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Title: Current status of handheld otoscopy training: a systematic review

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ABSTRACT

Objective: Otoscopy is a frequently performed procedure and competency in this skill is important across many specialties. We aim to systematically review current medical educational evidence for training of handheld otoscopy skills.

Methods: Following the PRISMA guideline, studies reporting on training and/or assessment of handheld otoscopy were identified searching the following databases: PubMed, Embase, OVID, the Cochrane Library, PloS Medicine, Directory of Open Access Journal (DOAJ), and Web of Science. Two reviewers extracted data on study design, training intervention, educational outcomes, and results. Quality of educational evidence was assessed along with classification according to Kirkpatrick's model of educational outcomes.

Results: The searches yielded a total of 6,064 studies with a final inclusion of 33 studies for the qualitative synthesis. Handheld otoscopy training could be divided into workshops, physical simulators, web-based training/e-learning, and smartphone-enabled otoscopy. Workshops were the most commonly described educational intervention and typically consisted of lectures, hands-on demonstrations and training on peers. Almost all studies reported a favorable effect on either learner attitude, knowledge, or skills. The educational quality of the studies was reasonable but the educational outcomes were mostly evaluated on the lower Kirkpatrick levels with only a single study determining the effects of training on actual change in the learner behavior.

Conclusion: Overall, it seems that any systematic approach to training of handheld otoscopy is beneficial in training regardless of learner level, but the heterogeneity of the studies makes comparisons between studies difficult and the relative effect sizes of the interventions could not be determined.

Key words: handheld otoscopy; technical skills training; otology; assessment; competency-based medical education.

INTRODUCTION

Otoscopy is a key procedure for the diagnosis of middle ear disease, which is especially common in young children but can present in all age groups.[1,2,3] The procedure is therefore performed on a daily basis in many specialties including pediatrics, family medicine, otorhinolaryngology and at emergency/urgent care departments. Multiple studies have reported that undergraduate and postgraduate training in otoscopy often is sparse, and hence the ability to recognize ear pathology inadequate.[1,4]

Because of the frequency of patients presenting with ear complaints and since the treatment is guided by the correct diagnosis established from the otoscopy, obtaining sufficient competency and good clinical skills in handheld otoscopy is important. Handheld otoscopy can be trained on peers, standardized patients, or real patients, or on non-human models such as manikins, technology-enhanced simulators, or using internet-based learning. Simulation-based training has potential benefits such as increased clinical experience without training on real patients, standardized presentations/cases, and ease of repeated practice over time, which facilitates retention of knowledge and increases diagnostic accuracy.[1]

Skills in handheld otoscopy are compound and consists of a cognitive component (i.e. the ability to recognize different pathologies, resulting in diagnostic accuracy) and a technical skills component (i.e. the ability to technically perform a sufficient examination of the ear canal and ear drum using a handheld otoscope). There is currently no evidence-based or best practice guidelines for how training of handheld otoscopy skills should be organized or which training models are superior. We therefore aim to systematically review the literature to map current training opportunities and medical educational evidence for training of handheld otoscopy skills.

Our specific research questions were:

1. How is handheld otoscopy being trained?
2. What is the educational evidence for the different handheld otoscopy training modalities?
3. Can best practice guidelines for training of handheld otoscopy be suggested based on the current literature?

METHOD

Our review follows the PRISMA statement.[5]

Search strategy and data sources

We searched PubMed, Embase, OVID, the Cochrane Library, PloS Medicine, Directory of Open Access Journal (DOAJ), and Web of Science, from inception to 30th November 2019. The search was updated 13th of July 2020. Our search terms included otoscop* AND (training OR assessment OR skills); or otoscop* AND (simulat* OR model). Our initial scoping search in PubMed revealed key papers known to the authors. Finally, we also reviewed the reference lists of the included studies to identify additional potentially eligible studies.

Eligibility criteria

Studies that met all of the following criteria were eligible for inclusion in this systematic review:

- Population: Health care professionals/students at all levels of training/experience.

- Intervention: Studies of training and/or assessment of performance or competency in handheld otoscopy with/without pneumatic otoscopy using any training modality (peers, patients, standardized patients, manikins, physical models, virtual reality (VR) simulation, internet-based learning).
- Comparison: Studies with educational interventions or with educational observations.
- Outcomes: Any outcome in relation to training/learning.
- Design: Any quantitative educational study design.
- Context: Studies conducted in any healthcare or medical educational setting reported in English.

Exclusion criteria

- Full text not available.
- Commentaries, editorials, and reviews.

