Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Pandemics and pediatric otolaryngology

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The objective is to describe how the COVID pandemic changed the epidemiology and management of pediatric otolaryngologic diseases, which may influence clinical decision-making in the future. Many changes were made to the structure of healthcare delivery to minimize transmission of coronavirus. As a result, there was a widespread adoption of telehealth. Additionally, guidelines were published with new protocols for evaluation and management of common pediatric otolaryngologic conditions, which in many circumstances, delayed or replaced surgical intervention. Now, as we evaluate the impact of these clinical changes, we have gained new understanding about the pathophysiology of certain pediatric conditions, namely otitis media, for which upper respiratory infection exposure may play a larger role than previously thought. As we have altered practice patterns for common pediatric otolaryngologic conditions, we recognize that ongoing research may help us determine if surgical interventions have been overutilized in the past and help guide clinical practice guidelines moving forward.

A historical perspective

Over the last 50 years, we have seen the dramatic impact of epidemics and vaccines on pediatric otolaryngologic disease epidemiology and treatment. Vaccines have directly impacted the epidemiology of pediatric diseases. For example, prior to vaccine development, haemophilus influenza type b (Hib) would infect 200,000 individuals annually and was the leading cause of pneumonia, epiglottitis, and bacterial meningitis.[1] Like the SARS-CoV-2 virus, Hib enters the body through the nasopharynx prior to disseminating along the respiratory tract. Prior to vaccinations, about 0.5% of children would develop bacterial meningitis, of which two-thirds were under the age of 18 months.[1] The Hib polysaccharide vaccine was initially developed in 1985 then replaced with the conjugate vaccine in 1987, which was widely available in the United States by the 1990s. As a result, cases of invasive Hib decreased to 3,400 in 10 years after the development of vaccinations. More recently, Hib infections have decreased to 2.08 per 100,000 population. As a result, the incidence, pathogens, and demographic distribution of acute epiglottitis, previously predominantly caused by Hib, has changed dramatically in the postvaccine era.[2]

Similarly, prior to the development and distribution of the MMR vaccine, measles was acquired by nearly 90% of children.[3] Mumps was a common cause of parotitis.[4] Pertussis affected over 200,000 individuals annually, predominantly children, in the pre-vaccine era.[5] More recently, we have seen the distribution of HPV vaccination dramati-

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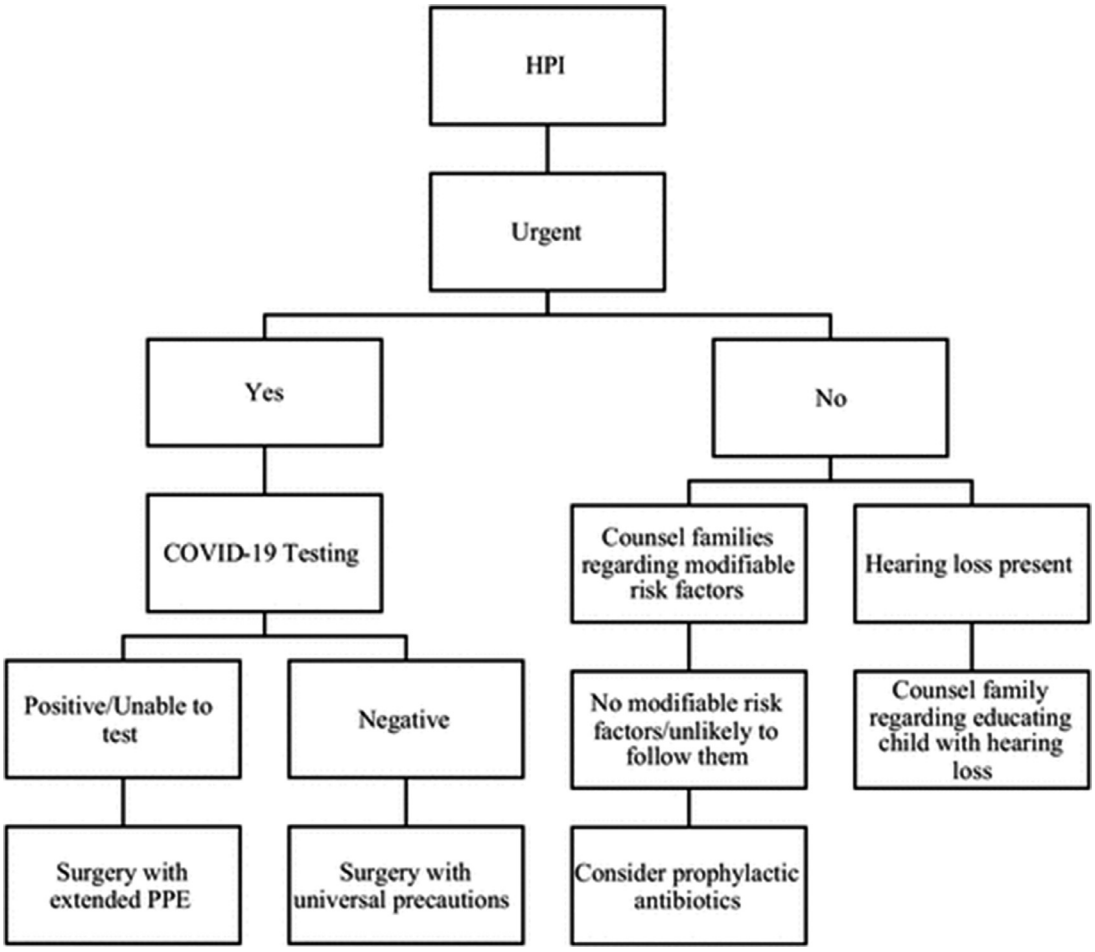

