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Review Article

Telemedicine in pediatric otolaryngology: Ready for prime time?

Austin Schafer [a], Sarah Hudson [c], Charles A. Elmaraghy [a,b,c,*]

[a] The Ohio State University Wexner Medical Center, Department of Otolaryngology-Head and Neck Surgery, Columbus, OH, USA
[b] The Research Institute at Nationwide Children's Hospital, Center for Surgical Outcomes Research, Columbus, OH, USA
[c] Nationwide Children's Hospital, Department of Pediatric Otolaryngology-Head and Neck Surgery, Columbus, OH, USA

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ABSTRACT

The purpose of this paper is to explore the current literature on telemedicine in otolaryngology, focusing on the potential for telemedicine in the field and the major modalities available. Ultimately, the goal is to summarize telemedicine implementation in otolaryngology during the COVID-19 pandemic and potential long term applications. This paper analyzes a variety of studies that have evaluated the efficacy of different telemedicine approaches in otolaryngology, with commentary on what these results mean for the potential of telemedicine during the COVID-19 pandemic. Otolaryngology is well-suited for telemedicine, and this technology is viewed favorably by both patients and physicians. However, its application cannot be generalized to such a wide-ranging specialty. Furthermore, store and forward technology, which has been traditionally used to provide care to remote and underserved populations, and synchronous technology both have the potential to limit unnecessary in-person visits—ultimately keeping both patients and providers safe as social distancing continues.

1. Introduction

The practice of telemedicine can be defined as the use of any technology that provides remote-access medical care, most frequently to isolated or underserved populations. Historically, specialties such as radiology, dermatology, cardiology, and psychiatry have adopted the most widespread telemedicine initiatives [1]. However, in the midst of the COVID-19 pandemic, the applications of telemedicine are rapidly expanding to include the entire medical field [2]. Otolaryngology may be one of the most important specialties to address when it comes to the implementation of telemedicine in the era of COVID-19, as otolaryngologists are at a particularly high risk of viral transmission via aerosol generating procedures [3].

Despite many studies demonstrating its potential, telemedicine has not been widely adopted in the specialty of otolaryngology [4]. This may be attributed to concerns over the diagnostic accuracy of remote evaluations, training requirements, and an uncertainty over which of the many telemedicine approaches yield the best results [5–7]. Fortunately, multiple studies agree that otolaryngology is a specialty well-suited for telemedicine [8]. The challenge, however, is determining which telemedicine approaches are the most appropriate, and how to effectively implement these protocols during the COVID-19 pandemic and beyond.

1.1. Potential for telemedicine in otolaryngology

1.1.1. The importance of anatomy

Otolaryngology is a robust specialty that involves the treatment of a variety of ear, nose, throat, and in some practices, head and neck conditions. Due to this variation, diagnostic exams are not standardized between patients, and the technology needed to accurately assess a patient's condition may vary from case to case [6]. Ultimately, it is the pertinent anatomy that will determine how a patient is evaluated. Thus, in an effort to develop efficient protocols, it is important to determine which otolaryngology cases are amendable to telemedicine.

In a study published in 2018, McCool and colleagues [4] attempted to discern which otolaryngology patients may benefit the most from telemedicine. To do this, they estimated the rates of telemedicine eligibility among specific diagnoses through a retrospective cohort study. A total of 1385 otolaryngology encounters over a 2-year period were classified as either "eligible" or "ineligible" for telemedicine, on the basis of whether or not a specialized procedure was performed during the visit. Overall, 62% of encounters were considered eligible for telemedicine. More importantly, however, is that eligibility varied with anatomic subsite. While 92% of inner ear diagnoses were considered eligible for telemedicine, only 39% of laryngeal diagnoses were similarly eligible. Although this study has limitations being a retrospective

* Corresponding author. The Ohio State University Nationwide Children's Hospital, 700 Children's Drive, Columbus, Ohio, 43205, USA.
E-mail address: Charles.elmaraghy@nationwidechildrens.org (C.A. Elmaraghy).

