, among the 27 paper about COVID-19 vaccine included, we considered 4 good, 24 fair and 6 poor. Thus, despite the lack of some detail, most studies are considered to provide fair reports of auditory vestibular symptoms.

Discussion

A set of studies have released otorhinolaryngological illness in people infected with COVID-19 or vaccines, Notably, ear symptoms are not unusual in COVID-19 infection or COVID-19 vaccine recipients, and affect patients' prognoses, normal conversations, and social life. The result of the present study indicates the morbidity of ear symptoms of COVID-19 patients is 13% for vertigo, 10% for tinnitus, 8% for hearing loss, 5% for earache, and 13% for aural fullness. The incidence of ear symptoms in COVID-19 vaccine recipients was vertigo 7%, tinnitus 6%, hearing loss 2%. Although ear symptoms are less life-threatening and less common than symptoms such as headache, runny nose. Hearing loss, tinnitus, vertigo after COVID-19 or vaccines can last for a longer period and severely interfere with normal social life, early detection and rapid isolation of infected patients can help stop the spread and reduce the severity of the disease. Therefore, knowledge of the symptoms and incidence of ear symptoms in this patient population will facilitate the detection of COVID-19 and the development of more effective treatment

Table 1: Literature included in ear symptoms related to COVID-19: A systematic review and meta-analysis.

Reference	Study Design	No. of pts (overall)	No. of pts (hearing loss)	No. of pts (tinnitus)	No. of pts (vertigo)	Median (IQR) or Mean ± SD* age in yr	No. of pts (earache or aural fullness)	NIH
Abdel Azim [40]	Retrospective	107			34	41.23 ± 13.94		Fair
Ahmad [41]	Retrospective	214			36	58.7		Fair
Aldè [42]	Retrospective	1512			251	51 ± 18.4		Fair
Alhumaid [43]	Retrospective	1014			18	47.2 ± 19.3		Fair
Alizadehsani [44]	Retrospective	319			11	45.48±18.50		Fair
AlJasser [45]	Retrospective	300	13	15	15	44.2		Fair
Armocida [46]	Cross sectional	127					Earache, 4	Fair
Bhatta [47]	Retrospective	331	13	6		32 ± 4.3	Earache 6	Good
Bin Abdulrahman [48]	Cross-sectional	223				32.5 ± 10.7	Earache 9	Fair
Carcamo Garcia [49]	Cross-sectional	199			68	43		Good
Chen [50]	Retrospective	103			8	42.38 ± 11.507		Fair
Chen [51]	Retrospective	145			29	47.5		Fair
Dharmarajan [18]	Cross-sectional	100	11	12		21-60	Earache 5	Fair
Dilber [52]	Retrospective	382			42	7.14 ± 5.84		Poor
Dusan [53]	Cross-sectional	74	30			60.83 ± 11.32		Fair
E. Elibol [54]	Retrospective	155	1	2			Earache4	Fair
Espinoza-Valdez [55]	Cross-sectional	209	6	17	24			Poor
Freni [56]	Prospectively	50	20	10		37.7 ± 17.9		Fair
Ghaffari [57]	Retrospective	361	3		88	61.90 ± 16.76		Fair
Gosavi [58]	Retrospective	70	4	2		50.35 ± 17.41		Fair
Hong [59]	Retrospective	67			3	45.0 ± 15.2		Fair
Iltaf [60]	Cross-sectional	350			12	49.5 ± 17.4		Good
Kökoğlu [61]	Retrospective	101	5	11	6	33.86 ± 8.8		Fair
Liang [62]	Retrospective	86		3		6-57		Fair
Liguori [63]	Retrospective	103	2		27	55 ± 14.65		Fair
Liotta [64]	Retrospective	509			26	58.51 (16.93)		Good
Makda [65]	Cross-sectional	114			20	51 ± 14		Fair
Micarelli [66]	Online survey	1380		144	86	23-72	Earache114	Fair
Nejad [67]	Cross-sectional	891	156		405			Poor
O'Keefe [68]	Retrospective	337			102	44.1-47.2		Fair
Özçelik Korkmaz [69]	Retrospective	116	6	13	37	57.24 ± 14.32		Fair
Romero-Sánchez [70]	Retrospective	841			51	66.42 ± 14.96		Fair
Sampaio Rocha-Filho [71]	Retrospective	613			9	54 (41-68)		Fair
Savtale [72]	Cross-sectional	180		120		37.8 ± 12.5		Fair
Tawaku [73]	Retrospective	79			11	63.6		Poor
Thrane [74]	Retrospective	225	24	37	66	45.5 (19-76)		Fair
Viola [75]	Online questionnaire			43	34	19-81		Fair
Wang [76]	Retrospective	90			12	53.90 ± 16.9		Fair
Yan [77]	Retrospective	1,682			15	50 [39-58]		Fair
Zhong [78]	Retrospective	48			5	44.35 ± 15.76		Poor
JF Thrane, A [79]	Retrospective	470	24	37		19-76		Fair