Figure 1 Management algorithm limiting patient contact for pediatric otitis media with effusion during the COVID-19 pandemic. Extended PPE (personal protective equipment) includes N95 mask, face shield, gown, and gloves or powered air-purifying respirator. HPI, history of present illness. Ref: Chorney, Otolaryngol Head Neck Surg, 2020. (Color version of figure is available online.)

cally decrease rates of pediatric respiratory papillomatosis. Within 10 years of introducing the HPV vaccination, rates of HPV infections among female adolescents have gone down by 86%.[6]

COVID and pediatric otolaryngology

Coronavirus (CoV), like these other pathogens, has had a dramatic impact on children. It is estimated that 9.5 million children have been infected by COVID-19, making up 18% of all CoV infections.[7] Fortunately, mortality rates among the pediatric population have remained low with less than 0.02% of all pediatric COVID infections resulting in mortality. While the manifestations in the pediatric population have been quite variable and generally milder than the adult population, there have been cases of severe multisystem inflammatory syndrome in children. Fortunately, only 0.1%-1.5% of pediatric COVID-19 infections required hospitalization, and fewer than 0.02% resulted in deaths[7].

COVID and development

However, beyond the direct physical manifestations of COVID-19 infections, there has been a dramatic impact on the daily life of children growing up in a global pandemic. Early data has suggested that children born during the SARS-CoV-2 pandemic, irrespective of direct exposure to the virus, had lower gross motor, fine motor, and social development at 6 months of age[8] and up to 12 months of age.[9] Models have demonstrated that regular masks and N95 masks attenuate sound by 4dB and 12 dB, respectively.[10] While this deficit would still fall within a normal hearing range, it could be enough to collectively diminish access to sound and consequent development. There has been rising concern that mask wearing and virtual education has disproportionately impacted the pediatric deaf and hard of hearing population who rely heavily on visual cues for communication. Furthermore, the loss of visual cues due to mask wearing or virtual learning may limit speech processing and language acquisition during critical periods for language development.[11] Children with auditory processing disorders can find virtual education particularly challenging given the limitations of discriminat-

Figure 2 Management algorithm limiting patient contact for pediatric sleep-disordered breathing during the COVID-19 pandemic. Extended PPE (personal protective equipment) includes N95 mask, face shield, gown, and gloves or powered air-purifying respirator. CPAP, continuous positive airway pressure; HPI, history of present illness; OSA, obstructive sleep apnea. (Color version of figure is available online.)

