Middle Ear Viral Load Considerations in the COVID-19 Era: A Systematic Review

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Objective: To systematically review the available medical literature to investigate the viral load in the middle ear and mastoid cavity and the potential risk of exposure to airborne viruses during otologic surgery.
Data Sources: PubMed, MEDLINE, and Cochrane databases.
Study Selection: This review was performed using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Protocol.
Data Extraction: Using the Boolean method and relevant search term combinations for terms ''mastoid,'' ''middle ear,'' ''virus,'' ''exposure'' ''COVID-19'' ''SARS-CoV-2.'' PubMed, MEDLINE, and Cochrane databases were queried. A total of 57 abstracts were identified and screened by two independent reviewers. Following inclusion and exclusion criteria, 18 studies were selected for the final analysis.
Data Synthesis: Due to the heterogeneity of clinical data, a meta-analysis was not feasible.
Results: Rhinovirus, followed by respiratory syncytial virus are reported to be the most prevalent viruses in MEF samples but formal statistical analysis is precluded by the heterogeneity of the studies. Drilling was identified to have the highest risk for aerosol generation and therefore viral exposure during otologic Surgery.
Conclusions: The medical literature has consistently demonstrated the presence of nucleic acids of respiratory viruses involving the middle ear, including SARS-CoV2 in a recent postmortem study. Although no in vivo studies have been conducted, due to the likely risk of transmission, middle ear and mastoid procedures, particularly involving the use of a drill should be deferred, if possible, during the pandemic and enhanced personal protective equipment (PPE) used if surgery is necessary. **Key Words:** Exposure—Mastoid—Middle ear—Respiratory—Virus.

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The Coronavirus disease of 2019 (COVID-19), first reported in Wuhan, China on December 31, 2019, has gone on to become a global pandemic with confirmed cases present in over 160 countries, affecting over 2.5 million individuals, and resulting in over 190,000 deaths. This has subsequently placed a strain on healthcare systems in all fields of medicine and has resulted in a shortage on personal protective equipment (PPE) (1).

The 2019 novel Coronavirus, now named SARS-CoV2, spreads by droplet transmission and is known to have a viral reservoir in the upper aerodigestive tract. Through discussion with physicians in Wuhan, it was recognized that otolaryngologists are at particularly high risk for nosocomial infection due to direct mucosal contact during a head and neck examination as well as due to involvement in aerosol generating procedures involving the oral cavity, oropharynx, nasal cavity, and nasopharynx (2–4). Consequently, the American Academy of Otolaryngology–Head and Neck Surgery (AAO-HNS) has published guidelines regarding COVID-19 testing before elective cases as well as recommendations on categorizing cases into emergent, urgent, time-sensitive, and routine allowing providers to prioritize cases based on risk and available resources (5).

While there have been recommendations and guidelines published on performing aerodigestive surgery during the COVID-19 pandemic, there is limited data on the safety of performing otologic procedures and the risk of aerosolization of middle ear tissue. It is known that otologic procedures carry a risk of contracting blood-borne illnesses due to the utilization of sharp instruments, high-speed drills, and needle tips. It is unclear, however, whether there is a significant enough reservoir of respiratory viruses within the middle ear to be a risk to the surgical team.

Therefore, the goal of this systematic review is to evaluate the current evidence regarding the presence of a viral load in the middle ear and mastoid cavity during a middle ear infection (acute otitis media, otitis media with

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effusion, or tube otorrhea) and ascertain the potential risk of exposure to airborne viruses during otologic surgery.

MATERIALS AND METHODS

Search Strategy

This review was designed and performed using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Protocol. Independent searches of the PubMed, MEDLINE, and Cochrane databases were performed on April 8, 2020 by the authors to identify studies which specifically described the presence of respiratory viruses in the middle ear using the Boolean method and relevant search term combinations for terms ''mastoid,'' ''middle ear,'' ''virus,'' ''exposure,'' ''COVID-19,'' ''SARS-CoV-2.'' PubMed, MEDLINE, and Cochrane databases were queried from inception to April 8, 2020. Articles were sorted by best match without limitations on article type, text availability, or publication dates. To identify additional articles, the reference lists of relevant articles were hand searched as well as citing articles.

