

## Review Article

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# The role of smartphone applications in clinical practice: a review

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## Abstract

**Objective.** The number of medical mobile phone applications continues to grow. Although otorhinolaryngology-specific applications represent a small proportion, there are exciting innovations emerging for the specialty. This article will assess the number of applications available and review how they may be used in clinical practice.

**Method.** The application stores of the two most popular mobile phone platforms, Apple and android, were searched using multiple search terms.

**Results.** A total of 107 ENT applications were identified and categorised according to intended use. Eight applications were reviewed in more detail and assessed on whether a doctor or allied health professional was involved in their design and if they were evidence-based.

**Conclusion.** There are a number of ENT-specific smartphone applications currently available. As the technology progresses, their scope has extended beyond being purely for reference. Nevertheless, it remains difficult to assess the validity and security of these applications.

## Introduction

The use of mobile phones in the workplace by medical professionals has become increasingly common. Although it can be difficult to distinguish between personal and professional use of mobile devices in the workplace, quick access to good quality information is undoubtedly an aid to clinical care. With the development of not only smartphones but also adjunct technology, the scope of smartphone applications has expanded beyond them being purely reference platforms. There are a growing number of applications designed to be used directly in patient assessment, including applications to convert smartphones into otoscopes, endoscope viewers and numerous hearing test applications.

Nevertheless, with the increasing number of applications, it can also be difficult to establish which products provide accurate, secure and up-to-date information. Users cannot rely on the limited information supplied on the mobile phone platforms from which the applications are downloaded; further research is always required to establish the application's evidence base, which may be time consuming and limited by a lack of readily available information.<sup>1</sup> Additionally, given the basic search functions of the application stores themselves (no function to filter applications intended for professional use and limited results for technical terms) even identifying potentially useful applications can be an arduous process.

The purpose of this article is to establish the number and type of ENT-specific applications currently available. In addition, a small selection of applications have been reviewed, in order to highlight some of the innovative ways in which smartphone applications can be used in clinical practice and to analyse the ease with which their validity and evidence base can be assessed.

## Materials and methods

The application stores of the two most popular mobile phone platforms, Apple® (iOS App Store) and Google® (Google Play), were searched for ENT-specific mobile applications. Search terms used included: 'ENT', 'otolaryngology', 'otology', 'rhinology', 'laryngology', 'head and neck', 'hearing' and 'otoscope'. The descriptions were reviewed to ensure the applications were appropriate and relevant to the specialty. Applications were excluded if the description was not written in English or if the applications were not intended for clinical use (Figure 1).

Eight applications returned from the search were then selected for more detailed review; these were chosen to represent the different categories of ENT-specific applications available, such as reference, clinical assessment and those aimed at the patients themselves. Each of the applications had over 100 downloads on the Google Play store or a rating of over 4+ on the Apple iOS store. Application quality was assessed by ascertaining whether a doctor or allied health professional was involved in their development (both application description and developer website were reviewed) and whether there was a readily accessible evidence base for the application (research publications available either via a PubMed search or the developer website).