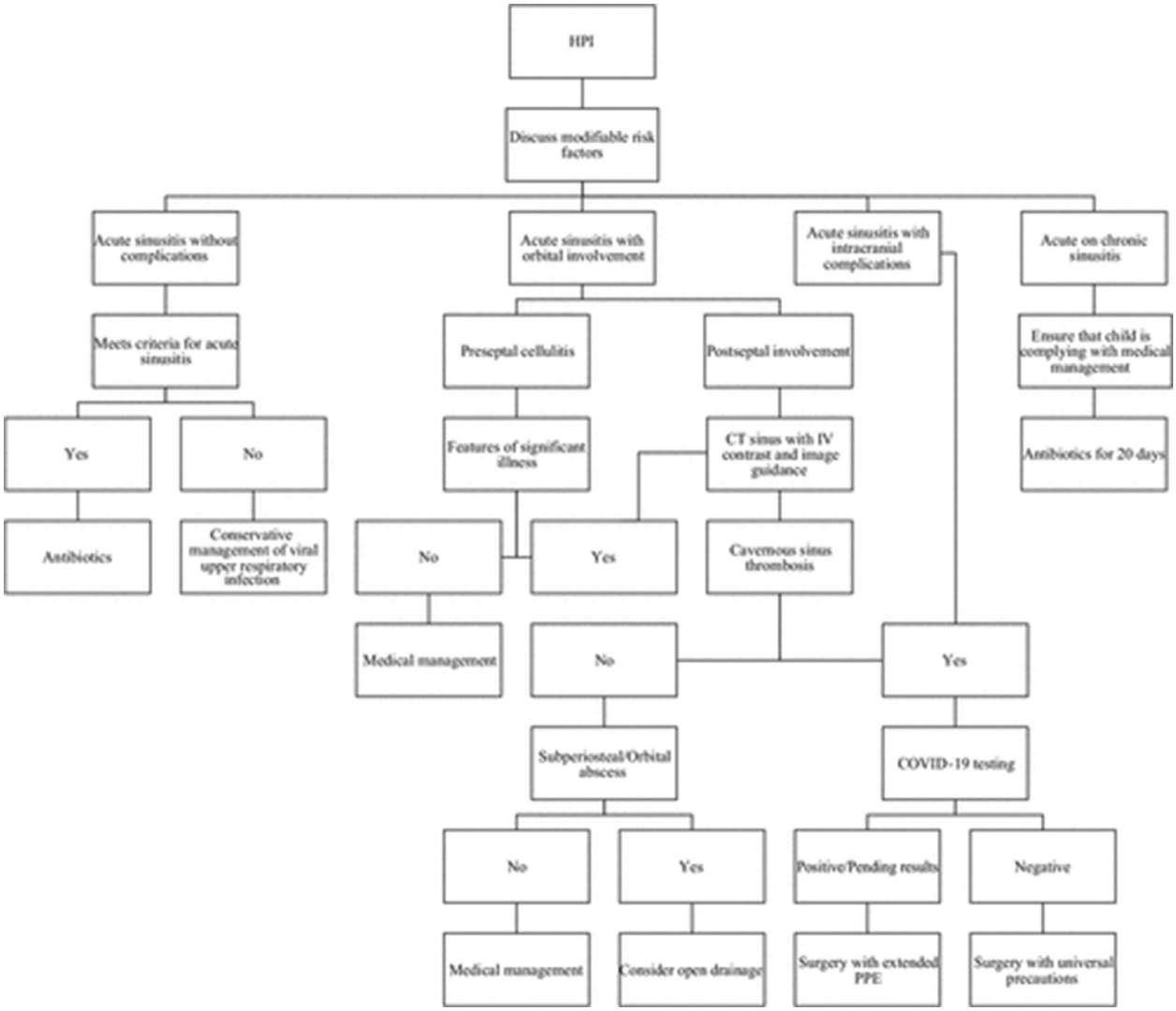

Figure 3 Management algorithm limiting patient contact for pediatric acute rhinosinusitis (ARS) during the COVID-19 pandemic. Extended PPE (personal protective equipment) includes N95 mask, face shield, gown and gloves, or powered air-purifying respirator. CT, computed tomography; HPI, history of present illness; IV, intravenous. (Color version of figure is available online.)

ing between background noise and the speaking voice.[12] While measures to prevent contagion including mask wearing, physical distancing and remote learning were critical in controlling infection rates, we may see unintended secondary effects of these measures manifest in other realms including development.

