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MAIN ARTICLE

Initial assessment of hearing loss using a mobile application for audiological evaluation

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Abstract

Objective: This study aimed to compare an Apple iOS mobile operating system application for audiological evaluation with conventional audiometry, and to determine its accuracy and reliability in the initial evaluation of hearing loss.

Methods: The study comprised 32 patients (16 females) diagnosed with hearing loss. The patients were first evaluated with conventional audiometry and the degree of hearing loss was recorded. Then they underwent a smartphone-based hearing test and the data were compared using Cohen's kappa analysis.

Results: Patients' mean age was 53.59 ± 18.01 years (range, 19–85 years). The mobile phone audiometry results for 39 of the 64 ears were fully compatible with the conventional audiometry results. There was a statistically significant concordant relationship between the two sets of audiometry results ($p < 0.05$).

Conclusion: Ear Trumpet version 1.0.2 is a compact and simple mobile application on the Apple iPhone 5 that can measure hearing loss with reliable results.

Key words: Smartphone; Mobile Applications; Hearing Loss; Audiometry

Introduction

With the recent advances in mobile technology, many mobile medical applications ('apps') have been developed. As smartphones are mobile, applications are upgradable and the results can be obtained quickly. Hence, mobile applications may offer a good alternative to conventional methods, especially where conventional methods are not available, in restricted conditions, and in some emergency situations.[1] Physicians and patients commonly prefer to use smartphone applications for drug queries because of their ease of use and simplicity.[2] Applications related to obesity, neurosurgery, colorectal diseases and infectious diseases are also available on the mobile market for clinicians and patients. However, the reliability of many of these applications is generally untested and their usage should be studied, especially in cases where they are measuring important data.

Hearing loss is a common reason for referral to otolaryngologists and general physicians. Differential diagnosis is important as hearing loss is a symptom of a wide spectrum of diseases. Patient history and physical examination, in combination with pure tone audiometric evaluation, are essential for an accurate diagnosis. In cases where conventional methods are not available (in restricted testing conditions), surveys performed with smartphone applications provided by the emergency services may be a good option for initial evaluation. This study aimed to clarify the reliability of smartphone-based audiometric evaluation when compared to conventional pure tone audiometry (PTA).

Materials and methods

The study comprised 32 patients with hearing loss. The study had been approved by the Clinical Research Ethics Committee and Institutional Review Board of Mugla Sitki Kocman University. All patients had given their informed consent.

Hearing loss evaluation was performed by conventional PTA testing on an AC40 clinical audiometer, with DD45 and B71 headsets (Interacoustics, Assens, Denmark), in a soundproof booth. After diagnosis, a second audiometric evaluation was performed in a quiet room using the Ear Trumpet mobile application (version 1.2.0; Praxis Biosciences, Irvine, California, USA) on an Apple iPhone 5 smartphone running the iOS 7.1.2 platform with a Philips SHP 1900 headset.

Ear Trumpet is an Apple iOS mobile operating system application that uses a modified Hughson–Westlake

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method for hearing threshold determination.[3] The patients using the application were requested to push a virtual button when they could hear an audible signal (Figure 1).

If the threshold difference between the two ears was equal to or over 35 dB, the mobile application ran a masking procedure. In the masking procedure, narrow-band noise was used and was applied to the better ear at 35 dB below the ear being tested. Masking was limited to 60 dB. Because only airway thresholds are measurable with the Ear Trumpet application, comparisons were only conducted for airway thresholds. At the end of the test an audiogram is displayed on the screen (Figure 2).

Hearing loss was classified as mild (20–40 dB hearing loss), moderate (40–60 dB hearing loss) or severe (60–80 dB hearing loss). Hearing loss of less than 20 dB was considered normal.

Mean audiological threshold values were studied with Cohen's kappa analysis, and the coefficient values were calculated. Data analysis was performed with SPSS software, version 15.0 (Statistical Package for the Social Sciences, Chicago, Illinois, USA). *P* values of less than 0.05 were considered statistically significant.

Results

Thirty-two patients (64 ears) were included in the study. Patients' mean age was 53.59 ± 18.01 years (range, 19–85 years). Sixteen patients were male and 16 were female. Conventional PTA showed hearing loss in 52 of the 64 ears. Of these, 24 were left ears and 28 were right ears. Of the remaining 12 ears with normal hearing, 8 were left ears and 4 were right ears. Twelve patients had bilateral hearing loss (Table I).

The second audiometric evaluation, performed using the mobile application, confirmed normal hearing in 3 of the 12 ears found to have normal hearing on PTA, while 9 of the 12 were misdiagnosed as having mild hearing loss (Table I). Conventional PTA diagnosed 29 ears with mild hearing loss and the mobile application confirmed 21 of these as mild. Fourteen ears were diagnosed by PTA with moderate hearing loss; this was confirmed by the mobile application for 10 ears. Nine ears had severe hearing loss on PTA; this was confirmed by the mobile application for five ears.