Selection Criteria

Eligible articles included English and full-length original articles with clinical descriptions of respiratory viruses detected in middle ear fluid via reverse transcription polymerase chain reaction (RT-PCR), or transmission of respiratory viruses via middle ear or mastoid surgery.

Exclusion criteria include duplicates, absent full-text articles, and non-English articles. Articles that performed assays other than RT-PCR were excluded. Articles that described surrogate measures of the middle ear viruses such as through nasopharyngeal swabbing without direct assay of middle ear fluid, or through alternative methods such as via immunoassay were excluded from this analysis.

Data Extraction

Information was extracted from each article using standardized data extraction forms for assessing study characteristics (design, setting, inclusion, and exclusion criteria), patient characteristics (age, conditions studied), sample size, number of positive results, and viral agents detected in MEF. The participants, interventions, comparisons, outcomes, timing, and study design (PICOTS) is demonstrated in (Table 1).

Data Analysis

A formal meta-analysis could not be performed due to the heterogeneity among the studies as there were significant differences in study population, setting, timing of assay, and viruses evaluated. We extracted the prevalence of viruses reported in the middle ear fluid (MEF), or recalculated these from the reported data.

RESULTS

A database search resulted in 1,724 publications, with 833 publications after duplicates were removed. After screening titles and abstracts, 57 publications appeared to be relevant. Of these 57 studies, 18 met the inclusion criteria, with nine specifically reporting coronavirus testing (Fig. 1).

Risk of Bias

Given that the majority of publications that met criteria were cross-sectional studies or cohort studies, the Risk of Bias Assessment tool for Non-randomized Studies (RoBANS) (Fig. 2) was used to assess risk of bias across six metrics: selection of patients, confounding variables, intervention (exposure) measurement, blinding of outcome measurement, incomplete outcome data, selective outcome reporting, and evaluated by two reviewers (6). A breakdown of the risk of bias is demonstrated in Table 2.

Level of Evidence

The Oxford Centre for Evidence-Based Medicine 2011 Levels of Evidence was used to assess each publication for level of evidence and evaluated by two reviewers (7). The level of evidence determined for each publication is listed in Table 2.

Study Characteristics

The characteristics of the included studies are presented in Table 3. Overall, the selected studies included approximately 5,312 MEF samples from 3,295 patients with either acute otitis media or otitis media with effusion. Study sizes ranged from 26 to 611 patients with the number of ears sampled ranging from 37 to 1,491. Ages ranged from 1 month to 12 years of age. The majority of studies were performed at tertiary care facilities although the studies with the largest sample sizes were longitudinal studies drawn from the Finnish Otitis Media (FinOM) Cohort study or the Finnish Otitis Media (FinOM) Vaccine Trial which were both performed at primary and secondary centers.

Otitis Media

Acute otitis media (AOM), when described, was defined as the presence of otoscopic findings of an abnormal tympanic membrane (in regard to color, position, mobility suggesting the presence of middle ear fluid), or perforation of the tympanic membrane with or without symptoms such as fevers, otalgia, and ear tugging. This definition is consistent with AOM as defined by the American Academy of Family Physicians and American Academy of Pediatrics, which define AOM as either 1) moderate to severe bulging of the tympanic membrane (TM) or new onset of otorrhea not due to acute otitis externa, or 2) mild bulging of the TM and recent (<48 h) onset of ear pain (holding, tugging, rubbing of the ear in a nonverbal child) or intense erythema of the TM (8).

Bulut et al. (9) and Pitkäranta et al. (10,11), make the distinction of AOM from Otitis Media with effusion (OME) with the criteria for diagnosis of OME being the presence of effusion behind an intact tympanic membrane as determined by pneumatic otoscopy, tympanometry, or confirmed by myringotomy tube placement.