H Verma [80]	Retrospective	78	11			35.78 ± 11.93		Fair
Y Yang [81]	Cross-sectional	1589	485			Dec-26		good
R Gallus, A [19]	Retrospective	48	4	2	3	45 (9.6)		Fair
M Tofanelli, V [82]	Cross-sectional	30	14					Poor
RE Africa, Z K [83]	Retrospective	922,681	289	735		49		Good
K Dorobisz, [84]	Cross-sectional	58	38	30		23-75		Good
AA Almishaal [85]	Retrospective	794	73	98	224		aural fullness 181	Good
A AlJasser, W [86]	Retrospective	300	24		15			Poor
FS Obeidat, A [87]	Cross-sectional	209	31		54			Good
O Durgut, M [88]	Retrospective	20	1	4	3		aural fullness 2	Fair
B. Öztürk, H [89]	Cross-sectional	33		11		18-45	aural fullness 1 Earache 1	Good
M. Aldè, F [23]	Retrospective	132		11	16	05-Nov	aural fullness 33 Earache 23	Good
E. W. Beukes, D [90]	Retrospective	3400	795	1306		58 (14.7)		Poor
S. Leong, B. M [91]	Retrospective	420	21	26	33	56.6 (19.0, 16-101)		Fair
V. Vielsmeier, SC [92]	Cross-sectional	28	1	3				Poor
M. Eldeeb, D [93]	Cross-sectional	245	34	31			aural fullness 30	Fair
AA Almishaal [94]	Retrospective	301	19	30	73	36.58 (12.54)	aural fullness 57	Fair
L Wu [95]	Retrospective	2247	261	428	583	28-46	aural fullness 386	Good
H Avcı [96,97]	Retrospective	1454	2		18	19-71	aural fullness 22	Poor

Table 2: Included literature of the Ear symptoms related to COVID-19 vaccine: A systematic review and meta-analysis

Reference	Study Design	Vaccine	No. of pts (overall)	No. of pts (hearing loss)	No. of pts (tinnitus)	No. of pts (vertigo)	Median (IQR) or Mean ± SD* age in yr	No. of pts (earache or aural fullness)	NIH
Wichova H [20]	Retrospective	Moderna Pfizer	1325	25	15	13	60.9 ± 13.8		Fair
Beukes E [21]	Cross-sectional	Comirnatry/ Pfizer, Astra Zeneca or Moderna	327	13	24	23	63 (11)	20 aural fullness	good
Leong S [98]	Cross-sectional	Pfizer, Moderna, Johnson & Johnson	500	21	26	52			fair
Aldè M [23]	Retrospective		140		2	5	7.8 ± 2.3	4aural fullness	good
Avcı H [99]	Retrospective		1454	2		18	35.95 ± 10.3		fair
Kadali RAK [100]	Cross-sectional	BNT162b2 mRNA	803	3					poor
Kadali RAK [101]	Cross-sectional	mRNA-1273	1116	2		63		Earache 7	fair
Dutta S [102]	Cross-sectional	5,638 BNT162b2 , 2,751 AZD1222 , 1,075 mRNA-1273, 8 Vero , 2 Covaxin	15616			2549			fair
Elgendy MO [103]	Cross-sectional	80 BBIBP-CorV, 25 BNT162	105			6			poor
Dar-Odeh N [104]	Cross-sectional	Pfizer- BioNtech, AstraZenec, Sinopharma	348			4	35.75 ± 11.74		fair
Kushwaha P [105]	Cross-sectional		408			10	29.02 ± 8.71		poor

