The Journal of Laryngology & Otology

cambridge.org/jlo

Sinus, middle-ear and mastoid radiological findings of severe acute respiratory syndrome coronavirus-2

E Watts, E Balai, D Kwatra, S Banerjee and E Hoskison

Department of ENT Surgery, University Hospitals Coventry and Warwickshire, Coventry, UK

Abstract

Objective. To assess the incidence of radiological inflammation within the paranasal sinuses, middle ear and mastoid in patients with confirmed severe acute respiratory syndrome coronavirus-2.

Methods. A retrospective cohort study was conducted to examine consecutive adults (aged over 18 years) with coronavirus disease 2019 (confirmed on polymerase chain reaction within 7 days of imaging) who underwent computed tomography of the head between 1 March 2020 and 24 June 2020. Lund–Mackay and mastoid and middle-ear opacification scores were used to categorise the extent of sinus and mastoid opacification on axial and coronal computed tomography images.

Results. Of 147 patients originally identified, only 83 met the inclusion criteria. Sinus opacification was present in 51.8 per cent of patients ($n = 43$), and middle-ear or mastoid opacification was observed in 24.1 per cent ($n = 20$). There was no statistically significant difference in sinus or middle-ear and mastoid opacification between patients after stratification based on 30-day all-cause mortality.

Conclusion. Radiological computed tomography findings suggest mild mucosal disease within the sinuses, middle ear and mastoid. There was no statistical correlation between such opacification and 30-day mortality.

Introduction

Single-stranded RNA coronaviruses have pervaded the human microbiome for centuries.[1] Endemic within human populations,[2] coronaviruses contribute to 15–30 per cent of common colds,[3] manifesting as rhinorrhoea, sinusitis, fever, cough, tachypnoea and odynophagia.[4] However, clinical manifestations of severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) – responsible for the current coronavirus disease 2019 (Covid-19) pandemic – are broad, ranging from mild cough to acute respiratory disease syndrome and multi-organ failure.[5] Although mortality rates are falling, the long-term impact of SARS-CoV-2 remains uncertain.[6]

Emulating its relatives, the novel coronavirus spreads via droplet transmission,[7] forming reservoirs within the upper aerodigestive tract.[8] Single-cell RNA analysis suggests the nasal cavity carries significant expression of angiotensin-converting enzyme (ACE2; the cell surface receptor for SARS-CoV-2).[9] Such increased viral load inspired the generation of reverse-transcriptase polymerase chain reaction assays using nasopharyngeal swabs.[10]

Contrary to expectations, Hasanoglu *et al.*[11] found increased SARS-CoV-2 viral load occurs in asymptomatic patients. Additionally, coronaviruses have long been associated with middle-ear pathology,[12] and consequent inflammation is represented as mastoid and middle-ear effusion on computed tomography (CT) imaging.[13] Coronaviruses are implicated in the pathogenesis of acute otitis media.[14,15] Hence, the first isolation of the SARS-CoV-2 virus from middle-ear autopsy specimens in July 2020 was unsurprising.[16]

The long-term implications of the presence of SARS-CoV-2 in the middle ear, mastoid and sinonasal tract are not yet quantified. Case reports suggest SARS-CoV-2 may be linked with sensorineural hearing loss,[17–22] and its association with anosmia is well documented.[23,24] However, the radiological implications of SARS-CoV-2 and predictors of mortality remain unclear.

This study aimed to assess the incidence of radiological inflammation within the paranasal sinuses, middle ear and mastoid cavity in patients with confirmed SARS-CoV-2, and to determine whether this has any relationship with all-cause mortality.

Materials and methods

This retrospective cohort study examined radiological findings in 147 consecutive adults with confirmed Covid-19 who underwent CT of the head between 1 March 2020 and 24 June 2020. Patients aged over 18 years with confirmed SARS-CoV-2 infection within 7 days of imaging by reverse-transcriptase polymerase chain reaction testing were included.