Bulut et al. (9), Buzatto et al. (12), and Stol et al. (13), defined OME as evidence of middle ear fluid revealed by tympanometry. Monobe et al. (14), Pitkäranta et al. (10,11) defined OME as evidence of effusion determined by pneumatic otoscopy. Nokso-Koivisto et al., Sawada et al., and Yatshyshin et al. diagnosed OME via visual appearance of the tympanic membrane with no mention of pneumatic otoscopy or tympanometry (15–18).

TABLE 1. *PICOTS (population, interventions, comparators, outcomes, timing, and setting)*

Year	Author	Journal	Population	Intervention	Comparators	Outcomes	Type of Study	Timing and Setting
2019	Sawada	The Pediatric Infectious Disease Journal	Children w/AOM, 122 patients aged 4 months to 3 years	Tympanocentesis, RT-PCR, culture of MEF and NPA samples	Comparison between viral infection, bacterial infection, and coinfection	Prevalence of bacteria and respiratory viruses	CSS	Sampling during acute care visit at time of diagnosis, Tertiary care center
2017	Buzatto	Plos One	37 Children w/OME, 14 children undergoing Cochlear implant (control), aged 2–12 years	Tube placement, RT-PCR of Middle ear washing, Adenoid biopsy	Comparison between respiratory viruses	Prevalence of respiratory viruses	CSS	Intraoperative tympanocentesis of middle ear washings, Tertiary care center
2016	Yatsyshina	Diagnostic Microbiology and Infectious Disease	Children w/AOM, 179 pts aged 1 month to 5 years	Tympanocentesis, RT-PCR of MEF and NPA samples	Comparison between viral infection, bacterial infection, and coinfection	Prevalence of bacteria and respiratory viruses	RCS	Sampling during acute care visit at time of diagnosis, Tertiary care center
2015	van Dongen	The Pediatric Infectious Disease Journal	Children w/tube otorrhea, aged 1 to 10 years	Tympanocentesis, RT-PCR, Culture of MEF and NPA samples	Comparison between viral infection, bacterial infection, and coinfection	Prevalence of bacteria and respiratory viruses	RCS	Sampling during acute care visit before and 2 weeks after AOM treatment, Tertiary care center
2012	Stol	The Pediatric Infectious Disease Journal	Children w/OME, 116 patients up to 5 years of age	Tube placement, RT-PCR, Cytometry of MEF samples	Comparison between viral infection, bacterial infection, and coinfection	Prevalence of bacteria and respiratory viruses, presence of inflammatory exudate	RCS	Intraoperative tympanocentesis during scheduled tympanostomy tube placement, Tertiary care center
2011	Wiertsema	Journal of Medical Virology	Children w/ROM, 180 patients ranged 6 mo to 3 years	Gram staining/ culture, RT-PCR of MEF and NPA samples	Comparison between viral infection, bacterial infection, and coinfection	Prevalence of bacteria and respiratory viruses	CSCS	Intraoperative tympanocentesis during scheduled tympanostomy tube placement, Tertiary care center
2007	Bulut	European Journal of Pediatrics	Children w/AOM, 100 patients ranged 6 months to 12 years	Tube placement, Gram staining/ culture, RT-PCR of MEF samples	Comparison between viral infection, bacterial infection, and coinfection	Prevalence of bacteria and respiratory viruses	CSCS	Sampling during acute care visit at time of diagnosis, Tertiary care center
2006	Ruohola	Clinical Infectious Diseases	Children w/tube otorrhea, 79 patients aged 7 months to 6 years	RT-PCR of MEF samples	Comparison between viral infection, bacterial infection, and coinfection	Prevalence of respiratory viruses, coinfection	CSS	Sampling during acute care visit at time of diagnosis, Tertiary care center
2005	Kleemola	Journal of Infection	Children w/AOM, 940 patients aged 2 months to 2 years	EIA, RT-PCR of MEF samples	Comparison between respiratory viruses	Prevalence of respiratory viruses	RCS	Sampling during acute care visit at time of diagnosis, Primary care center

