Video-otoscopy recordings for diagnosis of childhood ear disease using telehealth at primary health care level

Leigh Biagio1, De Wet Swanepoel1,2,3, Claude Laurent1,4 and Thorbjörn Lundberg5

Summary
We studied the diagnoses made by an otologist and general practitioner (GP) from video-otoscopy recordings on children made by a telehealth facilitator. The gold standard was otomicroscopy by an experienced otologist. A total of 140 children (mean age 6.4 years; 44% female) were recruited from a primary health care clinic. Otomicroscopic examination was performed by an otologist. Video-otoscopy recordings were assigned random numbers and stored on a server. Four and eight weeks later, an otologist and a GP independently graded and made a diagnosis from each video recording. The otologist rated the quality of the video-otoscopy recordings as acceptable or better in 87% of cases. A diagnosis could not be made from the video-otoscopy recordings in 18% of ears in which successful onsite otomicroscopy was conducted. There was substantial agreement between diagnoses made from video-otoscopy recordings and those from onsite otomicroscopy (first review: otologist k = 0.70 and GP k = 0.68; second review: otologist k = 0.74 and GP k = 0.75). There was also substantial inter-rater agreement (k = 0.74 and 0.74 at the two reviews) and intra-rater agreement (k = 0.77 and 0.74 for otologist and GP, respectively). A telehealth facilitator, with limited training, can acquire video-otoscopy recordings in children for asynchronous diagnosis. Remote diagnosis was similar to face-to-face diagnosis in inter- and intra-rater variability.

Accepted: 26 May 2014

Introduction
The incidence of acute otitis media (AOM) is up to eight times higher in sub-Saharan African than in other regions of the world.1 Unfortunately, there are relatively few otolaryngologists in sub-Saharan Africa, about 4–7 per million people.2 Early diagnosis and subsequent treatment of ear disease is therefore difficult to achieve, because hearing health services and hearing professionals are very limited.3 Specialist services can be extended to rural and underserved areas by use of video-otoscopy and telemedicine.3,4 Still images or video recordings can be transmitted to otolaryngologists anywhere in the world for assessment.5–6 Use of video-otoscopy in telehealth programmes has been reported, using both synchronous (real-time) and asynchronous (store-and-forward) evaluation.5–9 Previous studies have demonstrated that asynchronous video-otoscopy images are equivalent in quality to onsite otoscopy, and the diagnostic agreement is average to good.4,5,8,9

In a recent study, video-otoscopy images in adult patients were acquired by an ear and hearing telehealth facilitator with no formal health care education.6 Subsequent diagnoses from the recorded video images were in moderate agreement with onsite diagnoses made by the same otolaryngologist.

Both real-time and asynchronous video-otoscopy were employed by Smith et al.7,8 These authors reported a higher agreement between onsite otoscopy diagnoses and real-time diagnoses than asynchronous diagnoses. However, real-time diagnosis is not always possible, due to the time constraints on the staff involved. Real-time diagnosis also requires high speed broadband connectivity, which is often unavailable in areas such as sub-Saharan Africa.

Video-otoscopy recordings in the study by Smith et al.7,8 were acquired by a paediatrician or a research nurse, neither of whom are commonly available in remote health

1Department of Communication Pathology, University of Pretoria, South Africa
2Ear Sciences Centre, School of Surgery, University of Western Australia, Nedlands, Australia
3Ear Science Institute Australia, Subiaco, Australia
4ENT Unit, Department of Clinical Science, Umeå University, Sweden
5Family Medicine, Department of Public Health and Clinical Medicine, Umeå University, Sweden

Corresponding author:
Leigh Biagio, Department of Speech-Language Pathology and Audiology, University of Pretoria, Pretoria 0002, South Africa.
Email: leigh.biagio@up.ac.za
clinics. However, video-otoscopy images can be captured at primary health care level by a telehealth facilitator with limited or no formal health training. This may be a powerful method of identifying pathology early, and making appropriate recommendations whilst avoiding excessive waiting times and costs related to travelling. This is particularly important for children in remote areas who may be more prone to ear disorders, such as otitis media.

In studies comparing asynchronous diagnosis using video-otoscopy, conventional otoscopy has usually served as the reference or gold standard. The ideal method of ear examination is by use of an operating otomicroscope with the ear canal free of cerumen. In practice this is rarely available to a clinician. Nevertheless, the use of otomicroscopy instead of conventional otoscopy should provide a more accurate gold standard for comparison of diagnostic concordance with video-otoscopy recordings.