Main Article

Ms E Watts takes responsibility for the integrity of the content of the paper

Cite this article: Watts E, Balai E, Kwatra D, Banerjee S, Hoskison E. Sinus, middle-ear and mastoid radiological findings of severe acute respiratory syndrome coronavirus-2. *J Laryngol Otol* 2023;**137**:76–80. https://doi.org/10.1017/S0022215122002304

Accepted: 23 September 2022
First published online: 20 October 2022

Key words:
COVID-19; SARS-CoV-2; Mastoid, Diagnostic Imaging; Paranasal Sinuses, Diagnostic Imaging

Author for correspondence:
Ms Emma Hoskison,
Department of ENT Surgery,
University Hospitals Coventry and Warwickshire, Clifford Bridge Road,
Coventry CV2 2DX, UK
E-mail: emma.hoskison@uhcw.nhs.uk

Table 1. Lund–Mackay sinus scoring

Score	Description
0	No opacification
1	Partial opacification
2	Complete opacification

Table 2. Middle-ear and mastoid opacification scoring

Score	Description
0	No opacification
1	Partial opacification
2	Complete opacification

All CT images were reviewed and reported by a consultant radiologist; patients were excluded from the study if there was any evidence of temporal bone or skull base fracture. We were unable to obtain access to full patient notes for retrospective data collection; therefore, we were unable to exclude patients who had undergone previous otological or rhinological surgery.

Axial and coronal CT images were analysed to determine the extent of paranasal sinus, middle-ear and mastoid opacification. Patients were excluded if there was any evidence of temporal bone or skull base fracture. The Lund–Mackay 3-point scoring system was used to individually categorise opacification of maxillary, frontal, anterior and posterior ethmoidal, osteomeatal complex and sphenoid sinuses bilaterally (Table 1 and Figure 1), with a maximum total score of 24. Similarly, mastoid and middle-ear opacification was graded bilaterally using a 3-point scale (Table 2 and Figure 2), with a maximum total score of 8. Mortality was recorded if it occurred within 30 days of the date of imaging. Our outcomes were compared against pre-pandemic studies examining the prevalence of incidental mastoid[25] and sinus[26] opacification.

A Mann–Whitney U test was used to determine whether there were differences in total Lund–Mackay sinus scores or middle-ear and mastoid opacification scores between patients who had died or survived at 30-days' follow up. *P*-values of less than 0.05 were considered a statistically significant result. Statistical analysis was performed using SPSS Statistics software for MacBook, version 28.0.1.0 (IBM, Armonk, New York, USA).

Results

Of 147 patients originally identified, only 83 patients had a positive polymerase chain reaction test result within 7 days of imaging, thereby meeting the criteria for inclusion. Forty-nine patients (59.0 per cent) were male and 34 (41.0 per cent) were female (Table 3). Mean age was 77.3 years (standard deviation = 14.5), with an age range of 19–98 years. Thirty-eight patients (45.8 per cent) died within 30 days of the date of imaging. The most common indications for CT of the head were suspected intracranial haemorrhage (31.3 per cent, $n = 26$) and suspected cerebrovascular accident (26.5 per cent, $n = 22$) (Table 4).

The incidence of opacification by anatomical subsite is reported in Table 5. Out of 83 patients, 43 had some form of sinus opacification (51.8 per cent); of these 43 patients, 21 had bilateral sinus opacification (48.8 per cent). Twenty of the 83 patients had some middle-ear or mastoid opacification (24.1 per cent); of these 20 patients, 9 had bilateral ear involvement (45 per cent).

Lund–Mackay sinus score

The median total Lund–Mackay sinus score for all included patients was 1.0 (interquartile range = 2.0). A Mann–Whitney U test was performed to determine whether there were differences in the total Lund–Mackay sinus score between patients who were alive at 30 days post imaging and those who had died. Distributions of the Lund–Mackay sinus score between the two groups of patients were similar, as assessed by visual inspection. Median total Lund–Mackay sinus scores for patients who survived (1.0, interquartile range = 2) and those who died (0.5, interquartile range = 1) were not statistically significantly different (U = 747.5, $p = 0.294$).