TABLE 1 *(Continued)*

Year	Author	Journal	Population	Intervention	Comparators	Outcomes	Type of Study	Timing and Setting
2004	Nokso-Koivisto	Journal of Medical Virology	Children w/ AOM, 940 patients aged 2 months to 2 years	RT-PCR of MEF and NPA samples	Comparison between respiratory viruses	Prevalence of respiratory viruses, coinfection	CSCS	Sampling during acute care visit at time of diagnosis, Primary care center
2003	Monobe	International Journal of Pediatric Otorhinolaryngology	Children w/ AOM, 79 patients aged 5 months to 6 years	RT-PCR of MEF samples	Comparison between viral infection with or without bacterial coinfection	Persistent AOM, recurrent AOM, early recurrent AOM	CSS	Sampling during acute care visit at time of diagnosis, Tertiary care center
2000	Chonmaitree	The Pediatric Infectious Disease Journal	Children w/AOM, 40 patients	RT-PCR/EIA of MEF samples	Comparison between respiratory viruses	Prevalence of respiratory viruses, coinfection	RCS	Sampling during acute care visit at time of diagnosis, Primary care center
2000	Moyse	Archives of Otolaryngology Head and Neck Surgery	Children w/OME, 26 patients aged 2 to 11 years	RT-PCR of MEF samples, Mucosal biopsy	Comparison between respiratory viruses	Prevalence of respiratory viruses, inflammatory exudates	CSS	Intraoperative tympanocentesis during scheduled tympanostomy tube placement, Tertiary care center
2000	Nokso-Koivisto	The Pediatric Infectious Disease Journal	Children w/AOM, 329 patients aged 2 months to 2 years	RT-PCR of MEF and NPA samples	Comparison between Coronavirus strains	Prevalence of Coronavirus	RCS	Sampling during acute care visit, Primary care center
1998	Pitkäranta	The Journal of Pediatrics	Children w/OME, 92 patients aged 3 months to 7 years	RT-PCR of MEF and NPA samples	Comparison between respiratory viruses	Prevalence of respiratory viruses, coinfection	CSS	Sampling during acute care visit at time of diagnosis, Tertiary care center
1998	Pitkäranta	The Journal of Pediatrics	Children w/OME, 100 patients aged 6 months to 12 years	RT-PCR of MEF samples	Comparison between respiratory viruses	Prevalence of respiratory viruses, coinfection	CSS	Intraoperative tympanocentesis during scheduled surgery at time of diagnosis, Tertiary care center

CSCS indicates cross-sectional cohort study; CSS, cross-sectional study; RCS, retrospective cohort study.

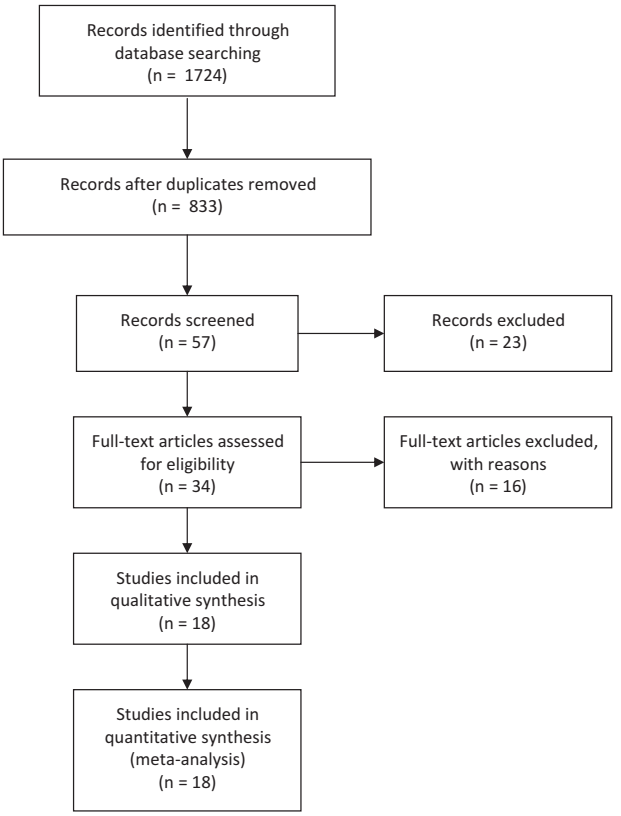

FIG. 1. Flowchart outlining the paper selection process of the systematic review (based on PRISMA guidelines). PRISMA indicates preferred reporting items for systematic reviews and meta-analyses.