The aim of the present study was therefore to investigate asynchronous interpretations of video-otoscopy recordings made by a telehealth facilitator, using onsite otomicroscopy as the gold standard. Because there are a limited number of otolaryngologists available in sub-Saharan Africa, diagnosis is often left to general practitioners (GPs). Therefore we studied video-otoscopy interpretations made by an otologist and a GP.

**Methods**

The study was approved by the appropriate ethics committee. A convenience sample of children aged 2–16 years of age was recruited from the Witkoppen Health and Welfare Centre, a primary health care clinic that provides services to the Diepsloot community north of Johannesburg, South Africa. Diepsloot is a densely populated, poor socio-economic settlement with more than 90% of the population unemployed. There is no hospital in Diepsloot, despite a very high prevalence of HIV and associated TB infections.

Participants were recruited from patients attending the clinic, irrespective of reason for attendance. Caregivers were informed of the procedure and gave consent before any data collection commenced. Biographical information and history of earache, ear discharge or hearing loss during the two weeks prior to participation in the study was then recorded.

**Otomicroscopy**

The otomicroscopy was conducted by an experienced otologist (>35 years of practice). The onsite otomicroscopy examination was considered the gold standard diagnosis. Cerumen was removed manually in order to obtain a clear view of the tympanic membrane. Cerumen removal was discontinued if any discomfort was noted. Thereafter, observations regarding ear canal obstruction, presence of any discharge, tympanic membrane patency, translucency and position, as well as the concluding diagnosis were documented.

The tympanic membrane status was assessed by visual otomicroscopic examination alone, without objective assessment of the tympanic membrane mobility. The types of otitis media were classified as either AOM, otitis media with effusion (OME) or chronic suppurative otitis media (CSOM). Classification of the types of otitis media were recorded according to the following criteria: AOM diagnosis was based on clinical data (e.g. rapid onset of fever, otalgia or irritability) and otomicroscopic findings of either a bulging intact tympanic membrane or a wet, contourless, perforated tympanic membrane. Diagnosis of OME was based on suspicion of seromucoid or serous effusion in the middle ear (completely filled or air-fluid level or bubbles), with an intact tympanic membrane without symptoms of acute infection. Diagnosis of CSOM was based on the presence of perforation, deep retraction pocket or cholesteatoma, with or without purulent discharge. Ears without disease were classified as normal.

**Video-otoscopy recordings**

Following otomicroscopy, video-otoscopy recordings of 9-33 s in duration (mean 26 s) were completed by an ear and hearing telehealth clinic facilitator from each ear of participants. The facilitator had no formal health care or tertiary education. Prior to data collection, the otologist provided training over a two-day period on how to conduct video-otoscopy recordings. Training included patient positioning, visual inspection of the external ear, appropriate hand position, manipulation of direction of speculum, focus adjustment, recording capture, video-otoscope software use and equipment cleansing.

Data collection, which included acquisition of case histories, onsite otomicroscopy result and acquisition of video-otoscopy recordings by the facilitator (see Figure 1), was completed over a period of two weeks.

**Equipment**

Otomicroscopy was carried out using a surgical otomicroscope (Leica M525 F40) with a zoom magnification (1.2 to 12.8 x) and 300 W xenon fibre optic illumination. An ear scope (AMH-EUT Dino-Lite Pro Earscope), with a 3, 4 or 5 mm speculum was used to acquire the video-otoscopy recordings (Figure 1). The ear scope had an LED light, a magnification of 10–20 x, a frame rate of 30 frames per second and 1.3 Mpixel resolution. The video-otoscope was attached, via a USB video cable, to a laptop computer. Software (DinoCapture 2.0, AnMo Electronics Corporation) was used to record and view the video-otoscopy recordings. The recordings were saved as WMV files and ranged from 0.9-7.6 MByte in size (mean 3.6 MByte).

**Asynchronous assessment**

After data collection was completed, the video-otoscopy recordings, the participant’s demographic information
and case history were uploaded to a server, using a file transfer service (Dropbox). Recordings were assigned random numbers by an independent investigator prior to the first evaluation (review 1) and again prior to the second evaluation (review 2). Four and eight weeks after data collection, an otologist (the same otologist who performed the otomicroscopy) and a GP, who were blinded to the randomised numbering of recordings, accessed the server. Each rater made an independent grading of the video-otoscopy recordings, and made observations regarding ear canal obstruction, presence of secretion, tympanic membrane patency, translucency and position, and diagnosis from each video recording. The overall image quality was graded (0 to 2) with reference to image focus, light, cerumen and composition. A grading of 0 indicated that the image quality was not acceptable, and it was not possible to assess the entire tympanic membrane and to make a diagnosis. A grading of 1 indicated an acceptable image quality, enabling evaluation of the status of the tympanic membrane. A grading of 2 indicated high image quality, with tympanic membrane easily assessable. The diagnosis was made using the same classification as was used during the original otomicroscopy.