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analysis, it supports visualization of pertinent anatomical structures is relevant. Moreover, it demonstrates that otology can be eligible for telemedicine, validate by other studies [1]. This is significant for pediatric practices, as otitis media is one of the most common causes of healthcare visits in this population [9].

Another study published in 2020 by Miller and colleagues [6] evaluated the reliability and accuracy of remote nasopharyngolaryngoscopy (NPL) examinations in pediatric patients. The group conducted a prospective, blinded study in which the NPL was performed by an in-office otolaryngologist using an iPhone attachment to record the examination. A second, remote otolaryngologist later evaluated the recording. Both physicians completed the same diagnostic survey, evaluating a variety of anatomic subsites and ultimately providing a final diagnosis for the 45 patients who underwent NPL. Inter-rater agreement was calculated using the κ statistic for each subsite and for the final diagnosis. A percentage agreement was also calculated.

Overall, there was 80% agreement on the final diagnosis ($\kappa = 0.71$). However, the agreement varied considerably depending on the anatomic subsite, with the nasopharynx and oropharynx having the highest inter-rater agreements ($\kappa = 0.75$). Interestingly, McCool and colleagues [4] determined that diagnoses of the oral cavity (75%), nasal passage (75%), sinuses (58%), and pharynx (58%) were the most telemedicine-eligible diagnoses after the ear (middle and inner) and skin. Furthermore, the anatomic subsite with the lowest inter-rater agreement in the study by Miller and colleagues [6] was the larynx and its components, such as the epiglottis ($\kappa = 0.43$), the arytenoids ($\kappa = 0.34$), and the aryepiglottic folds ($\kappa = 0.20$). Although these sites maintained modest percentage agreements, they were still relatively lower than the values for the nasopharynx and oropharynx. Once again, there is concordance with McCool and colleagues [4], as diagnoses of the larynx were deemed the least eligible for telemedicine in their study.

Although these are very different studies, it is clear that there are certain ENT diagnoses for which telemedicine is better suited. It may more appropriate to remotely evaluate the inner ear middle ear, nasopharynx, and oropharynx, than to remotely evaluate the larynx. Understanding these differences and stratifying patients accordingly could improve the efficiency and cost-effectiveness of telemedicine in otolaryngology during the COVID-19 pandemic.

1.1.2. Surgical consultations and preoperative planning

In response to the COVID-19 outbreak, the American Academy of Otolaryngology-Head and Neck Surgery released guidelines to provide only “time sensitive” or “emergent” surgical care. With many surgical consultations now taking place via telemedicine, it is important to ensure that these visits appropriately triage patients and maintain diagnostic accuracy [10]. If telemedicine can be successfully employed as a reliable method of surgical consultation and preoperative planning, otolaryngologists can productively make use of clinical time that may have been previously spent in the operating room.

In a 2008 study, Smith and colleagues [5] attempted to determine concordance between pediatric otolaryngology diagnoses and surgical management plans made via a live videoconference and a subsequent, in-office consultation. Regional pediatricians conducted the physical exams under the remote guidance of an ENT specialist. Among the 68 patients with both consultations, there was diagnostic agreement in all but 1 case (99%). Moreover, surgical management plans were concordant in 63 of the 67 cases (93%). It is important to note that of the 5 patients who underwent procedures that differed from the original videoconference plans, 4 had only minor alterations—such as the addition of tympanostomy tubes to an adenotonsillectomy. The remaining patient had a perforated tympanic membrane for which a myringoplasty was performed after conservative management failed. One limitation of this study is this a single surgeon study. Nonetheless, the results demonstrate that live videoconference should be considered as a reliable alternative to in-office surgical consultation.