Virology

Since the late 1990s, nucleic acid amplification tests (NAATs), namely quantitative real-time PCR (qRT-PCR), has been used for the diagnosis of respiratory viruses (19). Quantitative real-time PCR has demonstrated improved sensitivity when compared to prior techniques such as direct fluorescent immunoassays. Per inclusion criteria, all studies used RT-PCR in the diagnosis of respiratory viruses in the middle ear.

Formal statistical analysis of the prevalence of all respiratory viruses, however, is precluded by the heterogeneity of the studies. Many of the studies were noted to omit several common respiratory viruses. This is especially notable with earlier studies due to the novelty of RT-PCR.

From the studies reviewed, however, RT-PCR was able to detect the presence of viral nucleic acids in the pediatric population with otitis media in 11 to 71% of ears. Rhinovirus, and respiratory syncytial virus are most commonly reported to be present in the middle ear (Table 3) (9–25).

DISCUSSION

Our review demonstrates that PCR can detect the presence of viral nucleic acids in the pediatric population with otitis media in 11 to 71% of ears. The Enteroviruses, including rhinovirus, and respiratory syncytial virus are reported to most commonly be present in the middle ear (Table 3). Other common respiratory viruses include Parainfluenza, Coronavirus, and Adenovirus.

Limitations

There are several limitations to determining the true prevalence of these viruses. The first limitation is the aforementioned novelty of qRT-PCR. Many of the earlier studies omitted commonly accepted respiratory viruses due to the non-existence of viral specific primers as well as the lack of a standardized multiplex qRT-PCR.

The second limitation was the fact that the diagnosis of viral otitis media was also a secondary endpoint for many of these studies. The focus of many studies was directed at diagnosing bacterial AOM due to its prevalence and clinical significance with a much less comprehensive approach directed at viruses. While there is certainly a role that respiratory viruses play in the pathogenesis of otitis media, the clinical relevance of diagnosing the presence of respiratory viruses is unclear. There also continues to be a debate on whether any viral diagnosis in the middle ear is representative of an active pathogen, or bystander.

The third limitation is the lack of reporting of viral load in the middle ear. Measurement of viral load is performed by Cycle threshold (Ct), defined as the number of cycles required for a fluorescent signal to be detectable. Ct

Domain	Description	Risk of bias
Selection of participants	Selection bias caused by inadequate selection of participants	□ Low □ High □ Unclear
Confounding variables	Selection bias caused by inadequate confirmation and consideration of confounding variable	□ Low □ High □ Unclear
Intervention (exposure) measurement	Performance bias caused by inadequate measurement of intervention (exposure)	□ Low □ High □ Unclear
Blinding of outcome assessment	Detection bias caused by inadequate blinding of outcome assessment	□ Low □ High □ Unclear
Incomplete outcome data	Attrition bias caused by inadequate handling of incomplete outcome data	□ Low □ High □ Unclear
Selective outcome reporting	Reporting bias caused by selective outcome reporting	□ Low □ High □ Unclear

FIG. 2. The developed and validated version of RoBANS.

values are indirectly proportional to the amount of target nucleic acid in the sample (i.e., the higher the Ct, the lower the nucleic acid in the sample and therefore the lower the viral load). None of the studies reported Ct value, and therefore made any attempt at quantifying viral load. Furthermore, most diagnostic qRT-PCR performed in a clinical setting are quantified as positive, indeterminate, or negative, obscuring the clinical relevance of measuring viral load.