The assessments were recorded on a spreadsheet and uploaded to the server once completed. The delay in asynchronous assessment was included to reduce the possibility of a memory effect for onsite diagnoses made previously. The second assessment four weeks after the first allowed assessment of intra-rater agreement.

Analyses

Descriptive statistics were used to summarise the recording quality rating for video-otoscopy recordings and the frequency with which ear canal obstruction and presence of secretion was identified, as well as the tympanic membrane patency, translucency and position. The frequency of diagnosis of the different types of otitis media was also measured. For analysis of ears where an asynchronous diagnosis could not be made (labelled as not possible to diagnose or NPD), participants were divided into a younger and an older age group. The two groups represented preschool children (2–5 years of age) and children in formal education (6–16 years). Comparisons between the number of undiagnosed ears and the age group were made using Pearson’s chi-squared test. Pearson’s chi-squared test was also used for comparing the quality grading of video-otoscopy recordings acquired during the first and second week of data collection.

The kappa statistic ($\kappa$) was used to quantify the diagnostic agreement between onsite otomicroscopic examination and video-otoscopy recordings. The same statistics were used for inter- and intra-rater agreement on diagnosis from video-otoscopy recordings. For calculations of diagnostic concordance between onsite examination and video-otoscopy recordings, the ears where a diagnosis could not be made by either assessment method were excluded from the calculations. For inter- and intra-rater concordance, the ears where a diagnosis could not be made during asynchronous assessment were excluded.

By classifying the diagnosis as normal or abnormal, the sensitivity, specificity, positive and negative predictive value of diagnosis from video-otoscopy recordings was calculated using the otomicroscopic examination as the gold standard.

Results

A total of 140 children agreed to participate (mean age 6.4 years, SD 3.5; 44% female). Otomicroscopy was completed for 136 participants (272 ears); four participants did not cooperate. One of the 136 participants did not cooperate for video-otoscopy in either ear, while another
participant did not allow video-otoscopy to be completed in one ear. Therefore video-otoscopy recordings were made on 135 participants and 269 ears.

The otologist graded the video-otoscopy recordings as unacceptable in 13% of ears for the first and second review, whilst the GP graded 22% and 26% unacceptable for the two review sessions, respectively (Table 1). Both the otologist and the GP judged more video-otoscopy recordings as excellent in quality in the second compared to the first week of data collection (otologist mean number of excellent ratings for each review 5% and 10% for week 1 and 2, respectively; GP mean number of excellent ratings 25% and 32%, respectively). This was true at both the first and second review sessions. The improvement in quality ratings between the first and second week of data collection was not significant.

Mean intra-rater agreement at review one and two, was 87% and 74% on recordings labelled as either acceptable or excellent for the otologist and GP respectively. Inter-rater agreement on video-otoscopy recordings graded as either acceptable or excellent was 77% for the first review and 72% for the second review.

Poor video-otoscopy recordings were more common in younger children (2–5 years of age), compared to older children (6–15 years of age) for both raters (Table 2), but the difference was not significant.

During onsite assessment, manual cerumen removal was deemed necessary and attempted for 36% of participants (24% of ears) in order to obtain a clear view of the tympanic membrane for otomicroscopic diagnosis. After reasonable attempts were made to remove any cerumen without causing discomfort, cerumen still partially or completely occluded the ear canal in 13% of participants for either or both ears (8% of ears) preventing a diagnosis from being made (Table 3). During asynchronous diagnosis, the inability of the otologist and GP to make a diagnosis was due to partial or complete occlusion of the ear canal (due to lack of visualisation of the entire tympanic membrane), or poor video-otoscopy recording quality. At the two reviews, the otologist was unable to make a diagnosis in 25% and 23% of ears. The GP was unable to make a diagnosis for 28% and 27% of ears at the two reviews. Diagnosis from video-otoscopy recordings could therefore not be made from a mean (calculated from mean between reviews of both raters) of 18% of ears for whom successful onsite otomicroscopy was conducted.