Baydar O [106]	Cross-sectional study		1268			66			poor
Fathi HM [107]	Questionnaire		200			20	37.9 ± 8.5		poor
Kaur S [108]	Cross-sectional	ChAdOx1 nCoV-19	1036			10	29-46		fair
Saunders GH [109]	Cross-sectional		6681	602	701				fair
Dzantor EK [110]	Cross-sectional s		463			85	33.4 ± 9.7		poor
Rahmat H [111]	Cross-sectional	Pfizer-BioNTech	240			42	24-55		fair
Akrami M) [112]	Observational cohort	Sputnik V	126			12	37.19 ± 7.73		good
Wang G [113]	Cross-sectional	Aikewei	4458			30			fair
Gee J [114]	Cross-sectional	Pfizer-BioNTech Moderna	6994			1151	17-104		fair
El-Shitany NA [115]	Cross-sectional	BioNTech	442			8			fair
Loosen SH [116]	Cohort Study	BioNTech, Pfizer Moderna, AstraZeneca	28287			5063			fair
Hatmal MM [117]	Cross-Sectional		2213			615			fair
Yavuz E [38]	Prospective observational	BNT162b2, CoronaVac	182			9			fair
Kamble B [118]	Cohort study	ChAdOx1	836			30	35.75 ± 9.52		fair
Gianfredi V [119]	Cross-Sectional	Pfizer, Astrazeneca, Moderna, Janssen	1409			296	47.5		fair
García-Alanis M [120]	Cross-sectional	BNT162b2, ChAdOx1 nCov-19, Ad5-nCoV, CoronaVac, rAd26-rAd5	19163			5435	17-101		good
O. Cohen Michael, S [121]	Prospective	BNT162b2	2,05,000						fair
A. Ciorba, C [122]	Observational	Comirnaty ; Spikevax ; Vaxzevria	49512799		278	2384			Fair
S. Leong, B. M [91]	Prospective	Moderna, Pfizer, J&J	87		10	4			Fair
D. Lin and A. M [123-125]	Observational	Janssen Moderna, Pfizer,	27		13		41-84		Fair

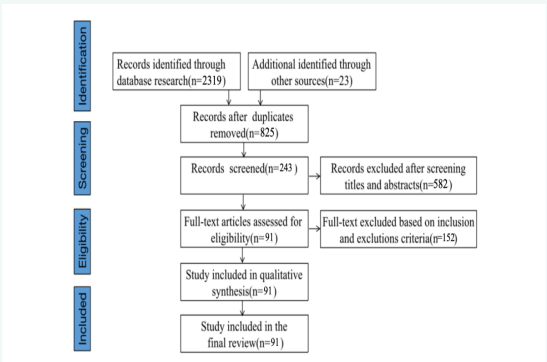

Figure 1 PRISMA flow diagram demonstrating the summary of the literature search and screening process. PRISMA, preferred reporting items for systematic reviews and meta-analyses.

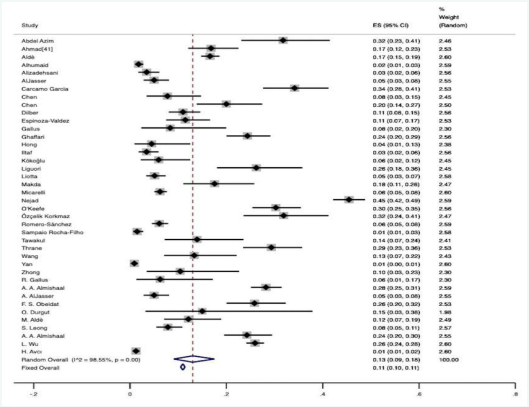

Figure 2 Forest map of vertigo after COVID-19 infection: 40 studies were included in this forest map. The ER of vertigo was 13%, with a CI between 0.09 and 0.18 (df = 39, I^2 = 98.55%, $P \leq 0.001$).

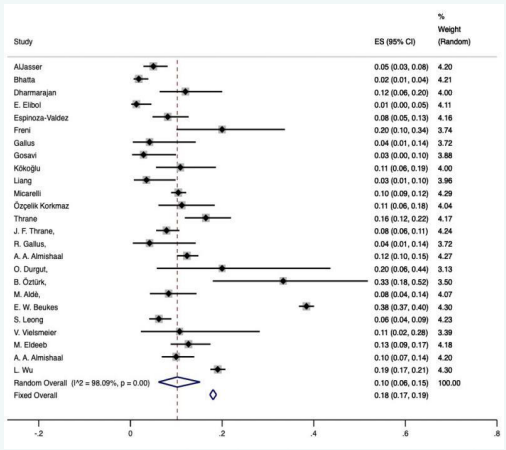

Figure 3 Forest map of tinnitus after COVID-19 infection: 25 studies were included in this forest map. The ER of tinnitus was 10%, with a CI between 0.06 and 0.15 (df = 24, I^2 = 98.08%, $P \leq 0.001$).