In 2010, Kokesh and colleagues [11] published a study aimed at determining the feasibility of using telemedicine to accurately plan ear surgery. The group reviewed charts for 45 elective major ear surgeries (tympanoplasty, tympanoplasty with canalplasty, mastoidectomy, stapedectomy, or stapedotomy and myringoplasty) referred via telemedicine over a 13-month period and documented the recommended surgeries and estimated operative times. These cases were then matched with 45 patients seen in-office who ultimately had identical surgeries recommended. Importantly, telemedicine evaluations accurately predicted the eventual surgical procedure 89% of the time, compared to 84% for the in-office evaluations. Furthermore, the average difference between the actual operative time and estimated operative time between telemedicine evaluations (32 min) and in-office evaluations (35 min) was not statistically significant. Although it is retrospective with a limited sample size, this study demonstrates that telemedicine can be used for accurate preoperative planning, especially in otology—although pediatric providers should note that tympanostomy tube placement was not included in this study.

Overall, it is clear that there is a role for telemedicine in surgical consultations and preoperative planning in otolaryngology. While more data is certainly needed, both of these studies support telemedicine as an accurate alternative to the traditional in-office consultation. As COVID-19 protocols continue, the ability to utilize telemedicine as a means of reliably diagnosing and triaging surgical patients will go a long way in maintaining efficiency, and most importantly safety— among both patients and providers alike.

1.2. Current telemedicine modalities in otolaryngology

1.2.1. The store and forward approach

The store and forward approach, one of the original telemedicine modalities used in otolaryngology, involves a referring physician or trained health worker collecting patient history and imaging, and subsequently forwarding this data to a consulting physician for review [1]. This system is asynchronous, meaning that it does not require the providers to align their schedules for a patient consultation. Moreover, the consulting physician can review cases at his or her own discretion, when time is available [12]. Limitations to this approach must be noted, however, such as physical exam limitations and a loss of the traditional, face-to-face patient-physician interaction [13]. Furthermore, although the store and forward approach provides more flexibility for review, the consulting physician should be aware that a patient’s condition is subject to change, especially as the time from referral to consultation increases [11].

Due to its format, the store and forward approach has been especially successful in providing ENT care to remote and underserved populations. There are multiple examples of otolaryngology clinics utilizing audiologists or specially trained health workers to perform the in-person visits, with otolaryngologists subsequently reviewing the captured data [1]. In a 2011 publication, Kokesh and colleagues [12] described their experiences using store and forward telemedicine to provide ENT care to patients in rural Alaska. Between 2002 and 2011, the ENT Department at the Alaska Native Medical Center (ANMC) completed nearly 10,000 telemedicine consultations, relying on community health workers as well as audiologists to provide the initial visits. The authors explain that a single otolaryngologist was responsible for responding to the influx of telemedicine consultations on a given day, and that this responsibility rotated daily. At the time of publication, telemedicine cases had a 75% same-day response rate, and a 90% 24-h response rate. Moreover, 73% of telemedicine consultations prevented patients from having to travel—a significant benefit for a remote population. This group has published an assortment of studies detailing the successful use of store and forward telemedicine in their practice [11,12,14].

More recently, Gupta and colleagues [7] published a study in 2020 that examined the feasibility of equipping trained health workers with a store and forward telemedicine device to triage underserved otology patients in India. ENTraview, the telemedicine device utilized in this

study, is a camera-enabled phone integrated with an otoscope. The health workers underwent extensive training with this device, as well as 3 months of otology curriculum. Community clinics were then organized, and the five health workers screened 3000 patients with subjective ear complaints over a 6-month period. While 1619 (54%) patients were referred to an ENT specialist based on their screening results, only 13% had followed-up at the time of publication. While this may be a promising model for widespread screening coverage in developing countries, the results demonstrate that asynchronous technology may lead to gaps in the continuum of care in some cases.

While much of the literature focuses on store and forward telemedicine in the context of providing care to remote or underserved populations, its benefits should be considered by all ENT practices during the COVID-19 era, as advances in technology have improved its cost effectiveness and convenience [9]. One of these advances, smartphone otoscopy, may be particularly well suited for use during the current pandemic [15].

1.2.2. Smartphone otoscopy

A smartphone-enabled otoscope can be configured by attaching a modified otoscope head to the camera of an existing smartphone. In many cases, these attachments are commercially available online [16]. This technology is ideal for use in the pediatric population as it theoretically enables parents to capture images and subsequently send them to an otolaryngologist for remote review and diagnosis [9]. Until recently, studies validating the use of smartphone otoscopy have utilized only trained healthcare professionals to capture images—not parents. However, new studies have examined the ability of parents to effectively use this technology [9,16].