Otitis media was identified in 13-17% of ears, with OME being the most common type of otitis media (8–10% of ears), followed by CSOM (4–7% of ears). The otologist reported a larger number of ears with CSOM during asynchronous assessment (mean number of ears with CSOM diagnosed at review one and two 7%) compared to either onsite otomicroscopy (5% of ears) or asynchronous video-otoscopy assessment by the GP (5% of ears).

There was substantial agreement between video-otoscopy diagnoses compared to onsite otomicroscopic diagnoses (Table 4). A slightly higher diagnostic concordance was found at review two for both the otologist (κ = 0.74) and for the GP (κ = 0.75) than for the first review (otologist κ = 0.70; GP κ = 0.68).

Agreement between diagnoses made using video-otoscopy recordings was substantial between raters (κ = 0.74 and 0.74 at first and second review) and within raters (κ = 0.77 and 0.74 for otologist and GP respectively; Table 5).

Specificity and negative predictive values were higher than sensitivity and positive predictive values for asynchronous video-otoscopy interpretations for both raters (Table 6). The sensitivity of the interpretation of the video-otoscopy recordings was slightly better for the otologist (mean sensitivity of 78%) than for the GP (mean sensitivity of 72%). Slightly higher positive predictive values were determined from the GP evaluation of video-otoscopy recordings (positive predictive value of 81%) compared to those of the otologist (positive predictive value of 74%).

**Discussion**

The video-otoscopy recordings acquired by the facilitator were rated as acceptable or better in quality for 74–87% of

---

**Table 1. Grading of video-otoscopy recordings acquired during the first and second week of data collection. (R1, Review 1; R2, Review 2).**

<table>
<thead>
<tr>
<th>Grading</th>
<th>Week 1 (%) (n = 134 ears)</th>
<th>Week 2 (%) (n = 135 ears)</th>
<th>Total (%) (n = 269 ears)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Otologist</td>
<td>GP</td>
<td>Otologist</td>
</tr>
<tr>
<td>0 Unacceptable</td>
<td>14</td>
<td>13</td>
<td>22</td>
</tr>
<tr>
<td>1 Acceptable</td>
<td>79</td>
<td>84</td>
<td>52</td>
</tr>
<tr>
<td>2 Excellent</td>
<td>7</td>
<td>2</td>
<td>26</td>
</tr>
</tbody>
</table>
cases by the otologist and GP. This is similar to the proportion of adequate video-otoscopy cases acquired by a nurse and an otolaryngologist in previous studies. The similarity in quality judgements reported in the present study and in previous studies are of consequence for three reasons. First, the telehealth facilitator who captured the video-otoscopy recordings had no formal health care training, unlike the health care personnel in earlier studies. Second, video-otoscopy recordings in the present study were found to be equivalent in quality compared to the video-otoscopy images acquired previously. Third, the present study targeted a paediatric population who were likely to be less cooperative than the adult population of Biagio et al.

The number of video-otoscopy recordings rated excellent by the otologist and GP was higher (albeit not significantly) for recordings acquired during the second week and may suggest a learning effect with increased experience by the facilitator (mean excellent gradings by otologist in the first week increased from 5% to 10%; mean excellent gradings by GP increased from 25% to 32%). An improvement in the quality of video-otoscopy images acquired over time was also demonstrated by Lundberg et al. The quality of video-otoscopy recordings is likely to be affected by the amount of training and the proficiency of the person making the recordings, which will affect the diagnostic accuracy.

A diagnosis from video-otoscopy recordings could not be made from 18% of ears in which successful onsite otomicroscopy was completed. This may have been due to poor video quality, insufficient visualisation of the entire tympanic membrane or partial occlusion of the ear canal by cerumen. In previous studies, when the entire tympanic membrane could not be visualised, Eikelboom et al. and Biagio et al. reported the presence of partial or total cerumen occlusion, rather than stating that a diagnosis could not be made. Kokesh et al. stated that images were discarded due to poor image quality or cerumen, but did not indicate how many. Removing cerumen is likely to reduce the number of undiagnosed ears from video-otoscopy, if performed prior to the recording. Cerumen removal could be performed by a nurse at a clinic immediately prior to video-otoscopy recording.

Poor video-otoscopy image quality or a lack of sufficient information was reported as the reason for being unable to diagnose 14% of ears in the study by Patricoski and colleagues compared to 18% in the present study. In a previous study, Biagio et al. reported a lower number of ears where a diagnosis could not be made. The values shown in Table 3 represent percentages of participants (% ears).

### Table 3. Onsite diagnoses made by the otologist using otomicroscopy compared to the diagnoses made by the otologist and GP using video-otoscopy recordings. (R1, Review 1; R2, Review 2). The values shown represent percentages of participants (% ears).