Undoubtedly, there has been an increase in parental anxiety and stress because of the pandemic.[13] Prior research has illustrated that maternal stress correlates with cognitive and social development of children.[14-16] There has been early research raising concern for negative effects of COVID-related stress on child development;[16] however, this area of study will likely grow in the coming years as we have more longitudinal data to determine the impact of development in the years to come.

The roll-out of the SARS-CoV-2 vaccine within the pediatric population not only aimed to reduce infections, but it has allowed children to return to the classroom. Studies have demonstrated that deaf and hard of hearing children often did not receive educational support during virtual learning.[17] Many children rely on school-based services and were consequently under-resourced during the pandemic. Vaccinations allowed them to return to school and obtain the critical educational support and speech therapy services.

Impact of COVID-19 virus on pediatric otolaryngology healthcare delivery

To prevent the spread of the COVID-19 virus to both patients as well as the healthcare workforce, dramatic changes were made to the healthcare delivery system to reduce the number of patients entering healthcare facilities, waiting in shared spaces, and limit aerosol generation. Within 1 week of the WHO declaring a global pandemic, hospital systems nationwide were implementing significant changes to their practices, with immediate reduction in ambulatory visits and postponement of elective procedures.[18]

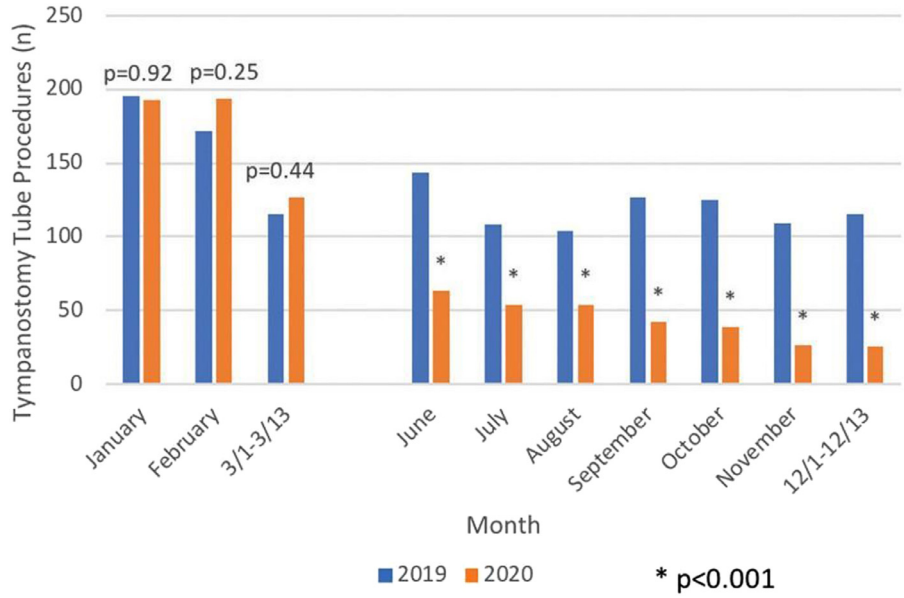

Figure 4 Pre- and post-COVID-19 pandemic surgical procedures. Ref: Diercks, Otolaryngol Head Neck Surg, 2021. (Color version of figure is available online.)

Additionally, there was the rapid adoption and implementation of telehealth. In 2019, only 8% of Americans utilized telehealth.[19] Within 1 month of the declaration of the global pandemic, televisits increased by 600%.[20] Part of this was enabled by both the market demand, new reimbursement by insurers, as well as the US department of Health and Human Services to waive the Health Insurance Portability and Accountability Act regulations which then allowed the use of consumer audio and video communication during telehealth consultations. As a result, by mid-April 2020, the number of telehealth visits in certain systems had risen by nearly 700%.