Middle-ear and mastoid opacification score

The median middle-ear and mastoid opacification score for all included patients was 0 (interquartile range = 0). A Mann–Whitney U test was performed to determine whether there were differences in the total middle-ear and mastoid opacification score between patients who were alive at 30 days post imaging and those who had died. Distributions of the temporal bone opacification score between the two groups of

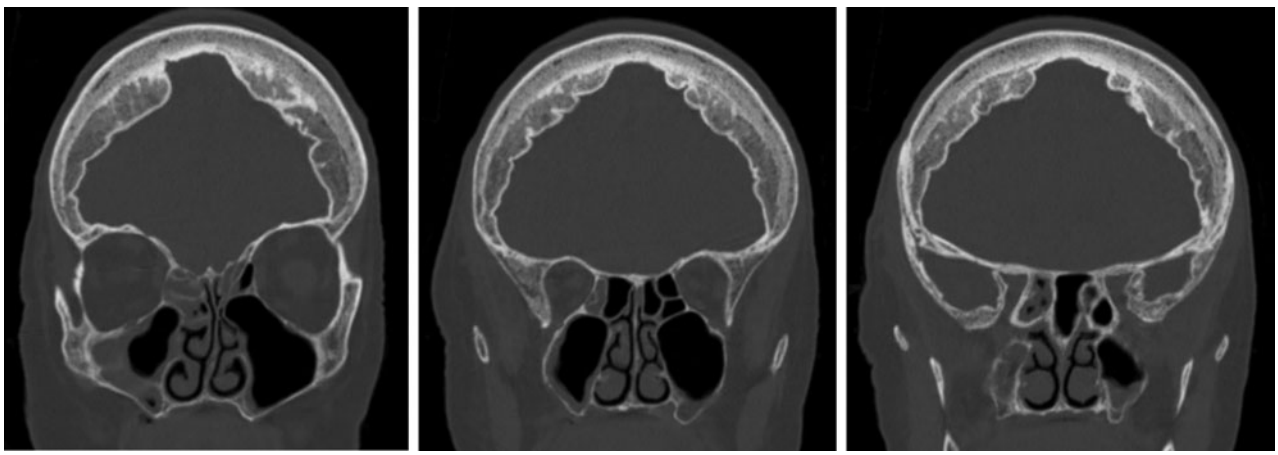

Fig. 1. Example of Lund–Mackay sinus scoring. Non-contrast coronal computed tomography images of the head of a patient with a total Lund–Mackay sinus score of 4: partial opacification of left anterior ethmoid sinus (1 point); partial opacification of right maxillary sinus (1 point); partial opacification of right anterior ethmoid sinus (1 point); and partial opacification of right sphenoid sinus (1 point).

https://doi.org/10.1017/S0022215122002304 Published online by Cambridge University Press