<table>
<thead>
<tr>
<th>Onsite diagnosis</th>
<th>Asynchronous diagnosis n = 135 (269 ears)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Otologist (%)</td>
</tr>
<tr>
<td></td>
<td>n = 136 (272 ears)</td>
</tr>
<tr>
<td>Normal</td>
<td>66 (76)</td>
</tr>
<tr>
<td>Otitis media:</td>
<td>22 (17)</td>
</tr>
<tr>
<td>AOM</td>
<td>1 (0.7)</td>
</tr>
<tr>
<td>CSOM</td>
<td>6 (5)</td>
</tr>
<tr>
<td>OME</td>
<td>14 (11)</td>
</tr>
<tr>
<td>NPD</td>
<td>13 (8)</td>
</tr>
</tbody>
</table>

*Table 3. Onsite diagnoses made by the otologist using otomicroscopy compared to the diagnoses made by the otologist and GP using video-otoscopy recordings. (R1, Review 1; R2, Review 2). The values shown represent percentages of participants (% ears).*

### Table 4. Agreement of diagnoses made using video-otoscopy recordings by the otologist and GP compared to onsite otomicroscopy. (n = 176 ears; R1, Review 1; R2, Review 2).

<table>
<thead>
<tr>
<th>Inter-rater diagnosis</th>
<th>R1</th>
<th>R2</th>
<th>R1</th>
<th>R2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kappa value</td>
<td>SE</td>
<td>SE</td>
<td>SE</td>
<td>SE</td>
</tr>
<tr>
<td>Otologist</td>
<td>0.70</td>
<td>0.07</td>
<td>0.74</td>
<td>0.07</td>
</tr>
<tr>
<td>GP</td>
<td>0.68</td>
<td>0.07</td>
<td>0.75</td>
<td>0.07</td>
</tr>
</tbody>
</table>

### Table 5. Agreement of diagnoses made using video-otoscopy recordings between and within the otologist and GP. (n = 249 ears; R1, Review 1; R2, Review 2).

<table>
<thead>
<tr>
<th>Inter-rater diagnosis</th>
<th>R1</th>
<th>R2</th>
<th>R1</th>
<th>R2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kappa value</td>
<td>SE</td>
<td>SE</td>
<td>SE</td>
<td>SE</td>
</tr>
<tr>
<td>Otologist</td>
<td>0.74</td>
<td>0.04</td>
<td>0.77</td>
<td>0.04</td>
</tr>
<tr>
<td>GP</td>
<td>0.74</td>
<td>0.04</td>
<td>0.74</td>
<td>0.04</td>
</tr>
</tbody>
</table>

*Table 4. Agreement of diagnoses made using video-otoscopy recordings by the otologist and GP compared to onsite otomicroscopy. (n = 176 ears; R1, Review 1; R2, Review 2).*

*Table 5. Agreement of diagnoses made using video-otoscopy recordings between and within the otologist and GP. (n = 249 ears; R1, Review 1; R2, Review 2).*

AOM = acute otitis media; CSOM = chronic suppurative otitis media; OME = otitis media with effusion; NPD = not possible to diagnose.
made from video-otoscopy images acquired by a telehealth facilitator in adult subjects (10% of images). This difference may be partly due to participant age (paediatric versus adult participants) and consequent variability in co-operation.

### Diagnostic accuracy

Agreement between onsite otomicroscopy and video-otoscopy recordings in the present study was substantial ($\kappa = 0.68–0.75$) and equivalent to concordance previously reported using video-otoscopy images and otoscopy ($\kappa = 0.64–0.76$).\textsuperscript{14,15} The similarity suggests that the telehealth facilitator in the present study, with no formal health care training, was capable of acquiring video-otoscopy recordings similar in quality to personnel with formal health care education in previous video-otoscopy reports.\textsuperscript{14,15} The validity of asynchronous diagnoses in the present study is similar to that reported by Smith and colleagues where a nurse completed the video-otoscopy recording.\textsuperscript{7} Agreement in diagnosis was 81% and agreement on clinical management recommendations was 76%.\textsuperscript{7}

Intra-rater concordance was substantial for diagnosis using video-otoscopy recording (otologist $\kappa = 0.77$; GP $\kappa = 0.74$), which corresponds to previous findings.\textsuperscript{14,15} The substantial inter-rater concordance for the diagnoses made in the present study suggest good agreement between diagnosis made by the otologist and the GP. Inter-rater concordance was equivalent to that reported between otolaryngologists.\textsuperscript{14,15} The inter- and intra-rater concordance in the present study was also similar to the diagnostic concordance between on-site otomicroscopy and remote diagnosis. This suggests that the variability of remote diagnosis, using video-otoscopy recordings, is similar to typical diagnostic variability that can be expected within and between clinicians.