In a 2018 study, Shah and colleagues [9] examined the diagnostic reliability of videos of the tympanic membrane captured by parents using an iPhone otoscope (CellScope). In the clinic, parents were given the device and instructions, and watched the standard training video within the application. Without additional assistance, they attempted to capture recordings of the TM with the device. A second-year otolaryngology resident then captured videos of the same ears, and both recordings were later reviewed by an attending pediatric otolaryngologist who attempted to discern diagnoses from the videos. Pneumatic otoscopy was also performed by a different pediatric otolaryngologist for comparison. Eighty ears (40 patients) were included in the study.

While there was high agreement ($\kappa = 0.74$) between pneumatic otoscopy and remote diagnosis when the recordings were obtained by an otolaryngologist, there was low agreement ($\kappa = 0.42$) when the remote recordings were obtained by a parent. In other words, many of the videos obtained by the parents were not of diagnostic quality, as opposed to the videos captured by the physician. The effectiveness of the device when operated by a specialist is something that has been previously described in multiple studies [17,18]. However, this study indicates that the CellScope is only reliably effective in the hands of a capable user—which might not be a parent just yet. It is important to note that despite these shortcomings, 92% of participating parents reported that they would feel comfortable using the device at home. Thus, if the learning gap is bridged, CellScope certainly has the potential to be successfully utilized by parents.

In 2019, Erkkola-Antinnen and colleagues [16] published a similar study in which they evaluated the ability of parents to reliably perform smartphone otoscopy for the eventual diagnosis of acute otitis media (AOM). Eligibility for this study was contingent on at least 1 diagnosis of AOM in the 90 days leading up to the study. At the initial visit, study participants were allocated to either an immediate teaching group, or a delayed teaching group. During this same visit, parents of children allocated to the immediate teaching group were given an introductory presentation on the basic anatomy of the middle and inner ear, as well as a tutorial on how to use the smartphone otoscope (CellScope). Conversely, parents of children allocated to the delayed teaching group did not receive this training until at least a week later. All parents from both groups were asked to perform a bilateral smartphone otoscopy on at least 5 days during the first study week. After that, parents were asked to perform bilateral smartphone otoscopy at various frequencies depending on their child's condition. Over the 6-month study period, 1442 videos were obtained from 40 participants.

During the first study week, 62% of the videos from the immediate teaching group were of sufficient technical quality, compared to only 22% from the delayed teaching group. After the teaching intervention, however, 64% of the videos from the delayed group were sufficient, demonstrating the importance of instruction for proper smartphone otoscopy technique. After all participants underwent training, 67% of the videos were of sufficient technical quality. Of these videos, 53% enabled a diagnosis to be made. While a specific diagnosis was often difficult to come by, it is important to note that AOM could at least be detected or excluded in most (87%) of the videos obtained from symptomatic children. Furthermore, 85% of parents agreed that performing smartphone otoscopy was easy, while 95% agreed that they learned to recognize the appearance of a healthy middle ear.

Both of these studies indicate that smartphone otoscopy can be performed by parents; however, the diagnostic reliability of the captured media must improve for this technology to be widely implemented. Furthermore, a teaching intervention is critical for parents to successfully utilize smartphone otoscopy, which takes time and resources. Despite these shortcomings, most parents view the technology favorably and find it easy to use. Furthermore, the fact that parents were able to capture videos that could reliably detect or exclude AOM in symptomatic children is a huge success. During the COVID-19 pandemic, using smartphone otoscopy in this manner could prevent unnecessary emergency room or primary care visits, limiting exposure to both patients and providers.