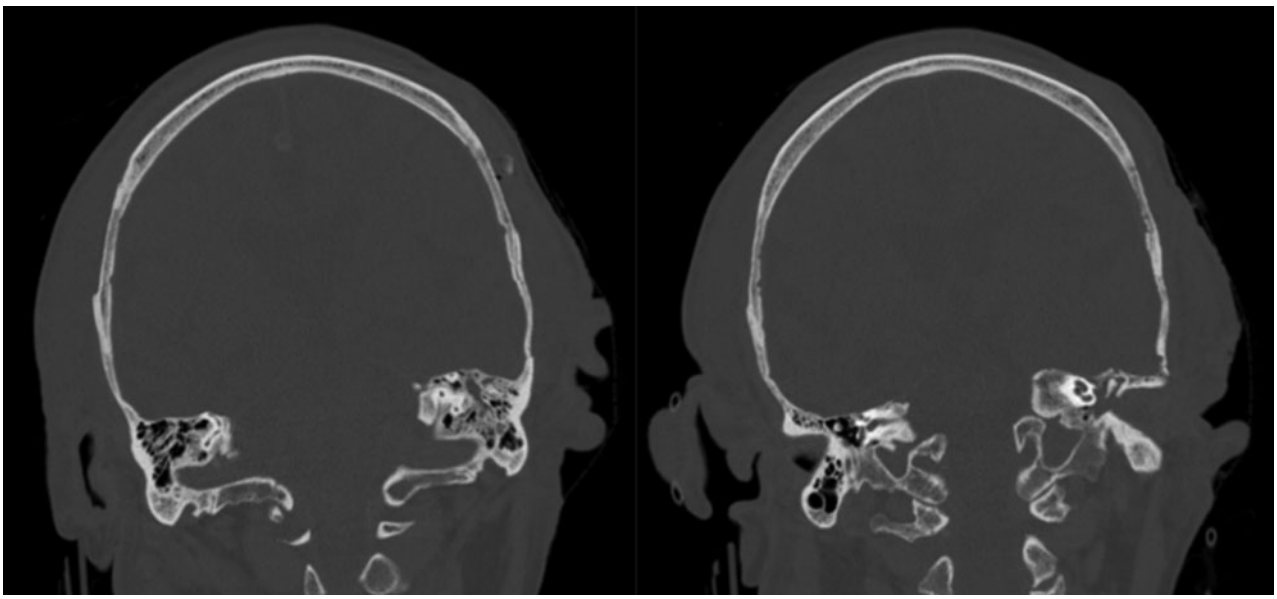

Fig. 2. Example of middle-ear and mastoid opacification scoring. Non-contrast coronal computed tomography images of the head of a patient with a total middle-ear and mastoid opacification score of 3: partial opacification of left mastoid (1 point) and total opacification of left middle ear (2 points).

patients were similar, as assessed by visual inspection. Median temporal bone opacification scores for patients who survived (0, interquartile range = 1.0) and those who died (0, interquartile range = 0) were not statistically significantly different (U = 839, $p = 0.845$).

Discussion

Of 83 patients eligible for inclusion, 51.8 per cent ($n = 43$) had evidence of sinus opacification and 24.1 per cent ($n = 20$) had evidence of middle-ear or mastoid opacification. The median total Lund–Mackay sinus score for all patients was 1.0 (interquartile range = 2.0), and the median middle-ear and mastoid opacification score was 0 (interquartile range = 0). There was no statistically significant difference in sinus or middle-ear and mastoid opacification between patients after stratification based on 30-day all-cause mortality.

Marginally lower rates of sinus and mastoid opacification in patients with Covid-19 are reported in the literature (Table 6);[25–30] 41.8 per cent of Moonis and colleagues' cohort of 55 patients had sinus disease, yet only 7 per cent demonstrated mastoid opacification.[29] Similarly, İslamoğlu *et al.* reported much lower levels of mastoid opacification in a cohort of 129 patients, at only 2.32 per cent.[30]

Our results reflect higher levels of sinus opacification in patients with Covid-19 when compared with a 14.8–37 per cent rate of incidental prevalence of sinus opacification on CT prior to the SARS-CoV-2 pandemic.[26] However, Naeini *et al.* analysed CT imaging of patients with anosmia secondary to Covid-19 infection, and found that most patients (83.7 per cent) had a Lund–Mackay score of 0, discrediting a conductive pathophysiology for anosmia.[27] Similarly, a systematic review of radiological imaging in Covid-19 patients with anosmia, by Keshavarz *et al.*, suggested sinus opacification in only 12.5 per cent.[28] The pattern of sinus involvement was also variable. Maxillary and ethmoidal sinus involvement predominated in our study, whereas frontal sinus involvement was uncommon. Similarly, ethmoidal, maxillary and sphenoid sinuses were most commonly affected in Moonis and colleagues' cohort.[29]