Study selection

Search results from databases was saved and imported into the Covidence online platform for systematic reviews (covidence.org). Duplicates were removed automatically. Titles and abstracts were screened independently by two reviewers from the author group (A.F., S.A.). Any study deemed potentially relevant from the title/abstract screening by any reviewer was included for full-text screening. Full-texts were obtained and screened by the same two reviewers and disagreements on final inclusion were resolved by discussion within the entire author group.

Data extraction

A data extraction form was constructed in Excel 2016 (Microsoft Inc., Redmond, WA) and piloted on five randomly selected studies by two reviewers (A.F. and S.A). Disagreements were resolved by discussion and the data from the remaining papers were extracted by one reviewer (A.F. or S.A.). We extracted the following descriptive information from the included studies:

- Study information: authors, year, country, study design (descriptive/observational/interventional) and study aim.
- Learners: level, health care professional background, number of learners.
- Educational intervention: training modality (peers, patients, standardized patients, manikins, VR simulation, internet-based learning), resources, platform,
- Training outcome: assessment of diagnostic accuracy, technical performance or other evaluation.
- Main results of the trial: A brief description of the main results of the educational intervention.
- Training protocol: Details on training such as amount of training, case variability, assessment details, number of assessors, observation type (live, video-recorded)
- Analysis: Kirkpatrick hierarchy (level 1: participation; level 2a: modification of attitudes/perceptions; level 2b: modification of knowledge/skills; level 3: behavioral change, transfer; level 4a: change in organizational practice; level 4b: benefits to patients); educational quality analysis (Appendix 1);

Data synthesis and analysis

The synthesis was based on descriptive methods to map the current reports on handheld otoscopy training concerning training modalities, the number of participants and level of participants in the studies. Further assessment according to a quality assessment tool presented in Gordon et al[6] was performed on all studies (Appendix 1) as well as Kirkpatrick hierarchy describing the level of educational outcomes.

Results

Our search strategy resulted in 6,064 studies (see flow chart). Of these, 83 full-text articles were assessed for eligibility. References of included papers were screened for relevant studies but no additional studies were added. Altogether, 33 studies fulfilled the inclusion criteria and were included for the qualitative synthesis. We categorized the included studies based on the type of educational intervention used for otoscopic skills training, resulting in the following four categories: Workshops, physical simulators, web-based training/e-learning, and smartphone-enabled otoscopy. Some studies used more than one modality in the training program and are therefore included in more than one category.

Workshops

Workshops were defined as a course of a single to a few days (massed practice) with smaller or bigger groups of learners. These could either be supplemental to an already existing curriculum or independent from training programs, residency-training programs, or other forms of established teaching by faculty. These workshops typically included didactic lectures on anatomy of the middle ear and interpretation of tympanic membrane findings, often with live or video demonstrations on performing otoscopy and/or pneumatic otoscopy presented to all learners. Lectures were often then followed by instructor-led hand on exercises on peers or physical simulators to support the didactic teaching. In contrast to other studies that used massed practice, one study[7] reported on a workshop (with clinical training) that was organized in a distributed fashion, i.e. over a longer period of time (4 months).

Workshops were the most common training intervention among the included studies (n=22/33) and included the highest number of participants (n=4,477) (Table 1). Across studies, participants represented all types of learners from medical students with minimal or no experience with otoscopy to experienced otolaryngologists with years of practice. The most studies had medical students as learners. However, workshops were the most common training modality among experienced learners. In the quality assessment, these studies were assigned a quality score in each category between 1 and 2. Further, all studies on workshops for teaching handheld otoscopy was classified as Kirkpatrick level 2: mainly level 2a, meaning that the impact of the educational intervention was evaluated as an effect on thinking/problem-solving, psychomotor and/or social skills (Supplementary material). However, the primary outcomes being investigated varied from objective improvement in participant's skills[7] to a theoretical multiple-choice test.[8] A single study did not investigate objective improvement but had self-reported confidence as primary outcome.[9] Womald et al.[10] described how 10 otolaryngology residents attending a structured training workshop reduced misinterpretation and diagnostic errors in cases of various tympanic membranes both with and without pathologies from 57% to 34% in the training setting

Sixteen of eighteen studies found a positive effect of the intervention studied (Supplementary material); overall, this indicates a positive effect on skills and/or knowledge of any sort of workshop-based intervention for teaching handheld otoscopy.