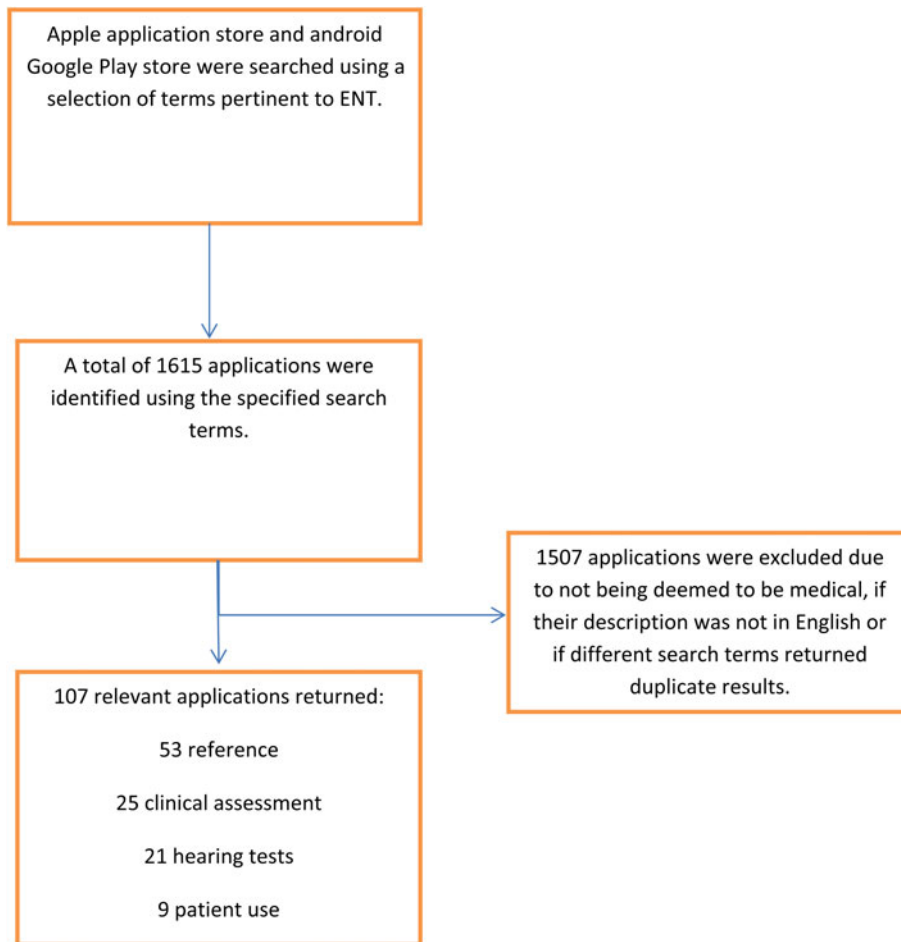


Fig. 1. A flow diagram of the search method used.

## Results

The search was undertaken in July 2019. A total of 107 ENT-specific applications were identified and categorised according to their intended use (Table 1). Of the applications identified, 48 per cent ( $n = 53$ ) were reference applications. These applications included textbooks, study aids and question banks aimed at both medical students and ENT trainees. The remaining applications were predominantly intended for clinical assessment ( $n = 25$ ). There were a notably large number of hearing test applications available (19 per cent,  $n = 21$ ). Aside from hearing tests, other applications intended for use during assessment included otoscope applications, endoscope viewers and screening tools. The smallest category consisted of applications intended for patient use ( $n = 9$ ), which included symptom trackers and self-management applications.

Table 2 contains a more detailed analysis of eight applications. Six of these eight applications had either a named doctor or allied health professional associated with their development. Of these applications, four also had readily accessible published research relating to the application (ENT Ward Handbook,<sup>2</sup> Draw MD,<sup>3</sup> Cupris Health<sup>4</sup> and e.audiologia Hearing Test<sup>5</sup>). The two remaining applications had no clear evidence base, and it was not stated whether the developers were medically trained or allied health professionals.

## Discussion

This study highlights a wide range of ENT-specific applications that are available. A number of studies on smartphone

usage amongst medical trainees have been published,<sup>6–8</sup> in addition to specialty specific (maxillo-facial,<sup>9</sup> urology<sup>10</sup> and plastic surgery<sup>11</sup>) reviews. In comparison with a study conducted in the USA in 2015 that detailed the availability of ENT-specific mobile applications,<sup>12</sup> our study suggests both an increasing number and diversity of ENT-specific applications. As pre-empted in the review by Wong and Fung,<sup>12</sup> evolving technology has resulted in an increasing number of applications allowing smartphones to be directly used in clinical assessment.