Although the nasopharynx has been demonstrated to host high titres of SARS-CoV-2,[9,10] literature suggests this is not reflected in radiological findings.[29,30] Moonis *et al.* further demonstrated that olfactory cleft opacification and nasopharyngeal thickness did not correlate with Covid-19 infection.[29] Such limited sinonasal involvement does not reflect radiological findings reported for other viral upper respiratory tract infections.[31] Moonis *et al.* also reported minimal radiological evidence of sinusitis secondary to SARS-CoV-2, which correlated with their clinical findings; less than 10 per

Table 3. Patient demographics and incidence of opacification on head CT

Parameter	All patients*	Survival at 30-days follow up†	Deceased at 30-days follow up‡
Age (mean (SD); years)	70.2 (14.7)	77.2 (14.5)	82.2 (14.0)
Gender (M/F; *n*)	49/34	26/19	23/15
Sinus opacification (*n* (%))	43 (51.8)	24 (53.3)	19 (50)
Middle-ear & mastoid opacification (*n* (%))	20 (24.1)	9 (20)	11 (29)

*$n = 83$; †$n = 45$; ‡$n = 38$. CT = computed tomography; SD = standard deviation; M = male; F = female

Table 4. Indication for head CT

Indication	Patients (*n* (%))
Suspected intracranial haemorrhage	26 (31.3)
Suspected CVA	22 (26.5)
Low GCS score	11 (13.3)
Trauma	11 (13.3)
Seizure	5 (6.0)
Confusion	3 (3.6)
Headache	2 (2.4)
Other	3 (3.6)

CT = computed tomography; CVA = cerebrovascular accident; GCS = Glasgow Coma Scale

https://doi.org/10.1017/S0022215122002304 Published online by Cambridge University Press

Table 5. Incidence of opacification by subsite

Subsite	No opacification (%)	Partial opacification (%)	Complete opacification (%)
Frontal sinuses	90.4	9.6	0
Anterior ethmoid sinuses	77.1	21.7	1.2
Posterior ethmoid sinuses	81.9	16.9	1.2
Maxillary sinuses	54.2	45.8	0
Osteomeatal complex	100	0	0
Mastoid	69.9	27.7	2.4
Middle ear	90.4	8.4	1.2

cent of their study population reported symptoms of upper respiratory tract infection.[29] Systematic reviews[32] and case series[33–35] suggest sinonasal symptoms are atypical in Covid-19 infection, with lower respiratory tract infection and constitutional symptoms predominating. Reports suggest nasal congestion and rhinorrhoea are less common symptoms,[32] in comparison to fever, fatigue, cough and shortness of breath.[33–35] Although magnetic resonance imaging modalities were beyond the scope of this paper (as they were not available for the patients), other studies have correlated anosmia with loss of olfactory bulb volume, opacification of the olfactory cleft and a T2-weighted fluid-attenuated inversion recovery ('FLAIR') hyperintensity of the olfactory tract.[36–38]

Mastoiditis is a frequent incidental radiological finding on CT of the head, as fluid collects in mastoid air cells whilst the patient lies supine as the scan is performed.[25] Mughal *et al.* reported that 8.4 per cent of head CT scans suggested incidental mastoid opacification.[25] Acute otitis media is a common sequelae of upper respiratory tract infection,[10,30] with consequent middle-ear effusion and mastoid opacification identifiable on radiological imaging.[15] Thus, Covid-19 was postulated to manifest as ontological involvement. However, İslamoğlu *et al.* evaluated temporal CT scans of patients with Covid-19 and found no significant middle-ear or mastoid inflammation,[30] reflecting findings seen in our study, which shows a 24.1 per cent rate of ontological radiological signs.

We recognise that our study has some limitations. A comparator group of coronavirus-negative patients undergoing CT of the head was deemed impractical owing to initially high false negative polymerase chain reaction results.[39] Whilst Moonis *et al.*[29] correlated imaging with patient symptoms, contemporaneous assessment of clinical features was renounced owing to the contagious nature of Covid-19 and concomitant pressures on healthcare workers. Similarly, pure tone audiology would have provided an objective assessment of hearing, but was deemed unfeasible for the purposes of this study as the patients were in isolation and, in some cases, critically unwell.