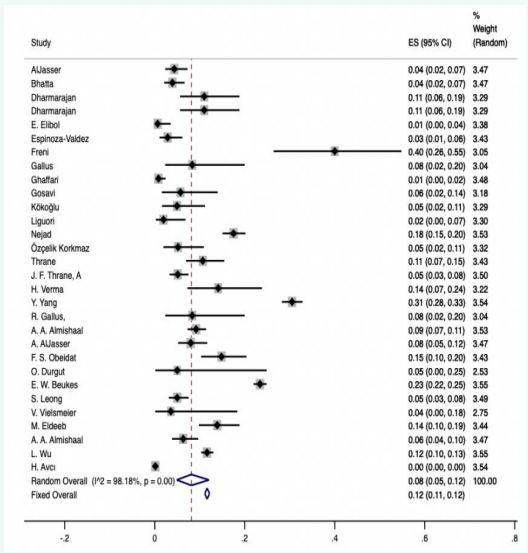

Figure 4 Forest map of hearing loss after COVID-19 infection: 31 studies were included in this forest map. The ER of hearing loss was 8%, with a CI between 0.05 and 0.12 (df = 30, I^2 = 98.18%, $P \leq 0.001$).

options. Although there are few literatures included and the incidence is low, it still provides data support for further improvement of the vaccine.

Several scholars have researched independent systematic reviews of the morbidity of vertigo, tinnitus, and epicophosis in infection with COVID-19. Zahra Jafari, et al. showed which the incidence of vertigo and tinnitus was 12.2% (CI: 7%-20.4%) and 4.5% (CI: 0.012-0.053), respectively [11]. Eldre Beukes, et al. found that the pooled estimated prevalence of tinnitus after COVID-19 was 8% (CI: 0.05-0.13) [12]. Zahra Jafari reported the incidence of hearing loss caused by COVID-19 was 3.1% (CI: 0.011-0.09) [11]. Ibrahim Almufarrij, et al. released that

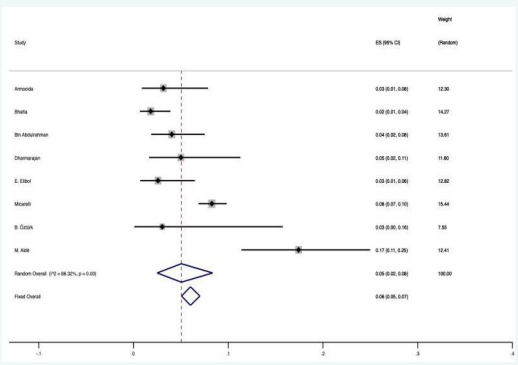

Figure 5 Forest map of earache after COVID-19 infection: 8 studies were included in this forest map. The ER of earache was 5%, with a CI between 0.02 and 0.08 (df = 7, I^2 = 88.32%, $P \leq 0.001$).

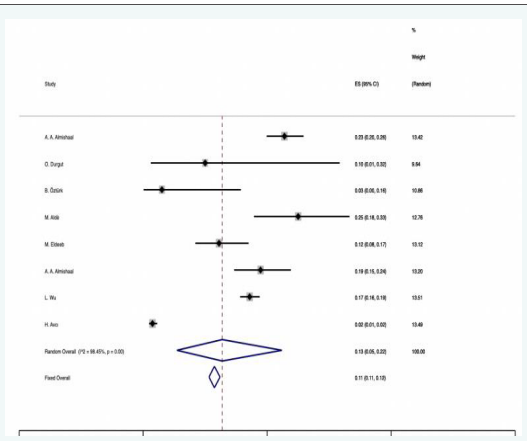

Figure 6 Forest map of aural fullness after COVID-19 infection: 8 studies were included in this forest map. The ER of aural fullness was 13%, with a CI between 0.06 and 0.22 (df = 7, I^2 = 98.45%, $P \leq 0.001$)

the incidence of deafness caused by COVID-19 was 7.6 (CI: 0.02.5-12.1) [13]. This meta-analysis sought to supplement the literature highlighting the need for otolaryngologists to understand the relevance of ear to COVID-19. It is also hoped that the phenomenon of vertigo, tinnitus and hearing loss after vaccination will be concerned.