The ability to use smartphones as a tool for clinical assessment has huge potential for telemedicine, as discussed in a study by Swanepoel and Clark.<sup>13</sup> The ability to accurately measure hearing with minimal equipment, using applications such as the e.audiologia Hearing Test, provides the opportunity to deliver hearing healthcare to communities where previously it would have been unfeasible. Additionally, the ability to capture otoscope views with a smartphone and to share them remotely facilitates improved ENT care for those in isolated communities. Studies have shown the benefits of using telemedicine to aid triage in the community, providing an effective way to manage referral to tertiary ENT care.<sup>14</sup> Smartphone applications that convert the phone into an otoscope are beneficial to such community triage schemes; the Cupris otoscope was shown to be a low-cost tool to screen for ear disease in remote locations in low- and middle-income countries.<sup>4</sup>

Remote image sharing would also be advantageous in a National Health Service setting. The secure sharing of images via smartphones is particularly pertinent to ENT departments, where the senior on call is often not resident. The ability to

**Table 1.** ENT-specific applications identified on the Apple App Store and GooglePlay

Application name	Developer	Type	Cost	Hardware required?
Cell Scope Lite	Cell Scope	Clinical assessment	Free	Yes
D + R Balance	Triball	Clinical assessment	£18.99	No
Digital Otoscope	MobDx	Clinical assessment	Free	Yes
Draw MD	Visible Health	Clinical assessment	Free 9 (in app purchases)	No
Ears2U	Steven Gold MD	Clinical assessment	£1.26	No
Endoscope Camera	Novotech Industries	Clinical assessment	Free	Yes
Endoscope HD Camera	Novotech Industries	Clinical assessment	Free	Yes
Facelt	Steven Gold MD	Clinical assessment	£1.68	No
FireflyPro Mobile	Fresh Pond Ventures	Clinical assessment	Free	Yes
Head & Neck Cancer @POC	At Point of Care	Clinical assessment	Free	No
hearScope	hearX Group	Clinical assessment	Free	Yes
iScope	Vivolight	Clinical assessment	Free	Yes
Middle Ear Risk Index	Orl.ist	Clinical assessment	Free	No
MiVUE Ear	GorillatapStudio	Clinical assessment	Free	Yes
MobiEye	Ann Sean Software	Clinical assessment	Free	Yes
Mobile Airway Card	Joseph Allward	Clinical assessment	Free	No
OtoScope	Mo-Link.com	Clinical assessment	Free	Yes
OtoscopeApp	Austin Rose	Clinical assessment	Free	Yes
Save My Scope	Save My Scope	Clinical assessment	Free	Yes
Scopecam	Mo-Link.com	Clinical assessment	Free	Yes
Screening of Obstructive Sleep Apnoea	ENT@K	Clinical assessment	Free	No
TM-Rotator	Purefox Oy	Clinical assessment	Free	Yes
USB Otoscope	lijiahong	Clinical assessment	Free	Yes
Voice Online Lab	Voice Clinical Systems	Clinical assessment	Free	No
WiFi Otoscope	lijiahong	Clinical assessment	Free	Yes
Audicus Hearing Test	Audicus	Hearing test	Free	No
Check Your Hearing	US App Studio	Hearing test	Free	No
Check Your Hearing - Pro	US App Studio	Hearing test	£2.89	No
Eartone Hearing Test	Manut Utoomprurkporn	Hearing test	Free	No
Hearing Test	e-audiologia.pl	Hearing test	Free	No

(Continued)

Table 1. (Continued.)