Images were reviewed by otolaryngologists with prior experience in analysing CT scans of the sinuses and temporal bones. Ideally, imaging findings would be independently corroborated by a second reviewer, or reported by a specialist head and neck radiologist.[29] Emulating Moonis *et al.*,[29] further analysis could have assessed nasopharyngeal thickness and olfactory recess opacification. Intubated patients or those with nasogastric tubes at the time of imaging were not excluded, as cross-sectional imaging was not always sufficiently caudal. Finally, patients who had previously undergone sinus surgery or required prior otological procedures were not excluded from this study.

Although there was no statistical correlation between sinus opacification or middle-ear and mastoid opacification and mortality, there have been no assessments of long-term sequelae. This is pertinent to ENT, with known long coronavirus effects of anosmia[40] and sensorineural hearing loss[17] publicised. Additionally, the statistics presented may prove beneficial when explaining radiological imaging to patients in clinic.

- This study assessed paranasal sinus, middle-ear and mastoid radiological inflammation in coronavirus disease 2019 (Covid-19)
- Sinus opacification levels were higher in Covid-19 patients compared with incidental prevalence prior to the pandemic
- High titres of severe acute respiratory syndrome coronavirus-2 have been identified previously in the nasopharynx and mastoid
- Only mild mucosal disease within the sinuses, middle ear and mastoid was identified radiologically
- This study does not demonstrate a statistically significant correlation between sinus or middle-ear or mastoid opacification and 30-day mortality

Table 6. Literature review of studies examining incidence of sinus and mastoid and middle-ear opacification

Study	Patients (*n*)	Sinus involvement (%)	Mastoid & middle-ear involvement (%)
Watts *et al.* (current paper)	83	51	24
Nazri *et al.*[26]	115	14.8–37	N/A
Mughal *et al.*[25]	246 288	N/A	8
Moonis *et al.*[29]	55	41.8	7
Islamoghu[30]	129	N/A	2.32
Naeini *et al.*[27]	49	16.3	N/A
Kesharvarz *et al.*[28]	129	12.5	N/A

N/A = not applicable

Variable sinus and mastoid and middle-ear opacification may occur between different coronavirus variants. There may be value in repeating this study in another time cohort, to assess whether there is any variation in results with a different viral genotype, or variation in symptoms of otitis media with effusion, hearing loss, rhinosinusitis or Eustachian tube dysfunction.

Conclusion

Radiological findings on CT imaging in patients with SARS-CoV-2 infection suggest only mild mucosal disease within the paranasal sinuses (51.8 per cent), middle ear and mastoid cavity (24.1 per cent). There is no statistical correlation between sinus or mastoid opacification and mortality.

Competing interests. None declared

References

1 Yamamoto S, Saito M, Tamura A, Prawisuda D, Mizutani T, Yotsuyanagi H. The human microbiome and COVID-19: a systematic review. *PLoS One* 2021;**16**:e0253293

2 Cereda PM, Pagani L, Romero E. Prevalence of antibody to human coronaviruses 229E, OC43 and neonatal calf diarrhea coronavirus (NCDCV) in patients of Northern Italy. *Eur J Epidemiol* 1986;**2**:112–17

https://doi.org/10.1017/S0022215122002304 Published online by Cambridge University Press