Physical simulators

Physical simulators fall in two categories: A) technology-enhanced simulators with display of the tympanic membrane on a digital screen, and B) “manual” simulation models where changing the case requires the manual and physical exchange of a module/cartridge on the simulator. The technology-enhanced simulators most commonly used were the OtoSim otoscopic simulator (OtoSim Inc., Toronto, Ontario, Canada) and the OtoSim Mobile (OtoSim Inc., Toronto, Canada). Among the “manual” simulators used in training was the Life/form Diagnostic & Procedural Ear Trainer, Ear Examination Simulator, (Kyoto Kagaku Co., Ltd, Kyoto, Japan) and a non-commercial simulator presented by Gao et al..[10] The physical simulators offers hands-on examination and practice with standardized presentations of different pathologies with the possibility of built-in or instructor feedback and/or assessment because the participant’s otoscopic view typically is displayed simultaneously on a PC-screen.

Physical simulators were the secondly most used (n=15) modality for teaching otoscopy often in combination with didactic teaching such as workshops/lectures. The majority of the participants were medical students or residents (n=586). In the quality assessment, these studies were assigned a score in each category between 1 and 2. The Kirkpatrick level varied considerably: several studies included on level 1 evaluation (i.e. participation), most included level 2b evaluation (modification of knowledge/skills), and two studies included level 3 outcomes (behavioral change), which is the highest level among the enrolled studies (Supplementary material).

Studies on the use of physical simulators as a training-aid for teaching otoscopy skills mainly used post-intervention test/performance within the simulated setting and all studies found a positive effect on diagnostic skills.[1,11–16] One study, aiming at gathering validity evidence for a new digital otoscopy training model, only evaluated the participants’ opinion on the training model, which cannot be considered a learning outcome or contributing to validity of the model.[10] Three studies investigated transfer to real-life patients. All three studies investigated how a training on physical models in combination with didactic training or alone had an impact on theoretical knowledge and real-life patient skills comparing an intervention and control group. The three studies used their own skills-assessment scoring sheet and found that clinical ability, diagnostic skills and knowledge improved.[17–19] Three studies only reported on the learners' views on the learning experience and found a positive attitude towards physical simulators.[20-22] Finally, a single study aimed at determining the sequence of simulation-based training versus lectures in a discovery learning context but did not find any effect of sequence on knowledge acquisition or retention.[23]

Web-based training/e-learning

The category of web-based training/e-learning includes various online educational courses/resources related to training of handheld otoscopy. Consequently, both the educational intervention and the content varies greatly between studies: for example, some of these interventions only present students for educational content with minimal or no interaction[15] whereas other interventions allow the learner to examine a range of tympanic membrane pathologies and test themselves with integrated multiple-choice tests.[24] Common for the web-based training are that they were made available for students outside the physical learning environment, as a supplement to the curriculum, and were available online at any time. Some of the online courses were provided before specific workshops and were implemented as supplemental educational tools whereas others represented "true", standalone web-based training.

In total, six studies included the web-based training modality with a total of 459 participants. Four of these studies included medical students, one study included residents, and one study included other health professionals such as audiology doctoral students. In the quality assessment, these studies were assigned a score of 1 or 2 in each category and were assessed as including Kirkpatrick's hierarchy level 2b evaluation evidence. Only two studies did not combine the modality with other training interventions[24,25] and both found a positive effect on medical students' theoretical knowledge of handheld otoscopy and pathology but did not assess whether the web-based training had a positive effect on their practical skills. For the remaining studies, the effect of web-based training could not be isolated because of the integration with other training modalities.

Smartphone-enabled otoscopy

A single study used smartphone-enabled otoscopy in training of novices.[26] The smartphone-enabled otoscope is a relatively new technology that can serve as a potentially effective tool for telemedicine.[27] This technology allows the user's view to be shared with an instructor and the view can further be magnified. This could make real-time feedback easier as well as more accessible for several students at one time.[26] The study included training of 60 medical students. In the quality assessment the study received educational quality scores between 1 and 2. The outcomes of the study were assessed as including Kirkpatrick level 2a educational outcomes with participants' self-reported ability to visualize the tympanic membrane and confidence in performing middle ear examination but there was no evaluation of the students (60 medical students) ability to identify pathology or effects on knowledge or technical performance.