The fourth and last limitation is the rarity of performing viral RT-PCR for tympanocentesis. The use of tympanocentesis has since declined since the advent of

TABLE 2. *Reporting risk of bias and level of evidence as well as risk of bias utilizing the Oxford Centre for evidence-based medicine 2011 levels of evidence and the risk of bias assessment tool for non-randomized studies (RoBANS) respectively*

Identifier	Selection of Participants	Variable Bias	Intervention Bias	Blinding of Outcome	Incomplete Data	Outcome Bias	Level of Evidence	Study Type
Pitkäranta (1998)	L	L	L	U	L	L	2	CSS
Pitkäranta (1998)	L	L	L	U	L	L	2	CSS
Chonmaitree (2000)	L	L	H	L	U	L	2	RCS
Moyse (2000)	L	L	U	U	L	L	2	CSS
Nokso-Koivisto (2000)	L	L	L	L	U	L	2	RCS
Monobe (2003)	L	L	L	U	L	L	2	CSS
Nokso-Koivisto (2004)	L	L	L	U	U	L	2	CSCS
Kleemola (2005)	L	L	L	U	U	L	2	RCS
Ruohola (2006)	L	L	L	L	L	L	2	CSS
Bulut (2007)	L	L	L	H	L	H	2	CSCS
Wiertsema (2011)	L	H	L	H	U	H	2	CSCS
Stol (2012)	L	L	L	L	L	L	2	RCS
van Dongen (2015)	L	L	L	H	H	H	2	RCS
Yatsyshina (2016)	H	H	L	L	L	L	2	RCS
Buzatto (2017)	L	H	L	H	L	L	4	CCS
Sawada (2019)	L	L	H	H	L	L	2	CSS

CSCS indicates cross-sectional cohort study; CSS, cross-sectional study; RCS, retrospective cohort study.

TABLE 3. *Reporting patient demographics and results of RT-PCR*

Year	Author	Journal	Demo-graphic	Patients (n)	Samples	Virus (+) Samples	RSV (%)	Rhinovirus (%)	Influenza A/B (%)	Adenovirus (%)	Coronavirus (%)	Parainfluenza (%)	Enterovirus (%)
2019	Sawada	The Pediatric Infectious Disease Journal	Children w/AOM	122	122	67	26 (38.8%)	6 (9.0%)	3 (4.5%)	10 (14.9%)	Not tested	18 (26.9%)	Not tested
2017	Buzatto	PLoS One	Children w/OME	37	37	19	0%	2 (5.4%)	0%	0%	0%	0%	13 (35.1%)
2016	Yatsyshina	Diagnostic Microbiology and Infectious Disease	Children w/AOM	179	216	24	1 (4.2%)	17 (70.8%)	0	6 (25%)	0	0	0
2015	van Dongen	The Pediatric Infectious Disease Journal	Children w/tube otorrhea	217	217	45	8 (17.7%)	11 (24.4%)	1 (3.4%)	2 (6.9%)	Not tested	7 (24.1%)	Not tested
2012	Stol	The Pediatric Infectious Disease Journal	Children w/OME	116	116	63	Not reported	53 (84.1%)	Not reported	Not reported	4 (6.3%)	Not reported	9 (7.6%)
2011	Wiertsema	Journal of Medical Virology	Children w/ROM	180	143	102	50 (49%)	66 (64.7%)	0	6 (5.9%)	7 (6.9%)	5 (4.9%)	12 (11.8%)
2007	Bulut	European Journal of Pediatrics	Children w/AOM	120	120	43	20 (46.5%)	11 (25.6%)	4 (9.3%)	2 (4.7%)	5 (11.6%)	1 (23.2%)	Not tested
2006	Ruohola	Clinical Infectious Diseases	Children w/tube otorrhea	79	79	55	11 (20%)	16 (29%)	2 (3.6%)	0	2 (3.6%)	5 (9.1%)	8 (14.5%)
2005	Kleemola	Journal of Infection	Children w/AOM	527	529	284	32 (11.3%)	207 (72.9%)	10 (3.5%)	4 (1.4%)	Not tested	10 (3.5%)	Not tested
2005	Kleemola	Journal of Infection	Children w/AOM	162	364	233	35 (15.0%)	81 (34.8%)	9 (3.9%)	4 (1.7%)	Not tested	9 (3.8%)	Not tested
2004	Nokso-Koivisto	Journal of Medical Virology	Children w/AOM	329	1088	265	47 (17.7%)	197 (74.3%)	9 (3.3%)	6 (2.3%)	Not tested	6 (2.3%)	Not tested
2004	Nokso-Koivisto	Journal of Medical Virology	Children w/AOM	611	1491	603	89 (14.8%)	236 (39.1%)	16 (2.7%)	4 (0.7%)	Not tested	29 (4.8%)	226 (37.5%)
2003	Monobe	International Journal of Pediatric Otorhinolaryngology	Children w/AOM	79	93	39	29 (74%)	3 (7.7%)	2 (5.1%)	8 (20.5%)	Not tested	0	Not tested
2000	Chonmaitree	The Pediatric Infectious Disease Journal	Children w/AOM	40	65	18	9 (50%)	Not tested	4 (22.2%)	Not tested	Not tested	10 (55.6%)	Not tested
2000	Moyse	Archives of Otolaryngology Head and Neck Surgery	Children w/OME	26	49	28	25 (89.2%)	Not tested	Not tested	Not tested	Not tested	5 (17.9%)	Not tested
2000	Nokso-Koivisto	The Pediatric Infectious Disease Journal	Children w/OME	279	391	10	Not reported	Not reported	Not reported	Not specified	10	Not reported	Not reported
1998	Pitkäranta	The Journal of Pediatrics	Children w/OME	100	100	30	8 (26.7%)	19 (63.3%)	Not tested	Not tested	3 (10%)	Not Tested	Not tested
1998	Pitkäranta	The Journal of Pediatrics	Children w/AOM	92	92	44	17 (38.6%)	22 (50%)	Not tested	Not tested	7 (15.9%)	Not Tested	Not Tested