3 Liu DX, Liang JQ, Fung TS. Human coronavirus-229E, -OC43, -NL63, and -HKU1 (Coronaviridae). In: Bamford DH, Zuckerman M, eds. *Encyclopaedia of Virology*, 4th edn. Cambridge, MA: Academic Press, 2021;428–40
4 Su S, Wong G, Shi W, Liu J, Lai ACK, Zhou J *et al.* Epidemiology, genetic recombination, and pathogenesis of coronaviruses. *Trends Microbiol* 2016;**24**:490–502
5 Zhou F, Yu T, Du R, Fan G, Liu Y, Liu Z *et al.* Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. *Lancet* 2020;**395**:1054–62
6 Desforges M, Gurdasani D, Hamdy A, Leonardi AJ. Uncertainty around the long-term implications of COVID-19. *Pathogens* 2021;**10**:1267
7 Li Q, Guan X, Wu P, Wang X, Zhou L, Tong Y *et al.* Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. *N Engl J Med* 2020;**382**:1199–207
8 Liaw J, Saadi R, Patel VA, Isildak H. Middle ear viral load considerations in the COVID-19 era: a systematic review. *Otol Neurotol* 2021;**42**:217–26
9 Sungnak W, Huang N, Bécavin C, Berg M, Queen R, Litvinukova M *et al.* SARS-CoV-2 entry factors are highly expressed in nasal epithelial cells together with innate immune genes. *Nat Med* 2020;**26**:681–7
10 Zou L, Ruan F, Huang M, Liang L, Huang H, Hong Z *et al.* SARS-CoV-2 viral load in upper respiratory specimens of infected patients. *N Engl J Med* 2020;**382**:1177–9
11 Hasanoglu I, Korukluoglu G, Asilturk D, Cosgun Y, Kalem AK, Altas AB *et al.* Higher viral loads in asymptomatic COVID-19 patients might be the invisible part of the iceberg. *Infection* 2021;**49**:117–26
12 Elkhatieb A, Hipskind G, Woerner D, Hayden FG. Middle ear abnormalities during natural rhinovirus colds in adults. *J Infect Dis* 1993;**168**:618–21
13 Brennan T, Saadia-Redleaf M. Occult middle ear and mastoid fluid in acute otitis externa. *Laryngoscope* 2012;**122**:2067–70
14 Bulut Y, Güven M, Otlu B, Yenişehirli G, Aladağ I, Eyibilen A *et al.* Acute otitis media and respiratory viruses. *Eur J Pediatr* 2007;**166**:223–8
15 Pitkäranta A, Jero J, Arruda E, Virolainen A, Hayden FG. Polymerase chain reaction-based detection of rhinovirus, respiratory syncytial virus, and coronavirus in otitis media with effusion. *J Pediatr* 1998;**133**:390–4
16 Frazier KM, Hooper JE, Mostafa HH, Stewart CM. SARS-CoV-2 virus isolated from the mastoid and middle ear: implications for COVID-19 precautions during ear surgery. *JAMA Otolaryngol Head Neck Surg* 2020;**146**:964–6
17 Koumpa FS, Forde CT, Manjaly JG. Sudden irreversible hearing loss post COVID-19. *BMJ Case Rep* 2020;**13**:e238419
18 Kilic O, Kalcioglu MT, Cag Y, Tuysuz O, Pektas E, Caskurlu H *et al.* Could sudden sensorineural hearing loss be the sole manifestation of COVID-19? An investigation into SARS-COV-2 in the etiology of sudden sensorineural hearing loss. *Int J Infect Dis* 2020;**97**:208–11
19 Degen C, Lenarz T, Willenborg K. Acute profound sensorineural hearing loss after COVID-19 pneumonia. *Mayo Clin Proc* 2020;**95**:1801–3
20 Abdel Rhman S, Abdel Wahid A. COVID-19 and sudden sensorineural hearing loss, a case report. *Otolaryngol Case Rep* 2020;**16**:100198
21 Mustafa MWM. Audiological profile of asymptomatic Covid-19 PCR-positive cases. *Am J Otolaryngol* 2020;**41**:102483
22 Sriwijitalai W, Wiwanitkit V. Hearing loss and COVID-19: a note. *Am J Otolaryngol* 2020;**41**:102473