At the start of the pandemic, the American Academy of Otolaryngology Head and Neck surgery recommended delaying elective surgeries. Several recommendations were published comparing tympanostomy tube placement and observation while avoiding contributing factors to otitis media such as second-hand smoke exposure, mitigating allergic symptoms, limiting pacifier use, improving gastroesophageal reflux (GERD), reducing daycare visits, and keeping up to date with vaccination schedules, and management with antibiotics (Figure 1).[18] Urgent tympanostomy tube placement was recommended for children with otitis media in the setting of a high-risk factor including: being immunocompromised, having exacerbating comorbidities, acute mastoiditis, facial nerve palsy or intracranial complications.[18] This same panel provided formal recommendations and algorithms for the evaluation and management of pediatric obstructive sleep apnea (Figure 2),[18] typically a more chronic condition, as well as acute sinusitis (Figure 3),[18] for which time-sensitive intervention can be critical. Surgical management of obstructive sleep apnea was generally deferred unless evidence of severe obstructive sleep apnea, defined as more than 10 apneic or hypopneic episodes per hour, with concerns for consequential impact on development. Acute rhinosinusitis, defined as severe, worsening URI symptoms for more than ten days with worsening symptoms, fever, and 3 days of purulent nasal drainage was managed with medical therapy including antibiotics. However, in the presence of complications of acute sinusitis, including subperiosteal or orbital abscess, cavernous sinus thrombosis, or intracranial extension, surgical intervention was generally recommended either through open or endoscopic approaches.

COVID and tympanostomy tube placement

The SARS-CoV-2 pandemic has upended long term trends in prevalence of otitis media. Social behavior, such as mask wearing, frequent temperature checks, school closures and social distancing measures on a wide scale has resulted in a decline in rates of upper respiratory illnesses (URI) transmission, Acute Otitis Media (AOM) and Otitis Media with Effusion (OME) and, as a result, tympanostomy tube surgeries. The decline in viral-associated upper respiratory infections from social distancing and masking measures has further reinforced the URI-driven pathophysiology of otitis media.

The level of impact on ear tube surgery has been shown in a multitude of timely studies during this pandemic. Marom et al performed a review of international publications related to reduction in otitis media burden during the pandemic. They found 16 publications with nearly all showing a significant reduction in number of otitis media visits, incidence of mastoiditis and emergency department visits related to OM.[21]

The decline in upper respiratory infections and as it relates to OM has been illustrated by several authors. Ponmani et al studied pediatric ED visits in Birmingham, UK and found a 65%-75% reduction in URI, tonsillitis, and otitis media-related visits.[22] A study in Italy found out of 102