RT-PCR indicates reverse transcription polymerase chain reaction.

antibiotics and is reserved for complex and refractory cases. Furthermore, as otitis media is thought to be caused by transmission of microorganisms through the Eustachian tube, nasopharyngeal samples have been used as a surrogate for MEF aspiration. There is therefore limited data on the presence of viruses in the middle ear, and the extent to which MEF RT-PCR would correlate with nasopharyngeal sampling.

Our goal in this review was not to determine this correlation, but to determine the prevalence of respiratory viruses in the middle ear and, by corollary, the risk of these viruses to the surgeon performing middle ear surgery.

The Risk of Viral Exposure During Otologic Surgery

The emergence of new respiratory viruses such as the severe acute respiratory syndrome coronavirus (SARS-CoV), avian influenza virus H5N1, swine influenza H1N1, and most recently, the SARS-CoV-2, have presented diagnostic challenges as the delay in availability of commercially available PCR primers hampers the clinician's ability to diagnose infections caused by emerging viruses. There is therefore a need for new and improved diagnostic tests to diagnose both traditional and emerging respiratory virus infections with improved sensitivity.

In the setting of the current COVID-19 pandemic, diagnostic testing for SARS-CoV-2 is novel. To this date, there has been one paper reporting the presence of SARS-CoV-2 in the middle ear in postmortem patients. Frazier et al. (26) reported isolation of SARS-CoV2 from two out of six mastoids and three out of six middle ear specimens in cadavers. Cycle thresholds ranged from 24 to 36 indicating a moderate to high viral load. Although no in vivo studies have been performed as of yet, it is reasonable to derive that there is an appreciable risk for viral transmission through contact with middle ear contents. Below, we present several stages in the procedure that place the operating room personnel at risk when performing otologic surgery and recommendations to prevent transmission.

Airway Management/Intubation

Instrumentation of the upper airway should be treated with extreme caution as they are considered aerosol generating. Minimizing intubation time is recommended given this risk and the 2015 Difficult Airway Society guidelines should be followed, with intubation performed by the most senior practitioner available using enhanced PPE (27). Enhanced PPE is defined as the use of a N95 mask or powered, air-purifying respirator (PAPR), along with disposable surgical cap, disposable gown, and gloves. Operating room staff at the time of intubation should be minimized and limited to anesthesia personnel.

The time to enter the room after an intubation will likely be based upon the type of PPE they are wearing and the air exchange rate (Air Changes/Hour or ACH) of the room. As reported by the CDC, an operating room with approximately 15 ACH can expect 99% of the airborne pathogens removed within 18 minutes and 99.9% within 28 minutes (28).