1.2.3. The synchronous approach

The live, or synchronous approach, refers to telemedicine that is conducted in real-time between a patient and a provider. This modality is advantageous in that it maintains the structure of an in-office encounter, providing the traditional patient-physician interaction. Moreover, synchronous telemedicine offers a better platform for taking patient histories and performing physical exams [13]. However, it can be extremely difficult to coordinate these appointments, making this modality potentially more expensive and logistically challenging than the store and forward approach [1]. While the use of synchronous telemedicine remains limited in otolaryngology, technological advances have made it worthy of further exploration, especially as healthcare delivery evolves due to COVID-19.

In a 2018 study, Seim and colleagues [13] evaluated the fidelity and diagnostic concordance of synchronous technology for use in a telemedicine ENT clinic. Twenty-one patients at an existing community ENT clinic in rural Ohio were evaluated by an on-site physician, who used the Quintree system to stream the encounter to a consulting physician for remote participation and evaluation. Both physicians were experienced otolaryngologists. After the physical exam was complete, the remote physician muted the encounter while the on-onsite physician recorded a diagnosis and counseled the patient. After this, the remote physician had the opportunity to ask the patient any follow-up questions before documenting a diagnosis. Post-encounter surveys were completed by both patients and physicians.

Overall, the physicians were satisfied with the technology, with satisfaction rates of 98% and 100% for image and audio quality, respectively. Other than anterior rhinoscopy (59%), all of the other exams (otoscopy, oral cavity, laryngoscopy) were satisfactory in at least 88% of cases. Patients were equally satisfied, with 95% indicating that they felt comfortable during the encounter, and 90% indicating that they would use the technology again. Furthermore, diagnostic concordance was seen in all but 1 case (95%), with the single exception due to a lack of diagnostic specificity. However, it is important to note that kappa coefficients could not calculated because the diagnoses were recorded in

an open-ended format.

Although this was a pilot study with a limited sample size, it nonetheless supports synchronous telemedicine as a viable approach to patient care in otolaryngology. The results are consistent with the previously mentioned study by Smith and colleagues [5] in 2008, which evaluated the diagnostic concordance between real time telemedicine and in-office consultations. Furthermore, a 2019 publication by Philips and colleagues [19] has since validated synchronous telemedicine as a cost-effective option for ENT clinics. As far as implementing this technology during the COVID-19 pandemic and beyond, following the protocol evaluated by Smith and colleagues [5] may be a reasonable approach. By having pediatricians or general practitioners perform specialized physical exams under the remote guidance of ENT physicians, patients would remain distanced from large medical centers in urban settings, where a majority of ENT physicians practice [1]. However, more studies are needed to evaluate the efficacy of such protocols, especially in regard to new technology.

2. Conclusion

Unlike other specialties, otolaryngology has been slow to adopt telemedicine into practice. As specialized physical exams are needed to make many ENT diagnoses, there has been concern over the diagnostic reliability of telemedicine technology. Moreover, much of the focus has been on utilizing telemedicine to provide ENT care to remote or underserved populations, as there has not been a need for telemedicine in the general population—until now, that is. Social distancing protocols due to COVID-19 have brought telemedicine to the forefront of patient care. While previous literature has demonstrated that otolaryngology is amendable to telemedicine, there is no doubt that its potential is greater now than it has ever been, especially considering its support from both patients and physicians. However, for successful implementation, it is important to understand where exactly this potential lies, and what modalities are available for use.

ENT care is incredibly wide-ranging; thus, it is not appropriate to generalize the evaluation of telemedicine to the entire field of otolaryngology. Specifically, there is evidence that telemedicine can be successfully used for surgical consultation and planning. Furthermore, otology visits seem to be more suitable for telemedicine than visits pertaining to other anatomical sites, such as the larynx. This is especially important for pediatric practices, with such a high prevalence of otitis media in this population. While more data is needed on store and forward technology in the hands of parents, such as smartphone otoscopy, it is certainly worthy of further exploration as a means of preventing unnecessary healthcare visits. Likewise, synchronous technology has the potential to reduce avoidable in-person contact, keeping both patients and providers safe during the COVID-19 pandemic and beyond.

Declaration of competing interest

Elmaraghy- Consulting for Smith and Nephew 2016–2019.

- Shares in Zotarix
- Shares in Otologic Technologies Inc

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