Application name	Developer	Type	Cost	Hardware required?
Hearing Test	Sylvain Saurel	Hearing test	Free	No
Hearing Test	Lemonapps	Hearing test	Free	No
Hearing Test	EBMACS	Hearing test	Free	No
Hearing Test	Android Crazy Studio	Hearing test	Free	No
Hearing test - Tone - Audiometry	IT4YOU	Hearing test	Free	No
Hearing Test & Ear Age Test	Yuichi Sakashita	Hearing test	Free	No
Hearing Test App iOS	Zipdev	Hearing test	Free	No
Hearing Test Pro	e-audiologia.pl	Hearing test	£2.86	No
Hearing Test Pro Free	UpWithApps	Hearing test	Free	No
Jacoti Hearing Centre	Jacoti	Hearing test	Free	No
MFA Hearing Test	Seychelles Unlimited	Hearing test	Free	No
Mimi Hearing Test	Mimi Hearing Technologies	Hearing test	Free	No
Signia Hearing Test	Sivantos Pte	Hearing test	Free	No
Specsavers Hearing Checker	Specsavers Opticians	Hearing test	Free	No
Tablet Hearing Test	MobileMedico	Hearing test	£2.19	No
TuneFork	Listening Applications	Hearing test	Free	No
BPPV Relief	Burston Software	Patient	£5.99	No
Head & Neck Cancer Manager	At Point of Care	Patient	Free	No
HNC Virtual Coach	Vibrent	Patient	Free	No
MOTT ENT Post op: Tonsillectomy	The University of Michigan	Patient	Free	No
Oropharyngeal exercise - MFT for OSA	ENT@K	Patient	Free	No
Tinnitus Balance	Phonak	Patient	Free	No
Tinnitus Describer	US App Studio	Patient	Free	No
Tinnitus Sound Therapy Tinnitus Calmer White Noise	soundsofthesoul	Patient	Free	No
AudioNotch	AudioNotch	Patient	Free (in-application purchases)	No
Illustrated ENT Handbook	ChmSmartApps	Reference	Free	No
100 Cases in ENT	Modelapps	Reference	Free	No
3D Skull Atlas	UpSurgeOn	Reference	Free	No
ABC of Ear, Nose & Throat	Indextra AB	Reference	£27.98	No
Absolute Ear: Diagnostics	Khels Preferens	Reference	Free	No
AcademyQ	Amphetamobile	Reference	Free (in-application purchases)	No
All Ear Diseases & Mangement	Modelapps	Reference	Free	No
All Nose Diseases & Management	Modelapps	Reference	Free	No
BioTK Head & Neck	Numerica LTDA	Reference	Free	No
Buckingham Virtual Tympanum	Miriam Redleaf	Reference	Free	No
CT Neck	MD Toolkit	Reference	Free	No
Current Diagnosis & Treatment, 3 Ed	Indextra AB	Reference	£49.98	No
DOHNS VLE	Appwiz W.11	Reference	Free	No
Ear, Nose & Throat: Otolaryngology ENT Dictionary & Terminology	Michael Quach	Reference	Free	No
Ear-Nose-Throat	MMI	Reference	Free	No
Easy Ways Head, Neck & Limbs	Instant Anatomy	Reference	£4.19	No
ENT	Kakuapps	Reference	Free	No
ENT & Orthopaedics by GLB	Supersimplevideo	Reference	Free	No

(Continued)

**Table 1.** (Continued.)

Application name	Developer	Type	Cost	Hardware required?
ENT Atlas & Treatment Guide	Medico_Guide	Reference	Free	No
ENT by Dr. Sarvejeet Singh	PrepLadder	Reference	Free	No
ENT by Sanjay Agarwal	MegaExams	Reference	Free	No
ENT Handbook	Luke Campbell	Reference	Free	No
ENT Instruments	Balasubramanian Thiagarajan	Reference	Free	No
ENT Surgery Handbook	CSSL	Reference	Free	No
ENT Ward Handbook	Shane Lester	Reference	Free	No
ENT_MCQ	Balasubramanian Thiagarajan	Reference	Free	No
ENTConnect Mobile App	Results Direct	Reference	Free	No
ENTSHO	Intrafacar	Reference	Free	No
ENTSURGERY	Balasubramanian Thiagarajan	Reference	Free	No
Essential Otolaryngology 11e	Indextra AB	Reference	£91.99	No
Face 3D Plus	Centro de Estudos Superiores Positivo	Reference	Free	No
Head & Neck Digital Anatomy	Focus Medica India Pvt	Reference	Free	No
Head & Neck Lectures	Instant Anatomy	Reference	£3.99	No
Head & Neck Mnemonics	Motiveapps	Reference	Free	No
Head & Neck: 3D RT- Sub	Primal Pictures	Reference	Free (in-application purchases)	No
International Forum of Allergy & Rhinology	John Wiley & Sons	Reference	Free (in-application purchases)	No
Key Clinical Topics in Otolaryngology	Indextra AB	Reference	£36.95	No
Learn ENT	Scott Kohlert	Reference	Free	No
My Ear Anatomy	Visual 3D Science	Reference	Free	No
OmnisciENT MD	Alec Szecsei	Reference	Free	No
OTO Central App	Amphetamobile	Reference	Free	No
Otolaryngologyonline	Balasubramanian Thiagarajan	Reference	Free	No
Otolaryngology - Dictionary	Focus Medica India Pvt	Reference	Free	No
Otolaryngology - Understanding Disease	Focus Medica India Pvt	Reference	Free	No
Otorhinolaryngology Exam Review - 1100 Terms & Quiz	Tourkia CHIH	Reference	£1.99	No
Otorhinolaryngology Study Guide & Test Bank App	Tourkia CHIH	Reference	£1.99	No
Otoscope Simulator	Holcroft Solutions	Reference	Free	No
Sinus ID	Blue Tree Publishing	Reference	£2.99	No
Small Atlas of Otolaryngology	Nano ID Group	Reference	Free	No
Surgery Otolaryngology	StatPearls Publishing	Reference	Free (in-application purchases)	No
The Laryngoscope	John Wiley & Sons	Reference	Free (in-application purchases)	No
The mechanism of hearing educational VR 3D	Mozaik Education	Reference	Free	No
Updated E.N.T Cases and Multiple Choice Questions	Plab apps	Reference	Free	No