Ear symptoms of varying severity can appear in COVID-19 infection, and can appear in the initial stage of infection or after treatment [14]. Tinnitus rarely occurred as an isolated hearing impairment, with 46% of participants experiencing hearing and/or hyper hearing (23%) and phonophobia (6%) [15]. A new study of asymptomatic patients who confirm COVID-19 indicated an increase in high-frequency pure-tone thresholds and a significant decrease in transiently evoked otoacoustic emissions [16,17]. Case series, cross-sectional studies, and retrospective studies all reported hearing loss after SARS-CoV-2 infections. Sensorineural Hearing Loss (SSNHL) is more common than conductive and mixed hearing loss and is often along with by tinnitus and dizzy, and COVID-19 patients were also found to have high-frequency hearing loss [17-19]. A series of case studies, cross-sectional studies, and retrospective studies have described vestibular dysfunction after vaccination [20-23].

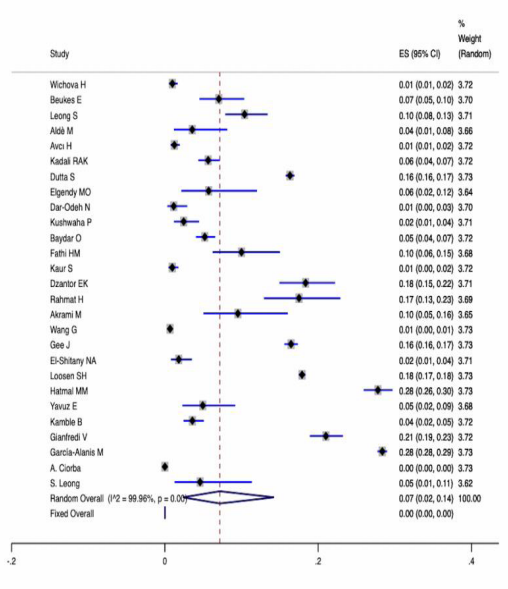

Figure 7 Forest map of vertigo after COVID-19 vaccine: 27 studies were included in this forest map. The ER of vertigo was 7%, with a CI between 0.05 and 0.11 (df = 26, I^2 = 99.96%, $P \leq 0.001$).

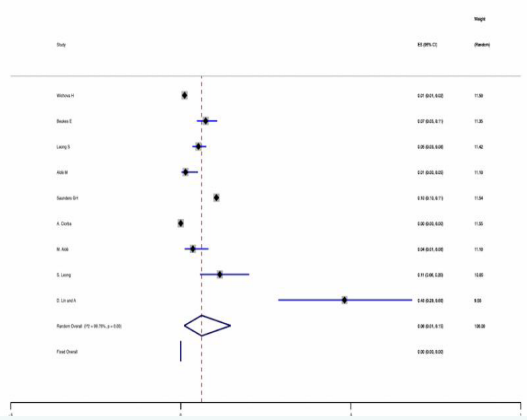

Figure 8 Forest map of tinnitus after COVID-19 vaccine: 9 studies were included in this forest map. The ER of tinnitus was 6%, with a CI between 0.01 and 0.15 (df = 8, I^2 = 99.76%, $P \leq 0.001$).

The most common adverse events after COVID-19 vaccines that have been described in the literature are auditory-vestibular symptoms, such as tinnitus, sudden sensorineural hearing loss, vertigo [7]. Consecutive adult patients at two tertiary care centers and one community clinic in the U.S. diagnosed with SSNHL within 3 weeks of COVID-19 vaccination [24]. Three cases of sudden onset of unilateral tinnitus after BNT162b2 mRNA vaccine injection were reported, with rapid resolution in two of the three cases. However, the mechanism of its development remains unclear. Hypersensitivity with an abnormal autoimmune reaction or a vasculitis event may be related to this [25]. A more serious incidental complication was a case report of a 61-year-old woman who developed sensory hearing loss with intralabyrinthine hemorrhage after the third

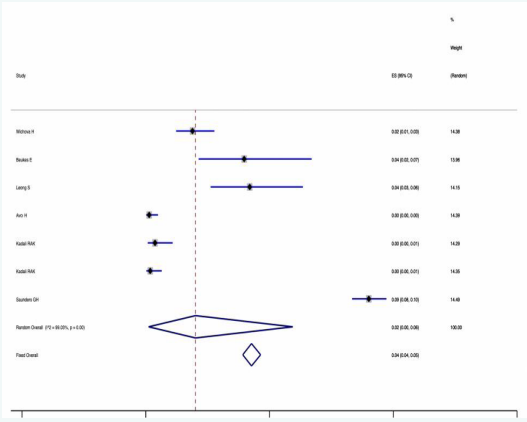

Figure 9 Forest map of tinnitus after COVID-19 vaccine: 9 studies wForest map of hearing loss after COVID-19 vaccine: seven studies were included in this forest map. The ER of tinnitus was 2%, with a CI between 0.00 and 0.06 (df = 6, I^2 = 99.03%, $P \leq 0.001$).

dose of the COVID-19 vaccine [26].