DISCUSSION

Summary of the main findings

In this study, we have mapped the current methods and medical educational evidence for training of handheld otoscopy skills. We categorized handheld otoscopy training into the following educational modalities: workshops, physical simulators, web-based training, and smartphone-enabled otoscopy. The most widely used were workshops and physical models and most studies found a favorable effect on attitude, knowledge or skills in handheld otoscopy. Only one study used smartphone-enabled otoscopy and overall, more studies are needed to assess the use of this modality for training handheld otoscopy. The educational quality of the studies was reasonable as most studies were assessed as level 1 to 2. The educational outcomes were mostly evaluated on the lower Kirkpatrick levels (1, 2A and 2B). Joyce et al (13) reached Kirkpatrick's level 3 as the outcome was use of pneumatic vs basic otoscopy in the clinical examination after training pneumatic otoscopy but could not show an increase in the use of pneumatic otoscopy after training. Heterogeneity of the studies including differences in educational context, interventions, content, learner levels (from novice students to more experienced practitioners), and educational outcomes make comparisons and conclusions difficult.

Consequently, we cannot establish an effect-size or make recommendations on which of the different modalities is the most effective for example specific types of learners or contexts. Nevertheless, one study found physical simulation superior to web-based training and lectures with regard to improvement of diagnostic and clinical skills.[19] Two more studies showed how a combination of physical simulation training and didactic training had a positive impact on both diagnostic and clinical skills of pediatric residents and medical students.[17,18] Overall, a systematic approach to training of handheld otoscopy using any of the described modalities seems to have a positive effect regardless of learner level.

Strengths and limitations

A strength of this study is the systematic approach which has identified 33 studies on the effect of relevant training interventions with a total of 5,468 participants. The overall positive effect found regardless of intervention raises concern of reporting bias in the literature (i.e. negative findings not being reported/published). Another limitation of our study is the lack of quantification of the interventions effect, due to the heterogeneity of the included studies. In addition to the previously mentioned factors such as differences in educational context and outcomes, also the variations of the procedure limits comparability. Some studies mainly focused on training of pneumatic otoscopy skills either alone or in combination with "regular" handheld otoscopy and consequently focus of the training might be too different for direct comparison.

Implications

It is well-established that simulation-based training has positive effects on procedural skills learning.[28] Often, simulation-based training of technical skills is used to provide a safe learning environment for procedures where basic competencies are required before further supervised training in the clinical environment. In the case of handheld otoscopy, patient safety concern is not the primary reason to consider using simulation-based training models. Rather simulation-based training offers a standardized and controlled learning experience where relevant normal variations and pathologies can be presented for the learner, which can be more difficult to achieve in a classroom setting. Morris et al.[14] showed how 1.5 hours structured training using a physical simulator resulted in medical students being able to more acurrate diagnose middle ear effusion compared to untrained subjects (79.2% vs 57.3%). Oyewumi et al.[1] had similar positive findings, but in a population of more skilled learners (Famliy and Community medicine, pediatric and otolaryngology residents) showing improvement in diagnostic skills in a simulation setting after physical simulation training. These interventions can to some extent be alleviated through supporting traditional classroom activities with web-based/e-learning activities as illustrated in some of the examples of workshops found.

Based on the studies included, it is not possible to make any specific best practice recommendations for the training of skills in handheld otoscopy. Each modality has different strengths and limitations and there is a paucity of studies with higher level learning outcomes to inform actual effects on behavioral change and patient outcomes. Table 2 suggests strengths and weaknesses of each modality.

The following best practice recommendation is therefore based on knowledge from other procedures and contemporary educational theoretical frameworks. The principles of directed, self-regulated learning (DSRL) has demonstrated long-term benefits on procedural performance compared with instructor-regulated learning[29]: DSRL represents a self-directed learning experience where trainees regulate their own learning scaffolded by intentional instructional design and learning supports provided by the educator without the continued presence of a human instructor.[30] Regardless of training leaning on instructor-led or self-directed practice, feedback is important has consistently been identified as a key feature of successful simulation-based training.[31,32] Appropriate feedback should therefore be considered when designing the training curriculum for handheld otoscopy. For psychomotor skills training, distribution of training over a longer period of time is superior to massed practice where training is condensed over a short period of time.[33,34] Nevertheless, most of the workshop formats found represented massed learning events with training only for a single day or a few consecutive days

Finally, assessment of skills is key in competency-based medical education. Structured assessment can be used for progress monitoring and summative feedback that can be used to determine when the learner is proficient (i.e. mastery learning).[35] In handheld otoscopy, adequate skills consist both of the ability to make the correct diagnosis but also the ability to technically perform the procedure and systematically evaluate the external ear canal and tympanic membrane. Assessment of technical skills performance is mostly not used in the identified studies. We have recently developed an assessment tool for technical skills performance in handheld otoscopy and established a pass/fail standard[36], which can supplement assessment of the learners diagnostic skills.