For all 64 ears (including the normal ears), the kappa coefficient value was 0.423. Comparison of the audiometry thresholds between the mobile application and conventional PTA yielded a statistically significant concordant relationship ($p < 0.05$).

Discussion

Smartphones are now indispensable in our daily lives. They may be helpful to doctors in medical situations just as they are in many other fields. In cardiology, Sivrioglu *et al*. conducted a study with 100 patients and showed that cardiothoracic ratios could be measured accurately and quickly with a mobile application.[4] Ege *et al*. conducted a study evaluating the hallux valgus using mobile applications in 32 patients, and the results were found to be reliable.[5]

FIG. 1
Screenshot of Apple iOS Ear Trumpet version 1.0.2 mobile application with virtual push button for patient use.

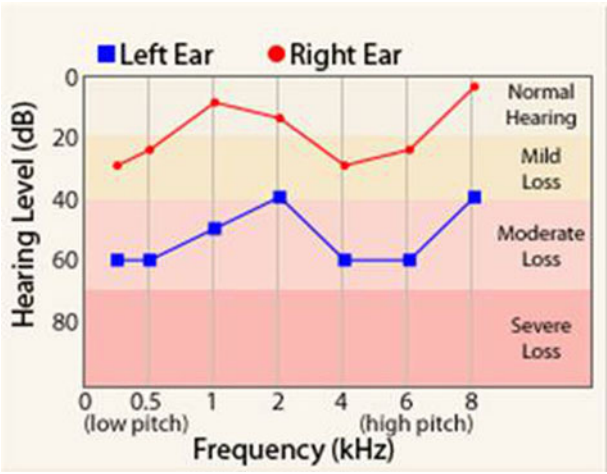

FIG. 2
Example audiogram from Ear Trumpet version 1.2.0 mobile application at the end of a test.

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TABLE I
HEARING EVALUATION WITH MOBILE APPLICATION COMPARED WITH CONVENTIONAL PTA FOR ALL EARS*

Hearing loss determined using conventional PTA	Hearing loss determined using mobile application				
	Normal hearing	Mild	Moderate	Severe	Total
Normal hearing	3	9	0	0	12
Mild	0	21	7	1	29
Moderate	0	1	10	3	14
Severe	0	1	3	5	9
Total	3	32	20	9	64

Data represent numbers of ears. *$p < 0.05$. PTA = pure tone audiometry

Lin *et al*. found that Apple iPhone recordings were useful in determining voice quality changes in the evaluation of clinical voice disorders, post-operative follow up and treatment success.[6] Nast *et al*. used the Apple iPhone 4S and five mobile applications to measure the sound levels of hazardous noise sources in daily life, and compared the values with conventional sound level measurements.[7] The main problem they experienced was with the calibration of these applications. They found that only one of the five mobile applications gave results which were compatible with conventional measurements.[7]

Hearing loss is a common problem worldwide. One-third of the population aged over 65 years experience hearing problems, which can result in depression, social isolation and loss of confidence.[8] Hearing loss may also be an emergency condition that needs to be diagnosed urgently so that treatment can start as quickly as possible. Thus, it is important for general practitioners to perform an immediate audiometric evaluation.

It may also be necessary for otolaryngologists to evaluate hearing loss with tuning fork tests in the absence of audiometry. Several applications have been designed to tackle this problem. Na *et al*. tested their own smartphone application.[9] Swanepoel *et al*. investigated the accuracy of a mobile application in hearing screening in 162 children. The application results were comparable with conventional screening.[10] Although we have not included any paediatric patients in this study, the screening or evaluation of hearing may be conducted in children using the Ear Trumpet mobile application.

Handzel *et al*. tested the uHear™ mobile application with an Apple iPod in 32 patients diagnosed with sudden sensorineural hearing loss.[11] They concluded that uHear is a useful program for initial diagnosis and can support steroid treatment. Four of our 32 patients were diagnosed with sudden sensorineural hearing loss and Ear Trumpet was able to identify these 4 patients correctly. Ear Trumpet was developed and previously tested by Foulad *et al*. using the Apple iOS-based mobile platform.[3] Our study differs from that study as we used an iPhone 5 device with an iOS 7.1.2 platform.

- **The mobile audiometry application investigated in this study is very useful for initial hearing loss evaluation**
- **The usability and speed of the mobile application are excellent, giving audiometry thresholds comparable with conventional audiometry**
- **A drawback of this application is its inability to measure bone conduction levels**
- **The application can be used to evaluate patients with sudden hearing loss who are referred to emergency services**

Our study investigated the Ear Trumpet version 1.0.2 mobile application running on an Apple iPhone 5. The usability and speed of the program are excellent, with a reasonable outcome. A drawback of the application is its inability to measure bone conduction levels. Conventional audiometry requires a special isolated cabin, a PTA device, and an audiometrist or audiologist. In many rural regions, it is generally unusual to find this equipment and personnel in a hospital. In addition, it can be problematic diagnosing sudden sensorineural hearing loss in emergency medicine. Thus, we propose that this mobile application may be very useful for initial evaluation and for treatment.

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