share otoscopy images would facilitate juniors seeking senior advice, and the option to store images would allow clinicians to monitor a patient's progress chronologically without having to rely on documentation or memory.

The quality of advice that can be given remotely clearly depends on the quality of the images, and this is something that can be expected to improve as the applications become more widely used and smartphone technology progresses.

**Table 2.** Detailed review of eight applications

Application name (developer)	Type	Description	Doctor or allied health professional involved in development?	Evidence-based?
ENT Ward Handbook (Shane Lister)	Reference	Designed by James Cook University Hospitals. Details clinical protocols with clear advice regarding when to seek senior ENT support.	Yes	Yes <sup>2</sup>
CT Neck (MD Toolkit)	Reference	Provides interactive CT neck images in order to develop the user's understanding of both the imaging & anatomy. Users are able to zoom & scroll through different views.	Not stated	No
Draw MD (Visible Health)	Clinical assessment	Designed to aid consultations by providing sets of custom illustrations which clinicians can then annotate on their phones when explaining conditions or procedures to a patient. ENT is one of 18 specialties available.	Yes	Yes <sup>3</sup>
Save My Scope (Save My Scope)	Clinical assessment	With use of an adaptor, an iPhone can be used as an endoscope viewer. Voice activation allows images to be recorded hands free. Images are uploaded & stored on a secure server, allowing for monitoring a patient's condition over time.	Yes	No
Cupris Health (Cupris)	Clinical assessment	With the use of an attachment, clinicians are able to use their smartphone as an otoscope. Detailed images are captured & can be annotated & shown to the patient. Compatible with standard Welch Allyn specula.	Yes	Yes <sup>4</sup>
Hearing test (e-audiologia.pl)	Hearing test	This application allows pure tone audiometry to be performed using a smartphone. Bundled headphones may be used, or the device can be calibrated. The test results may be annotated & shared using the application.	Yes	Yes <sup>5</sup>
BPPV Relief (Burstson software)	Patient use	This application contains animations to demonstrate the commonly used Epley & Dix Hallpike manoeuvres. Although it is described as an education tool for health professionals, it also states it can be used by patients who have been diagnosed with BPPV & have been advised to perform these manoeuvres as part of their self-management or to treat recurrences.	Yes	No
Head & Neck Cancer Manager (At Point of Care)	Patient use	This application allows patients to track their symptoms & manage their medications & treatments. It also allows for uploading photographs of visible symptoms to be shared with care providers. Information can also be shared to allow the care provider to monitor progress between face-to-face appointments.	No	No

CT = computed tomography; BPPV = benign paroxysmal positional vertigo

Although small scale, one study has shown that an accurate diagnosis can be obtained from still images taken using a mobile phone otoscope. However, some conditions, such as middle-ear effusion, proved more difficult to visualise and correctly diagnose.<sup>15</sup> When comparing smartphone otoscopes to traditional otoscopes, clinicians preferred the phone attachment. There are clinical implications when switching to a smartphone otoscope after examining with a standard otoscope because clinicians often changed their diagnosis.<sup>16</sup> Patient feedback was positive during a study comparing traditional microscopy to the new phone-based otoscope; patients appreciated the opportunity to visualise the pathology and felt it gave them a better understanding of their condition. When clinicians diagnosed from the smartphone images, the positive predictive value was 97 per cent.<sup>17</sup>