Video-otoscopy recordings could be used for diagnosis to correctly identify ears without pathology more often in the present study (specificity 95% and 97% for otolaryngologist and GP respectively) than has been previously reported for diagnosis from video-otoscopy images (specificity =89%).\textsuperscript{6} Negative predictive values for normal ears in the present study were equally high (negative predictive value 96% and 95% for otolaryngologist and GP respectively). However, sensitivity values in the present study (sensitivity 78% and 72% for otolaryngologist and GP, respectively) were lower than was previously reported for asynchronous diagnosis using video-otoscopy images (sensitivity 80% and 85% for images acquired by an otolaryngologist and telehealth facilitator respectively).\textsuperscript{6}

Video-otoscopy recordings may pose several advantages in comparison with video-otoscopy images for asynchronous diagnosis. Video-otoscopy recordings provide the possibility of pausing, rewinding and reviewing the recording several times, an opportunity rarely granted when examining a child. Video-otoscopy recordings appear to provide better depth perception than still images, because they offer several angles of view of the tympanic membrane.\textsuperscript{6,14} Asynchronous diagnosis by the otologist compared to onsite assessment indicated slightly more CSOM ears. This may reflect the advantage afforded by asynchronous assessments, which permits several reviews with no time pressure. Another advantage is that both the child and caregiver are able to see the ear canal and ear drum, providing good counselling and learning opportunities. In one case, a child cooperated willingly for video-otoscopy by the telehealth facilitator, but not for the otomicroscopic examination. Video-otoscopy may be a less intimidating assessment for some children. In addition, a telehealth facilitator, who might originate from the community the clinic serves, and who speaks the child’s home language, may also be perceived as less threatening than a doctor. The video-otoscope selected for the present study was portable and easy to operate with some training. In comparison with a surgical otomicroscope, a video-otoscope is substantially less expensive.

### Conclusion

A telehealth facilitator with limited training was capable of acquiring good quality video-otoscopy recordings in a paediatric clinic for asynchronous diagnosis. Asynchronous video-otoscopy recordings have high intra- and inter-rater reliability for diagnoses made by an otologist and GP. Remote diagnosis was equivalent to inter- and intra-rater variability. However, asynchronous diagnosis could not be made for about 20% of paediatric video-otoscopy recordings, due to residual cerumen in the ear canal or poor video-quality. Increasing the telehealth facilitator’s training and applying cerumen management strategies prior to video-otoscopy recordings may reduce the number of ears left undiagnosed after asynchronous assessment.

### Acknowledgements

We thank Ms Violet Mugodo, Dr Dirk Koekemoer, Dr Jean Bassett and the clinic staff and patients for their help. We are also grateful to Mr Headley Isserow (Tecmed, Midrand, South Africa) and the telehealth facilitator in the paediatric clinic for asynchronous diagnosis.

---

**Table 6.** Sensitivity, specificity, positive and negative predictive values (%) for normal and abnormal classifications of video-otoscopy recordings as assessed by an otologist and GP. ($n = 176$ ears; R1, Review 1; R2, Review 2).

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Positive predictive value</th>
<th>Negative predictive value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Otologist</td>
<td>R1: 79%</td>
<td>93%</td>
<td>70%</td>
<td>96%</td>
</tr>
<tr>
<td></td>
<td>R2: 76%</td>
<td>96%</td>
<td>79%</td>
<td>95%</td>
</tr>
<tr>
<td></td>
<td>Mean: 78%</td>
<td>95%</td>
<td>74%</td>
<td>96%</td>
</tr>
<tr>
<td>GP</td>
<td>R1: 72%</td>
<td>95%</td>
<td>75%</td>
<td>95%</td>
</tr>
<tr>
<td></td>
<td>R2: 72%</td>
<td>98%</td>
<td>88%</td>
<td>95%</td>
</tr>
<tr>
<td></td>
<td>Mean: 72%</td>
<td>97%</td>
<td>81%</td>
<td>95%</td>
</tr>
</tbody>
</table>
Africa) for providing the otomicroscope used for on-site diagnoses. Partial funding from the National Research Fund of South Africa is gratefully acknowledged.

References