Ultimately, training of handheld otoscopy should be designed for the specific context which might be medical students as is the case in 20 of the 33 studies in this review. However, specific procedural training could also be targeted at more experienced learners such as pediatricians or general practitioners. It is therefore important to map the needs of the intended learners, choose relevant learning objectives, and design the educational intervention and implementation strategy accordingly. We recommend using a structured approach such as Kern's six-step approach to curriculum design.[37]

CONCLUSION

In this systematic review, we identified 33 studies on handheld otoscopy training using either workshops, physical simulators, web-based training/e-learning, or smartphone-enabled otoscopy as the training model. Almost all studies reported a favorable effect on attitude, knowledge or skills but the heterogeneity make comparisons and conclusions difficult. Overall, it seems that any systematic approach to training of handheld otoscopy is beneficial for any learner level.

There is a need to better understand the positive effects to inform which components of the structured approach works, for whom the different educational interventions have the greatest effect, and what the optimal amount of training is.

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TABLES

Table 1. Characteristics of the included trials

Trial characteristics	No. of trials	No. of participants*
All trials	33	5,468
Study design		
Randomized, controlled trial	12	794
Non-randomized trial	1	121
Observational	14	4,055
Survey	4	303
Cross sectional	2	195
Training modalities		
Workshop	22	4,477
Physical simulators	15	773
Web-based training/e-learning	6	459
Smartphone-enabled otoscopy	1	60
Technical skill		
Otoscopy	26	5,020
Pneumatic otoscopy	6	503
Video-otoscopy	2	200
Smartphone-enabled otoscopy	1	60
Participants		
Medical students	20	1,373

Residents (Pediatrics and ENT)	5	279
General practitioners	4	795
Otorhinolaryngologists	1	317
Pediatricians	1	2,331
Healthcare professionals	3	323
Outcome (cf. Kirkpatrick)		
Level 1 - Participation	2	63
Level 2a – Modification of attitudes/perceptions	3	69
Level 2b – Modification of knowledge/skills	27	5,221
Level 3 – Behavioral change	1	115
Level 4 – Benefit to patients/clients	0	0

*Numbers reflect the number of participants enrolled in the trials.

**The number of trials and participants may add up to more than the total number for all trials because several studies fit within more than 1 study design and included more than 1 type of simulation model.

Table 2 – Modalities strengths and weaknesses

Modality	Strengths	Weaknesses
Workshops	- Good interaction between learners and teachers - Useful for improving theoretical skills through traditional didactics and group discussion - Reasonable possibility of supervision if the number of participants is low	- Time consuming for instructors and administration. - Limited possibility for hands-on practice unless traditional didactics are combined with other training modalities or training on patients/peers. - Typically instructor-led with limited opportunity for self-regulated learning - Limited possibility of repeated practice
Physical simulator	- Useful for training technical and diagnostic skills - Case-variability can easily be introduced - Good possibility of supervision - Repeated practice and self-regulated training if the simulator is always accessible.	- Often requires a supervisor or instructor to give feedback - Availability/facilities with simulators can be a limiting factor - Can be more costly to acquire and maintain than other modalities
Web-based/e-learning	- Convenience of training for the learners especially if always available - Possibility of repeated practice/review of material - Possibility of a high number of cases	- Technical aspects of the procedure cannot be trained hands-on - If dedicated time for practice is not scheduled this might influence time spent on training
Smartphone-enabled otoscopy	- Possibility of sharing view with an instructor also on a distance - Low cost compared with a classic otoscope	- New technology with only scarce evidence on training effectiveness - Limited possibility of integrated feedback i.e. requires instructor

		present/present at a distance - Limited possibility of repeated practice and self-regulated learning as an instructor is needed

APPENDIX 1: Quality assessment tool(6)

Quality assessment Score (n=1-3)	**High quality (1)**	**Medium quality (2)**	**Low quality (3)**
Educational Underpinning	Clear and relevant description of theoretical models or conceptual frameworks that underpin the study	Some limited discussion of underpinning, with minimal interpretation in the context of the study	No mention of underpinning
Curriculum	Clear description of the process and outcomes of the curriculum / syllabus / assessment design	Some limited description that will not facilitate replication	No mention of curriculum
Setting	Clear details of the educational context and learner characteristics of the study	Some description, but not significant as to support dissemination	No details of learner characteristics or setting
Pedagogical	Clear description of relevant pedagogy employed to support delivery	Some pedagogical alignment mentioned but limited detail as to how applied	No details of pedagogy
Content	Provision of detailed materials (or details of access)	Some elements of materials presented or summary information	No educational content presented
Conclusion	Conclusions of the study reflect the findings	Some mismatch between the conclusions and findings	No correlation between the findings and conclusions