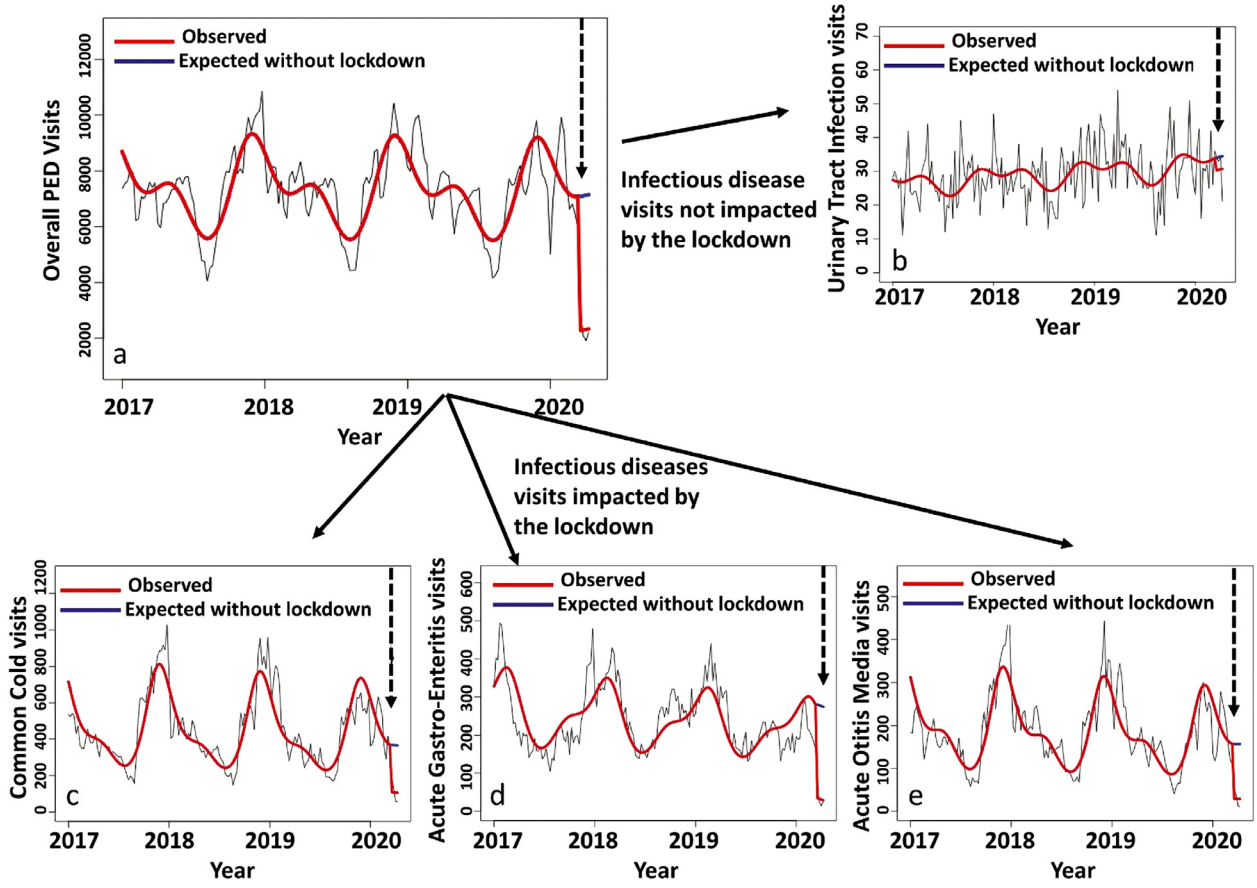

Figure 5 Impact of lockdown on weekly pediatric emergency department visits. Ref: Angoulvant, Clinical Infectious Disease, 2021. (Color version of figure is available online.)

children with recurrent otitis media pre-pandemic, 82% of them had resolution of infections and 90% had a normal ear exam during lockdown periods.[23]

Diercks et al at Massachusetts Eye and Ear Infirmary studied tympanostomy tube volume over 29 providers and 2,652 patients. They performed month-to-month comparisons of tympanostomy tube volume before and during the pandemic and found significant reduction in ear tube volume, a shift of surgeries to tertiary care and an increase in the age of children receiving ear tubes[24] (Figure 4). This data contributed to the argument that viral URIs are a common pathogenic precursor to OM. McBride et al were able to calculate relative risk of AOM during school closures compared to other years since 2015. They found a relative risk (RR) developing AOM to be 0.6, $P < 0.001$[25].

One of the largest studies of pandemic-related epidemiologic changes of URI and OM was in France. A nationalized health care system allows rapid data collection from integrated hospitals across the country. Angoulvant et al examined 871,543 pediatric visits to Emergency Departments (ED) from 2017 to April 2020 (pandemic was declared on March 11, 2020). The French Pediatric Emergency Departments experienced a 69% reduction in ED visits and 45% reduction in admissions to the hospital.[26] Acute gastroenteritis visits reduced the most, and "common cold" AOM-related visits had similar declines (Figure 5). Non-URI related illnesses, such as urinary tract infections were not impacted by the lockdown period. There was a large difference in visits between URI related and non-URI related, and we can expect variation in outpatient surgical volume between surgical subspecialties such as Otolaryngology and Urology.

Conclusions

The SARS-CoV-2 pandemic has led to dramatic changes in healthcare delivery. It has led to robust development of telehealth, a method of healthcare delivery anticipated to continue beyond this pandemic. There have been changes in mass public behavior such as social distancing, mask wearing, social interaction and activity that could have durability for years depending on the post-pandemic course. If mask wearing and protective behavior become more ingrained in our culture, it is possible we will experience persistent reduction in URI related illnesses, such as OM. This could have tremendous downstream effects including altering the epidemiology of OM/PE tubes, influencing practice patterns and improvement in speech and hearing for many children. The pandemic will provide a large volume of new data and prompt further research to

understand the influence of protective measures on URI prevalence and associated disorders such as otitis media.

Disclosure

DEC is a board member and shareholder for Respiratory Intelligence.

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