Per the anesthesia patient safety foundation, a high quality viral filter should be placed on the endotracheal tube to prevent contamination of the circuit for known and suspected COVID patients. The endotracheal tube should also be clamped whenever disconnecting the circuit to maintain a closed system and prevent aerosolization (29).

Skin Incision

The primary concern regarding transmission of communicable disease in the operating room has been via direct physical contact. Sterile technique has likewise been developed to reduce the risk of contamination and infection. What is not well recognized, however, is the potential for disease to be spread through the use of electrocautery devices, lasers, and ultrasonic scalpels - producing aerosols and smoke plumes carrying viable viruses. There is substantial evidence that demonstrates viable viruses such as human papilloma virus and human immunodeficiency virus in smoke plumes, with a documented report of a surgeon contracting laryngeal papillomatosis following laser treatment of a HPV induced condylomata (30–34). Thus, the use of drills, microdebriders, and electrocautery should be limited whenever possible in favor of traditional cold instrumentation to minimize the dissemination of aerosolized viral particles. Per the National Institute for Occupational Safety and Health (NIOSH) also recommends the use of both general room exhaust and local exhaust ventilation to reduce particulate load generated by smoke (35).

Mastoid Cavity/Bone Drilling

Similar to the risk of viral exposure from smoke plumes generated by electrocautery, there is a risk of infection from aerosolized particles generated from microdebridement or high speed drilling. Anecdotal reports from Wuhan, China of intraoperative SARS-CoV-2 transmission to multiple members of a care team from an endoscopic sinus surgery following microdebrider and high speed drill use (36). In one instance, most of the OR staff caring for a patient developed COVID-19 regardless of the use of enhanced PPE.

Workma net al. (37) confirms the aerosolization risk of endonasal instrumentation in a recent cadaver study, where surgical aerosolization was measured using fluorescein, blue-light filter, and digital image processing. Endonasal procedures evaluated include endoscopy, non-powered instrumentation, suction microdebridement, and high speed drilling. No fluorescein contamination was demonstrated outside the nasal cavity with non-powered instrumentation (rigid endoscopy assisted through-biting of the middle turbinate) or with suction microdebridement of septum or nares. However, with high-speed drilling at 70,000 rpm and a 5 mm cutting burr, fluorescein droplets were detected up to 30 cm away from the nares. The authors concluded that procedures requiring use of a high-speed drill carry a significant risk of aerosol

generation. Although otologic procedures were not specifically evaluated by the authors, the conclusions drawn from their study are applicable to middle ear surgery due to the similarity in instrumentation and presence of a viral load.

A study by Hilal et al. (38), conducted specifically on mastoid drilling, evaluated corneal contamination by bony microspicules in an animal model. Mastoid drilling was shown to scatter in all directions up to 3.5 ft. with bony microspicules detected on an unprotected cornea. The authors conclude that blood particles and bone dust travel directly as aerosols during high speed drilling and a corneal route of transmission is possible. Loupes and the operative microscope can provide some form of protection but there are no studies to measure this.

In evaluating techniques for minimizing transmission via drilling, David et al. (39) at describes a negative pressure isolation drape used at the University of California, San Francisco, consisting of a plastic drape suspended above the patient's head and surgical field with a smoke evacuator suction placed inside the chamber to minimize aerosol and droplet contamination in endoscopic anterior skull base surgery. To date, a similar precaution has not been evaluated while performing otologic surgery.

CONCLUSION

A recent postmortem study has demonstrated an appreciable presence of SARS-CoV2 in the middle ear. Review of the literature has also consistently demonstrated the presence of nucleic acids of common respiratory viruses such as Rhinovirus, Respiratory Syncytial virus, and Coronavirus involving the middle ear. The mastoid air cells directly communicate with the middle ear through the aditus and would demonstrate a similar viral load. Studies on cadaver and animal models demonstrate the high speed drill as an aerosol generating procedure. Therefore, surgeries involving the use of a drill should be deferred if possible, and enhanced PPE used if the use of a drill is necessary.

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