Ear manifestation, for example vertigo, tinnitus and hearing loss may as well be caused by cures for COVID-19, such as chloroquine, hydroxychloroquine, azithromycin, lopinavir-ritonavir and ivermectin [27]. Some articles do not clearly distinguish vertigo from dysequilibrium, presyncope, and light-headedness. These reasons may increase the ER of ear symptoms caused by COVID-19.

The reason and machine of ear manifestation of patient of infect SARS-CoV-2 is not fully understood. Some investigators conject that the virus enters neuronal tissue through the circulation system and integrate the Angiotensin-Converting Enzyme 2 Receptor (ACE2) located in the capillary endothelium [28]. Some authors have supported the hypothesis that the blood vessels of the inner ear may be affected by inflammation, ultimately leading to vasculitis or endotheliitis [29]. Tinnitus symptoms have been shown to be closely related with anxiety and intranquil [30]. Anxiety tendencies and attendant stress during the pandemic may be additional potential risk factors for worsening tinnitus [31]. The management of vertigo, tinnitus, and deaf after COVID-19 is mainly based on symptomatic and supportive treatment. Vertigo presenting in COVID-19 patients is treated using antiemetics, antihistamines, and sedatives [32]. During the pandemic, where governments have severely restricted personal contacts and social or daily life activities to prevent further transmission, Internet-based interventions can be considered as the mainstay of tinnitus treatment [33]. Understanding and screening for SSNHL after COVID-19 allows for early steroid use, which provides the best chance of hearing recovery [34]. In Wichova H study, the onset of symptoms for an average of 10.2 ± 9 days after vaccination, at the same time, the onset time of Immunoglobulin G (IgG) production, which may have some correlation with each other [20,35]. Other hypotheses as to why COVID-19 vaccines might cause sudden hearing loss include viral reactivation, Both the Pfizer and Moderna vaccines use an RNA adenovirus vector that has a high seroprevalence among the crowd, leading to an anticipative immune response [36]. The studies we included provide strong support for this hypothesis. Zoccali F reported deafness, vertigo, tinnitus after the third dose of vaccine [37]. Similar symptoms occurred with the first and second doses of the vaccine [38]. Magnetic resonance imaging and angiography of the brain and inner auditory canal after the onset of hearing loss are normal. The combination of glucocorticoids and

acetylsalicylic acid caused by almost entire recovery from hearing loss after 15 days [39].

Although other systematic reviews in the literature have focused on ear dysfunction in COVID-19 infection, we expanded the scope of discussions to include COVID-19 vaccine, particularly those related to the association COVID-19 vaccine and ear symptoms. The main limitations of this study include the lack of a control group, an insufficient sample size, and unclear case descriptions, especially audiogram details. If we can count the gender, age, and underlying diseases of patients with ear symptoms, we can analyze the incidence more accurately. Studies in larger populations are needed to confirm a correlation between ear symptoms and COVID-19 or vaccine. In addition, further research is required to determine whether these symptoms are caused by the novel coronavirus itself, a treatment regimen for COVID-19, or other unknown causes. In the case of vaccine-induced ear symptoms, the number of samples included was small, and it was not possible to compare the different incidence rates caused by different vaccines and doses, the extent of hearing loss is also reported in less detail, and the addition of pure-tone audiometry results would add to the quality of evidence. The time of onset of symptoms after injection, the type of vaccine, and whether the incidence of patients with primary ear disease will increase after vaccination also need to be discussed in more cohort studies.

Conclusions

There is increasing evidence that ear disorders may be partially of the clinical manifestation of COVID-19 and under this circumstance may mark the onset of the disease, as well as, a certain correlation between the vaccination of COVID-19 vaccine and tinnitus, vertigoearache. This realization must cause enough attention of otolaryngologist. Identification of rare SARS-CoV-2 manifestations in otolaryngology patients is essential, as this not only facilitates diagnosis, but also protects and reduces the exposure of otolaryngologists to potential risk of infection.

Authors' contributions

CW, HJW and ZHH: designed the research, conduct a literature search, review, extract and analyze data and wrote the first draft analysis. JJQ: checked data analysis and explanation. QC and LC: carefully amend the review for significant details. DWL, LML and YS: supervised data collection, explanation and complete the final draft. All authors read and approved the end draft.

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