23 Brann DH, Tsukahara T, Weinreb C, Lipovsek M, Van den Berge K, Gong B *et al.* Non-neuronal expression of SARS-CoV-2 entry genes in the olfactory system suggests mechanisms underlying COVID-19-associated anosmia. *Sci Adv* 2020;**6**:eabc5801
24 Zhang Q, Shan KS, Abdollahi S, Nace T. Anosmia and ageusia as the only indicators of coronavirus disease 2019 (COVID-19). *Cureus* 2020;**12**:e7918
25 Mughal Z, Charlton A, Clark M. The prevalence of incidental mastoid opacification and the need for intervention: a meta-analysis. *Laryngoscope* 2021;**132**:422–32
26 Nazri M, Bux SI, Tengku-Kamalden TF, Ng KH, Sun Z. Incidental detection of sinus mucosal abnormalities on CT and MRI imaging of the head. *Quant Imaging Med Surg* 2013;**3**:82–8
27 Naeini AS, Karimi-Galougahi M, Raad N, Ghorbani J, Taraghi A, Haseli S *et al.* Paranasal sinuses computed tomography findings in anosmia of COVID-19. *Am J Otolaryngol* 2020;**41**:102636
28 Keshavarz P, Haseli S, Yazdanpanah F, Bagheri F, Raygani N, Karimi-Galougahi M. A systematic review of imaging studies in olfactory dysfunction secondary to COVID-19. *Acad Radiol* 2021;**28**:1530–40
29 Moonis G, Mitchell R, Szeto B, Lalwani AK. Radiologic assessment of the sinonasal tract, nasopharynx and mastoid cavity in patients with SARS-Cov-2 infection presenting with acute neurological symptoms. *Ann Otol Rhinol Laryngol* 2021;**130**:1228–35
30 İslamoğlu Y, Ayhan M, Bercin S, Kalem A, Kayaaslan B, Güner R. Evaluation of middle ear and mastoid cells of COVID-19 patients. *J Ankara Univ Fac Med* 2021;**74**:130–3
31 Gwaltney JM, Phillips CD, Miller RD, Riker DK. Computed tomographic study of the common cold. *N Engl J Med* 1994;**330**:25–30
32 Lovato A, de Filippis C. Clinical presentation of COVID-19: a systematic review focusing on upper airway symptoms. *Ear Nose Throat J* 2020;**99**:569–76
33 Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y *et al.* Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet* 2020;**395**:497–506
34 Krajewska J, Krajewski W, Zub K, Zatoński T. COVID-19 in otolaryngologist practice: a review of current knowledge. *Eur Arch Otorhinolaryngol* 2020;**277**:1885–97
35 Zhang JJ, Dong X, Cao YY, Yuan YD, Yang YB, Yan YQ *et al.* Clinical characteristics of 140 patients infected by SARS-CoV-2 in Wuhan, China. *Allergy* 2020;**75**:1730–41
36 Laurendon T, Radulesco T, Mugnier J, Gérault M, Chagnaud C, El Ahmadi AA *et al.* Bilateral transient olfactory bulb edema during COVID-19-related anosmia. *Neurology* 2020;**95**:224–5
37 Kandemirli SG, Altundag A, Yildirim D, Tekcan Sanli DE, Saatci O. Olfactory bulb MRI and paranasal sinus CT findings in persistent COVID-19 anosmia. *Acad Radiol* 2021;**28**:28–35
38 Strauss SB, Lantos JE, Heier LA, Shatzkes DR, Phillips CD. Olfactory bulb signal abnormality in patients with COVID-19 who present with neurologic symptoms. *AJNR Am J Neuroradiol* 2020;**41**:1882–7
39 Kucirka LM, Lauer SA, Laeyendecker O, Boon D, Lessler J. Variation in false-negative rate of reverse transcriptase polymerase chain reaction-based SARS-CoV-2 tests by time since exposure. *Ann Intern Med* 2020;**173**:262–7
40 Walker A, Pottinger G, Scott A, Hopkins C. Anosmia and loss of smell in the era of covid-19. *BMJ* 2020;**370**:2808

https://doi.org/10.1017/S0022215122002304 Published online by Cambridge University Press