Although the use of smartphones during consultations can be expected to vary according to individual preference, the studies investigating the use of smartphone otoscopy noted a predominantly positive response from patients. There are a number of applications available to facilitate the doctor-patient

encounter, such as Draw MD, which allows the smartphone to be used to provide patients with visual information during a consultation. A study has shown that 40–80 per cent of information conveyed in a consultation is immediately forgotten, and of the information that is retained, up to 50 per cent is remembered incorrectly.<sup>18</sup> The use of illustrations when explaining to a patient has long been promoted and acknowledged to improve patient compliance.<sup>19</sup> When illustrations are used in combination with oral communication, their effectiveness is further increased.<sup>20</sup> Draw MD offers a modern and accessible way to provide the visual information patients require in order for them to understand and retain information accurately.

Hearing tests represent a significant proportion of the available applications, although one study has noted that very few have been validated in peer review studies.<sup>21</sup> Other examples of applications available for use in clinical assessment include an application to objectively measure the Unterberger and Romberg test,<sup>22,23</sup> and there has also been a preliminary study completed on a smartphone application to measure

bone conduction thresholds.<sup>24</sup> Smartphone otoscope technology has become more established, and there are numerous studies comparing their use to traditional otoscopy as previously discussed. The use of smartphones during nasal endoscopy, using applications such as Save My Scope, represents a relatively new area of development. As such, fewer research papers exist, but initial research has shown encouraging results.<sup>25</sup> The number of novel applications for use at the bedside will inevitably grow as technology progresses.

Data protection is an important consideration when using smartphone applications, and concerns regarding security could be a major deterrent for their usage. This is particularly relevant if the applications are used on personal devices or used to communicate patient-identifiable data or images. A lack of a regulatory framework for healthcare applications can leave the degree of security to the discretion of individual developers. One article assessing the usage of mobile phone applications in the management of bipolar disorder recommended that users exercise caution when using the applications because most lacked privacy policies.<sup>26</sup> Another article noted that even if the application did have a privacy policy they may be difficult to access and not specific to the application itself.<sup>27</sup> Nevertheless, there are an increasing number of recommendations regarding security and data protection measures for the applications,<sup>28</sup> including tools developed to help application designers improve the security of their software.<sup>29</sup> Although it remains the clinician's responsibility to be confident that the applications they use are secure, it can be expected that the security requirements will become more stringent as this field continues to grow.

In addition to security concerns, it also remains difficult to assess the quality of available applications. This review is limited in the same way as users trying to search for applications for clinical use. The mobile application stores' search functions are limited and do not allow for the use of filters. Searches return a large number of results without the ability to identify the applications intended for professional use. Specialist search terms return very few results, while more generic terms return large numbers of applications, which users have to sift through to find those that may be clinically relevant. Without downloading the application, which in some cases requires payment, this judgement can only be made on very limited information provided in the description of the application, and the quality and security of the application can be hard to determine.

As a consequence, further research is required to ascertain the quality of an application; it is often possible to establish the qualifications of the developers via the application's description or the developer's website. Of the eight applications reviewed, over half had a doctor or allied health professional involved in their development. The majority also had published research relating to the application; however, this was often a single article, in some instances authored by the application's developer. Finding an objective evidence base for smartphone applications is arduous, and the information is often lacking. Although the number of applications is growing, establishing their security and validity still represents a significant challenge.

## Conclusion

There are numerous medical applications available, and ENT-specific applications represent a very small proportion of these. However, the applications reviewed highlight the diverse range of clinical uses for these. It is clear that there

is a role for mobile phone applications within clinical practice, and it would be beneficial to ascertain exactly how this technology is currently being used within the specialty. Improved privacy policies and greater guidance on application quality would enable clinicians to integrate these applications into their clinical practice with more confidence. Mobile technology will continue to evolve at a rapid pace, and consequently so will the scope and usage of smartphone applications.

**Competing interests.** None declared

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